European Commission

# JRC Science for Policy Report
# Bioeconomy Report 2016

Joint Research Centre

This publication is a science for policy report by the Joint Research Centre, the European Commission's in-house science service. It aims to provide evidence-based scientific support to the European policymaking process.



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Abstract:

**First report providing horizontal analysis of the EU bioeconomy**

• The bioeconomy cuts across several economic sectors, academic disciplines and policy areas

• Bioeconomy R & I are heavily supported by EU funds

• The EU bioeconomy provides more than 18 million jobs with overall decreasing tendency due to structural changes, e.g. in agriculture

• The EU bioeconomy creates a turnover of EUR 2 trillion with increasing tendency

# JRC Science for Policy Report

## Bioeconomy Report 2016

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**EU policy framework relevant for the bioeconomy (2.4.):**
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**Quantifying economic indicators of the European bioeconomy (3.1.-3.3., 3.6.):**
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# Executive summary

## Context and objectives

'The bioeconomy [...] encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy.' This notion of the bioeconomy was formulated in the European Commission's (EC) bioeconomy strategy and action plan 'Innovating for sustainable growth: a bioeconomy for Europe' (EC 2012a), following reflections on the bioeconomy that had started in the middle of the last decade.

Following this definition, the bioeconomy brings together various sectors of the economy that produce, process and reuse renewable biological resources (agriculture, forestry, fisheries, food, bio-based chemicals and materials and bioenergy). Consequently, the 2016 bioeconomy report is relevant for the respective sectorial policies, in addition to specific bioeconomy policies at EU, national and regional level and to related cross-cutting policies such as environment, climate change, circular economy, waste, industrial policies, regional policies (smart specialisation), research and innovation and blue economy. These policies and sectors are crucial to address societal challenges such as a growing food demand, climate change and the decline of fossil resources.

This report was prepared in cooperation with experts from the EC's Joint Research Centre (JRC), other EC directorates-general (DG) (especially DG Research and Innovation) and external experts, and in consultation with the EC's Bioeconomy Inter-Service Group (ISG). It intends to inform EU policymakers, in particular for the ongoing review of the bioeconomy strategy, as well as policymakers in Member States and third countries, stakeholders including research, industry and non-governmental organisations (NGOs) and interested citizens.

The 2016 bioeconomy report is the first JRC science for policy report addressing the bioeconomy across its sectors as well as from angles such as bioeconomy policies, legislation and funding, jobs and growth, and the environment. However, holistic approaches to bioeconomy research and monitoring are still at an early stage. Therefore, this report cannot yet provide a comprehensive description and evaluation of the 'state' of the bioeconomy; it rather reflects the current state of 'knowledge' about the bioeconomy. Results are preliminary and need to be interpreted with caution. Further research is required, especially the development of methods for monitoring and of models for forecasting and the collection and evaluation of relevant data, in order to provide a more complete and precise picture of the bioeconomy in the future.

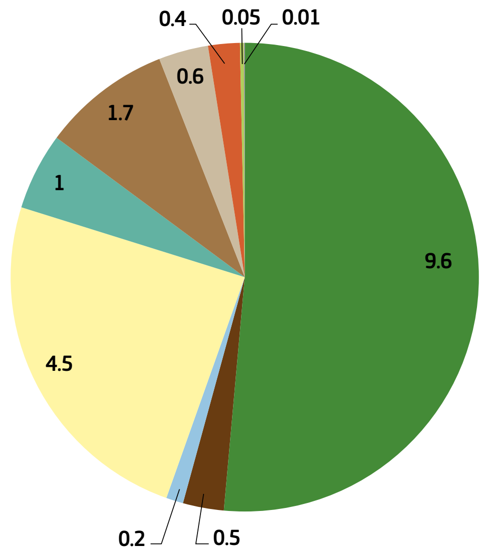
## Main findings and conclusions

### *Socioeconomic aspects*

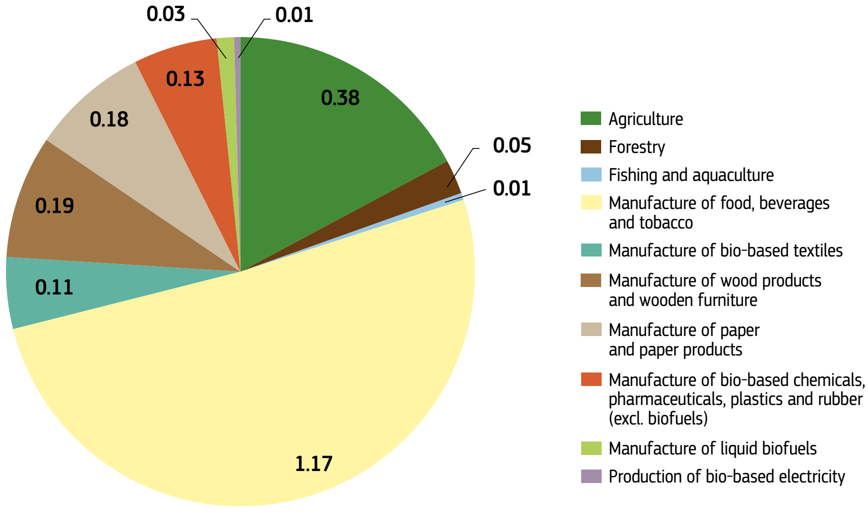
Despite significant caveats concerning data availability (it is especially limited for the blue economy) and methodologies for monitoring the bioeconomy, the analysis of two indicators presented in this report – employment and turnover – provides important insight into the economic size, impact and development of the EU bioeconomy.

The EU bioeconomy makes up an important part of the total economy in the EU. In 2014 it employed around 18.6 million people and generated approximately EUR 2.2 trillion. This means that the **bioeconomy represents around 9 % of all sectors of the economy** with regards to employment as well as to turnover.

The economic size of the bioeconomy sectors varies considerably. The **agriculture** and **food and beverages and tobacco** sectors together make up about **three quarters of the overall bioeconomy for employment** and about **two thirds of the overall bioeconomy for turnover** (see figures below).




*Employment [million persons employed] in the bioeconomy sectors of the EU (2014)*

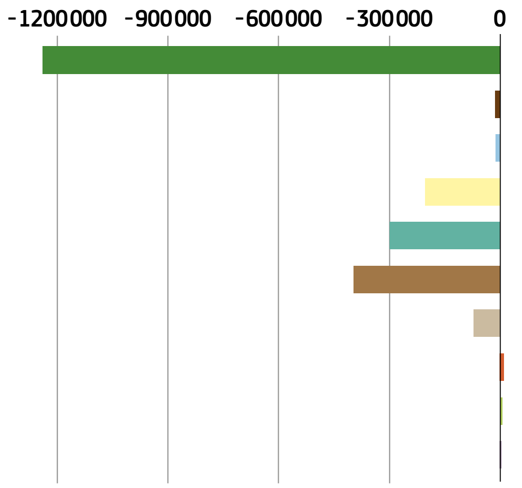



*Turnover [trillion EUR] in the bioeconomy sectors of the EU (2014)*

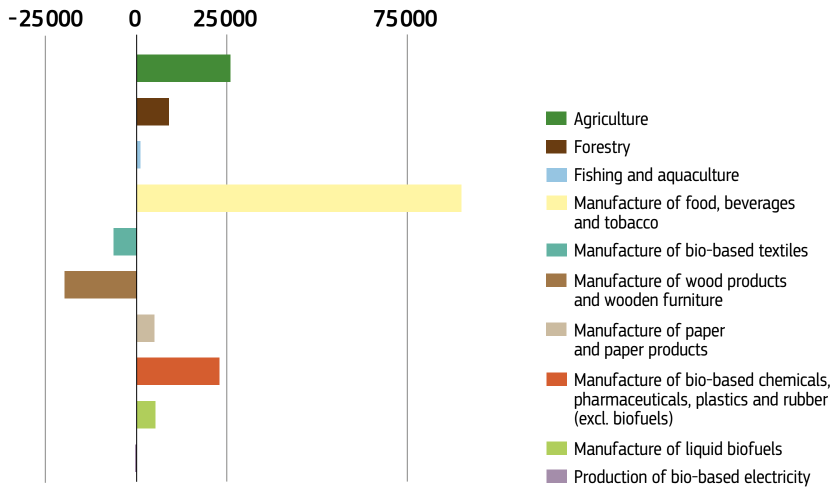
While the **number of jobs** in the EU bioeconomy **decreased** by 2.2 million (-10.5%) between 2008 and 2014, the **turnover increased** by EUR 140 billion (+7%), resulting in **substantial gains in turnover per person employed**.

Contributions of the different sectors to this development varied highly (see figure below). Jobs were lost mainly in the agricultural sector (-1.2 million people), due to the ongoing restructuration of the European agricultural sector, but also in the sectors of manufacture of wood products and of wooden furniture, of bio-based textiles and of food, beverages and tobacco. The increase in turnover was mainly driven by developments in the manufacture of food, beverages and tobacco products and, to a smaller extent, by developments in agriculture and the manufacture of chemicals, pharmaceuticals, plastics and rubber.

The overall number of jobs in all economic sectors in the EU-28 declined from 223 million to 218 million between 2008 and 2014. The share of jobs of the bioeconomy in the total employment in the Member States decreased from 9.3% to 8.5% (comparable data showing the development of turnover in all economic sectors of the EU-28 between 2008 and 2014 are not available).

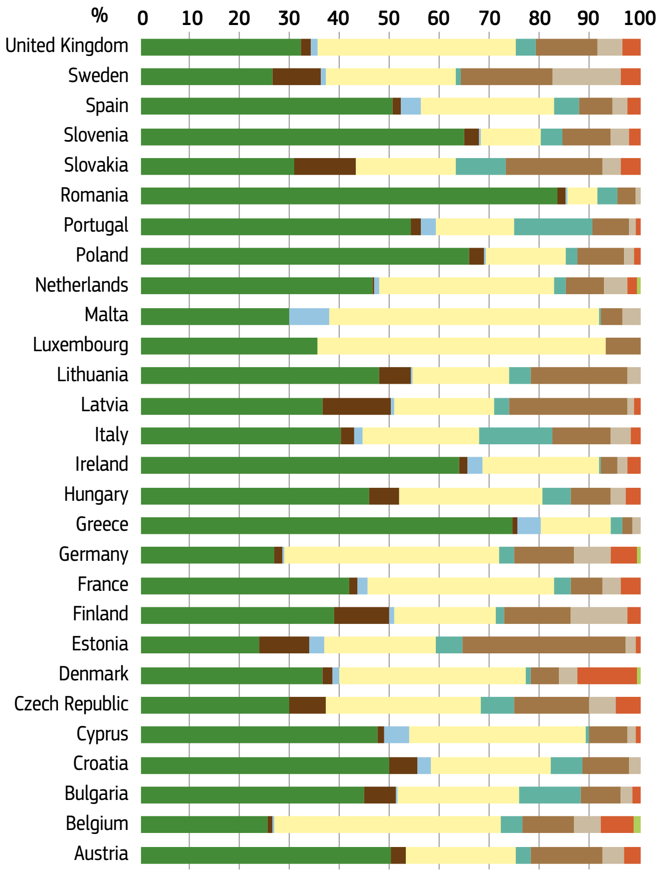



*Change in number of people employed in the bioeconomy sectors between 2008 and 2014*

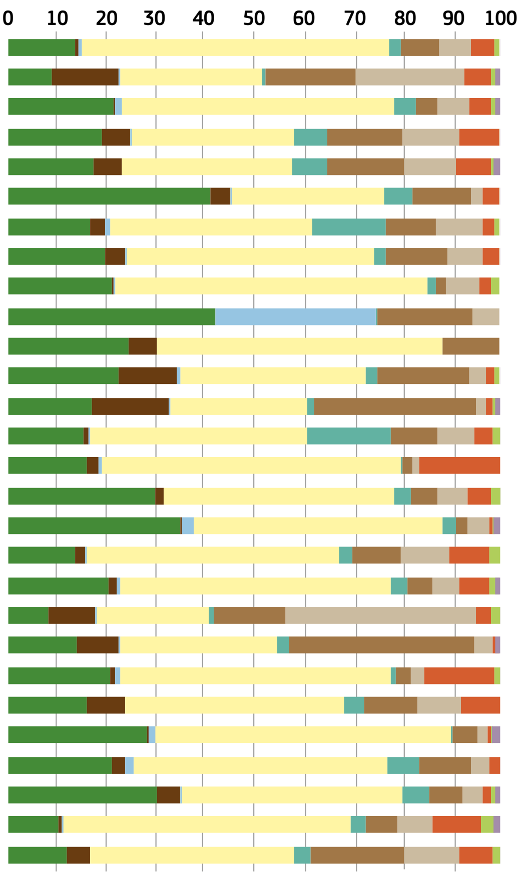



*Change in turnover [million EUR] in the bioeconomy sectors between 2008 and 2014*

Although the sectors of agriculture and of the manufacture of food, beverages and tobacco are widely dominating the bioeconomy in the EU, the Member States present very different patterns of their bioeconomy (see figure below). An even more diverse picture could be expected for an analysis at regional level. On the one hand, this shows that the bioeconomy concept, thanks to its versatility, can provide opportunities for many and possibly all of the Member States and their regions, independently of their very different natural resources endowment and different historical orientations of their domestic economy. On the other hand, such a diverse picture stresses the importance of cooperation within and between regions and Member States to exploit synergies between different sectors in the bioeconomy as the size of these sectors can greatly differ from one region and Member State to another.




*Employment in the bioeconomy sectors of activity in the 28 EU Member States, in percentage*




*Turnover in the bioeconomy sectors of activity in the 28 EU Member States, in percentage*

- Agriculture
- Forestry
- Fishing and aquaculture
- Manufacture of food, beverages and tobacco
- Manufacture of bio-based textiles
- Manufacture of wood products and wooden furniture
- Manufacture of paper and paper products
- Manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels)
- Manufacture of liquid biofuels
- Production of bio-based electricity

### *Environmental aspects*

In addition to societal and economic aspects, environmental issues such as waste reduction and climate change mitigation are a main focus of the bioeconomy discussion. A sustainable bioeconomy cannot be conceived without the sound management of biological resources, respecting the regeneration levels of all renewable resources and healthy ecosystems on land and in the sea.

As for the socioeconomic aspects, development of methods for the analysis of the environmental aspects of bio-based products is at an early stage and few relevant results are currently available. On the other hand, environmental impacts associated with bioenergy have been the subject of extensive investigation.

Two life cycle assessment (LCA) modelling principles, attributional LCA (A-LCA) and consequential LCA (C-LCA), provide answers to different research and policy questions. A-LCA modelling is the appropriate tool in situations such as benchmarking and accounting, while C-LCA is the appropriate principle for large-scale policy analysis.

C-LCA requires large modelling capabilities; it is scenario dependent and more uncertain. However, aspects of consequential thinking can also be applied to A-LCA studies and this has recently been done to provide a comprehensive assessment of the environmental risks associated with bioenergy. This 'advanced' A-LCA should: i) consider a counterfactual, non-energy use of the biomass feedstock (in addition to the factual energy use); ii) explicitly and dynamically account for all the flows of biogenic $CO_2$; iii) apply multiple climate metrics; and iv) include all relevant climate forcers and holistically assess all potential environmental impacts. This approach could be extended to all bio-based products when looking for the potential environmental risks of various alternative uses of biomass or land.

Different approaches of A-LCA applied to bio-based products have also been tested. It was shown that reliable and useful results require good availability, choice and evaluation of data and careful specification of the LCA models used and the system boundaries applied, as well as cautious interpretation.

Results from studies already available show that the bio-based products analysed (i.e. bio-based building blocks and polymers) produce lower environmental impacts in comparison to their fossil references for the impact categories of climate change and non-renewable energy consumption. On the other hand, for impacts regarding eutrophication, acidification and land use, the bio-based products may perform more poorly due to the agricultural activities related to biomass production (i.e. use of fertilisers and pesticides) and lower efficiencies in the production processes.

### *Bioeconomy policy and funding*

The bioeconomy strategy and action plan of 2012, together with other policies relevant for the bioeconomy, supports four of the priorities of the Juncker Commission: jobs, growth and investment; the energy union and climate change; the internal market and industrial base; and Europe as a stronger global actor. They can also support related international treaties and the EU commitments therein, such as the Paris Agreement negotiated at the United Nations Climate Change Conference 21 (COP21) and the United Nations sustainable development goals (SDG).

As for sectorial legislation, the common agriculture policy (CAP) and the common fisheries policy (CFP) have a significant impact on biomass availability, price and price volatility. Specific provisions of these policies promote development towards environmental sustainability. From the sectors using biomass, only the bioenergy sector is regulated by EU legislation promoting the use of biomass, which in turn can influence the availability and the price of biomass for other sectors and uses, such as food and bio-based chemicals and materials. Cross-cutting policies relevant for the bioeconomy, such as climate change, energy policy, circular economy and regional policy, can boost the bioeconomy.

While there is no specific bioeconomy legislation, funding for bioeconomy research and innovation is a key policy tool for promoting the bioeconomy. EU funding mechanisms include notably the HORIZON 2020 framework programme, the European Structural and Investment Funds (ESIF) and the European Fund for Strategic Investment (EFSI). Some 5.6% (EUR 4208 million) of the HORIZON 2020 budget is dedicated to the bioeconomy. HORIZON 2020 also provides approximately EUR 1 billion for the public-private partnership Bio-Based Industries Joint Undertaking (BBI JU), which are topped-up by private funds to an overall budget of EUR 3.7 billion.

### *Overall conclusions and outlook*

This report confirms that the bioeconomy is complex and cuts across several academic disciplines, industry sectors and policy areas. Because of this complexity and the fact that an EU bioeconomy strategy was only introduced in 2012, research supporting the monitoring of the bioeconomy and the analysis of its impact is still in its early stage.

For a fully fledged analysis of the impact of relevant policies, more research needs to be carried out. Considerable efforts are being made but still need to be reinforced in order to improve the accessibility to reliable data and to further develop and improve methodologies for monitoring and forecasting. In the socioeconomic and the environmental fields, modelling tools are being prepared and improved.

# 1. Introduction

'The bioeconomy […] encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy' (EC 2012a). This notion of the bioeconomy was introduced into the political discussion of the European Commission (EC) in the middle of the last decade, resulting in the publication in 2012 of the bioeconomy strategy and action plan 'Innovating for sustainable growth: a bioeconomy for Europe' (EC 2012a). Whereas this definition only focuses on tradable products, other sources include ecosystem services in their bioeconomy discussion (EC 2014d; Finnish bioeconomy strategy, 2014).

The main objectives of the bioeconomy strategy and action plan (EC 2012a) are tackling societal challenges such as ensuring food security, sustainably managing natural resources, reducing dependence on non-renewable resources, mitigating and adapting to climate change, creating jobs and maintaining European competitiveness. The examples of food security and climate change show how urgent it is to address these challenges, especially in a context of global population growth.

According to the report *World population prospects* – The 2015 revision of the United Nations (UN 2015), the world population is projected to increase by more than 1 billion people within the next 15 years, reaching 8.5 billion by 2030, and to increase to a further 9.7 billion by 2050 and 11.2 billion by 2100. The global food crises of 2008 and 2011 were striking reminders of the importance of innovation in agriculture to address global challenges such as population growth as well as consequences of climate change such as droughts.

The Joint Research Centre (JRC) PESETA II study (Ciscar et al. 2014) estimated that if the climate change projected for the 2080s would happen today and without public adaptation ([1]), then the EU household welfare losses would amount to around EUR 190 billion, almost 2% of EU gross domestic product (GDP). The lion's share of carbon dioxide emissions originates from the combustion of fossil fuel (Olivier et al. 2015). Deposits of fossil oil are finite and their availability in the future is cause for concern (Speirs et al. 2015). A transition to the use of renewable resources, including sustainable use of biomass, can contribute to reducing emissions and circumventing resource scarcity. A healthy bioeconomy is crucial for a successful and sustainable transition.

Biomass availability is limited, which leads to the potential competition for biomass between different biomass-using sectors. Natural resources needed to produce biomass, such as soil and aquifers, and certain biomass sources, such as forestry and fisheries, are called 'critical zone renewable resources'. While they are naturally renewed within short periods of time, they can be used to exhaustion depending on the degree and type of exploitation. In order for the bioeconomy to avoid the exhaustion of natural resources, a number of factors need to be taken into account, including the need for maintaining life support systems such as water services, essential biodiversity needs and potential competition for land between different sectors of primary biomass production.

In order to support bioeconomy and bioeconomy-related policies, the EC's Bioeconomy Observatory collects and analyses data and information about bioeconomy. This report provides a concise summary of information and analysis of specific dimensions of the bioeconomy carried out in the JRC in close cooperation with other DGs of the EC (especially DG Research and Innovation). This is complemented by contributions from external experts from different bioeconomy sectors and through consultation with the EC's Bioeconomy ISG.

The monitoring and analysis of the EU bioeconomy are still in their infancy. Despite persisting gaps in data and methodologies, the report aims to provide a picture of the main aspects. Chapter 2 shows the bioeconomy policy background by providing an overview of relevant EU initiatives, policies, legislation and funding including research and investment. Chapters 3 and 4 turn to the impact of the bioeconomy on growth, jobs and the environment. Taking a socioeconomic angle, Chapter 3 presents

1 Leading to a global temperature increase of 3.5 degrees and considered to be a business-as-usual scenario; based on the 'Reference scenario' in the report.

the state of play on jobs and growth figures in the EU bioeconomy as well as indications about the state and outlook for the bio-based industry in the EU according to a survey. Furthermore, an outlook is provided on efforts to understand the impact of different bioeconomy sectors on employment and on turnover in other sectors through a multiplier analysis as well as on ongoing research to quantify biomass potential, supply and demand. Environmental aspects, often quoted as a reason to further develop the bioeconomy, are featured in the analysis presented in Chapter 4, with a focus on both attributional and consequential life cycle assessment (LCA). Chapter 5 shows the bioeconomy from the perspective of stakeholders, and representatives of different sectors share why the bioeconomy is relevant to their sector and present case studies of promising and innovative value chains.

# 2. EU policy framework relevant for the bioeconomy

# 2. EU policy framework relevant for the bioeconomy

The bioeconomy concept brings together various sectors of the economy that produce, process and reuse renewable biological resources such as agriculture, forestry, fisheries, aquaculture, bioenergy and bio-based industry. The EC's bioeconomy strategy aims to support, enhance and develop the bioeconomy topic in its own right. Yet the strategy is also related to a diverse set of initiatives and policies – focussing on specific sectors of the bioeconomy and cross-cutting – linked to innovation, resource efficiency, sustainability and climate change adaptation and mitigation, as well as key societal challenges such as food and energy security.

In the EU, the bioeconomy concept was introduced in the middle of the last decade and resulted in the publication of the bioeconomy strategy (EC 2012a). However, because of its cross-cutting nature, the bioeconomy is additionally shaped by policies introduced much earlier in the EU. These initiatives and policies also often have an impact on each other's target sectors, for instance bioenergy policies may affect the availability and prices of biomass, not only for bioenergy but also for food production and for the bioeconomy as a whole.

EU policy can be divided into three separate levels (Haigh 2016):

1. treaties authorise EU institutions to pursue certain policies, introduce harmonised legislation in those fields and establish international agreements;
2. strategies and action programmes formulate the political intentions;
3. legislation supports the achievement of the poli-cy goals.

Knowing the wide and complex landscape of EU initiatives, the first step in understanding their potential impacts is through policies, legislation and funding relevant for the bioeconomy at all levels. This chapter provides a compact overview and makes no claim to provide a complete list.

It should also be noted that the EU bioeconomy policy framework is related to international treaties and the EU commitments therein, such as the Paris Agreement negotiated at the United Nations COP21 and the United Nations SDG. However, a more detailed presentation of this international dimension of the bioeconomy policy is beyond the scope of this report.

## 2.1. Treaties

The EU can only act within the limits of the competences conferred upon it by the EU treaties (EUR-Lex n.d.a). These are defined in Articles 2-6 of the Treaty on the Functioning of the EU (TFEU). There are four types (see Table 1). Most policies with relevance for the bioeconomy are included in Column 2 – Shared competence.

The **CAP** and the **CFP** were first formulated in the Treaty of Rome in 1958 (EP n.d.a and n.d.b). The Single European Act of 1986 established the legal basis for the **regional, environmental and research policies** (EP n.d.c). A chapter dedicated to **energy policy** was introduced by the Treaty of Lisbon in 2009 for the first time. The EU treaties do not make specific provisions for the bioeconomy.

In policy fields where the EU lacks specific competences, development of strategic policy documents for the coordination of national efforts is still possible. Whereas harmonised EU legislation in these policy fields does not exist, provisions may be included in the legislation of related policy fields. For example environmental legislation such as the Birds Directive (EU 2009d) and the Habitats Directive (EEC 1992) have an impact on forestry.

## 2.2. Strategies and action programmes

### *2.2.1. Europe 2020 and its flagship initiatives*

Europe 2020 (EC 2010a) is a 10-year strategy following the Lisbon strategy (2000-2010). Seven flagship initiatives were identified to boost the economy with respect to growth and jobs (Table 2), four of which are relevant for the bioeconomy (in bold). The strategy sees innovation as an effective approach for addressing societal challenges such as climate change, energy and resource scarcity. The Europe 2020 strategy and its flagship initiatives were further developed in specific policy sectors.

Jean-Claude Juncker (President of the Commission since 15 July 2014) set out the political agenda for the period 2014-2019 through 'political guidelines' focussing on ten policy areas (Table 3). Under priority 1, a review of the Europe 2020 strategy is foreseen.

Strategies produced before the presentation of the Juncker priorities are based on and refer to Europe 2020.

***Table 1:***
*EU competences relevant for the bioeconomy (as defined in Articles 2-6 of the TFEU)*

| Exclusive competence (see Article 3 TFEU) | Shared competence (see Article 4 TFEU) | Competence to provide arrangements within which EU Member States must coordinate policy (see Article 5 TFEU) | Competence to support, coordinate or supplement actions of the Member States (see Article 6 TFEU) |
|---|---|---|---|
| • conservation of marine biological resources under the CFP<br>• concluding international agreements:<br>- when their conclusion is required by a legislative act of the EU;<br>- when their conclusion is necessary to enable the EU to exercise its internal competence;<br>- insofar as their conclusion may affect common rules or alter their scope. | • economic, social and territorial cohesion<br>• agriculture and fisheries, excluding the conservation of marine biological resources<br>• environment<br>• transport<br>• energy<br>• research, technological development and space | • economic policy<br>• employment<br>• social policies | • industry |

***Table 2:*** *Flagship initiatives under the Europe 2020 strategy (flagship initiatives with core relevance for the bioeconomy in bold)*

| Smart | Sustainable | Inclusive |
|---|---|---|
| | Growth | |
| 1. Digital agenda for Europe | **4. Resource-efficient Europe (EC 2011a)** | **6. An agenda for new skills and jobs (EC 2008a)** |
| **2. Innovation union (EC 2010a)** | **5. An industrial policy for the globalisation area (EC 2010c)** | 7. European platform against poverty |
| 3. Youth on the move | | |

***Table 3:*** *The 10 Juncker priorities (priorities with core relevance for the bioeconomy in bold)*

| | | | |
|---|---|---|---|
| **01** | **A new boost for jobs, growth and investment** | 06 | A reasonable and balanced free trade agreement with the United States |
| 02 | A connected digital single market | 07 | An area of justice and fundamental rights based on mutual trust |
| **03** | **A resilient energy union with a forward-looking climate change policy** | 08 | Towards a new policy on migration |
| **04** | **A deeper and fairer internal market with a strengthened industrial base** | **09** | **Europe as a stronger global actor** |
| 05 | A deeper and fairer economic and monetary union | 10 | A union of democratic change |

### *2.2.2. Specific bioeconomy strategies and action plans*

The idea to consider, in a common context, various sectors of the economy that produce, process and reuse renewable biological resources has been discussed in Europe since the middle of the last decade (EC 2012b). Conferences organised under the British (2005), German (2007) and Belgian (2010) EU presidencies paved the way towards the preparation by the EC's DG Research and Innovation (EC 2015i) of the bioeconomy strategy and action plan 'Innovating for sustainable growth: a bioeconomy for Europe' (EC 2012a).

The main objectives of the bioeconomy strategy and action plan (EC 2012a) are tackling current societal challenges (see Section 2.2.1.).

The action plan focuses on three areas:
1. investment in research, innovation and skills;
2. reinforcement of policy interaction and stakeholder engagement;
3. enhancement of markets and competitiveness in bioeconomy sectors.

The bioeconomy strategy seeks synergies and respects complementarities with other policy areas (see Table 4, Sections 2.2.3. to 2.2.5.).

The bioeconomy strategy is currently under review. A bioeconomy manifesto is being drafted by selected stakeholders and is foreseen to define helpful stakeholder actions on the bioeconomy.

In the communication 'Towards a circular economy: a zero waste programme for Europe' (EC 2014e), the EC made a commitment to 'examine the contribution of its 2012 bioeconomy strategy to the circular economy and consider updating it if necessary'. The Council of the European Union made a similar request in the conclusions of the EU action plan for the circular economy (Council of the EU 2016).

Bioeconomy (or bioeconomy-related) strategies also exist or are being developed in many of the EU Member States (see Figure 1) and their regions (see Table 9). Bioeconomy strategies have also been established at international level (e.g. OECD bioeconomy agenda, OECD 2006) and in many third countries (German Bioeconomy Council 2016).

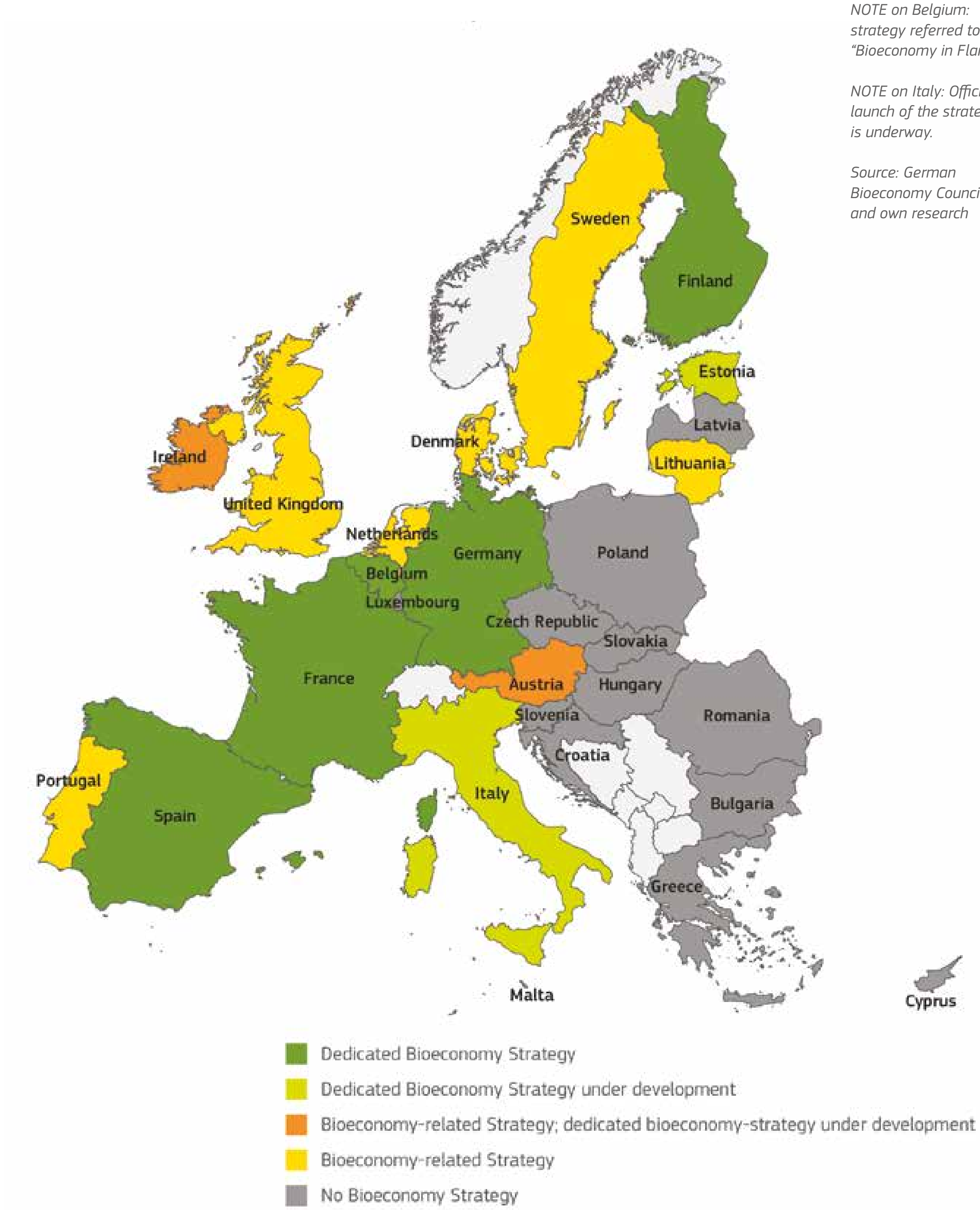



***Figure 1:*** *National strategies in the EU*

*NOTE on Belgium: strategy referred to is "Bioeconomy in Flanders"*

*NOTE on Italy: Official launch of the strategy is underway.*

*Source: German Bioeconomy Council and own research*

***Table 4:***
*EU policy strategies relevant for the bioeconomy*

| Strategies relevant to the bioeconomy | |
|---|---|
| **Bioeconomy horizontal** | - Commission communication 'Innovating for sustainable growth: a bioeconomy for Europe' (EC 2012a) |
| **Sectors supplying biomass** | |
| **Agriculture** | - Commission communication 'The CAP towards 2020: meeting the food, natural resources and territorial challenges of the future' (EC 2010d) |
| **Forestry** | - Commission communication 'A new EU forest strategy: for forests and the forest-based sector' (EC 2013a)<br>- Commission staff working document 'Multiannual implementation plan of the new EU forest strategy' (EC 2015a) |
| **Fisheries, aquaculture and algae** | - Commission communication 'Reform of the common fisheries policy' (EC 2011b)<br>- Commission communication 'Blue growth: opportunities for marine and maritime growth' (EC 2012e)<br>- Commission communication 'Strategic guidelines for the sustainable development of EU aquaculture' (EC 2013e) |
| **Waste** | - See cross-cutting policies (below) |
| **Sectors using biomass** | |
| **Food security** | - Commission communication 'An EU policy framework to assist developing countries in addressing food security challenges' (EC 2010e)<br>- Commission communication 'Increasing the impact of EU development policy: an agenda for change' (EC 2011c)<br>- Commission communication 'Enhancing maternal and child nutrition in external assistance: an EU policy framework' (EC 2013b)<br>- Commission communication 'The EU approach to resilience: learning from food security crises' (EC 2012c) |
| **Bioenergy** | - Commission communication 'An energy policy for Europe' (EC 2007a)<br>- Commission communication 'A European strategic energy technology plan (SET-plan) – Towards a low carbon future' (EC 2007b)<br>- Commission communication 'Limiting global climate change to 2 degrees Celsius – The way ahead for 2020 and beyond' (EC 2007c)<br>- Commission communication 'Energy 2020 – A strategy for competitive, sustainable and secure energy' (EC 2010f)<br>- Commission communication 'Energy roadmap 2050' (EC 2011d)<br>- Commission communication 'A policy framework for climate and energy in the period from 2020 to 2030' (EC 2014a)<br>- Commission communication: 'Accelerating Europe's transition to a low-carbon economy' (EC 2016k)<br>- Commission communication 'The role of waste-to-energy in the circular economy', (EC 2017a) |
| **Bio-based industries** | - Commission communication 'A lead market initiative for Europe' (EC 2007d)<br>- Commission communication 'Preparing for our future: developing a common strategy for key enabling technologies in the EU' (EC 2009)<br>- Commission communication: 'A stronger European industry for growth and economic recovery' (EC 2012d)<br>- Commission communication 'For a European industrial renaissance' (EC 2014f)<br>- Future strategy on plastics use, reuse and recycling (EC 2016l) |
| **Cross-cutting policies relevant for the bioeconomy** | |
| **Climate change and energy** | - See bioenergy (above) |
| **Circular economy – Waste** | - Commission communication 'Towards a circular economy: a zero waste programme for Europe' (EC 2014e)<br>- Commission communication 'Closing the loop – An EU action plan for the circular economy' (EC 2015b)<br>- Commission communication 'The role of waste-to-energy in the circular economy' (EC 2017a)<br>- Future strategy on plastics use, reuse and recycling (EC 2016l) |
| **Regional policies – Smart specialisation** | - Commission communication 'Regional policy contributing to smart growth in Europe 2020' (EC 2010g) |
| **Research and innovation** | - Commission communication 'Europe 2020 flagship initiative – Innovation union' (EC 2010a) |

### *2.2.3. Sectors supplying biomass*

The **agriculture, forestry, fisheries, aquaculture and algae** sectors are the main suppliers of biomass. In all three sectors, strategic documents have been developed under the relevant Europe 2020 flagship initiatives (EC 2010c, 2013a, 2011b and 2012e; see Table 2). The objectives formulated in the documents are very similar and all include sustainable and inclusive growth, stimulating innovation, sustainable exploitation of resources, resource efficiency, rural development and climate change mitigation and adaptation.

In the field of agriculture and fisheries policy, reforms supported by the strategic documents have taken place (see Section 2.3.1.). The new CAP and CFP apply for the period 2014-2020. The EC intends to boost the aquaculture sector through the CFP reform and strategic guidelines for the sustainable development of EU aquaculture (EC 2013e) and the 'Blue growth' strategy (2012e). The latter also recommends exploring the use of algae as a source of biofuels with high added-value chemicals and bioactive compounds. In the field of forestry, where no common policy exists (see Sections 2.1. and 2.3.1.), the strategy was complemented by a multiannual implementation plan (Forest MAP; EC 2015a).

A further source of biomass with increasing importance is **waste** coming from the agricultural, forestry and fishery sectors, but also from other sources such as households or manufacturing (see Section 2.2.4.).

### *2.2.4. Sectors using biomass*

#### *Food and feed*

Food security has been identified as a main societal challenge, taking into account among others unprecedented growth of the world population and the 2008 and 2011 food crises which followed surges of global food prices.

Guaranteeing long-term food security for European citizens and contributing to growing global food demand are at the heart of the CAP 2020 strategy (EC 2010d). Although they do not explicitly mention the term 'feed security', sustainable production of feed has an impact on food security as well. The bioeconomy strategy (EC 2012a) stresses the need to reconcile the competition of different sectors (food, feed and industrial uses) for biomass.

With the 2011 agenda for change (EC 2011c), the EU defined food security as a strategic priority for EU development policy. Since 2010, a comprehensive policy framework has been adopted to promote food security (EC 2011c) and combat malnutrition (EC 2013b), complemented by a strategy for promoting resilience in regions prone to food crisis (EC 2012d).

#### *Bioenergy*

Starting in 2007, several strategic policy documents (see EC 2007a, 2007b and 2010f) were introduced that promote the use of renewable energy (which includes bioenergy) and combat climate change. The following ambitious energy and climate change objectives for 2020 have been defined:

- to limit the global average temperature increase to less than 2 °C compared to pre-industrial levels;
- to reduce greenhouse gas (GHG) emissions by 20 % compared to the 1990 levels;
- to increase the share of renewable energy to 20 %;
- to reach at least a share of 10 % of transport fuels coming from renewable sources;
- to improve energy efficiency by 20 %.

A policy framework for climate and energy for the period from 2020 to 2030 (EC 2014a) defined the targets for 2030 ([2]):

- 40 % reduction of GHG emissions compared to 1990 levels;
- at least 27 % share of renewable energy;
- 27 % improvement in energy efficiency.

The EU has set itself a long-term goal of reducing GHG emissions by 80-95 % by 2050 compared to 1990 levels. The 'Energy roadmap 2050' (EC 2011d) explores the possible transition of the energy system in ways that would be compatible with this target while also increasing competitiveness and security of supply. Bioenergy is expected to have an important role in this development. The roadmap also emphasises the need to invest in new renewable technologies, such as ocean energy, concentrated solar power and second and third generation biofuels, and to improve existing ones, such as offshore wind turbines and photovoltaic panels.

The *EU reference scenario 2016* report (Capros et al. 2016) provides an outlook which projects energy, transport and GHG emissions trends in the EU up until 2050.

On 20 July 2016, the EC published a low-carbon economy package comprising:

- a legislative proposal for a regulation on the inclusion of GHG emissions and removals from land use, land-use change and forestry (LULUCF) into the 2030 climate and energy framework, covering the period 2021-2030;
- a legislative proposal for a regulation on binding GHG emission reductions for Member States (2021-2030) – 'effort-sharing' regulation;
- a communication 'A European strategy for low-emission mobility'.

2 EC (2014c) provides the impact assessment accompanying the Commission communication 'A policy framework for climate and energy in the period from 2020 to 2030'.

***Bio-based chemicals and materials***

Bio-based products are wholly or partly produced from biomass. They include products which were traditionally made from biomass, such as paper and textile. Product groups such as detergents, chemical building blocks and polymers, traditionally produced from fossil oil, are also increasingly based on biomass through novel value chains such as fermentation and biocatalysis. There is no policy strategy specifically dedicated to the bio-based industry. However, bio-based products and industrial biotechnology have been identified as selected market and selected technology under the following initiatives.

- The 'lead markets initiative for Europe' 2008-2011 (LMI, EC 2007d) aimed to support the uptake of six selected sectors, including the bio-based products market, by using policy instruments such as regulation, public procurement and standardisation.
- In 2009, five key enabling technologies (KETs), including industrial biotechnology, were identified by the KETs strategy (EC 2009) in order to support their implementation through state aid policies, lead markets, public procurement, trade policy, the European Investment Bank (EIB) financing instrument and venture capital financing, etc. ([3]).
- The communication 'A stronger European industry for growth and economic recovery' (EC 2012d) has identified bio-based product markets as one of the priority action lines aiming at speeding up the development of standards and their international recognition, promoting labelling and green public procurement and developing detailed proposals for a bioeconomy public–private partnership (PPP) (see Section 2.4.1. BBI JU).
- The communication 'For a European industrial renaissance' (EC 2014f) identified bio-based products as a strategic cross-cutting area. Priority should be given to 'granting access to sustainable raw materials at world market prices for the production of bio-based products. This will require the application of the cascade principle in the use of biomass and eliminating any possible distortions in the allocation of biomass for alternative uses that might result from aid and other mechanisms that favour the use of biomass for other purposes (e.g. energy)'.

There are no specific EU strategies in other sectors which traditionally use biomass, such as the **textile, wood and wooden furniture and pulp and paper sectors** (see also Chapter 3). However, they are co-vered by cross-cutting initiatives and policies such as the raw material initiative (EC 2008b), which emphasises the scarcity of biomass and the circular economy package.

### 2.2.5. Cross-cutting policies relevant for the bioeconomy

***Climate change and energy***

Climate change policy is closely connected with energy policy, since the biggest share in GHG emissions comes from energy production and use (see discussion above in Section 2.2.4.). The agriculture and forestry policy strategies (EC 2010d and 2013a) particularly emphasise the importance of carbon sequestration and reduction of GHG emissions, respectively. Bio-based products and industrial biotechnology are expected to contribute significantly to a low-carbon economy (EC 2007a, 2009a and 2012d).

***Circular economy – Waste***

The linear economic model of 'take-make-dispose' has proven to be unsustainable (EC 2015b). In contrast, the circular economy approach aims to maintain the value of products and materials for as long as possible whilst minimising resource use and gene-ration of waste.

In December 2015 the EC adopted the circular economy package (EC 2015b), which includes revised legislative proposals on waste (see Section 2.3.3.) as well as an action plan for the circular economy (EC 2015b).

The action plan acknowledges the potential of the bioeconomy to contribute to the circular economy by providing alternatives to fossil-based products and energy. Bio-based materials may also present advantages linked to their renewability and, if applicable, biodegradability or compostability. On the other hand, just as for other resources, using biological resources requires attention to their life-cycle environmental impacts, including sustainable sourcing. The strategy formulates the following actions concerning bio-based materials:

- guidance and dissemination of best practices on the cascading use of biomass and support for innovation in the bioeconomy;
- propose a target for recycling wood packaging and a provision to ensure the separate collection of biowaste.

In the communication 'Towards a circular economy: a zero waste programme for Europe' (EC 2014e), the EC made a commitment to 'examine the contribution of its 2012 bioeconomy strategy to the circular economy and consider updating it if necessary'. The Council made a similar request in the conclusions of the EU action plan for the circular economy (Council of the EU 2016).

3 The KETs Observatory provides information (quantitative and qualitative) on the performance of EU Member States and competing economies regarding the deployment of KETs (https://ec.europa.eu/growth/tools-databases/kets-tools/kets-observatory). Detailed information on the methodology used by the KETs Observatory to collect data on technology, production, demand, trade, business and composite indicators can be found in the methodology report (EC 2015c).

***Regional policies – Smart specialisation***
Under the 'Research and innovation strategies for smart specialisation' (RIS3; EC 2010g), the design of national/regional research and innovation strategies for smart specialisation is encouraged. This should lead to an integrated approach towards smart growth in all regions (see also Sections 2.3.3. and 2.4.2.).

***Research and innovation***
Research and innovation is at the heart of the flagship initiative 'Innovation union' (EC 2010a).

Many other horizontal policies such as environmental (including water), industrial, trade or internal market policies also have an impact on the bioeconomy. However, their discussion would exceed the scope of this report.

## 2.3. Legislation

The number of legislative acts in the policy sectors that are relevant for the bioeconomy is high (e.g. 2741 for agriculture, 1420 for fisheries, etc.) (EUR-Lex n.d.b). Therefore, it is only possible to take into account main legislative acts with immediate impact on the bioeconomy.

No specific EU bioeconomy legislation exists. However, sectorial legislation, which in many cases is considerably older than the bioeconomy concept, has major impact in the field.

### *2.3.1. Sectors supplying biomass*

***Agriculture***
Several environmental measures have been integrated into the CAP which is financed by two funds (EU 2013a):

*1. European Agricultural Guarantee Fund (EAGF)*

a) Direct payments to farmers (EU 2013b)
- Payments are 'decoupled' from the crop produced. Farmers now choose what type of biomass to produce on the basis of the likely return from the market, rather than on the basis of public support provided (as in previous times).
- Cross-compliance (EU 2014a) is a mechanism that links direct payments to farmers to compliance with basic standards concerning the environment, food safety, animal and plant health and animal welfare, as well as the requirement of maintaining land in good agricultural and environmental conditions (as defined in standards related to soil protection, maintenance of soil organic matter and structure, avoiding the deterioration of habitats and water management).
- In order to receive green direct payments (accounting for 30 % of the direct payment budget), farmers need to adopt practices that benefit the environment and climate, such as (i) diversify crops, (ii) maintain permanent grassland, and (iii) dedicate 5 % of arable land to 'ecologically beneficial elements' ('ecological focus areas' such as fallow land, hedges and trees).

b) Market measures (EU 2013c)
- These provide for, *inter alia*, public intervention in the case of market failure (e.g. buying in through the competent authorities of Member States and storage of products). This helps to stabilise biomass prices.

*2. European Agricultural Fund for Rural Development (EAFRD, EU 2013d)*
- This fund finances so-called agri-environment-climate measures.

These measures affect the availability, prices and price stability of biomass and the environmental impact of bioeconomy value chains using agricultural raw materials.

***Forestry***

There is no common forestry policy for the EU and therefore specific forestry legislation is dealt with at Member State level. At EU level, general principles are defined in the forest strategy (see also Section 2.2.3.) and forest-related provisions are also included in the harmonised legislation of related sectors, especially the environment (e.g. Birds (EU 2009d) and Habitats (EEC 1992) Directives) and rural development sectors (rural development funding as a funding instrument for forestry).

***Fisheries, aquaculture and algae***

The CFP is a set of rules for managing European fishing fleets and for conserving fish stocks (EU 2013e). It was first introduced in the 1970s and went through successive updates; the most recent took effect on 1 January 2014. The CFP has four main policy areas.

- Fisheries management – The current legislation stipulates that between 2015 and 2020, catch limits that are sustainable and maintain fish stocks in the long term should be set (EU 2013e). The practice of throwing unwanted fish back into the sea was prohibited with a so-called landing obligation (EU 2015a).
- International policy – The operation of European fishing boats outside EU waters and the international trade in fisheries products (the EU establishes autonomous tariff quotas for certain fish and fish products) are regulated.
- Market organisation – This includes marketing standards, consumer information, competition rules and marketing intelligence (EU 2013f).
- European Maritime and Fisheries Fund – One of the five ESIF (EMFF; EU 2014b) (see also Section 2.4.2.).

These measures have, *inter alia*, an important impact on the availability and prices of fish as a feedstock for the bioeconomy.

***Waste***

See circular economy, Section 2.3.3.

### *2.3.2. Sectors using biomass*

***Food and feed***

Food and feed need to comply with EU food and feed safety legislation (EU 2002) to ensure that they do not endanger the health of consumers and of livestock. This includes veterinary and plant health requirements. Contrary to the existence of this very comprehensive legislation on food and feed safety, there is currently no EU food and feed security legislation, i.e. on ensuring food availability and access, or nutrition security legislation.

***Bioenergy***

The Renewable Energy Directive (RED; EU 2009a) transposed the energy targets for 2020 (see Section 2.2.4.) into specific legislation for the sector. Key information is summarised in Table 5.

***Bio-based chemicals and materials***

There is currently no specific EU legislation for bio-based chemicals and materials. However, they have to comply with requirements for chemicals and materials in general, especially the regulatory framework for the management of chemicals (REACH, EU 2006). The European Chemicals Agency manages this integrated system for the registration, evaluation, authorisation and restriction of chemicals.

***Textile, wood and wooden furniture and pulp and paper sectors***

There is no specific legislation for these sectors that traditionally use biomass. They are subject to the more generally applicable legislation such as product safety standards and internal market legislation.

### *2.3.3. Cross-cutting policies relevant for the bioeconomy*

***Climate change and energy***

The sectors of activity in the bioeconomy are responsible for a significant share of the GHG emissions (Eurostat, 2016). For most of the economic activities, reduction of GHG emissions could be achieved either by using improved approaches for biomass production or by switching from fossil sources to sustainable biomass sources for energy, transport fuels and manufacturing of materials and products. However, potential competition for land used for primary production and competition for biomass-using sectors are limiting factors that need to be taken into account.

Key information on the most important climate change and energy legislation in the context of this report is summarised in Table 5.

***Circular economy – Waste***

The EU waste legislation includes the Waste Framework Directive (EU 2008) and many further legal acts regulating the shipments and the management of waste including incineration and landfills (EC n.d.a).

In 2015 the circular economy package (EC n.d.b) was adopted, which includes revised legislative proposals on waste (EC 2015j) and defines the following targets:

***Table 5:***
*Main EU climate change legislation*

*Source: EC (2016a)*

| | |
|---|---|
| **Emissions trading system – ETS (EU 2003)** | |
| **Principle and target** | - Works on the 'cap and trade' principle (4)<br>- Aims for emissions from covered sectors to be 21 % lower in 2020 than in 2005<br>- Limits emissions from more than 11 000 heavy energy-using installations (power stations and industrial plants) and airlines operating between these countries<br>- Sets aside 300 million allowances in the new entrants reserve programme to fund the deployment of innovative renewable energy technologies and carbon capture and storage |
| **Connection to bioeconomy** | - Use of certain types of bioenergy (one type of renewable energy) can help to achieve GHG emissions reduction targets (5) |
| **Effort-sharing decision – ESD (EU 2009e)** | |
| **Principle and targets** | - Member States have to define and implement appropriate national policies and measures in order to meet the targets established<br>- By 2020, the national targets, which have been set on the basis of Member States' relative wealth, will collectively deliver a reduction of around 10 % in total EU emissions from the sectors covered compared with 2005 levels<br>- Covers most of the sectors not in the ETS such as housing, agriculture, waste and transport (aviation, international shipping and LULUCF not included) |
| **Connection to bioeconomy** | - Use of certain types of bioenergy instead of fossil energy can help Member States achieve GHG emissions reduction targets |
| **Renewable energy directive – RED (EU 2009a) / Fuel quality directive – FQD (EU 2009b)** | |
| **Principle and targets** | - A share of at least 20 % of renewable energy in the final consumption of energy in the EU to be achieved through the attainment of individual national targets by 2020<br>- A share of at least 10 % of fuels from renewable sources in the final consumption of energy in transport in all EU Member States by 2020<br>- 6 % GHG reduction for the fuels used in transport in 2020<br>- RED and FQD include sustainability criteria for biofuels produced or consumed in the EU. Companies can show that they comply with the sustainability criteria through national systems or so-called voluntary schemes recognised by the EC |
| **Connection to bioeconomy** | - Setting targets for renewable energy and transport fuel shares promotes the uptake of renewable energy, including bioenergy |

- to increase the recycling target for municipal waste to 65 % by 2030;
- to gradually limit the landfilling of municipal waste to 10 % by 2030.

The circular economy package also includes several support actions that should help operators and thus Member States meet the targets for construction and demolition waste such as pre-demolition assessment guidelines for the construction sector, a voluntary industry-wide recycling protocol for construction and demolition waste and core indicators for the assessment of the lifecycle environmental performance of a building and incentives for their use.

The bioeconomy promotes the enhanced use of waste in existing value chains as well as the creation of innovative value chains using organic waste. This will result in an efficient bioeconomy approach and a reduction of waste at the same time.

### *Regional policies*

The ESIF (EU 2013g) consists of five main funds which support economic development across all EU countries, in line with the objectives of the Europe 2020 strategy (EU 2013h, 2013i, 2013e and 2014b). For further information see Section 2.4.2., Table 10.

4 A cap is set on the total amount of certain GHGs that can be emitted by installations covered by the system. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. They can also buy limited amounts of international credits from emission-saving projects around the world.

5 For the accounting for carbon dioxide emissions of biofuel, see Agostini et al. (2014) and EC (2016m), Chapter 2.1. and Annex 7.

### *Research and innovation*

Funding for research is provided at EU, national and regional levels. Financial instruments for the implementation of the Europe 2020 strategy and Juncker's priorities are Horizon 2020 (EU 2013j) and the EFSI (EU 2015b).

Many other horizontal policies such as environmental (including water), industrial, trade or internal market policies also have an impact on the bioeconomy. However, their discussion would exceed the scope of this report.

## 2.4. EU funding for bioeconomy research, innovation and investment

European funding for research and innovation is provided through a constellation of interlinked programmes. In 2014-2020, most funding comes from Horizon 2020 and the ESIF (Table 6; section 2.4.2.) (EC 2015d).

Horizon 2020, the financial instrument implementing the innovation union, is the largest programme and is fully dedicated to financing research, development and innovation activities across all policy fields. Other programmes that do not directly fund R&I activities are also connected (EP 2015a), such as COSME, the EU funding programme for smalland medium-sized enterprises (SMEs) (EU 2013k). Horizon 2020 funding can be combined with other EU funding instruments (EU 2013g: Art. 65(11); EU 2013g: Art.37).

In addition, the EFSI (Section 2.4.3.) implements the Juncker Commission's investment plan for areas like infrastructure, research and innovation and financing SMEs.

***Table 6:*** *Overview of main R&I financial instruments that include or can include actions on bioeconomy*

| | Research, development and innovation | Growth, jobs and cohesion |
|---|---|---|
| Management<br>Central (financial regulation)<br>Implementation<br>EU level | Horizon 2020<br>2014-2020<br>EUR 74.8 billion from the EU budget in current prices<br>(EU 2013j; EU 2015b) | |
| Management<br>Shared with Member States (common provisions regulation)<br>Implementation<br>National/regional level | EUROPEAN STRUCTURAL AND INVESTENT FUNDS (ESIF)<br>2014-2020<br>EUR 454 billion from the EU budget – EUR 637 billion with national co-financing included<br>(EU 2013g; EC [EU 2013g; EC 2015e]) | |
| Set-up<br>EIB-EIF<br>Implementation<br>Financial intermediaries | EUROPEAN FUND FOR STRATEGIC INVESTMENTS (EFSI)<br>2014-2017<br>Plan to mobilise EUR 315 billion in investment (EU 2015b) | |

Besides these three main blocs, NER 300 (EUR 3 million) funds innovative low-carbon energy demonstration projects and innovative renewable energy, while the LIFE programme 2014-2020 (EUR 3.4 billion (current prices)) aims at supporting environmental, nature conservation and climate action projects.

In November 2016, an investment package of EUR 222.7 million was approved from the EU budget to support Europe's transition to a more sustainable and low-carbon future (EC 2016q).

### *2.4.1. Horizon 2020*

The knowledge-based bioeconomy (KBBE) concept was explicitly included in the 7th framework programme for research and technological development (FP7, 2007-2013). Bioeconomy remains an important part of the current research framework programme, Horizon 2020 (2014-2020). In table 7, the Horizon 2020 areas that are related to bioeconomy are highlighted in blue.

***Horizon 2020 pillars***

Roughly estimated, around 5.6% of Horizon 2020 (6) is directly allocated to support the bioeconomy and its cross-cutting nature, mainly under the following.

***Table 7:*** *Horizon 2020 financial instrument*

| | **Research, development and innovation** |
|---|---|
| **Management**<br>**Central (financial regulation)**<br>**Implementation**<br>**EU level** | Horizon 2020<br>2014-2020<br>EUR 74.8 billion* (EU 2013j; EU 2015b) |

- Includes all EU research initiatives under one structure
- Focuses on three main priorities (EC 2016n): support for excellent science, support for industrial leadership and support
  for research in order to tackle seven societal challenges
- In addition to the EC and its Research Executive Agency, other bodies such as the **European Institute of Innovation and Technology** (EIT), the **JRC** and the **EIB** also implement parts of the actions funded by Horizon 2020

**HORIZON 2020 PILLARS**

| **Excellent science (EUR 24 232 million)**** | **Industrial leadership (EUR 16 467 million)**** | **Societal challenges (EUR 28 630 million)**** |
|---|---|---|
| European Research Council | Leadership in enabling and industrial technologies (LEIT) | 1. Health, demographic change and well-being |
| Future and Emerging Technologies | ICT | 2. Food security; sustainable agriculture and forestry; marine, maritime and inland water research; and the bioeconomy (EUR 3.7 billion) |
| Research infrastructures | Nanotechnology | 3. Secure, clean and efficient energy |
| Marie Skłodowska-Curie actions | Biotechnology (EUR 501 million) | 4. Smart, green and integrated transport |
| | Advanced materials | 5. Climate action, environment, resource efficiency and raw materials |
| | Advanced manufacturing and processing | 6. Europe in a changing world – Inclusive, innovative and reflective societies |
| | Space | 7. Secure societies |
| | Access to risk finance | |
| | Innovation in SMEs | |

| **FURTHER FIELDS/STRUCTURES FUNDED BY HORIZON 2020** |
|---|
| Spreading excellence and widening participation (EUR 817 million) |
| Science with and for society (EUR 445 million) |
| Non-nuclear direct actions of the JRC (EUR 1 856 million) |
| The EIT (EUR 2383 million) |

* This includes EUR 70.3 billion operational budget (Source: DG Research and Innovation Unit R2)

** EUR million in current prices

■ Most topics are relevant to the bioeconomy
■ Some topics are relevant to the bioeconomy

6 i.e. EUR 37078 million from Horizon 2020's second societal challenge + EUR 501 million from LEIT biotechnology = EUR 4208 million for bioeconomy (Horizon 2020 total: EUR 74828 million).

***A. Societal challenges (SC)***

Horizon 2020 reflects policy priorities of the Europe 2020 strategy by grouping funding in 'societal challenges'. Out of seven challenges, four are relevant to the bioeconomy.

**2 – Food security; sustainable agriculture and forestry; marine, maritime and inland water research; and the bioeconomy**

This challenge aims at accelerating the transition to a sustainable European bioeconomy through sufficient supplies of safe and high-quality food and bio-based products, productive and resource-efficient primary production systems and competitive and low-carbon supply chains (EC 2016n) through research and innovation, application and demonstration. The BBI JU (Box 4) receives approximately 28% (Figure 2).

The following challenges address bioeconomy to a lesser extent.

**3 – Secure, clean and efficient energy**

This challenge supports, *inter alia*, actions on bioenergy as part of 'the transition to a reliable, affordable, publicly accepted, sustainable, competitive and efficient low-carbon energy system' (EC 2016n) with reduced fossil fuel dependency (EC 2016c).

**4 – Smart, green and integrated transport**

This challenge targets the achievement of a transport system that is resource efficient, climate-and environment-friendly (EC 2016n) and supports, *inter alia*, actions facilitating the introduction and use of biofuels (EC 2016d).

**5 – Climate actions, environment, resource efficiency and raw materials**

This challenge supports activities on achieving an economy and society that are resource and water efficient and climate change resilient, a management of natural resources and ecosystems that are sustainable, and supply and use of raw materials that are sustainable in order to meet the needs of a growing global population within the sustainable limits of the planet's natural resources and ecosystems (EC 2016n).

The societal challenge pillar of the Horizon 2020 work programme 2016-2017 (EC 2016e) is also related to the cross-cutting initiative 'Industry 2020 in the circular economy'. It will grant over EUR 650 million for innovative demonstration projects that support the objectives of the circular economy and the industrial competitiveness by taking a systemic approach to eco-innovation and addressing resource efficiency and the reuse of products and product life cycles (EC 2016f).

***B. Industrial Leadership***

This pillar supports, inter alia, actions on **LEIT** by supporting KETs. One KET focuses specifically on technology development and on the demonstration of biotechnologies (EC 2016g).

The industrial leadership pillar also provides financing tools for R&I actions (access to risk finance) (Section 2.4.1.), especially in the private sector (companies, research centres, PPPs, joint ventures, etc.), and for developing innovative SMEs.

The Horizon 2020 work programme's key priorities for 2017 that are related to the bioeconomy are linked to policy areas such as the **new boost for jobs, growth and investment** (with a focus on SMEs and PPPs), **a resilient energy union with a forward-looking climate change policy** (including water and greening the economy and the food 2030 initiative) and **a deeper and fairer internal market with a strengthened industrial base** (such as 'Industry 2020 in the circular economy'), in addition to other cross-cutting initiatives (EC 2016i).

***An analysis of Horizon 2020 bioeconomy-related projects funded by the Horizon 2020 budget***

The *Horizon 2020 monitoring report 2015* highlights that 268 grants have been signed under the second societal challenge (grants issued with calls in 2014 and 2015, with the cut-off date for signed grants being 1.9.2016), representing a total EU contribution of EUR 748.7 million (EC 2016n).

Going into more detail, the following analysis (Figure 2 to Figure 5) shows the topics (divided under six priority activities) and projects funded and foreseen to be funded by Horizon 2020's second societal challenge and through the BBI JU (PPPs). It takes into consideration 233 topics included under the relevant annual work programmes and project-related information referring to 250 projects being funded under Horizon 2020 since 2014. 135 projects are funded through the SME instrument (related to marine and agri-food projects) and are mainly close to market activities.

In terms of the type of organisation, the funding of the second societal challenge is primarily allocated to academia, higher education and research organisations (67%), whilst funding allocated to SMEs represent slightly over one fifth (22%) of overall funding.

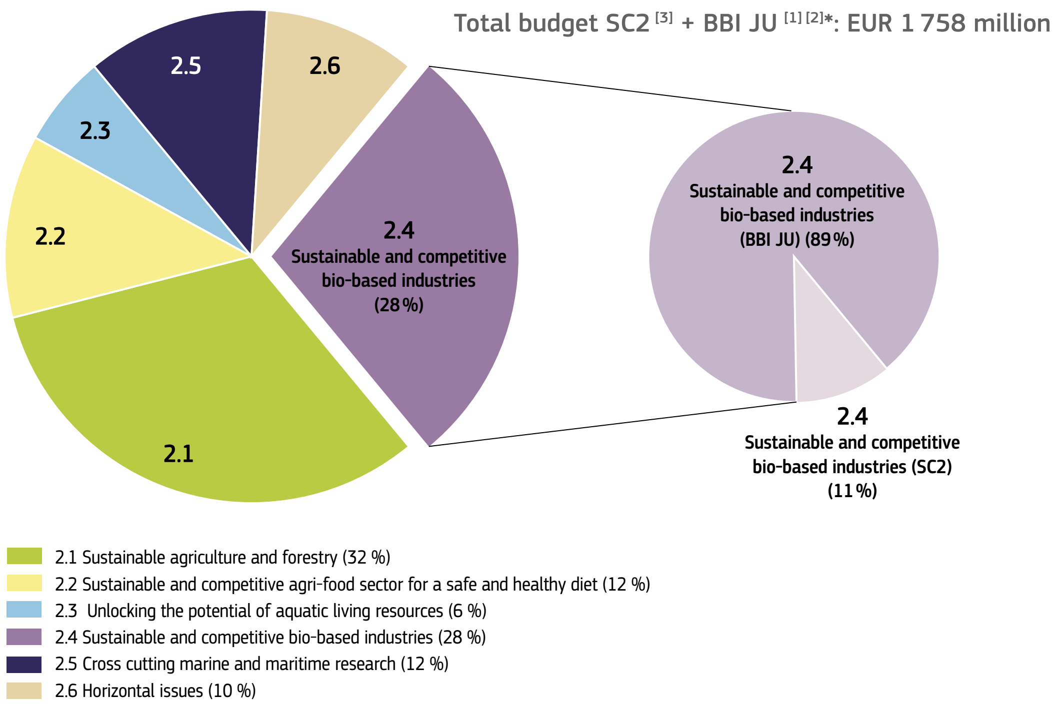



**Figure 2:** *Horizon 2020: 2014-2017 work programme budget analysed by activity, including the breakdown of Activity 2.4. between SC2 and BBI JU funding (%)*

*Source: DG Research and Innovation Unit F1*

This information is related to the SC2 2014-2015 and 2016-2017 work programmes and the BBI JU 2014-2016 annual work programmes.

[1] The total amount of the budget does not include the year 2017 of the BBI work programme.

[2] Funding under SC2 dedicated to 'other actions' was not included in the budget calculations.

[3] For some topics, the available SC2 budget was topped up with the budget from other societal challenges.

Most of the projects funded under SC2 are related to biorefineries, sustainable primary production, competitiveness of the agri-food chain, food safety, marine observation, marine biotechnologies and cross-cutting technologies (Figure 5).

### *Public–public cooperation under Horizon 2020*

In addition to the 'classic' project approach often used for R&I activities, many initiatives and networks also provide expert input to shaping research and innovation priorities. Article 185 initiatives and European Research Area Networks (ERA-NETs) (EC 2000) have this purpose, as well as Joint Programming Initiatives (JPIs). These initiatives can also receive funding from Horizon 2020. For instance, Horizon 2020 provides funding for national public administrations to implement and coordinate joint programmes in public–public partnerships (P2Ps) through ERA-NET Cofund instrument. The P2Ps also launch their own (not co-funded) activities to complement Horizon 2020 calls.

**Article 185** enables the EU to participate in research programmes undertaken jointly by several Member States.

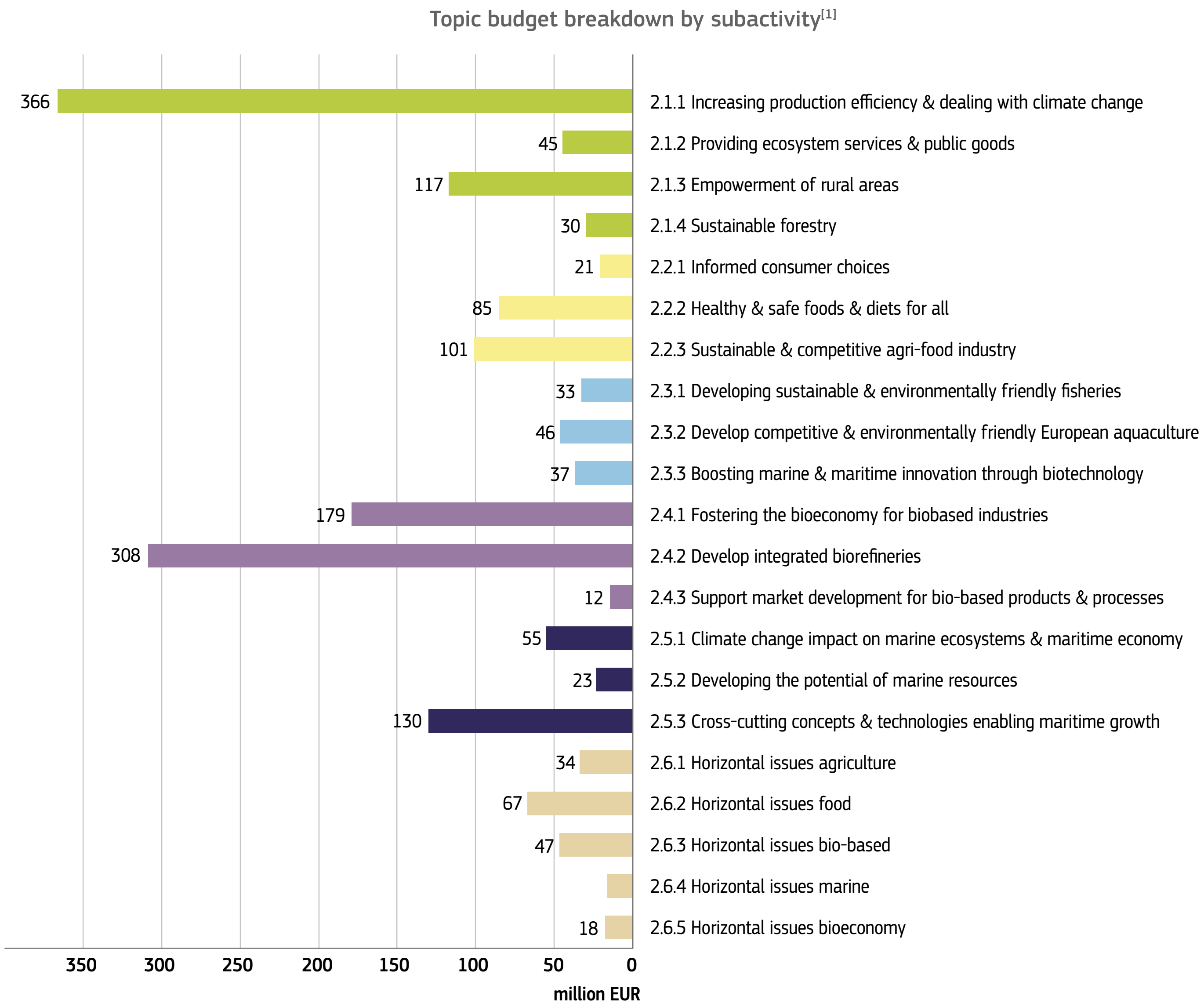
Article 185 BONUS, the Baltic Sea research and development programme (EU 2010) helps integrating national programmes, including on topics related to marine biomass. BONUS is funded with a total of EUR 100 million under FP7 (2011-2017).

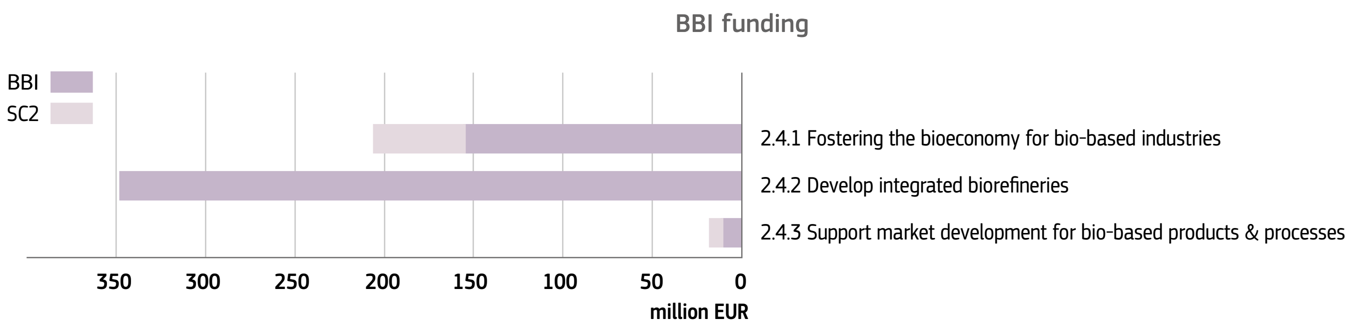
Another partnership starting in 2018 and based on Article 185 is the PRIMA initiative (Partnership for Research and Innovation in the Mediterranean Area), an international partnership for R&I in the Mediterranean basin aimed at the development and application of innovative solutions to optimise the management and use of fresh water for production and processing and to ensure food security. Funding for the EUR 400 million partnership will come from the participating countries matched by a EUR 200 million contribution from the EU through its current research framework programme, Horizon 2020 (EC 2016o).

**ERA-NETs** target the coordination of public research programmes at national and regional level. The PLATFORM project (Box1) is a forum that brings together ERA-NETs and other P2Ps in bioeconomy-relevant fields.

***Figure 3:***
*2014-2017 work programmes topic budget breakdown by subactivity between SC2 and BBI JU (in million EUR)*

*Source: DG Research and Innovation Unit F1*

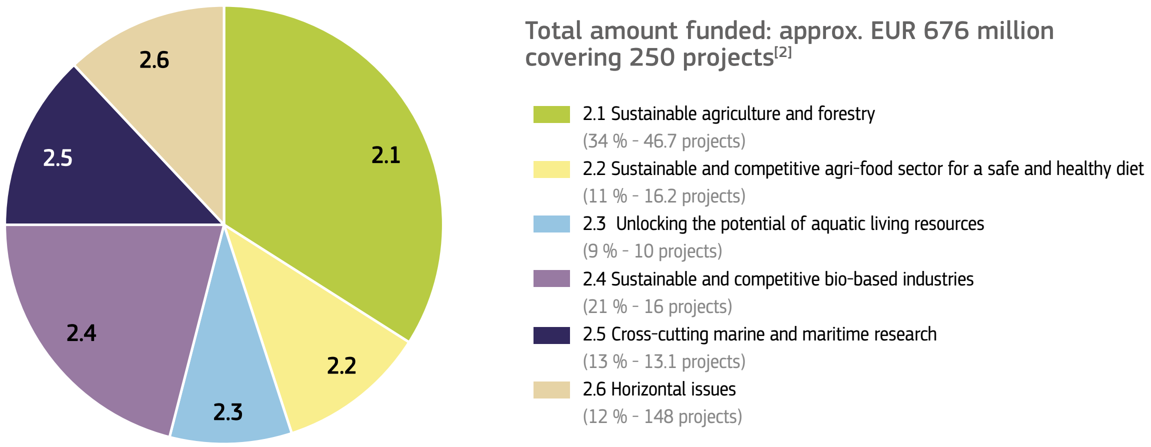



[1] To avoid counting issues twice, the budget of one single topic falling under several areas was split accordingly.

***Figure 4:***
*Projects being funded by Horizon 2020 SC2 and BBI JU in 2014-2015. Breakdown of budget (%) related to number of funded projects [1]*

*Source: DG Research and Innovation Unit F1*



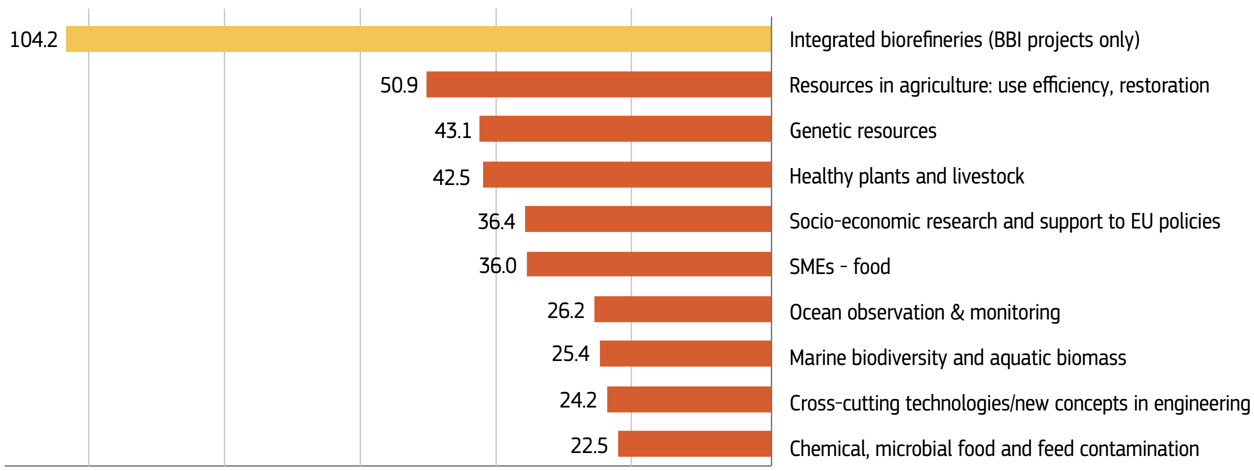

This analysis is based on 250 projects funded in 2014-2015 (SC2 and BBI JU).

[1] The graph includes projects funded in 2014-2015 (SC2 and BBI). However, some projects from the BBI call 2015.2 have not been signed yet (August 2016) and are therefore excluded from this graph.

[2] Projects can be attributed to several activities, which is why project numbers per activity are not always integers.

***Figure 5:***
*Top 10 SC2 research activities/themes for 2014-2015 work programme (in million EUR)[1]*

*Source: DG Research and Innovation Unit F1*




[1] Research activities/topics amounting to at least EUR 20 million in funding.

### Box 1: Platform of Bioeconomy ERA-NET Actions (PLATFORM)



PLATFORM which receives support from the EC under grants of FP7 and Horizon 2020 plays a role in facilitating and improving the coherence between the P2Ps in the bioeconomy. More than 70 ERA-NETs have been set up under the sixth and seventh EU research and innovation framework programmes and Horizon 2020. The network of ERA-NETs, Cofunds([7]) and JPIs is expanding as well as their interactions with, for example, the Standing Committee on Agricultural Research (SCAR), the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) and the BBI JU. Currently more than 30 P2Ps are active in the ERA-NET scheme.

The present **Platform Horizon 2020** project builds on activities developed by **Platform FP7** with actions related to events, workshops, master classes, surveys, analyses and engagement with actors such as ERA-NETs from neighbouring themes with bioeconomy relevance, with JPIs, with SCAR working groups (SCAR WGs) and also with the bioeconomy national contact points. Reflections and recommendations from the PLATFORM events are summarised in policy briefs. As a major information-providing service, PLATFORM FP7 produced a book on the bioeconomy ERA-NETs and their activities, including an overview of all joint calls and data on the funded research projects. PLATFORM Horizon 2020 greatly expanded the information collected to a database on all bioeconomy ERA-NETs and JPIs including the new Cofunds, all together responsible for organising more than 130 calls which fund more than one thousand research projects with budgets ranging between EUR 1 million and EUR 3 million. The database is integrated in the PLATFORM website and also shows call statistics. Impact assessments are on its way, such as on funding leverage.

**More information:** http://era-platform.eu/

In **JPIs**, EU Members States, associated countries and third country members develop common strategic research agendas(SRA) and implementation plans. JPIs are Member States Initiatives that give advice to the EC for the development and implementation of Horizon 2020. The EC has supported JPIs through coordinated and support actions and has done co-funded calls (ERA-NET Cofunds) with JPIs. However the Joint Actions are supported by the Member States;  within a JPI there is no EC funding.

There are 10 priority areas, of which five are linked to bioeconomy themes (see Box 3): the JPI on agriculture, food security and climate change (FACCE-JPI); the JPI A healthy diet for a healthy life (JPI HDHL); the JPI Healthy and productive seas and oceans (JPI Oceans); the JPI on water challenges for a changing world (Water JPI); and the JPI on climate (JPI Climate).

JPIs are open ended, in contrast to ERA-NETs or EU-funded projects.

#### *PPPs*

In addition to public sector activities, the EU also engages in **PPPs** (EC 2013c) to develop the bioeconomy. Examples include the **BBI JU**, a joint technology initiative (JTI) (jointly implemented by the EU and industry) and the contractual PPP **SPIRE** (sustainable process industry through resource and energy efficiency), which is based on an alliance of eight industrial sectors, including chemicals, and hence partially bioeconomy relevant. The total contribution foreseen from the EU budget is EUR 975 million and EUR 900 million, respectively, over the 7-year period of Horizon 2020.

JTIs usually originate in **European technology platforms** (ETPs) (see Box 3). ETPs are independent organisations recognised (but not funded) by the EC and can be involved in PPPs. They organise exchanges between industrial and public researchers and national government representatives about short- to long-term research and innovation agendas and roadmaps to be supported by both private and public funding. A relevant example for the bioeconomy is the ETP SusChem, which aims to provide a link between the chemical industry, industrial biotechnology and stakeholders in the bioeconomy (SusChem 2016).

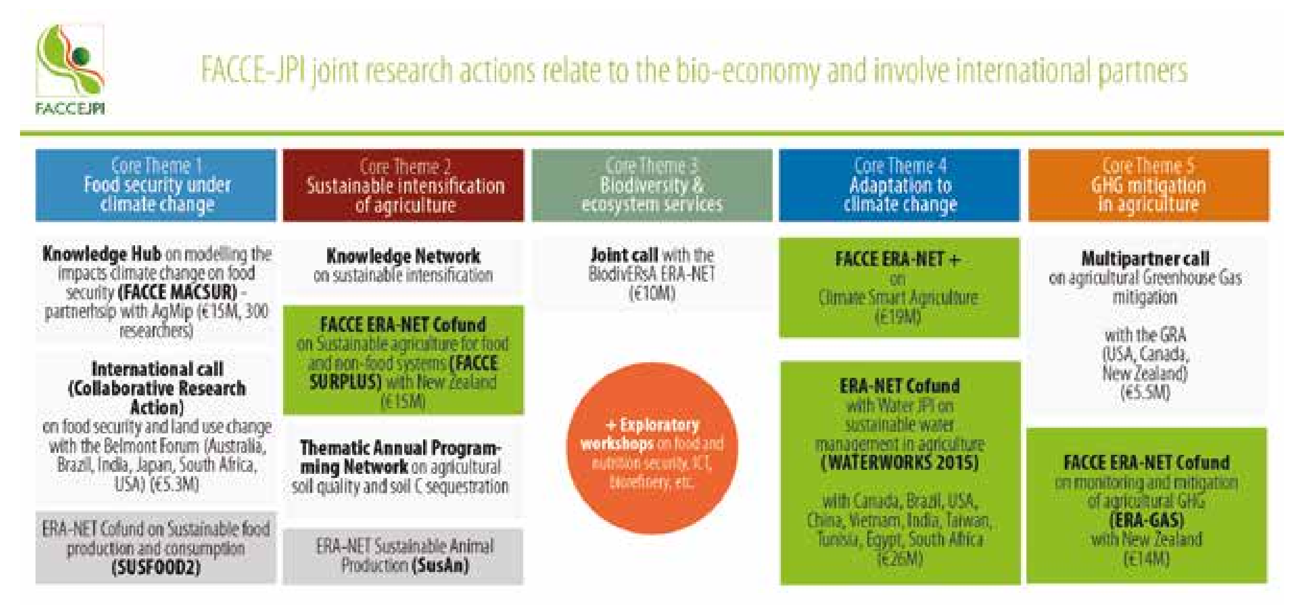
7 ERA-NET Cofund under Horizon 2020 is designed to support public-public partnerships, including JPI between Member States, in their preparation, establishment of networking structures, design, implementation and coordination of joint activities as well as Union topping-up of a trans-national call for proposals.

**Box 2: The FACCE-JPI**



The FACCE-JPI provides and steers research to address the interconnected and bioeconomy-related challenges of sustainable agriculture, food security and impacts of climate change.

The FACCE-JPI SRA describes five core research themes (see figure) and the implementation plans (IP) describe 10 bioeconomy-related joint research actions.




**More information:**
https://www.faccejpi.com/
https://www.faccejpi.com/Strategic-Research-Agenda

### Box 3: List of relevant ERA initiatives and partnering networks

| Initiative | Call | Call name | Research field | | | | |
|---|---|---|---|---|---|---|---|
| | | | Energy | Environment | Food, agriculture, forestry and fisheries | Production and processes | Transport |
| Article 185 | BONUS | The Baltic Sea research and development programme | | ● | ● | | |
| | PRIMA (starting 2018) | Partnership for Research & Innovation in the Mediterranean Area | ● | ● | ● | | ● |
| EIP | EIP Water | European Innovation Partnership on Water | | ● | | | |
| | EIP-AGRI | The Agricultural European Innovation Partnership | | | ● | | |
| | Raw materials | European Innovation Partnership on Raw Materials | | | | ● | |
| | Smart cities and communities | European Innovation Partnership on Smart Cities and Communities | ● | ● | | | ● |
| EIT-KICs | Climate-KIC | Knowledge and Innovation Communities on Climate | | ● | | | |
| | EIT raw materials | European Institute of Innovation and Technology on Raw Materials | | | | ● | |
| | food4future | European Institute of Innovation and Technology on Food | | | ● | | |
| | KIC InnoEnergy | Knowledge and Innovation Communities on InnoEnergy | ● | | | | |
| ETP | EATiP | The European Aquaculture Technology and Innovation Platform | | | ● | | |
| | ETIP Bioenergy | European Technology and Innovation Platform Bioenergy | ● | ● | | | ● |
| | ETPGAH | The European Technology Platform for Global Animal Health | | | ● | | |
| | food for life | The Food European Technology Platform | | | ● | | |
| | FTP | The Forest-based sector Technology Platform | | | ● | ● | |
| | Plants | The Plants for the Future | | | ● | | |
| | RHC | The European Technology and Innovation Platform on Renewable Heating and Cooling | ● | | | | |
| | SusChem | The Technology Platform for Sustainable Chemistry | ● | ● | | ● | |
| | wsstp | The European Water Platform | | ● | | ● | |
| | ZEP | The Zero Emissions Platform | ● | | | | |
| JPI | FACCE JPI | Joint programming initiative Agriculture, Food Security and Climate Change | | ● | ● | ● | |
| | JPI Climate | Joint programming initiative Connecting climate knowledge for Europe | ● | ● | ● | ● | |
| | JPI HDHL | Joint programming initiative A healthy diet for a healthy life | | | ● | ● | |
| | JPI Oceans | Joint programming initiative Healthy and productive seas and oceans | ● | ● | ● | ● | ● |
| | Water JPI | Joint programming initiative Water challenges for a changing world | | ● | | | |

In addition, there are more than 30 ERA-NET and ERA-NET Cofund actions in bioeconomyrelevant research fields, see LINK
**More information:** https://www.era-learn.eu/

Source: ERA-LEARN 2020 adapted

**Box 4: The BBI JU**
© BBI JU, 2016

BBI value chains are fragmented in terms of actors and geographical boundaries. They also face several risks, such as the lack of infrastructure and the need for heavy investments to scale up technologies to an industrial level. New biorefining technologies can help address these challenges.


The BBI JU is a EUR 3.7 billion PPP between the EU, represented by the EC, and the industrial partner, represented by the Bio-based Industries Consortium (BIC).

The **mission** of the BBI JU is to develop BBIs by implementing the strategic innovation and research agenda (SIRA) developed by industry. The **objective** is to **develop sustainable and competitive BBIs in Europe based on advanced biorefineries that sustainably source their biomass**.

What is the focus?

**Feedstock** – Foster a sustainable biomass supply with increased productivity and by building new supply chains.

**Biorefineries** – Optimise efficient processing through R&D and demonstrate their efficiency and economic viability at large-scale biorefineries.

**Products and markets** – Develop bio-based chemicals, building blocks, materials and consumer products and enable their market uptake.

The BBI JU funds large-scale collaborative R&I projects based on a technology-readiness level (TRL) scale (from TRL 3, i.e. the development and validation of technology, to TRL 8, i.e. the industrial scale-up). SIRA is developed by the industry partner, the BIC, in consultation with the EC. Topics for the annual work plans and calls for proposals are drawn from the SIRA and developed under the leadership of the BIC in consultation with the EC, which ensures that public interest is safeguarded.

BBI JU will fund projects aimed at:

- building new cross-sectorial value chains based on the development of sustainable biomass collection and supply systems (incl. co- and by-products);
- unlocking the utilisation and valorisation of waste and lingo-cellulosic biomass;
- bringing existing value chains to new levels through optimised use of feedstock and industrial side-streams while offering innovative value-added products to the market;
- bringing technology to maturity through research and innovation by upgrading and building demonstration and flagship biorefineries.

**More information:**
http://www.bbi-europe.eu/
http://biconsortium.eu/

### Box 5: Blue growth

**EU 'Blue growth' strategy**

The 'Blue growth' strategy (EC 2012e) supports sustainable growth, jobs and innovation in the marine and maritime sectors as a whole, including sectors directly related to the bioeconomy such as renewable energy, biotechnology or aquaculture.
Further bioeconomy-relevant initiatives supporting blue growth include the following two examples.

**The Atlantic Ocean Research Alliance**

This tripartite cooperation (EU, the United States and Canada) was launched in 2013 in order to implement the 'Galway statement on Atlantic Ocean cooperation' signed in 2013 on research to meet scientific and industry needs in the North Atlantic. Priority research areas include topics such as marine biotechnology, aquaculture, environmental observation or the establishment of a knowledge-sharing platform.

**The Bluemed initiative**

This initiative was set up in 2014 to foster the integration of knowledge and efforts of Mediterranean EU Member States and Portugal to jointly create new 'blue' jobs and sustainable industrial growth in the marine and maritime sectors of the Mediterranean Sea. In the 2015 Venice declaration, partners agreed, among other things, to coordinate and integrate efforts to implement the Bluemed strategic research and innovation agenda by actively promoting synergies and complementarities among all stakeholders at local, regional and national level.

**More information:**
http://www.atlanticresource.org/aora/
The Galway Statement: http://ec.europa.eu/research/iscp/pdf/galway_statement_atlantic_ocean_cooperation.pdf
Horizon 2020- and FP7-funded projects supporting the international dimension of the EU Atlantic strategy: http://www.atlanticresource.org/aora/sites/default/files/GalleryFiles/NewsEvents/FocusonAtlanticProjets.pdf
http://europa.eu/rapid/press-release_IP-13-459_en.htm
Bluemed SRIA: https://webgate.ec.europa.eu/maritimeforum/sites/maritimeforum/files/Bluemed%20SRIA_A4.pdf
Venice Declaration on Mediterranean Sea Cooperation: http://www.istruzione.it/allegati/2015/Venice_Declaration_final.pdf

**Box 6: The JRC bioeconomy project in 2017**

The JRC bioeconomy project will continue to contribute to the EU bioeconomy strategy by further developing the biomass project on data, models and analyses of EU and global biomass potential, supply, demand and related sustainability, as well as through the Bioeconomy Observatory and the proposed Bioeconomy Knowledge Centre.

**JRC bioeconomy project in 2017**

| Coordination of the project | |
|---|---|
| **EU Bioeconomy Observatory** | **Bioeconomy Knowledge Centre** |
| Forest-based sector biomass assessment and modelling | |
| Agricultural biophysical biomass assessment (crops and grassland) | |
| Marine algae bioeconomy and commercial fish stock supply assessment | |
| Bioenergy assessment and modelling | |
| Waste assessment and residues | |
| Key trends in the EU bioeconomy | |
| Assessment of environmental impacts | |
| Improved forest management models | |
| Sustainable innovative mobilisation of wood | |

The goal of this graph is to display some specific bioeconomy-related activities (work packages) planned in the JRC bioeconomy project for 2017. Most of the work packages are part of the JRC biomass study ([9]).

***Other bodies implementing Horizon 2020 actions***

Not all the budget for Horizon 2020 is allocated on the basis of competitive calls nor managed via separate calls published under specific partnerships with industry – PPPs – and with Member States – P2P – (EC 2013d). The EC's JRC is mainly an implementing body ([8]) (EPRS 2015b). The EIT and the EIB also implement parts of the actions foreseen in Horizon 2020.

As the EC's science and knowledge service, the JRC contributes to the overall objective of Horizon 2020. It provides scientific and technical support to Union policies. JRC activities are either funded by institutional resources, i.e. operational funding from Horizon 2020, or by competitive resources, i.e. additional funding from policy DGs and grant funding from Horizon 2020 (Box 6).

The EIT is an independent EU body established in 2008 and included in Horizon 2020 in 2013. It integrates the three components of the 'knowledge triangle', i.e. higher education, research and business under KICs and thematic EITs. KICs and thematic EITs are the operational part of the EIT.

KICs are autonomous entities based around a small number of interconnected innovation hubs and covering entire value chains through innovation projects that focus on business and that are complementary to other activities funded by Horizon 2020. The Climate-KIC (addressing climate change challenges) and the KIC InnoEnergy (tackling sustainable energy), established in 2009, are partly bioeconomy relevant (see Box 3). So far, the Climate-KIC has supported five bioeconomy projects. In 2016, the total annual allocation on bioeconomy ranged between EUR 3 million and EUR 3.5 million (source: Climate-KIC).

The thematic EIT Raw Materials, launched in 2014, focuses mainly on non-energy and non-agriculture raw material that could replace their fossil fuel-based equivalents. The EIT launched a call for a new KIC in the thematic area Food4Future - Sustainable Supply Chain from Resources to Consumers.

The EIB implements EU financial instruments such as loans to companies and guarantees to banks, as well as offering advisory services (EC n.d.d). For example, the EIB implements the cross-sectorial Horizon 2020 'Access

8 At the same time, the JRC is also one of the nine EC DGs that manages a share of the overall Horizon 2020 budget; however, this share is relatively small (EPRS, 2015b).

9 https://biobs.jrc.ec.europa.eu/biomass-assessment-study-jrc

***Table 8:***
*ESIF's financial instrument*

| | **Research, development and innovation** | **Growth, jobs and cohesion** |
|---|---|---|
| <u>Management</u><br>**Shared with Member States (common provisions regulation) (EU 2013g)**<br><u>Implementation</u><br>**National/regional level** | **EUROPEAN STRUCTURAL AND INVESTMENT FUNDS (ESIF) 2014-2020**<br>EUR 454 billion (EU 2013g and 2015e)<br>EUR 121 billion for R&I, ICT and support to small businesses (ERDF, EAFRD) (EC 2015g)<br>EUR 193 billion for energy, environment, climate, risk management and sustainable transport (EC 2015g) | |
| **European Regional Development Fund (ERDF, EU 2013g)**<br>• Research and innovation and low-carbon economy are key priority areas (EIP 2014)<br>• Aims to strengthen economic, social and territorial cohesion<br>• **Smart specialisation strategies** are ex ante conditionality for R & D funding (EC 2014b)<br>• Funds **European territorial cooperation** activities (INTERREG V) | | |
| **European Agricultural Fund for Rural Development (EAFRD, EU 2013d)**<br>• Part of CAP and covers agriculture, forestry and rural areas<br>• Supports, inter alia, innovation, competitiveness, sustainability (incl. resource efficiency and low-carbon economy), climate resilience and animal welfare<br>• Support for **EIPs** (EIP-AGRI operational groups) | | |
| **European Maritime and Fisheries Fund (EMFF, EU 2014b)**<br>• Supports sustainable fishing, coastal communities, their economies and quality of life | | |
| **Cohesion Fund (CF, EU 2013i)**<br>• Can support projects related to energy or transport if they clearly benefit energy efficiency and use of renewable energy | | |
| **European Social Fund (ESF)**<br>• Less relevance for the bioeconomy | | |

to risk finance' section, where companies engaged in research and innovation can receive financial funds from the bank that help the companies get easier access to markets and finance.

More specifically, the InnovFin instrument (EU finance for investors) offers financial products for SMEs and large companies, as well as for the promoters of research infrastructures. The financing tools under InnovFin include analysing and potentially improving the investment/lending conditions of companies/projects in the agriculture, food and beverages industry, in BBIs and in the blue economy. The aim of InnovFin is to make over EUR 24 billion debt and equity financing available to circular economy businesses and innovative companies to support EUR 48 billion of final R&I investment by 2020.

The EIB group also implements products under EFSI (Section 2.4.3.).

### *2.4.2. European Structural and Investment Funds*

While Horizon 2020 is centrally managed and based on a transnational approach, ESIF includes money from several funds co-managed by the EU and national or regional authorities. ESIF focuses on economic and social cohesion. Even if both the Horizon 2020 and ESIF promote R&I development, the first gives emphasis to individual projects across the ERA, while ESIF investment ultimately targets boosting jobs, growth and investment, particularly in least developed areas (EC 2015f).

Priority areas for investments in bioeconomy covered by ESIFs are: R&I (ERDF and EAFRD); low-carbon economy; climate change adaptation and risk prevention; environment protection and resource efficiency; transport and energy.

ESIF consists of five different funds, summarised under Table 8.

Smart specialisation or RIS3 (EU 2013h) is a strategic approach to economic development through targeted support for Research and Innovation. It implies concentrating R&I resources on areas where a region has, or could develop, a competitive advantage. Smart specialisation is the basis for structural funds investments in the field of research and innovation as part of the EU cohesion policy.

Regions thus need to develop a smart specialisation strategy to receive ERDF funding for R&I. These strategies focus on identifying areas where the respective region can be particularly competitive. The smart specialisation platform, managed by the JRC, includes three bioeconomy-relevant themes: energy, agri-food and industrial value chains.

In 2015 the bioeconomy working group of the European Regions Research and Innovation Network (ERRIN) carried out a survey on regional smart specialisation strategies in bioeconomy in which 24 regions of 11 countries participated. The key results are summarised in Table 9.

| MS | Regions | National or regional strategy for bioeconomy? | Is the bioeconomy included in RIS3? | Are ESIFs used for funding bioeconomy-released initiatives? |
|---|---|---|---|---|
| FI | Oulu | Yes | Yes | Yes |
| | South Ostrobothnia | Yes | Yes | Yes |
| | Central Finland | Yes | Yes | Yes |
| | North Karelia | Yes | Yes | Yes |
| | Kainuu | Yes | Yes | Yes, but in the future |
| | Satakunta | Yes | Yes | Yes |
| ES | Asturias | No | Yes | Yes |
| | Extremadura | No | Yes | Yes |
| | Castilla-León | Yes (RIS3) | Yes | Not answered |
| | Navarra | Yes (integrate) | Yes | Yes |
| SE | North Sweden | Yes (RIS3) | Yes | Yes |
| | Ostergotland (East Sweden) | Yes (RIS3) | Yes | Yes |
| | Varmland | Yes | Yes | Yes |
| IT | Lombardy | Yes (RIS3) | Yes | Yes |
| | Basilicata | Yes | Yes | Yes |
| FR | Normandy | No | Yes | Yes |
| BE | Flanders | Yes | Yes | Yes |
| DK | Central Denmark | In progress | Yes | Yes |
| PL | Łódzkie | No | Yes | Yes |
| NL | Gelderland | Yes | Yes | Yes |
| UK | Scotland | Yes | Yes | Yes |
| | Wales | Yes | Yes | Yes |
| | Northern Ireland | No | Yes | Not at the moment |

***Table 9:***
*Regional bioeconomy strategies in the EU*

*Source: ERRIN (2015)*

A study on 'Mapping of EU Member States'/regions' research and innovation plans and strategies for smart specialisation (RIS3) on bioeconomy' was being prepared at the time of writing of this report. The study aims at mapping the intended priorities and activities of EU Member States and regions with regard to research and innovation (R&I) on bioeconomy, according to the current national or regional smart specialisation strategies (RIS3) and programmes supported by the ESIF for 2014-2020. The final results of the study are expected to be published during the first semester of 2017 on the EC's website.

**Box 7: Synergies and the role of the smart specialisation for the bioeconomy**
© Bio-based Industries Consortium (BIC), 2016

The BIC, together with ERRIN, has developed a synergies guide on how BBI JU (Horizon 2020) and ESIF could be combined to deploy the European bioeconomy (BIC 2014).

The BIC also works closely together with the regions from the Vanguard initiative to support improved access to funding and awareness-raising activities.

The Vanguard initiative is a European network of industrial regions using smart specialisation. Vanguard focuses on thematic pilot projects based on a four-step approach: learn, connect, demonstrate and commercialise to explore opportunities for developing interregional joint demonstration. Bioeconomy is one of Vanguard's five thematic sectors, including a bioeconomy pilot project on implementing synergies in new bio-based value chains across regions.

**More information**
Bioeconomy pilot project: http://www.s3vanguardinitiative.eu/
ERRIN bioeconomy working group: http://www.errin.eu/content/bioeconomy

***Table 10:***
*EFSI instrument*

| | Research, development and innovation | Growth, jobs and cohesion |
|---|---|---|
| Set-up<br>Jointly between EC, EIB and EIF<br>Implementation<br>Local level by intermediaries | The European Fund for Strategic Investments - EFSI 2014-2017<br>EUR 315 billion investment plan (EU 2015b) | |
| • Key component of the Juncker investment plan (EP 2016)<br>• Designed to make smarter use of new and existing financial resources, including in sectors that can be relevant for the bioeconomy such as transport, energy, environment and resource efficiency, research, development and innovation<br>• Two components to support projects: one on infrastructure and innovation, and one on support for SMEs (EU 2016)<br>• Supports **strategic investment projects** through tailored financing tools for innovative companies, such as loans and guarantees, financing of research and development projects and equity investments (EP 2016)<br>• No grant funding provided (EU 2016) | | |

Synergies between authorities are also enabled. For example, the innovation investments under the EAFRD (Table 8) are also linked to EIP-AGRI.

EIPs have been established under the Europe 2020 strategy flagship initiative, 'Innovation union', to better coordinate existing instruments and initiatives and adding new actions where necessary. EIP AGRI, launched in 2012, supports the cooperation between farmers, advisors, researchers, agribusinesses, NGOs and other actors as partners in agricultural and forestry innovation. Together they form an EU-wide EIP network (EC n.d.e). The objective is to foster a competitive and sustainable agriculture and forestry that works in harmony with the environment and to help guarantee a steady and reliable supply of biomass as renewable raw material without compromising sustainability and fair income (EIP 2015).

EIP-AGRI is not a funding instrument as such, but different types of funding sources help the development of innovation projects such as the European rural development policy or the Horizon 2020. EIP-AGRI contributes to integrating different funding streams so that they work towards a same goal and duplicate results (EC n.d.e).

Another example is the EIP on Raw Materials (EC 2016p), which covers wood and wood fibre raw materials (from primary and secondary resources). Examples for actions launched within this platform under Horizon 2020 SC5 include the 2017 call on an 'EU regional network on sustainable wood mobilisation', an ongoing project on good practice on recovered paper collection (IMPACTRecPap), and the 'Study on the optimised cascading use of wood' (Vis et al. 2016) (and, as a follow-up, the ongoing work on the guidance on the cascading use of biomass and, under SC2/BBI JU, a call in 2016 on forest harvesting technologies).

**Box 8: Private investment from the BIC perspective**

The BIC is the private partner in the PPP BBI JU. The BIC covers a mix of sectors including agriculture, agro-food, biotechnology/technology providers, forestry/pulp and paper, chemicals, energy and end users.

The BIC's annual survey from 2015 indicates that BIC members – besides their investments in internal and external R&D programmes – currently invest more than EUR 2.1 billion in BBIs, mainly infrastructure for demonstration projects or new flagships. Most of the short-term investments are foreseen in the lignocellulosic- and forestry-based value chains, such as the transition of first-generation to second-generation ethanol production, with an expansion to chemical building blocks, a new production unit for food grade microfibrillar cellulose, specific development programmes for lignosulfonates and specialty cellulose, a new production plant for advanced products – such as new materials and new chemical building blocks – from lignin and cellulose streams of the pulp and paper industry, or improved processing and utilisation of new raw materials for the manufacturing of pulp suitable for textile production. In the value chain based on agricultural crops, investments planned include a new industrial scale flagship project that makes use of cardoon to extract vegetable oils to be further converted into bio-based products (bio-lubricants, cosmetics, bio-plastics, etc.).

**More information**
http://biconsortium.eu/

### 2.4.3. Bringing together R&I and investment funds – The European Fund for Strategic Investments

The EC's investment plan for Europe, in particular the EFSI (Table 10), provides new financing opportunities to bioeconomy projects with high-risk profiles (RTD 2015).

Less than 1 year into its existence, EFSI is supporting 64 projects and triggering more than EUR 100 billion of investment (EC 2016h). Examples of investment support for the bioeconomy include the construction of a first next-generation bio-product mill (METSÄ FIBRE OY) in Finland, the biggest ever forest-based investment in Europe and North America; large energy-related projects with a focus on biomass in Denmark; and development of an integrated supply chain in the field of biochemicals and bioplastics in Italy. The EFSI project list is available at http://www.eib.org/efsi/.

## 2.5. Standards, labels and public procurement

Standards, labels and public procurement can help to promote the market uptake of specific product groups.

The EC Expert Group for Bio-based Products is an advisory group (see Box 9) which is managed by the DG Internal Market, Industry, Entrepreneurship and SMEs and provides advice to the EC concerning measures for promoting the market uptake of bio-based chemicals and materials.

### 2.5.1. Standards

The lead markets initiative for Europe (EC 2007d), the bioeconomy strategy (EC 2012b) and the communication 'A stronger European industry for growth and economic recovery' (EC 2012a) have identified standards [10] for bio-based products as an important tool to promote market uptake.

Standards are developed by technical committees organised in standardisation bodies, which exist on international (International Organisation for Standardisation, ISO), EU (European Committee for Standardisation, CEN) and national level. CEN

**Box 9: EC Expert Group for Bio-based Products (EC n.d.c)**

An EC Expert Group for Bio-based Products was set up in mid 2013 for an initial period of 4 years. The group has 34 appointed members representing EU countries and state agencies, public procurers, NGOs, academia and businesses.

The expert group's objective is to advise the EC on tools for promoting the market uptake of bio-based chemicals and materials by:
- monitoring and supporting the development of the policy framework and the implementation of the priority recommendations proposed by the lead market initiative Ad hoc Advisory Group for Bio-based Products;
- proposing demand-side industrial policy actions conducive to the market uptake of bio-based products and processes (standardisation, public procurement, awareness raising, labelling, etc.);
- mapping of bio-based products and relevant bioeconomy-related activities and exchanging of good practices at regional, national, international and EU level aimed at increasing the competitiveness of European industry.

The group has finalised the following reports (EC n.d.c):
- *Report of the Working Group on Evaluation of the implementation of the lead market initiative for bio-based products' priority recommendations*
- *General document on awareness raising on bio-based products*
- *Recommendations of the Working Group Public Procurement of bio-based products*

10 'A standard is a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something. Standards are created by bringing together all interested parties such as manufacturers, consumers and regulators of a particular material, product, process or service. All parties benefit from standardisation through increased product safety and quality, as well as lower transaction costs and prices' (CEN).

***Table 11:***
*CEN technical committees developing standards in the field of bio-based products (CEN, n.d.)*

| CEN technical committees with relevance to bio-based products |
|---|
| **CEN/TC 411 — Bio-based products** |
| • **Horizontal aspects for bio-based products** such as consistent terminology, sampling, certification tools, bio-based content, application of and correlation towards life cycle analysis and sustainability criteria for biomass used and for final products.<br>• **Bio-solvents**: standards covering product functionality, biodegradability and, if necessary, product-specific aspects. |
| **CEN/TC 19 — Gaseous and liquid fuels, lubricants and related products of petroleum, synthetic and biological origin** |
| • Working Group 33 deals with specific aspects of bio-lubricants. |
| **CEN/TC 249 — Plastics** |
| • Working Group 17 deals with specific aspects of biopolymers. |
| **CEN/TC 276 — Surface active agents** |
| • Working Group 3 deals with specific aspects of biosurfactants. |

brings together the national standardisation bodies of 33 European countries. A European standard automatically becomes a national standard in these 33 countries (CEN n.d.). Key activities for metrology in resource sustainability will be carried out under the Horizon 2020 European metrology programme for innovation and research (EMPIR. n.d.a).

Standards for bio-based products can help to increase market transparency by providing common reference methods and requirements in order to verify claims about these products (e.g. biodegradability, bio-based content, recyclability and sustainability).

Within the framework of the lead market initiative for bio-based products (see Section 2.2.4.), the EC issued several standardisation mandates to CEN (M/429, M/430, M/491 and M/492). Information on published standards and the ongoing work programme is provided on the CEN website under the CEN technical committees developing standards in the area of bio-based products (see Table 11).

Three projects under FP7 and Horizon 2020, respectively, (see Table 12) support(ed) the development of standards and an EU ecolabel for bio-based products and the promotion of bio-based public procurement. The results of the projects feed among others into the work of the CEN/TC 411 Technical Committee. Issues of the sustainability of bio-based products were also discussed. Bio-based products may or may not be biodegradable, recyclable and/or incinerated for energy production (InnProBio, n.d.a).

A series of ISO standards (ISO 16620, part 1-5) on the determination of the bio-based content in plastic products has recently been published. The standards are applicable to plastic products and plastic materials, polymer resins, monomers or additives (e.g. plasticisers or modifiers), which are made from bio-based or fossil-based constituents. They are harmonised with the respective CEN standards.

### *2.5.2. Labels*

Labels inform consumers that the products carrying them fulfil specific criteria. The EU ecolabel, for example, helps consumers identify products and services that have a reduced environmental impact throughout their life cycle, from the extraction of raw material through to production, use and disposal.

In the United States, a specific label for bio-based products has been introduced under the BioPreferred programme (Golden et al. 2015, USDA n.d). In the

***Table 12:***
*Research projects funded by FP7 or Horizon 2020 supporting the development of standards, an EU ecolabel and the promotion of bio-based public procurement (BioBasedEconomy, n.d.)*

| Research projects |
|---|
| **Knowledge-based bio-based products' pre-standardisation (KBBPPS): 2012-2015**<br>• The project carried out pre-standardisation research for bio-based products focusing on bio-based carbon content, biomass content and biodegradability. The project analysed a variety of green labels with a view on already existing requirements of a certain minimum share of renewable raw materials and the feasibility of including such a requirement for additional product groups. |
| **Opening bio-based markets via standards, labelling and procurement (Open-Bio): 2013-2016**<br>• The project follows up the KBBPPS project. It especially focuses on the sustainability of the bio-based resources and potential testing methods for this criterion. The end-of-life research is expanded to different biodegradation scenarios, composting and recyclability. Open-Bio also conceptualises an ecolabel that can be applied to bio-based products. |
| **Forum for bio-based innovation in public procurement (InnProBio): 2015-2018**<br>• The project aims to work with the public sector to develop tools for purchasers, facilitate the creation of buyers groups and increase awareness and incentives in order to lower the barriers of procuring innovative bio-based products. |

EU, no specific bio-based label exists. However, the EU ecolabel already requires a minimum content of renewable carbon between 45% and 70% (depending on the category) for lubricants (EU 2011). The possibility to include such a requirement for other products is under investigation (see Table 12).

### *2.5.3. Public procurement*

Public procurement (i.e. the public purchase of works, goods or services) accounts for around 14% of GDP in the EU. It is one of the market-based instruments under the Europe 2020 strategy for achieving smart, sustainable and inclusive growth while ensuring the most efficient use of public funds. Under the directive on public procurement (EU 2014c), public authorities should make the best strategic use of public procurement to spur innovation.

In April 2016, the Public Procurement Working Group of the EC's Expert Group for Bio-based Products published 15 recommendations, including promotional campaigns, the roll-out of standards and labels and technical support to producers (EC 2016j).

A project on 'Guidance for public procurers on bio-based products' funded by COSME is currently being conducted.

The InnProBio project (Table 12) is exploring possibilities for the public procurement of innovative bio-based products.

# 3. Quantifying economic indicators of the European bioeconomy

# 3. Quantifying economic indicators of the European bioeconomy

Creating jobs and maintaining European competitiveness are central goals of both the Juncker plan (Section 2.2.1.) and the bioeconomy strategy (Section 2.2.2.). This chapter aims to support all stakeholders with relevant economic data and, more specifically, information about employment and turnover. In addition, the results of a survey about bio-based industries shed light on a sector that the EU actively tries to help develop, but on which there are still significant knowledge gaps. Finally, an outlook is provided on efforts to understand the impact of different bioeconomy sectors on employment and turnover in other sectors through multiplier analysis as well as on research to quantify biomass potential, supply and demand.

For the quantification of jobs and turnover, the bioeconomy has been broken down into sectors and subsectors, following the NACE rev. 2 classification [11] and using publicly available datasets by Eurostat and the Scientific, Technical and Economic Committee for Fisheries (STECF) (for codes A031 and A032) (see Table 13). The full methodology is described in a separated document (Ronzon et al. 2017). The data and predefined visualisations can be browsed at http://datam.jrc.ec.europa.eu/datam/mashup/BIOECONOMICS/index.html.

11 Statistical Classification of Economic Activities.

***Table 13:***
*Use of Eurostat NACE codes in this report.*

| NACE codes (1) used for calculations | Corresponding NACE labels | Labels used in this report (Parent categories in bold) |
|---|---|---|
| A01 | Crop and animal production, hunting and related service activities | **Agriculture** |
| A02 | Forestry and logging | **Forestry** |
| A03 | Fishing and aquaculture | **Fishing and aquaculture** |
| A032 | Aquaculture | Aquaculture |
| A031 | Fishing | Fishing |
| - | - | **Manufacture of food, beverages and tobacco** |
| C10 | Manufacture of food products | Manufacture of food |
| C11 | Manufacture of beverages | Manufacture of beverages |
| C12 | Manufacture of tobacco products | Manufacture of tobacco |
| - | - | **Manufacture of bio-based textiles** |
| C13* | Manufacture of textiles | Manufacture of bio-based textiles |
| C14* | Manufacture of wearing apparel | Manufacture of bio-based wearing apparel |
| C15 | Manufacture of leather and related products | Manufacture of leather |
| - | - | **Manufacture of wood products and furniture** |
| C16 | Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials | Manufacture of wood products |
| C31* | Manufacture of furniture | Manufacture of wooden furniture |
| C17 | Manufacture of paper and paper products | **Manufacture of paper** |
| - | - | **Manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels)** |
| C20* | Manufacture of chemicals and chemical products | Manufacture of bio-based chemicals (excl. biofuels) |
| C21* | Manufacture of basic pharmaceutical products and pharmaceutical preparations | Manufacture of bio-based pharmaceuticals |
| C22* | Manufacture of rubber and plastic products | Manufacture of bio-based plastics and rubber |
| - | - | **Manufacture of liquid biofuels** |
| C2014* | Manufacture of other organic basic chemicals | Manufacture of bioethanol |
| C2059* | Manufacture of other chemical products n.e.c. | Manufacture of biodiesel |
| D3511* | Production of electricity [12] | **Production of bioelectricity** |

*(1) Some categories mentioned in this report have no NACE code equivalent, either because NACE codes have been aggregated (e.g. the parent 'manufacturing of food, beverages and tobacco' has been attributed to NACE codes C10, C11 and C12) or because we have extracted a NACE code from its parent code (e.g. C2014 and C2059 are treated separately from their C20 parent).*

** Has been assigned to NACE codes corresponding to not fully bio-based sectors, meaning that for those NACE codes the present document refers only to the bio-based part of the corresponding sector (after the estimation of its bio-based share (12)).*

12 Bio-based shares have been determined by about 15 experts coming from different European countries and interviewed by nova-Institute between April 2015 and the summer of 2016. The experts came from different sectors of the bio-based economy, from companies and industrial associations including chemical industry (drop-ins, biotechnology, oleochemistry, organic acids, surfactants and paints) and the wood industry. Other shares were estimated by experts from nova-Institute (methodological details are given in Ronzon T, et al. 2017).

## 3.1. Employment in the EU bioeconomy and subsectors

This section compiles the statistics of persons employed for the activity sectors composing the bioeconomy, defined as the production of biomass and the manufacture of products incorporating biomass. The biomass-producing sectors are agriculture ([13]), forestry and fishing and aquaculture ([14]). Downstream sectors are those involved in the manufacturing of bio-based products as well as the production of bioelectricity.

In the case of the manufacturing sectors using both biomass feedstock and other kinds of feedstock, a share corresponding to the manufacture using biomass only has been estimated with the help of expert interviews carried out by nova-Institut GmbH. Consequently, the figures presented hereafter for the manufacture of bio-based textiles, wooden furniture, bio-based chemicals, pharmaceuticals, plastics and rubber, as well as for the production of bioelectricity have been estimated from official statistics disentangling the bio-based part of these sectors from their non-bio-based part.

This section relies on five publicly available datasets: Eurostat's labour force survey (LFS) (Eurostat 2015b; Eurostat 2015c), Eurostat's structural business statistics (Eurostat 2015d) and STECF's annual reports on the economic performance of the EU aquaculture sector and on the annual economic report on the EU fishing fleet (STECF 2014; STECF 2016).

### *3.1.1. Structure of the EU bioeconomy labour market*

The bioeconomy in the EU-28 employed around 18.6 million people in 2014 (or 19.5 million people on a 2008-2014 average). This represented 8.5% of the total EU workforce.

The agricultural sector and the manufacture of food, beverages and tobacco are by far the largest employment sectors, altogether providing three quarters of the total employment in the European bioeconomy (see Figure 6). The agricultural sector alone employs slightly more than half of it (9.6 million people as reported in lfsa_egan22d for 2014), and the manufacture of food, beverages and tobacco employs a quarter. The other sectors of the bioeconomy contribute less than 9% each to the total number of people employed. Among them, the manufacture of wood products and wooden furniture and the manufacture of bio-based textiles are the only ones employing 1 million persons or more.

The primary sectors (agriculture, forestry and fishing and aquaculture) provide 55% of the total employment in the EU bioeconomy and the manufacture of fully bio-based products provides another 35%, while the manufacture of partly bio-based products only employs 9% of the workforce in the EU bioeconomy.

### *3.1.2. Dynamics at stakes in the EU bioeconomy employment*

Although 18.6 million people worked in the bioeconomy of the EU-28 in 2014, this was approximately 2 million people less than in 2008. This declining trend is mainly driven by the ongoing restructuration of the European agricultural sector, still the main employment sector of the bioeconomy (see Figure 7).

In absolute numbers, major reductions in the number of people employed occurred in agriculture (-1.2 million people), in the manufacture of wood products and wooden furniture (-390000 people), in the manufacture of bio-based textiles (-300000 people) and in the manufacture of food, bever-

**Definition of the indicator**

The number of persons employed comprises persons aged 15 and over who work for the observation unit.
It includes part-time workers, workers on leave and unpaid persons employed.
Source: EU (2009d) and LFS series metadata (Eurostat, n.d.)

**NB: The case of agriculture**

Due to a number of specificities in agricultural employment (e.g. the importance of family and part-time and non-regular workforce), the number of persons employed in agriculture is very difficult to estimate.
This report is based on estimates from the LFS (coded lfsa_egan22d) conducted by Eurostat, a data source usually used when comparing employment data across different sectors of activities. It reports 9.6 million persons employed in agriculture (NACE rev.2 code A01), as their main activity, for the EU in 2014.
The farm structure survey (FSS, coded ef_lflegaa), also conducted by Eurostat, reports 22.2 million persons employed in agriculture, as their first, secondary and minor activity, for the EU in 2013. According to the same source, 11.4 million persons are working on agricultural enterprises generating EUR 4000 or more as an annual standard output.

13 Agriculture includes the production of vegetal and animal biomass for food, feed and other uses.
14 The algae production is not reported in fishing and aquaculture statistics used in this study.

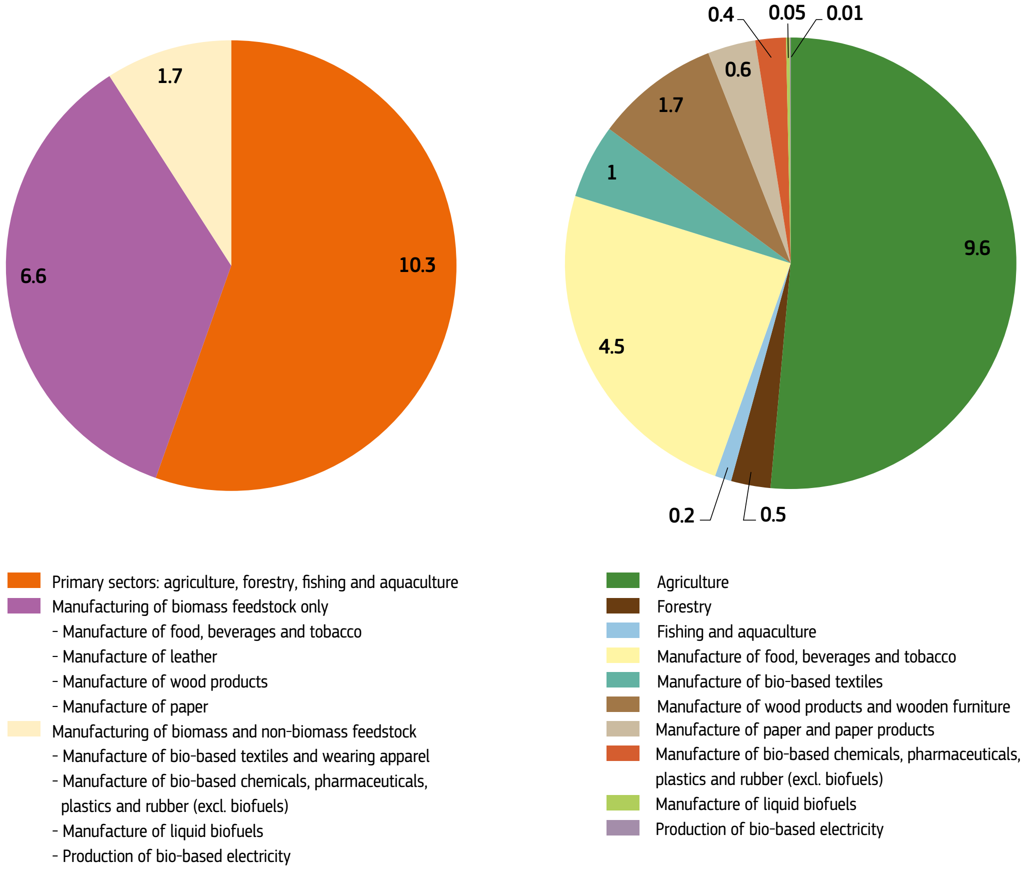



***Figure 6:***
*Employment in the bioeconomy sectors of the EU (million persons employed, 2014)*

*NB: Since some sectors represented in the pie chart on the right comprise both fully bio-based and partially bio-based subsectors, they have been disaggregated for the elaboration of the pie chart on the left (see legend).*

ages and tobacco (-200000 people) (see Figure 8). However, in relative terms, the workforce in the three former sectors has been reduced by respectively 11%, 19% and 23% between 2008 and 2014, while the 200000-people reduction in the manufacture of food, beverages and tobacco sector repre-sents a 5% reduction only.

- Job reduction in the manufacture of wood products and wooden furniture are almost equally distributed in the manufacture of wood products and in the manufacture of wooden furniture.
- The sector called 'manufacture of bio-based textiles' in this document comprises three subsectors: (i) the manufacture of bio-based textiles strictly speaking; (ii) the manufacture of wearing apparel; and (iii) the manufacture of leather products (see Table 13). The two former sectors are responsible for 85% of employment reduction in the manufacture of bio-based textiles.
- Similarly, the manufacture of food accounts for 70% of the job reduction in the manufacture of food, beverages and tobacco.

***Figure 7:***
*Development of the number of people employed by sector of the EU bioeconomy (2008-2014)*

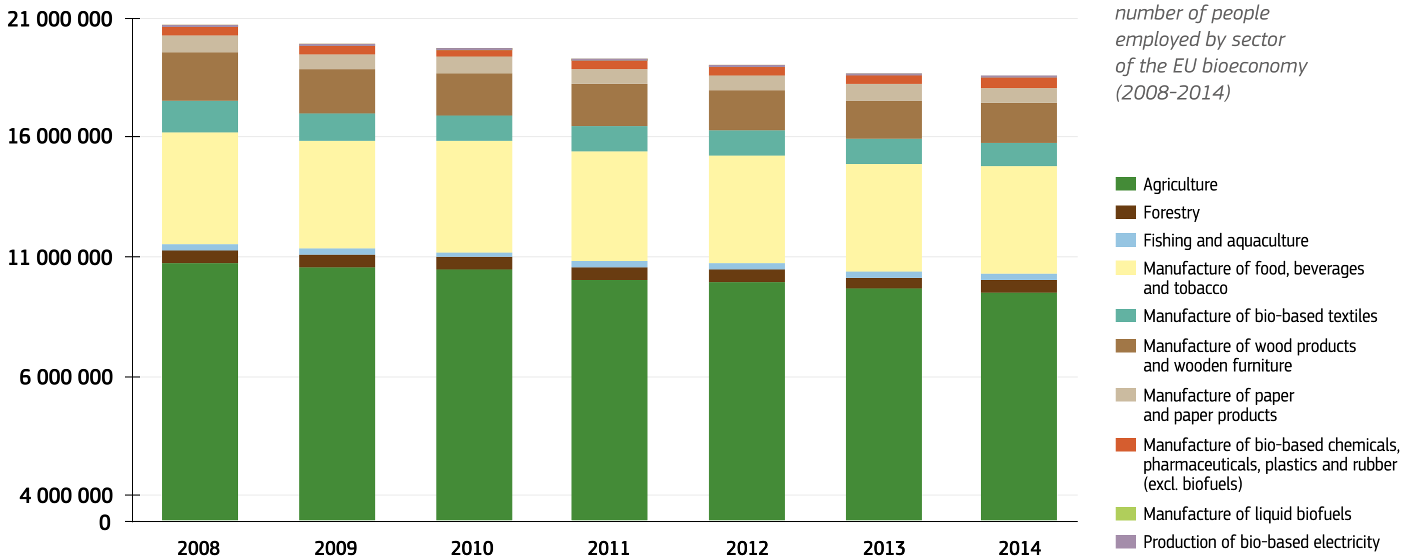
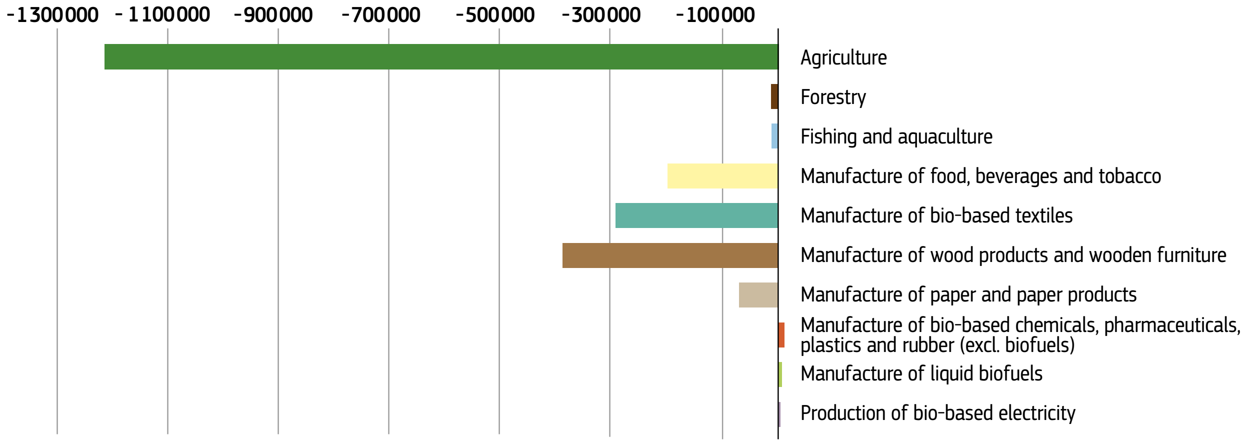
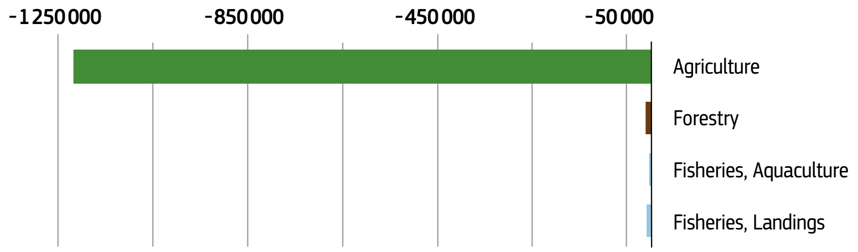


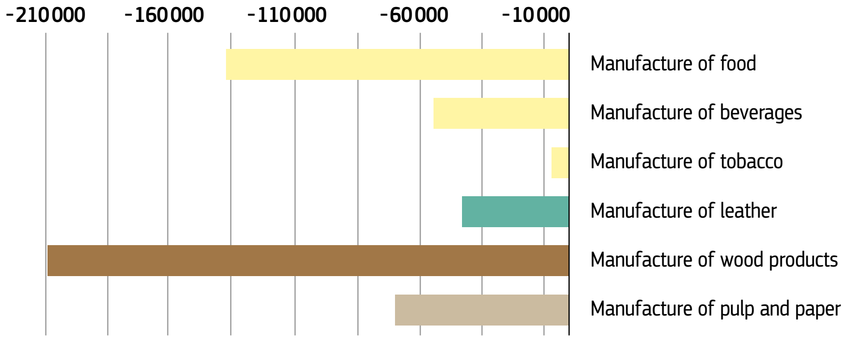
***Figure 8:***
*Change in the number of people employed in the bioeconomy sectors between 2008 and 2014*



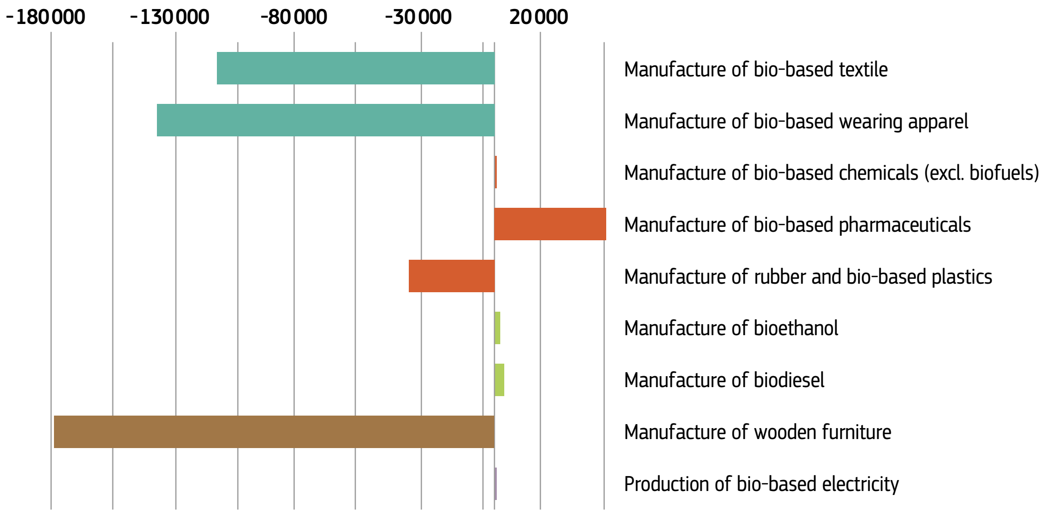

Primary sectors




Manufacture of biomass feedstock only



Manufacture of biomass and non-biomass feedstock




Representing less than 1% of the bioeconomy workforce, the manufacture of bio-based pharmaceuticals employed 45000 additional people in 2014 compared to 2008. This sector shows the highest gain in the number of persons employed over the same period.

The remaining sectors show little fluctuations over that period, with no clear upward or downward trend.

### *3.1.3. Labour market specialisation in the EU Member States*

Due to very different natural resources endowment and different historical orientations of their domestic economy, the EU Member States present diverse patterns of their bioeconomy. As far as employment is concerned, the location quotient is the indicator usually used to measure how 'concentrated' a sector is in a Member State compared with the EU, i.e. the share of Member State employment in the bioeconomy (or in a given sector of the bioeconomy) divided by the EU employment share in the bioeconomy (or in the same given sector).

| Member State | Location quotient | Member State | Location quotient | Member State | Location quotient |
|---|---|---|---|---|---|
| Austria | 1.05 | Germany | 0.58 | Netherlands | 0.51 |
| Belgium | 0.54 | Greece | 2.04 | Poland | 1.96 |
| Bulgaria | 1.59 | Hungary | 1.09 | Portugal | 1.76 |
| Croatia | 1.96 | Ireland | 0.99 | Romania | 3.89 |
| Cyprus | 1.01 | Italy | 0.96 | Slovakia | 0.95 |
| Czech Republic | 0.85 | Latvia | 1.66 | Slovenia | 1.66 |
| Denmark | 0.73 | Lithuania | 1.98 | Spain | 0.91 |
| Estonia | 1.27 | Luxembourg | 0.45 | Sweden | 0.58 |
| Finland | 0.93 | Malta | 0.47 | United Kingdom | 0.41 |
| France | 0.75 | | | | |

***Table 14:***
*Location quotient of the bioeconomy in the EU-28 Member States (2014)*

***Figure 9:***
*Member States' labour market specialisation in the bioeconomy (2014)*

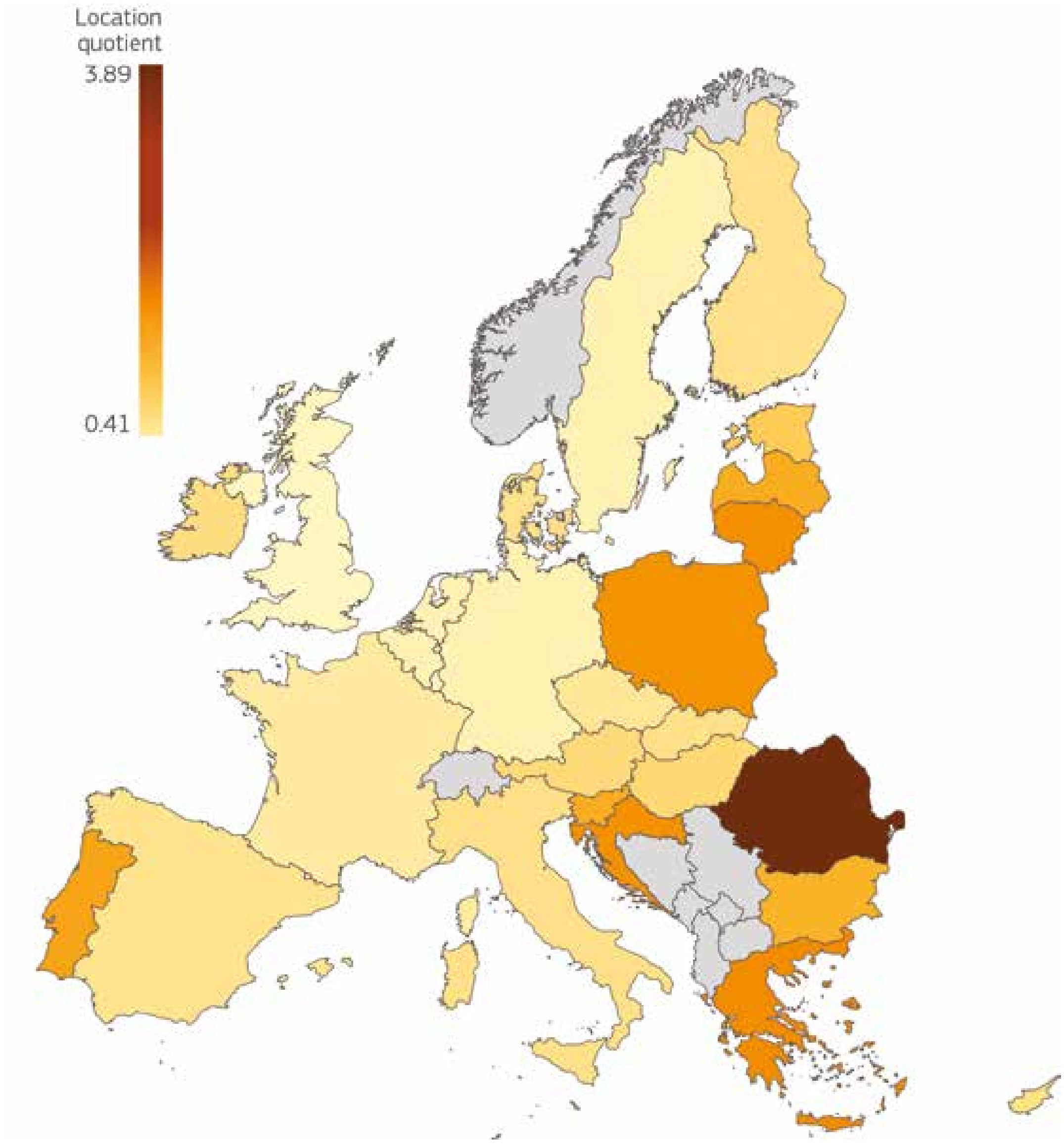



Figure 9 and Table 14 show the distribution of location quotients of the bioeconomy among the 28 Member States of the EU. Romania appears as the EU Member State most specialised in the bioeconomy with a location quotient of 3.9. This means that the share of people working in the Romanian bioeconomy is nearly four times higher than the share of people working in the 28 EU bioeconomy. In reality, this 'concentration' in the bioeconomy is principally due to a very high concentration of the Romanian labour market in agriculture. In 2014, 28% of the people employed in Romania were working in the agricultural sector and 83% of the people employed in the Romanian bioeconomy were working in agriculture.

With bioeconomy location quotients ranging between 1.5 and 2.1, Bulgaria, Croatia, Greece, Poland, Portugal, Latvia, Lithuania and Slovenia (in orange on Figure 9) rank after Romania, also driven by the high proportion of agricultural jobs in their national labour market.

In the rest of the EU, the bioeconomy location quotients vary between 0.4 and 1.3. The labour market in these Member states is not particularly concentrated in the bioeconomy, although some specific subsectors of the bioeconomy can show high location quotients. For instance, Cyprus shows a very high location quotient in the fishing and aquaculture sector. The Estonian bioeconomy is concentrated in the forestry and in the manufacture of wood products, showing location quotients higher than 4 in those two sectors. Fishing and aquaculture is also a developed labour market in Estonia compared with the EU average (location quotient higher than 3.2). Finland and Slovakia show location quotients exceeding 3.6 in the forestry sector and exceeding 3 in the Finish manufacture of paper and paper products. In Denmark, the bioeconomy labour market is concentrated in the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) (location quotient of 3.9).

Finally, the United Kingdom and Luxembourg are the EU Member States with the least specialised labour market in the bioeconomy.

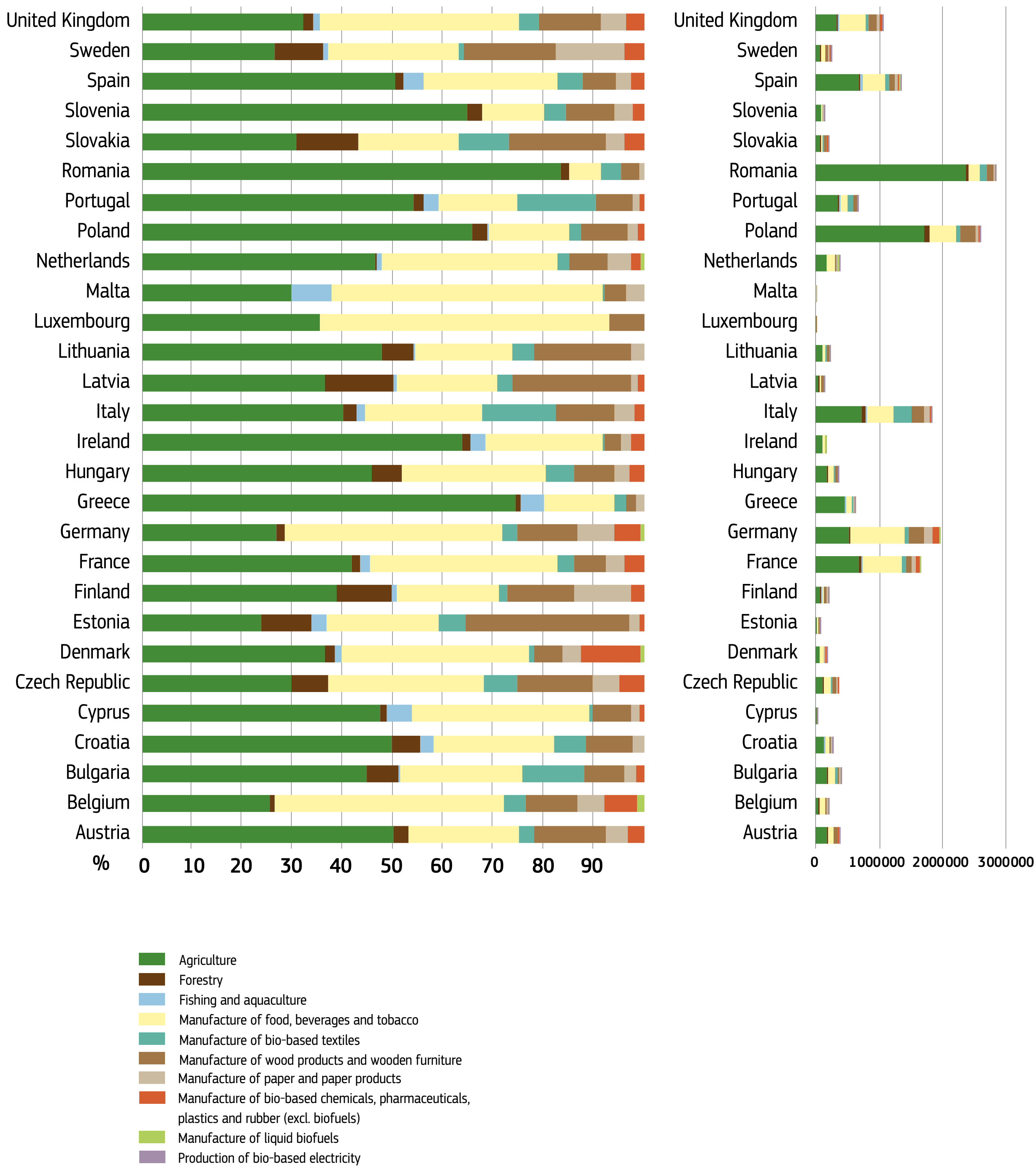
Figure 10 gives an overview of the labour market structure across EU Member States for the sectors composing the bioeconomy, and Table 15 summaries the three most specialised 28 EU Member States in the bioeconomy and its sectors of activity (as measured with the location quotient indicator).

| | Most specialised Member State | Location quotient | Sectorial employment in the EU (% total EU employment) |
|---|---|---|---|
| **Total bioeconomy** | Romania<br>Greece<br>Lithuania | 3.89<br>2.04<br>1.98 | 8.5% |
| **Agriculture** | Romania<br>Greece<br>Poland | 6.30<br>2.96<br>2.51 | 4.4% |
| **Forestry** | Latvia<br>Estonia<br>Lithuania | 8.16<br>4.48<br>4.34 | 0.2% |
| **Fishing and aquaculture** | Greece<br>Portugal<br>Croatia | 8.20<br>4.53<br>4.35 | 0.1% |
| **Manufacture of food, beverages and tobacco** | Croatia<br>Bulgaria<br>Lithuania | 1.94<br>1.59<br>1.56 | 2.1% |
| **Manufacture of bio-based textiles** | Portugal<br>Bulgaria<br>Romania | 5.11<br>3.69<br>2.83 | 0.5% |
| **Manufacture of wood products and wooden furniture** | Estonia<br>Latvia<br>Lithuania | 4.67<br>4.46<br>4.31 | 0.8% |
| **Manufacture of paper** | Finland<br>Sweden<br>Slovenia | 3.07<br>2.32<br>1.64 | 0.3% |
| **Manufacture of bio-based chemicals, pharmaceuticals and plastics and rubber (excl. biofuels)** | Denmark<br>Czech Republic<br>Slovenia | 3.95<br>1.95<br>1.61 | 0.2% |
| **Manufacture of liquid biofuels** | Belgium<br>Denmark<br>Germany | 2.53<br>1.98<br>1.80 | < 0.1% |
| **Production of bio-based electricity*** | Cyprus<br>Bulgaria<br>Romania | 5.95<br>4.41<br>3.95 | < 0.1% |

***Table 15:***
*Top three EU Member States in terms of job market concentration in the bioeconomy and in its sectors of activity (2014)*

**Data are missing for the Czech Republic, France, Germany, Ireland, Luxembourg and Malta.*

***Figure 10:***
*Employment in the bioeconomy sectors of activity on the 28 EU Member States, in percentage (left) and number of people employed (right) (2014)*



## 3.2. Turnover of the EU bioeconomy and subsectors

This section compiles the statistics of turnover (in current price) for the activity sectors composing the bioeconomy, defined as the production of biomass and the manufacture of products incorporating biomass. These include agriculture [15], forestry and fishing and aquaculture [16], the manufacturing of bio-based products and the production of bioelectricity.

Turnover is used as a market size indicator in the EU bioeconomy strategy [17]. The turnover of a given sector represents the value of sales from this sector. The turnover of the whole bioeconomy includes all the sales from the different activity sectors that compose the bioeconomy, including the sales of products from one sector to a downstream sector of the bioeconomy. It thus leads to occasional double counting throughout the value chain.

As for the estimation of the number of people employed, bio-based shares have been applied to disentangle the bio-based part of a sector from its non-bio-based part when this was not the case in the data source (see Section 3.1.).

This section relies on five publicly available datasets: Eurostat's economic accounts (Eurostat 2013; Eurostat 2015a), Eurostat's structural business statistics (Eurostat 2015d) and STECF's annual reports on the economic performance of the EU aquaculture sector and the annual economic report on the EU fishing fleet (STECF 2014; STECF 2016).

**Definition of the indicator**

The turnover comprises the totals invoiced by the observation unit during the reference period.
It covers the sales from companies operating in the EU and includes sales to extra-EU countries (exports).
Source: EU (2009c)

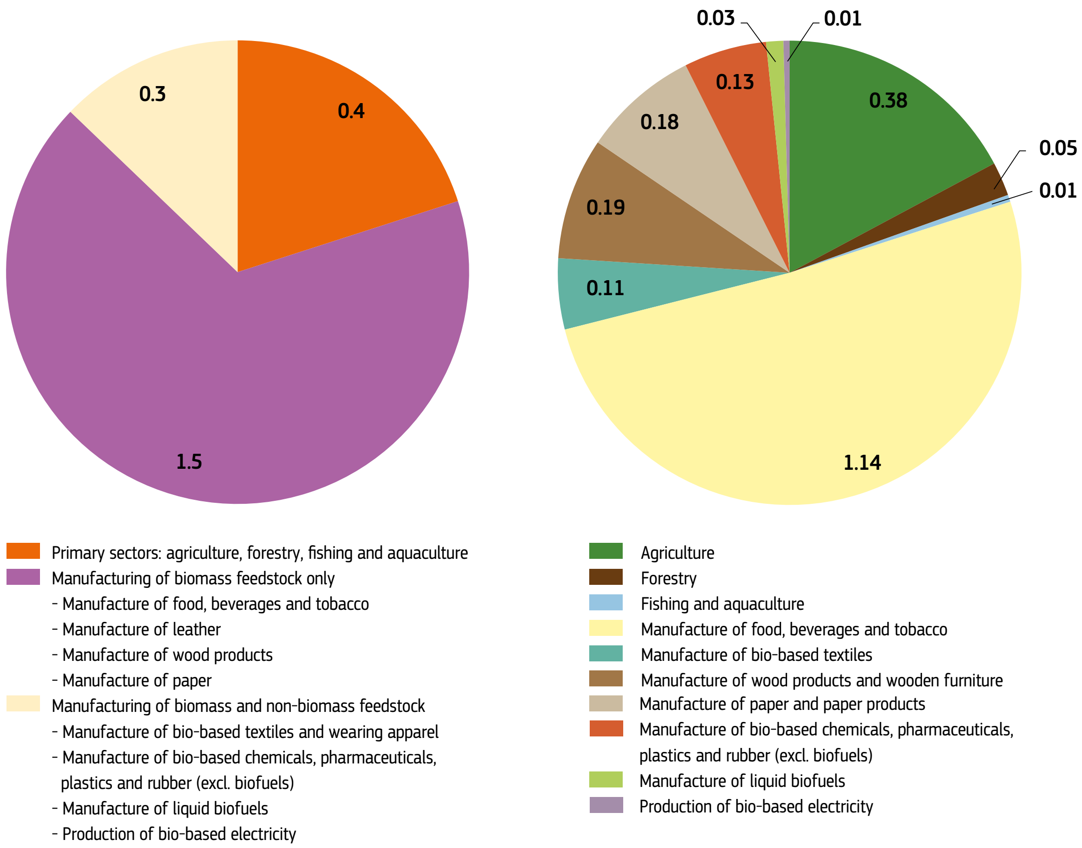



***Figure 11:***
*Turnover in the EU bioeconomy, by sector (in trillion EUR, 2014)*

*NB: Since some sectors represented in the pie chart on the right comprise both fully bio-based and partially bio-based sub-sectors, they have been disaggregated for the elaboration of the pie chart on the left (see legend).*

15 Agriculture includes the production of vegetal and animal biomass for food, feed and other uses.
16 The algae production is not reported in fishing and aquaculture statistics used in this study.
17 'The EU's bioeconomy sectors are worth EUR 2 trillion in annual turnover and account for more than 22 million jobs and approximately 9% of the workforce' in *Innovating for sustainable growth – A bioeconomy for Europe*, EC, 2012 (EC 2012a).

### 3.2.1. Sectorial contribution to the EU bioeconomy turnover

The bioeconomy in the EU-28 has generated approximately EUR 2.2 trillion in 2014 (or EUR 2.1 trillion on a 2008-2014 average).

As for the number of people employed, the manufacture of food, beverages and tobacco and the agricultural sector were by far the largest contributors to the EU bioeconomy turnover, providing altogether more than two thirds of it (see Figure 11). However, their relative contribution is inverted compared with the employment estimation: slightly more than half of the European bioeconomy turnover comes from the manufacture of food, beverages and tobacco (EUR 1.1 trillion in 2014), while 17% comes from agriculture. Four other sectors generated more than EUR 100 billion each of turnover in 2014: the manufacture of wood products and wooden furniture, the manufacture of paper, the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) and the manufacture (excl. biofuels) of bio-based textiles.

It is worth noting that the relative contribution of primary sectors to the bioeconomy is significantly lower in terms of turnover (20%) than in terms of the number of persons employed (55%). The manufacture of fully bio-based products alone contributes to 67% of the EU bioeconomy turnover (compared with 35% of the people employed). The manufacture of partly bio-based products shows quite a stable contribution when comparing the two indicators: 13% of the turnover in the EU bioeconomy vs. 9% of the people employed.

### 3.2.2. Trends in sectorial turnovers of the EU bioeconomy

Between 2008 and 2014, the turnover of the EU bioeconomy grew by approximately EUR 140 billion, accounting for a 7% rise. It is worth noting that the bioeconomy turnover as well as the sectorial turnovers underwent a significant drop between 2008 and 2009 (from EUR 2.1 trillion to EUR 1.9 trillion), most likely as an effect of the 2008 economic crisis. It then continuously rose during the period 2010-2014, reaching EUR 2.2 trillion in 2014 (see Figure 12).

The dynamic of the bioeconomy turnover is driven by the development of the manufacture of food, a sector that grew by EUR 98 billion of turnover over the 2008-2014 period (see Figure 12 and Figure 13).

Agriculture, the second sector contributing to the EU bioeconomy turnover, followed the average upward trend, showing a turnover growth rate of 7.3% over the same period, i.e. EUR 26 billion more in 2014 than in 2008. Nevertheless, the highest turnover growth occurred in the manufacture of liquid biofuels (+ 25%), the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) (+ 22%) and the forestry sector (+ 21%), generating altogether an additional EUR 37 billion of turnover compared with 2008. The manufacture of bio-based textiles shows a relatively constant turnover over the years.

Finally, some sectors are losing momentum: the manufacture of wood products and wooden furniture showed a turnover loss of EUR 20 billion in

***Figure 12:*** *Development of sectorial turnovers in the EU bioeconomy (in million EUR, 2008-2014)*

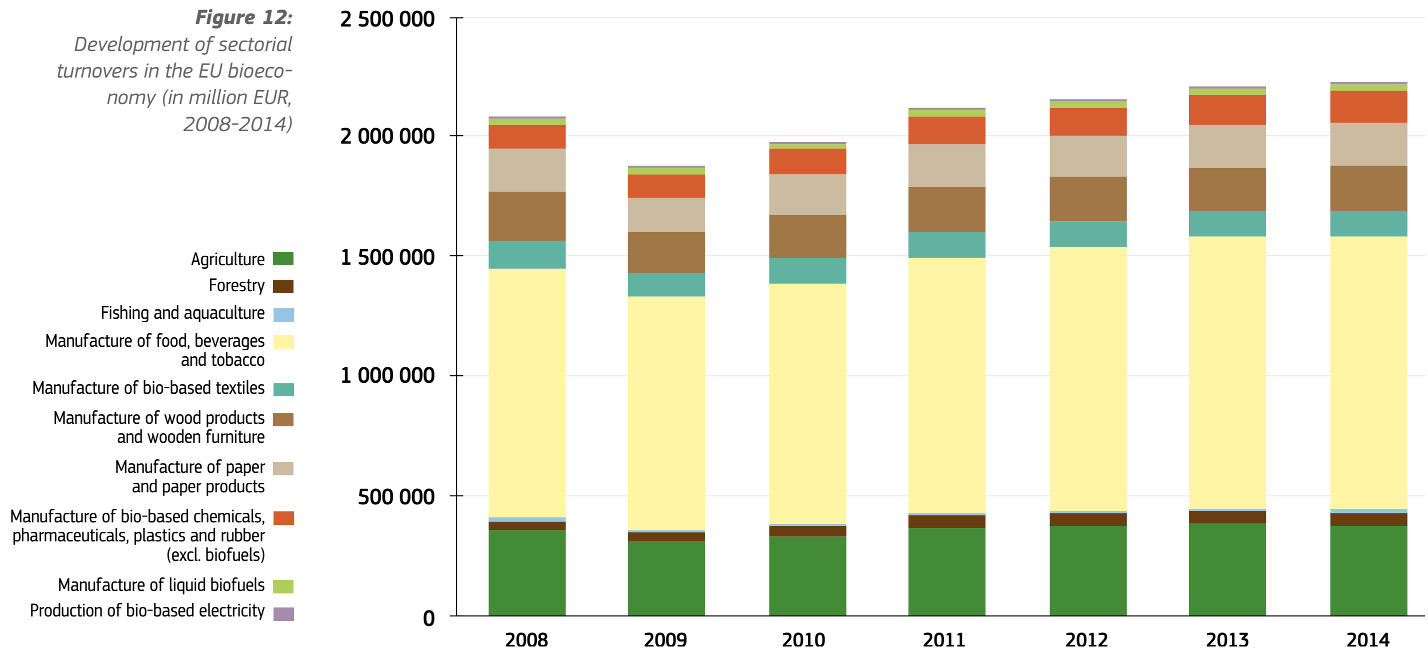
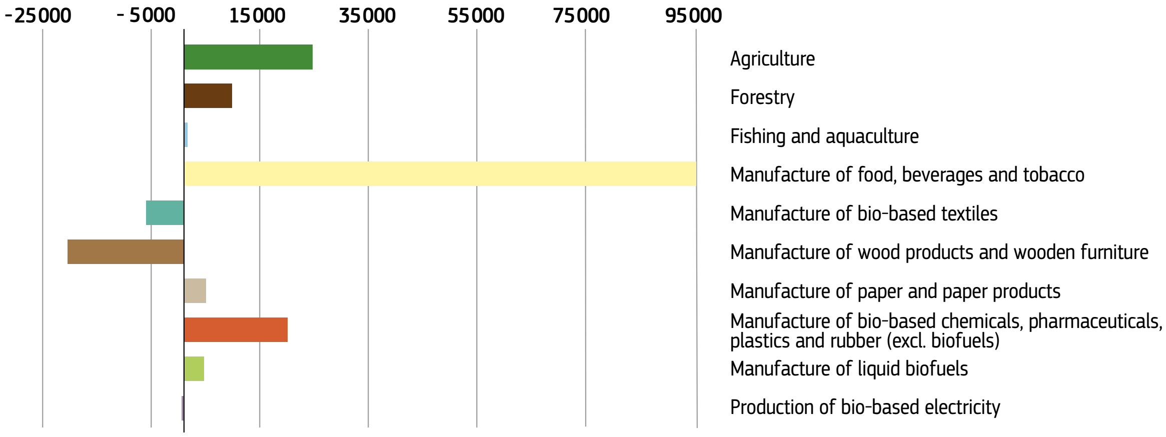
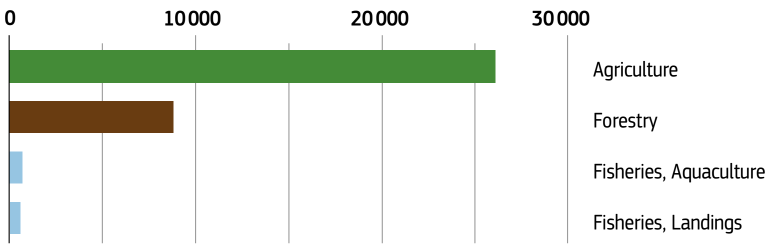


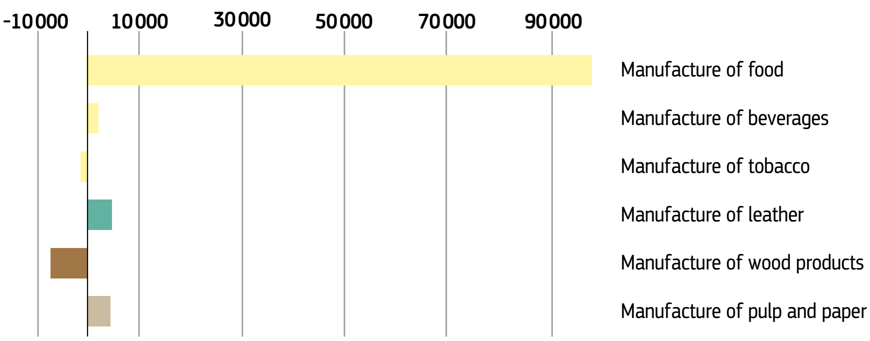
***Figure 13:***
*Change in turnover of bioeconomy sectors (in million EUR, 2008-2014)*



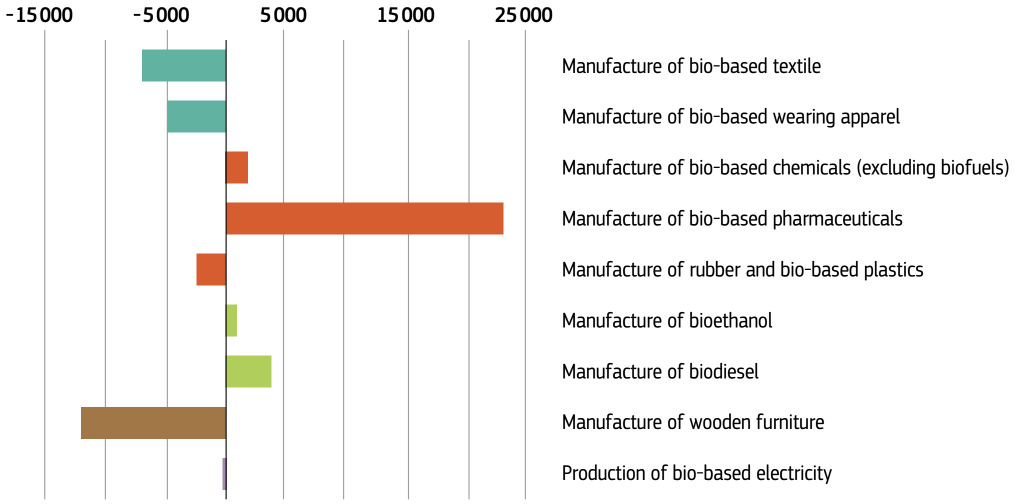

Primary sectors




Manufacture of biomass feedstock only



Manufacture of biomass and non-biomass feedstock




2014 compared with 2008 (of EUR 12 billion of turnover in the manufacture of wooden furniture and of EUR 8 billion in the manufacture of wood products). The turnover of the manufacture of bio-based textiles has not recovered its 2008 level (loss of EUR 7 billion in the manufacture of bio-based textiles *stricto sensu* and of EUR 5 billion in the manufacture of wearing apparel, partly compensated by an extra EUR 6 billion in the manufacture of leather).

### *3.2.3. Member States contribution to the EU bioeconomy turnover*

The distribution of the EU bioeconomy turnover across Member States shows a very contrasting picture compared with the location quotient map (compare Figure 14 to Figure 9). In 2014, nearly 50% of the total EU bioeconomy turnover was generated in only three Member States: Germany (18%), France (15%) and Italy (13%) (see Figure 14 and Table 16).

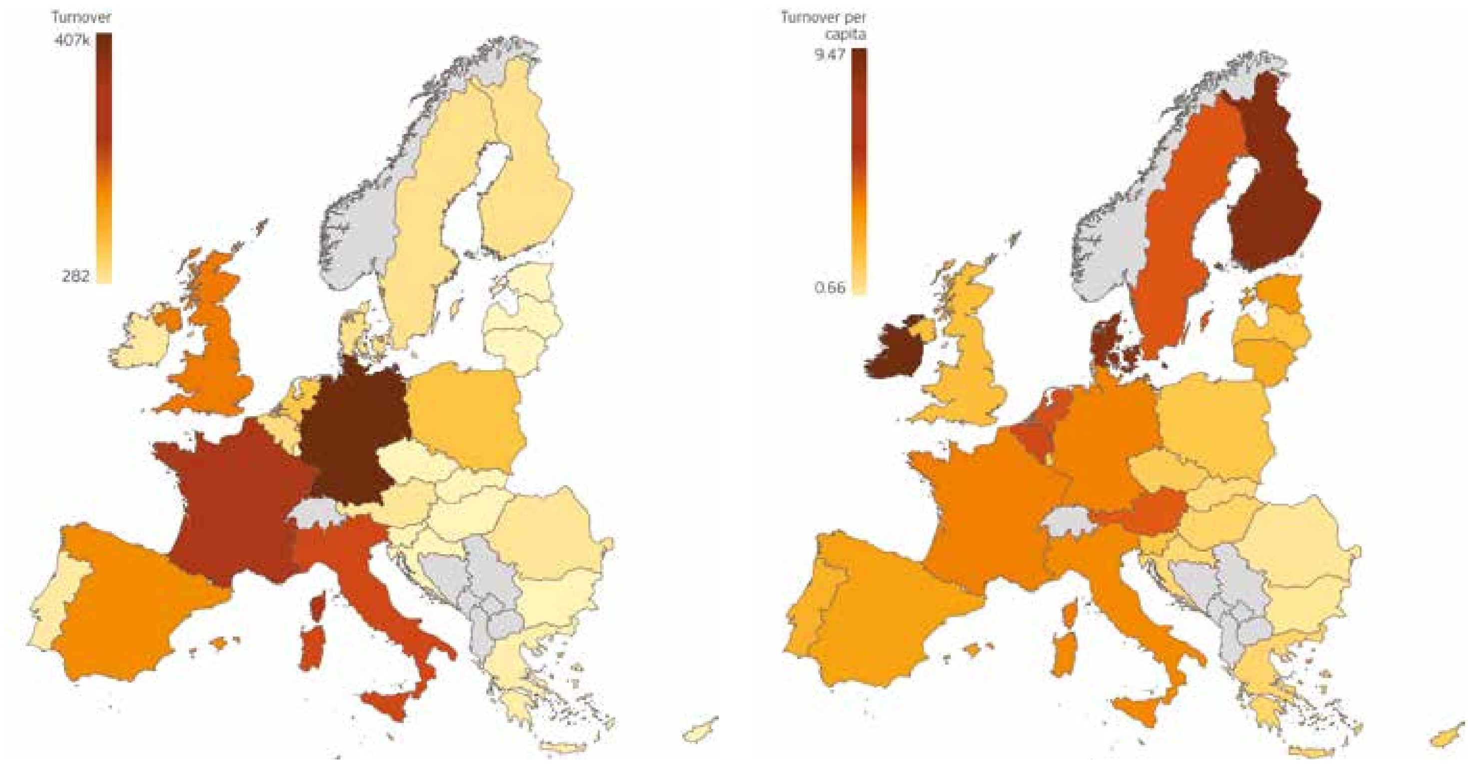



***Figure 14:*** *Distribution of the bioeconomy turnover across EU Member States (2014) Left: turnover in million EUR. Right: turnover per capita in thousand EUR per capita*

***Table 16:***
*Top three EU Member States in bioeconomy turnover and by bioeconomy sectors (2014)*

| | Member States with highest turnover | Turnover (billion EUR) |
|---|---|---|
| **Total bioeconomy** | Germany<br>France<br>Italy | 407<br>337<br>293 |
| **Agriculture** | France<br>Germany<br>Italy | 68.4<br>55.0<br>45.0 |
| **Forestry** | Germany<br>Sweden<br>France | 8.8<br>8.4<br>6.1 |
| **Fishing and aquaculture** | Spain<br>France<br>United Kingdom | 2.4<br>2.1<br>1.7 |
| **Manufacture of food, beverages and tobacco** | Germany<br>France<br>United Kingdom | 210<br>186<br>132 |
| **Manufacture of bio-based textiles** | Italy<br>France<br>Germany | 50.0<br>11.8<br>11.0 |
| **Manufacture of wood products and wooden furniture** | Germany<br>Italy<br>France | 40.3<br>27.8<br>17.5 |
| **Manufacture of paper** | Germany<br>Italy<br>Finland | 39.8<br>21.9<br>19.1 |
| **Manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels)** | Germany<br>France<br>Italy | 33.5<br>20.8<br>11.3 |
| **Manufacture of liquid biofuels** | Germany<br>France<br>Italy | 8.4<br>4.5<br>2.5 |
| **Production of bio-based electricity*** | France*<br>Spain*<br>Italy* | 2.3<br>1.4<br>1.2 |

**Data are missing for the Czech Republic, Germany, Ireland, Luxembourg, Malta and the Netherlands.*

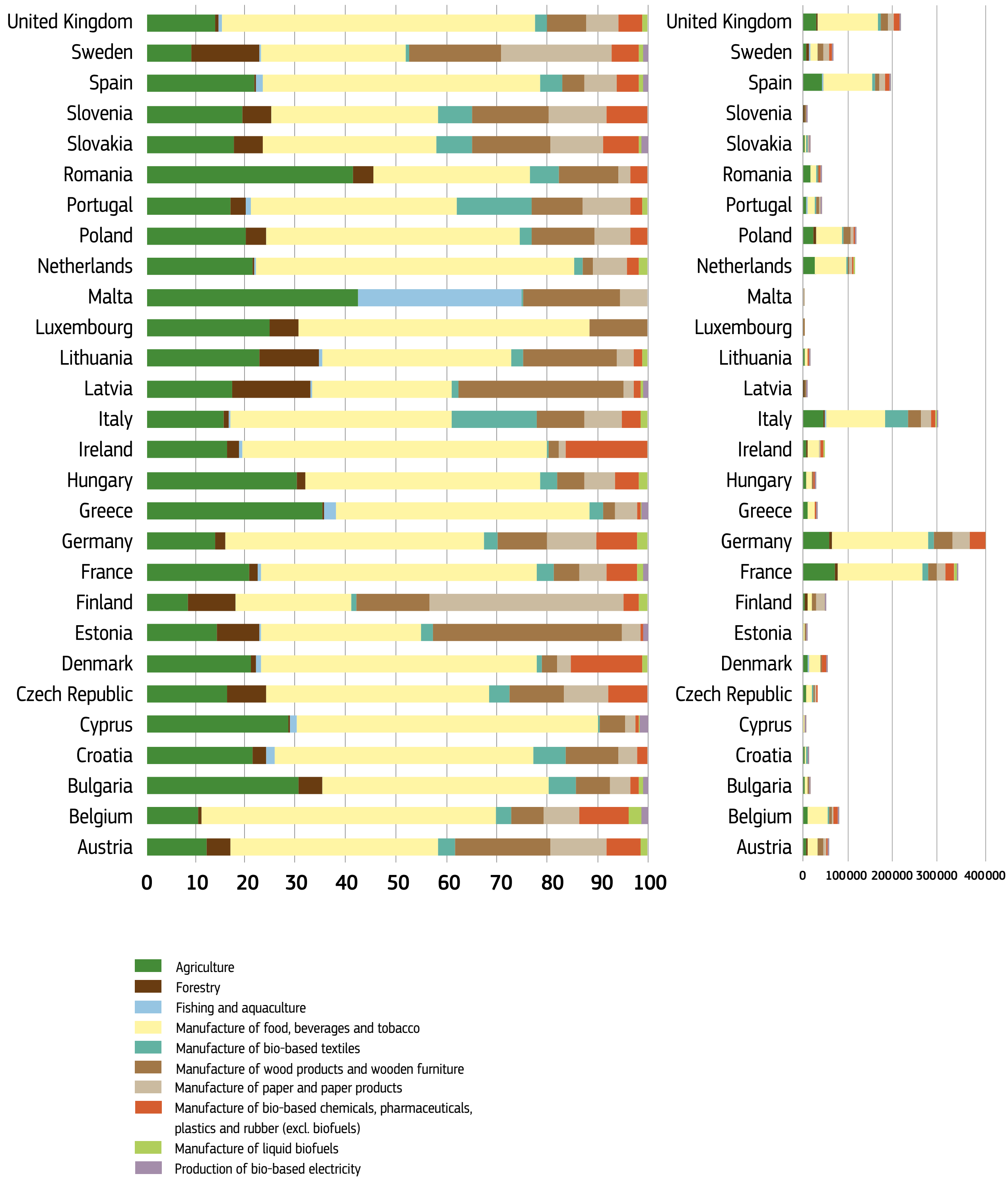
The United Kingdom and Spain are also significant contributors, each of them contributing 9% of the EU turnover. The 23 remaining Member States individually contribute 5% or less.

The five Member States mentioned above are also responsible for 67% of the EU turnover in the manufacture of food, beverages and tobacco, for 66% of the EU turnover in the manufacture of bio-based chemicals,

***Table 17:***
*Bioeconomy turnover in the EU-28 Member States (2014)*

| Member State | Turnover | | Member State | Turnover | | Member State | Turnover | |
|---|---|---|---|---|---|---|---|---|
| | million EUR | 1000 EUR per capita | | million EUR | 1000 EUR per capita | | million EUR | 1000 EUR per capita |
| **Austria** | 52 992 | 6.2 | **Germany** | 406 793 | 5.0 | **Netherlands** | 112 001 | 6.7 |
| **Belgium** | 77 680 | 6.9 | **Greece** | 27 149 | 2.5 | **Poland** | 114 650 | 3.0 |
| **Bulgaria** | 12 747 | 1.8 | **Hungary** | 24 841 | 2.5 | **Portugal** | 38 623 | 3.7 |
| **Croatia** | 10 111 | 2.4 | **Ireland** | 43 612 | 9.5 | **Romania** | 36 563 | 1.8 |
| **Cyprus** | 2343 | 2.7 | **Italy** | 293 071 | 4.8 | **Slovakia** | 12 445 | 2.3 |
| **Czech Republic** | 29 764 | 2.8 | **Latvia** | 6526 | 3.3 | **Slovenia** | 6502 | 3.2 |
| **Denmark** | 49 492 | 8.8 | **Lithuania** | 11 290 | 3.8 | **Spain** | 191 133 | 4.1 |
| **Estonia** | 5824 | 4.4 | **Luxembourg** | 1668 | 3.0 | **Sweden** | 62 298 | 6.5 |
| **Finland** | 48 793 | 9.0 | **Malta** | 282 | 0.7 | **United Kingdom** | 212 122 | 3.3 |
| **France** | 337 056 | 5.1 | | | | | | |

***Figure 15:***
*Turnover in the bioeconomy sectors of activity in the 28 EU Member States, in percentage (left) and in million EUR (right) (2014)*



pharmaceuticals, plastics and rubber (excl. biofuels) and for 62% of the EU turnover in agriculture. When excluding the United Kingdom, the other four Member States rank first in terms of EU turnover in the manufacture of bio-based textiles (74%). Spain, France, the United Kingdom and Italy are the top contributors to the EU fishing turnover (68%, comprising capture and aquaculture). Germany, Italy, France and the United Kingdom also show the highest EU turnover in the manufacture of wood products and wooden furniture (54%) (see Figure 15).

Germany, France, Italy and the United Kingdom generate 59% of the EU turnover in the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (exc. biofuels).

It is also worth noting that Sweden alone generates 16% of the EU forestry turnover, Finland is responsible for 10.6% of the EU turnover in the sector of the manufacture of paper and Belgium generates 9% of the EU turnover in the production of bioelectricity.

As a general feature, national bioeconomy turnovers mainly rely on two sectors: the manufacture of food, beverages and tobacco (on average 51% of the bioeconomy turnover) and agriculture (on average 17% of the bioeconomy turnover) (Figure 15). Although the contribution of the remaining Member States to the EU bioeconomy turnover is relatively small, specific features of their national bioeconomy are observed. The Maltese case is a very good illustration of sectorial specialisation, with 42% of the bioeconomy turnover reached in agriculture and 32% in fishing and aquaculture. The bioeconomy in Latvia, Sweden, Lithuania and Finland is geared towards the forestry sector, whose turnover exceeds 10% of their national bioeconomy turnover (compared to an average of 2% in the EU). In Italy and Portugal, 17% and 15%, respectively, of the bioeconomy turnover comes from the manufacture of bio-based textiles (compared to a 5% average). Also, Estonia and Latvia show a specific specialisation in the manufacture of wood products and wooden furniture (38% and 33%, respectively, of their national bioeconomy turnover compared to an average of 8% in the EU). Finland and Sweden generate 39% and 22%, respectively, of their national turnover in the manufacture of paper (compared to 8% on average in the EU). And finally, 16% of Ireland's and 14% of Denmark's bioeconomy turnover are generated by the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) (compared to an EU average of 6%).

It is important to note that the top five contributors to the EU bioeconomy turnover rank at intermediary levels in terms of turnover per capita. Only three of them are above the EU bioeconomy turnover per capita: France, Germany and Italy (from EUR 4800 to EUR 5100 per capita). Spain and the United Kingdom are below with, respectively, EUR 4100 and EUR 3300 per capita (compared to EUR 4.4 thousand per capita in the EU). In contrast, Ireland, Finland and Denmark show levels of turnover per capita higher than EUR 8800, followed by Belgium, the Netherlands, Sweden and Austria (EUR 6200 to EUR 6900 of turnover per capita) (see Table 17 and Figure 14 (right)).

## 3.3. Turnover per person employed in the bioeconomy subsectors.

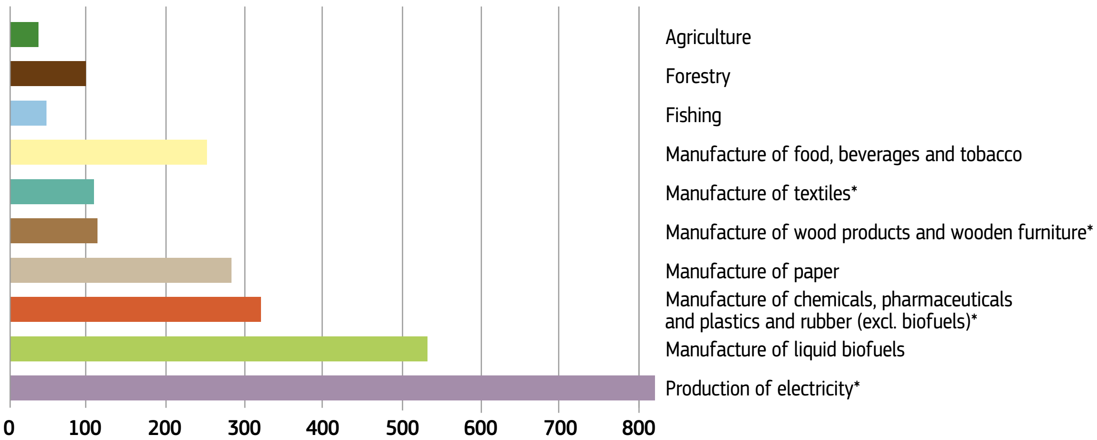
Among the sectors presented in Figure 16, the production of electricity and the manufacture of liquid biofuels show the highest levels of turnover per person employed (around EUR 820 thousand and EUR 530 thousand of turnover per person employed in 2014). The manufacture of chemicals, pharmaceuticals, plastics and rubber (excl. biofuels) ranks third, generating on average around EUR 320 thousand of turnover per person employed in the EU. Ranking fourth and fifth are the manufacture of paper and the manufacture of food, beverages and tobacco, where each still generates twice as much turnover per person employed than the EU average across all sectors of Figure 16 (i.e. around EUR 120 thousand per person employed on average in the EU). While the manufacture of wood products and wooden furniture, the manufacture of textiles and forestry are close to this average, the fishing and aquaculture and agriculture sectors reach less than half the average creation of turnover per person employed in the sectors presented in Figure 16.

The level of turnover per person employed has been growing in almost all the bioeconomy sectors during the 2008-2014 period. Figure 17 shows a particularly important growth of this indicator in the manufacture of liquid biofuels and the production of electricity, but this observation should be taken with caution since the statistical coverage of these sectors can be incomplete in some EU Member States.

There is a clear trend towards a reduction of the number of people employed relative to the turnover creation. Important reductions in turnover per persons employed have been reached in agriculture and forestry over the period 2008-2014.

***Figure 16:*** *Turnover creation per person employed in selected sectors of activity in thousand EUR turnover per person employed (EU-28, 2014)*

**Including non-bio-based activities (no estimations available for the bio-based part only).*



## 3.4. Survey to the EU bio-based chemicals and composites sector

Within the bioeconomy sectors in the EU, data on food/feed, energy and certain more traditional industrial sectors (e.g. the wood industry and the pulp and paper and the textiles sectors) are available in several databases, as described in the previous chapters, and therefore it is possible to obtain economic data that depict their state and evolution.

On the other hand, certain bio-based products and materials are not clearly described in the available databases because i) products are still emerging and can therefore not yet be found in official databases; and/or ii) these products are traditionally derived from fossil raw material and therefore available databases do not distinguish between bio-based and fossil-based products (e.g. polyethylene, polyethylene terephthalate, polypropylene, etc.) and represent the aggregation of both; or iii) that part of the product (e.g. of certain polymers or

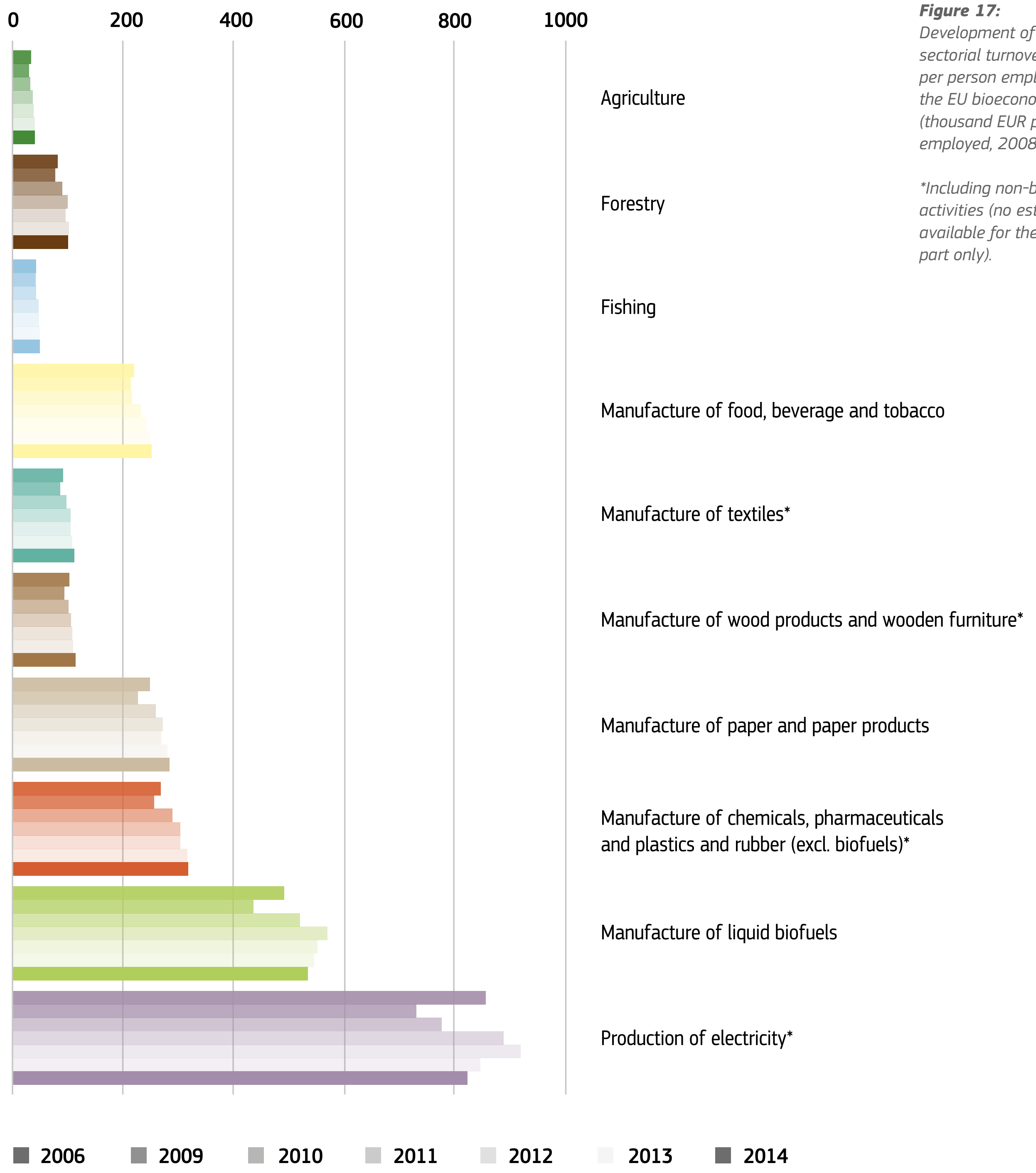



***Figure 17:*** *Development of the sectorial turnover creation per person employed in the EU bioeconomy (thousand EUR per person employed, 2008-2014)*

**Including non-bio-based activities (no estimations available for the bio-based part only).*

composites) but not the whole product is bio-based, and this distinction is not made in the database. Additionally, sometimes the databases available, for instance from the Food and Agriculture Organisation Corporate Statistical Database and the United States Department of Agriculture, only provide the aggregated data for both the industrial and the energy use of biomass (e.g. ethanol) (EC, 2014g).

Therefore, it is still difficult to describe the current situation and potential future evolution of the bio-based industrial material sector. In particular, it is still complicated to make the link between the feedstock and the final products and therefore to calculate the type and amount of biomass that goes to each branch of the sector. Certain studies have tried to compile data on this sector but could only provide estimations about the amount of biomass used by the industrial material sector (Carus 2012; Raschka et al. 2012), and the reliability of the data obtained is still limited.

This chapter complements the data provided in the previous sections by zooming in on the EU chemicals and composites sector and reporting a summary of the results of the survey conducted by the JRC on the bio-based chemicals and composites sector in the EU. The survey results are described in more detail in the JRC report of Nattrass et al. (2016).

### 3.4.1. Objectives and methods of the JRC survey

The general objective of the study conducted by the JRC in cooperation with the consultancies E4tech and AgraCEAS was to provide a description of the current status and evolution of the EU bio-based industry based on a list of relevant bio-based products and a survey of companies producing or about to produce these products (producing turnover or employing labour in the EU). The list, which contains some 70 products, was initially compiled in a previous study commissioned by the EC's JRC (Dammer et al. 2014) and further refined and validated by experts in several fora, including a dedicated workshop organised by the JRC and E4tech in Brussels on 16 September 2014. The final version of the list included 21 bio-based polymers; 18 bio-based organic acids; 16 bio-based products used in surfactants, solvents, binders, plasticisers, paints/coatings and lubricants; 6 bio-based alcohols; and 10 other bio-based products.

The specific objectives of the study included the quantification of business activity in the EU bio-based industry (e.g. number of companies; their size; number of companies producing a given product; turnover; number of employees) and the use of biomass in bio-based products. The study also aimed to determine the drivers and constraints affecting the development of bio-based products as well as to quantitatively and qualitatively compare the EU bio-based industry with key competitor countries.

Before engaging in the industry survey, the target population was identified and quantified (i.e. number of companies) based on the established list of bio-based products and using three main sources of information (F.O. Licht proprietary database, previous research and contacts with sector organisations like the European Chemical Industries Council and the BIC).

The survey targeted the total population of companies using a structured questionnaire administered online with email and telephone follow-ups. The survey was launched on 31 March 2015 and lasted for a couple of months. The questionnaire, which included more than 75 questions, was validated with experts in the sector, especially during the abovementioned workshop and also in a pilot survey directed to 20 companies.

### 3.4.2. Size of the target population and survey response rate

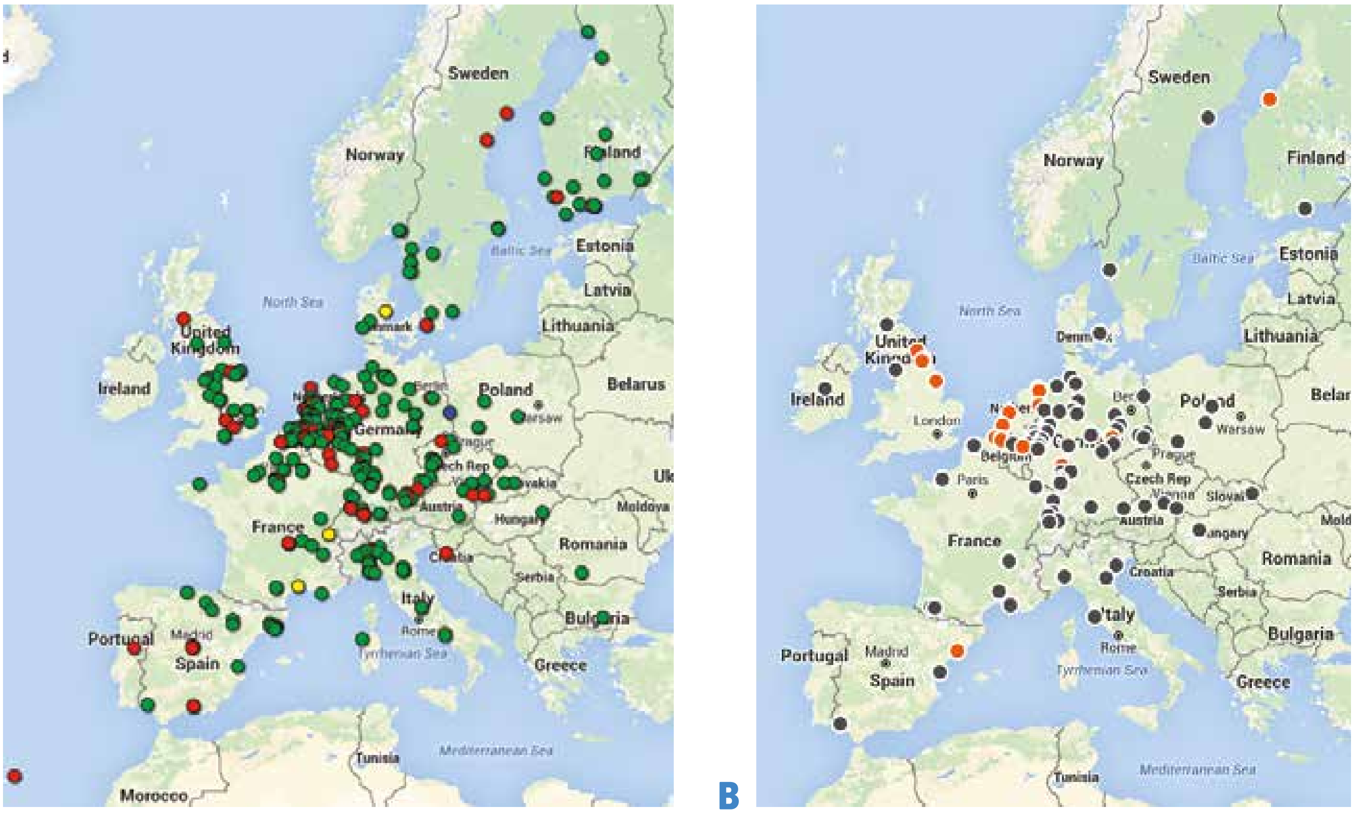
The target population consisted of 133 companies which operate at about 300 sites in the EU (as shown in Figure 18.A) and have some additional assets outside the EU. They are highly diverse in terms of size, products and time in the market. Some companies' operations are entirely bio-based, whereas for some others, bio-based products represent a relatively small fraction of their operations. The population includes companies producing commodity and speciality chemicals and material goods for a wide range of sectors. The target population of this study shows a similar distribution as the main European chemical industry clusters shown in Figure 18.B.

Fifty companies provided a response to the survey, resulting in an overall response rate of 38%. However, not all respondents provided a response to each question.

### 3.4.3. Description of business activities in the EU bio-based industry based on survey response

A large majority of the bio-based sector consists of private limited liability companies (67% of respondents). Both on the basis of the number of employees located in the EU in 2013 and of the annual turnover generated in the same year, most of the respondents are categorised as large companies employing more than 250 people and with sales exceeding EUR 50 million annually.

A




B

Different categories of bio-based products are currently produced or expected to be produced by the following number of companies by 2020: bio-based polymers by 27 companies; organic acids by 26 companies; bio-based alcohols by 19 companies; bio-based composites by 14 companies; bio-based surfactants by 14 companies; bio-based paintings and coatings by 11 companies; bio-based lubricants by 9 companies; bio-based binders by 7 companies; bio-based plasticisers by 6 companies; and bio-based solvents by 4 companies. In addition, 24 companies indicated that they currently produce or expect to produce 'other' bio-based products by 2020 that were grouped in the previous categories. Within these categories, esters constitute the most numerous product in the group (six companies); followed by hydroxymethylfurfural, fatty amines, ethylene and ethylene glycol (four companies each); and isosorbide and 'other polymer additives' (two companies each). Figure 17 shows how many times products of each category have been indicated in the survey by all respondents.

Forty-one companies provided information on 100 bio-based production plants located in the EU. The majority are commercial (74 plants, including one dormant plant) and a smaller number are pilot (16) and demonstration (10) plants. The largest numbers of plants are located in Italy, followed by Germany, France, the Netherlands and Spain. Germany has the largest number of commercial (active) plants (16), whereas Italy has the largest number of pilot and demonstration plants (8).

In addition, companies reported on bio-based production facilities located outside the EU. These are mainly located in Asia (primarily in China, Malaysia and Singapore) and North America.

Survey participants were asked to indicate the value of annual output, the annual turnover, the number of employees and of R&D-involved employees referring to their bio-based production for a time series of 4 years, between 2010 and 2013. Since not all participants provided data, it is not possible to obtain accurate numbers so the 4-year trends are analysed instead. Similarly for all indicators, SMEs with an annual production of bio-based products, < 50 000 tonnes are showing an increase in output, turnover and the number of employees in the four indicated years, while bigger companies (of a production between 50 001 and 5 million tonnes) are remaining more stable (or even slightly decreasing) in the 4-year period.

Forty-two respondents reported a total of 220 056 employees in 2013. It is very difficult to assess how many of these employees are engaged in bio-based activities but the survey showed that 55 % of respondents have more than 50 % of their employees linked to bio-based production. The number of employees engaged in bio-based R&D activities does not appear to represent more than 2 % of the total number employed in all bio-based activities.

***Figure 18.A:***
*Location of the target population premises within the EU*

*Colour code: headquarters (red), R & D sites (yellow), demonstration plants (blue) and production plants (green)*

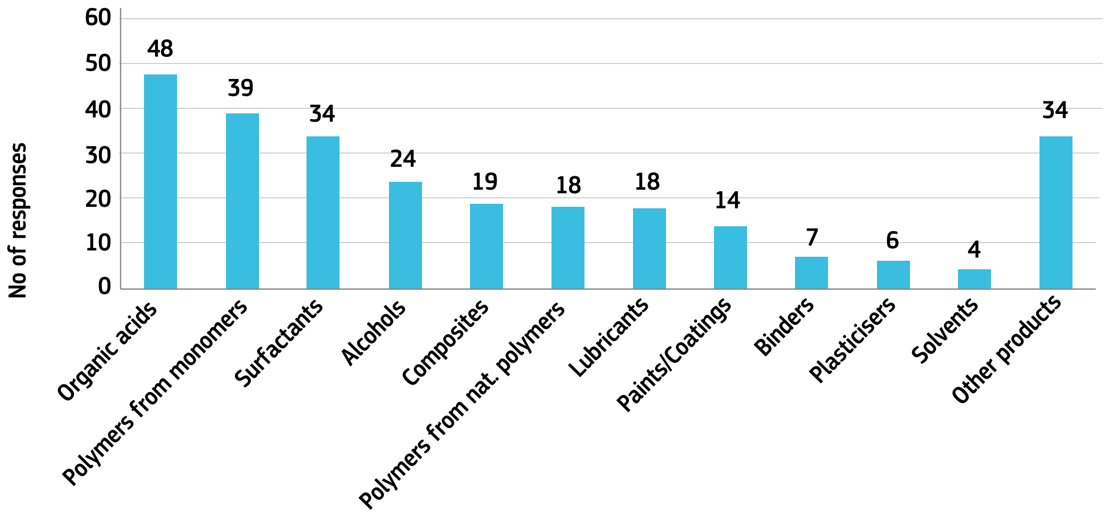
***Figure 18.B:***
*Location of major chemical parks in Europe*

*Colour code: no ECSPP members on park (grey), ECSPP members on park (orange)*

*Source: European chemical site promotion platform (ECSPP)*

*Figure 19:* *Number of bio-based products by category currently produced and/or expected to be produced by 2020 as reported by survey participants*

*Other products specified were epichlorohydrin, isoprene, farnesene, para-xylene, chelating agents, carbon nanotubes (from ethanol), limonene, lignosulphonates, acetaldehyde, ethyl acetate and fatty acid amides*




When it comes to the future evolution of the industry, 89 % of respondents expect that European bio-based product sales will increase by 2020 (49 % expect an increase of more than 100 %). Similarly, 72 % of respondents expect the share of bio-based output sold in the EU to increase by 2020 (41 % expect an increase of more than 100 %).

### *3.4.4. Relative economic size*

The study attempted to assess the relative economic size of the EU bio-based industry by using data on the number of companies included in the target population (133) compared to the entire EU chemical industries sector which consists of some 29 000 companies. This approach, based on survey data, cannot be done when it comes to the annual turnover and the number of employees due to the lack of full responses on these two variables. However, previous work (Clever Consult BVBA 2010) estimated that the annual turnover related to bio-based chemicals and plastics in the EU was EUR 50 billion for 2009 compared to the figure of CEFIC, the EU chemical industry umbrella organisation, which was EUR 527 billion for 2013 for the whole EU chemicals sector in the EU (CEFIC 2014). Such activities in bio-based chemicals and plastics contributed 150 000 jobs to the EU economy as compared to the 1.9 million employees of the total EU chemical sector (Clever Consult BVBA 2010).

### *3.4.5. Use of biomass in bio-based products*

The survey identified 20 companies using animal fats and vegetable oils; 19 companies using sugar and/or starch crops; and 11 companies using natural fibres. The most commonly used vegetable oils, reported in the number of companies using them, are rapeseed oil and palm oil, followed by coconut oil, soybean oil and castor oil. The types of vegetable oils and animal fats used remained consistent between 2010 and 2013, with several new users appearing in 2013.

The most commonly used natural sugar and starch feedstocks are maize, wheat and sugar beet, which are all edible feedstocks. No change in usage of these feedstocks was observed between 2010 and 2013, except that several companies reported diversification into sugar and starch feedstocks in 2013. The most commonly used natural fibre is wood and the number of users increased between 2012 and 2013. Finally, the co-products or intermediates used as feedstock are mainly glycerol, bioethanol and chemical pulp.

Half of all respondents claimed that more than 95 % of their feedstock is bio-based. In general, the survey shows that the proportion of bio-based feedstock in the total feedstock used did not change between 2010 and 2013. However, the majority of respondents expect this proportion to increase by 2020.

Finally, information on the use of domestic feedstock versus imports was provided by 28 companies, almost half of which source all bio-based feedstocks from within the EU. This supply includes a broad range of feedstocks (starch, sugar, vegetable oils, animal fats and wood fibre). Five companies declared that they import more than 95 % of their bio-based feedstocks into the EU. These companies mostly use vegetable oils, but also glycerol, bioethanol, animal fats and starch crops. This ratio of imported versus domestically supplied feedstock was constant during the period 2010-2013.

### *3.4.6. Drivers and constraints affecting the development of the industry*

Target companies were asked to declare and rank the importance of a given list of drivers and constraints that affect the development of the EU bio-based industry. The most important drivers are economic (including innovation) and directly relate to the bio-based product and its contribution to the profitability of the company: improved profitability; improved product competitiveness; and development of innovative products. These drivers are followed by improved environmental performance of the product. Policy is currently ranked as the least important driver, though could become more prominent in the future.

The main constraints for the development of the bio-based industry are declared to be the higher production cost of bio-based products compared to fossil-based ones; the high and/or variable feedstock prices; and the availability of funds to invest in production capacity. The existence of products and/or process patents, or other intellectual property issues, and the barriers for achieving product certification, while important for many companies, are ranked lowest on the list of constraints by the surveyed companies.

### *3.4.7. Comparison with EU competitors*

The study has, for the first time, tried to compare the EU bio-based industry with the United States, Canada, China, Brazil and Malaysia, following the recommendation of experts and existing reports that point to these countries as leaders in this sector (based on existing production capacity; planned production capacity; industrial innovation; the status of complementary industries – e.g. biofuels; and the availability of feedstock). Based on desk research, the EU compares favourably to other countries on many important indicators, especially on R&D and innovation capacity, with some limitations in feedstock availability and the current level of commercial activity.

Canada (in 2009) and the United States (in 2008 and 2015) carried out similar surveys on the bio-based sector, but due to the lack of harmonisation in the definitions of the industries, scope, indicators measured and methodology followed, direct comparisons are not reliable using primary information.

In February 2016 the JRC organised a workshop in cooperation with the Brazilian Ministry of Science, Technology and Innovation in the framework of the EU–Brazil sector dialogues (Parisi et al. 2016). The workshop gathered representatives from EU Member States, Brazil, the United States and Canada to exchange information and knowledge of the current status of their respective national bio-based industries (benchmark) and future developments.

### *3.4.8. Limitations and recommendations*

The survey described above was the first of its kind and scale to be carried out across the EU. It represents an important first step in a systematic approach to quantifying the EU bio-based economy. However, it is important to bear in mind that the survey is not able to provide a fully quantitative picture of the status and evolution of the EU bio-based industry. This is mainly due to the high number of products and their heterogeneity; to the amount of data that needs to be collected and the difficulty for the respondents to assemble it; and the incomplete response rate. Due to the lack of harmonisation in scope and methodologies between existing country reports, it is not possible to quantitatively compare the EU bio-based industry with important competing countries like Brazil, the United States and China. However, the survey conducted in this study provided a good starting point for future surveys aiming to provide a more complete picture.

## 3.5. Measuring the bioeconomy through multipliers: a JRC work in progress

The different sectors in the bioeconomy are linked through the supply and demand of intermediate products. For instance, residues may be converted into pellets, which are transported and used to produce bioelectricity or transformed into second-generation biofuels to serve the bio-based chemistry. These details are to a certain extent captured by the upcoming databases elaborated by the JRC, more specifically highly disaggregated input-output tables (IOTs) and social accounting matrixes (SAMs). They give insight into the economic interlinkages of the bioeconomy sectors in the EU Member states (see example of residues).

With the help of these databases, investments into one sector can be tracked, i.e. each euro spent and re-spent in other sectors of the economy, therefore generating economic activity or so-called economic multiplier effects. Multipliers allow the identification of those bioeconomic sectors which potentially maximise economic value added.

The economic and employment multipliers quantify not only the direct effects, but also the spill-over effects, thus the indirect and induced contributions. An indirect effect of an employment multiplier of two, for example, means that for every employee in the sector concerned, one additional person is employed in that sector's supply chain.

An initial analysis shows important divergences between sectors concerning the creation of additional economic value and/or jobs in the upstream or downstream value chain. Similar to the statistics in Chapter 3, the analysis will reveal important differences among EU Member States.

The JRC is preparing an economy-wide, quantitative assessment covering the full diversity of all bioeconomy sectors for all EU Member States. Based on national accounts and complemented with the statistics presented in Chapters 3.1 and 3.2, JRC is developing a consistent set of IOTs and SAMs benchmarked to the year 2013 for all EU-28 with agriculture, food and other traditional sectors (fishing, forestry, wood and pulp and paper) and an unprecedented disaggregation of bio-based sectors (biofuel, biochemical and bioenergy).

From a technical point of view, the new database will follow Eurostat's classification for non-agricultural, non-bio-based commodities. The disaggregation of agri-food follows the classification developed by Müller et al. (2009). Additionally, with the help of appropriate economic statistical techniques (i.e. the hierarchical clustering technique as used in Philippidis et al. (2014)), it will be possible to profile and assess comparative structural patterns inherent within each of the EU Member States' agri-food and bio-based sectors.

## 3.6. The ongoing quantification of biomass flows: a JRC collaboration

The quantification of biomass flows in the EU will help to understand how much and what kind of biomass is produced and traded by the EU and what are its current uses. This information is the basis for assessing the capacity of the EU and its Member States to produce, transform or trade its own biomass and develop efficient bioeconomy value chains.

The JRC is compiling and harmonising data from different sectors of production and use of biomass. The final biomass flows will report on the volumes of production of agricultural, forestry and aquatic biomass, their processing and the trade of raw biomass and bio-based products, as well as the main area of biomass uses and biomass waste along the bio-based value chains.

Beyond the quantification of volumes, efforts are made to decompose the flows into main biomass components, i.e. proteins, oils and fats, sugar and starch, cellulose and other components. These details give an indication as to the match between the different sources of biomass and their potential uses: one given type of biomass cannot serve all uses (i.e. starchy crops suit the needs of the starch industry well). Thus, this information is very important to understand which sectors organic waste could be used in as well as to assess the potential development of new value chains and their sourcing (e.g. domestic vs. extra-EU).

Further developments will follow, like the estimation of biomass flows in value or their conversion in new units (e.g. energy units).

# 4. Measuring the environmental impact of the bioeconomy

# 4. Measuring the environmental impact of the bioeconomy

The bioeconomy is not only important for creating jobs and growth (dealt with in Chapter 3), but also for addressing environmental challenges. For instance, replacing fossil-based fuels and materials with certain sustainable biofuels and bio-based materials can have the potential to reduce GHG emissions and fossil-fuel dependency. Applying adequate sustainability criteria is important for this. LCA is a key approach to assess the environmental benefits of the bioeconomy.

Chapter 4.1. presents three different approaches to LCA. Firstly, attributional LCA (A-LCA) is introduced that aims to assess environmental impacts associated with all stages of a pro-duct's life from cradle to grave (i.e. from raw material extraction through materials processing, manufacture, distribution, use, etc.). Secondly, advanced A-LCA methodology is presented, which looks beyond the immediate system boundaries by comparing multiple systems and by taking into account further GHG and environmental indicators. Finally, the consequential LCA (C-LCA) identifies the consequences that a decision in the foreground system has for other processes and systems of the economy, both in the analysed background system and on other systems outside the boundaries. The integrated modelling framework (IMF) that is being developed in the JRC fully implements C-LCA and will allow policy impact assessment once it is fully implemented.

Chapter 4.2. presents results from already available LCA studies in the field of the bioeconomy, from case studies using A-LCA and from advanced A-LCA.

## 4.1. LCA as a key approach to assess the environmental benefits of the bioeconomy

LCA has become one of the main methods used to inform policymakers and the public about potential environmental impacts of products and commodities. In the last decade, LCA has been increasingly integrated into EU legislation, for instance in the Waste Framework Directive (EU 2008), the RED and the FQD (EU, 2009a and 2009b).

LCA is a structured, comprehensive and internationally standardised method. It aims to assess all relevant flows of consumed resources and pollutant emissions associated with any goods or services ('products') in order to quantify the related environmental and health impacts and resource-depletion issues. LCA considers the entire life cycle of a product, from raw material extraction and acquisition, through energy and material production and manufacturing, to use and end-of-life treatment and final disposal.

### *4.1.1. Life cycle assessment (LCA): two modelling principles*

Two main Life Cycle Inventory (LCI) modelling principles are in use in LCA practice: A-LCA and C-LCA modelling, with the former being more widely used for historical and practical reasons. They represent with their logic two fundamentally different approaches of modelling the analysed system.

The attributional LCI modelling principle depicts the potential environmental impacts that can be attributed to a system (e.g. a product) over its life cycle, i.e. upstream along the supply chain and downstream following the system's use and end-of-life value chain. Attributional modelling makes use of historical, fact-based, average and measureable data of known (or at least knowable) uncertainty and includes all the processes that are identified to relevantly contribute to the system being studied. In attributional modelling the system is hence modelled as it is or as it was (or as it is forecast to be) (EC, 2010h).

The consequential LCI modelling principle aims at identifying the consequences that a decision in the foreground system has for other processes and systems of the economy, both in the analysed system's background system and on other systems outside the boundaries. It models the studied system around these consequences. This is the case, for example, for the environmental impact of a policy that affects several sectors of the economy. The consequential life cycle model is hence not reflecting the actual (or forecast) specific or average supply chain. Instead it models a hypothetical, generic supply chain that is modelled according to market mechanisms, and potentially includes political interactions and consumer behaviour changes (EC 2010h; Plevin et al. 2013). Secondary consequences may counteract the primary consequences (then called 'rebound effects') or further enhance the preceding consequence.

The JRC applies LCA methods in several contexts and projects, such as within the Bioeconomy Observatory and the Biomass project.

### 4.1.2. Attributional-LCA

Within the framework of the Bioeconomy Observatory, the JRC has performed a comprehensive, independent and evidence-based environmental sustainability assessment of various bio-based products and their supply chains using a life cycle perspective. This methodology is largely based on the product environmental footprint (PEF) method developed by the JRC [18] and on the Centre's previous research proposals (Nita et al. 2013). The application of the methodology may help to identify those parts of the production system that are most environmentally relevant in order to design actions to reduce the estimated environmental impacts. The methodology can also help to identify gaps in data and/or information availability or accessibility as well as to focus data collection on those parameters or parts of the production system that most influence its environmental performance.

In the framework of the LCA analysis, environmental factsheets have been compiled to provide uniform information on the environmental performance of bioeconomy value chains based on publicly available instruments (data, information and analyses) developed by EU, national and international organisations, and on the results of relevant EU-funded projects.

#### 4.1.2.1. Selected bioeconomy value chains

The analysed bioeconomy value chains are divided into three groups: (1) food and feed, (2) bio-based products and (3) bioenergy, including biofuels (Table 18).

18 The 2013 Commission Recommendation No 2013/179/EU 'on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations' supports the use of the PEF method when undertaking environmental footprint studies of products.

| Food and Feed | Bio-based products | Bioenergy | |
|---|---|---|---|
| Product | Product | Product | Via |
| Eggs | 1,3-Propanediol | Biodiesel | Transesterification |
| Milk | Acetic acid | Bio-based alcohols | Fermentation |
| Sugar | Adipic acid | Small-scale heat | Direct combustion |
| Tomato | Amino acids | Large-scale heat | Direct combustion |
| Wheat | Glycerol | Electricity | Direct combustion |
| Wine | Lactic acid | Combined heat and power | Direct combustion |
| | Natural rubber | Biofuels | Gasification |
| | Polyhydroxyalkanoates | Hydrogen | Gasification |
| | Polylactic acid | Combined heat and power | Gasification |
| | Pulp and paper | Biodiesel | Hydrogenation |
| | Succinic acid | Combined heat and power /fuel | Torrefaction |
| | | Combined heat and power | Anaerobic digestion |
| | | Combined heat and power/$H_2$ | Pyrolysis |

***Table 18:*** *Selected bioeconomy value chains within the BISO FP7 project*

#### *4.1.2.2. Methodology*

Continuous mapping and collection of data and information from various sources, complemented by critical review, analysis, assessment and calibration, were carried out for the production of the factsheets.

The literature review was conducted by mapping accessible LCA studies that provided an evaluation of the environmental performance of the selected bioeconomy value chains. The selection of these LCA studies was performed using the following criteria: (i) studies conducted under the EU framework programmes for research (http://cordis.europa.eu); (ii) peer-reviewed literature; (iii) priority was given to studies accounting for the highest number of impact categories and studies reporting environmental impacts calculated in line with the PEF methodology; (iv) studies with obsolete, incomparable (i.e. percentages or weighted figures) or dubious quality data were excluded.

For the LCA analysis, the PEF methodology was used, which includes 14 impact categories in order to provide comprehensive evaluation of the environmental performance of value chains.

The LCA data mapping was performed by identifying the minimum and maximum reported values for each impact category displayed for the same functional unit. Differences in methodological approaches among LCA studies such as allocation methods, geographical coverage and system boundaries were taken into account, which, however, may bias the robustness of the ranges provided. Therefore, the conclusions taken from these comparisons should be considered with some caution.

The LCA results were then normalised in order to express the impact scores of each impact category into the same units (dimensionless) and for assessing the relative importance of the impact category over a reference in order to compare results across categories ([19]). Using normalisation references, the relative magnitude of an impact may be related to other impacts in the life cycle of a product with a common unit and the relative magnitude of the contribution of the impact in one impact category may be compared with the magnitude of the contribution in another one. A reference region is commonly chosen to represent the background environmental burden related to all activities (e.g. economic, production activities) in that region under study, e.g. the overall impact of EU in 1 year (see Sala et al. 2015).

Normalisation was conducted whenever possible using normalisation factors that represent emissions from the EU-27 for the year 2010 based on the 'domestic emissions inventory' ([20]) reported in *Normalisation method and data for environmental footprints* (Benini et al. 2014). Otherwise the normalisation factors for EU emissions were taken from the ReCiPe impact assessment method (Sleeswijk et al. 2008).

In addition to the LCA analysis, for each of the bio-based value chains compiled in the factsheets, the main steps in the production process were depicted in a flow sheet, a technological overview on the state of the art was provided and an analysis of the technology readiness level and a strengths, weaknesses, opportunities and threats (SWOT) analysis (Sleeswijk et al. 2008) of the product/process were presented.

The environmental assessment factsheets are available at https://biobs.jrc.ec.europa.eu/analysis. Chapters 4.2.1. and 4.2.2. present case studies using A-LCA.

### *4.1.3. An advanced approach to A-LCA*

Recent studies have shown that A-LCA studies, which focus on the primary system only, may lead to incorrect conclusions because they neglect crucial phenomena linked to the temporal imbalance between emissions and removals of biogenic $CO_2$ as well as critical market-mediated impacts (Agostini et al. 2014, Soimakallio et al. 2015, Cherubini et al. 2014, Searchinger et al. 2009, Plevin et al. 2013).

These deficiencies are addressed by advanced approaches to A-LCA, which apply aspects of consequential thinking to A-LCA studies. Under proper system design and using appropriate analytical tools, A-LCA studies can be very helpful in evaluating the impacts of certain choices, even avoiding the use of complex and time-consuming tools such as large integrated modelling frameworks.

The main aspect of an 'advanced' A-LCA study is the analysis of multiple systems ('counterfactuals'). For instance, when assessing the potential environmental impacts of a bio-based commodity, it should be considered that the biomass feedstock and the land over which it is eventually grown is a limited resource. Therefore, multiple systems should be compared to partially integrate market-mediated effects to get a better picture of the potential risks associated to the bio-based commodity. In the case

19 Normalisation aims at better understanding the relative magnitude for each indicator result. Normalised values are calculated by dividing the resulting environmental load for each impact category by a selected reference value, in this case the emissions from the EU-27 in 2010 (e.g. for climate change, 4.60E12 kg $CO_2$ equivalent).

20 The 'domestic emissions inventory' includes all emissions originating from activities taking place within the EU territory.

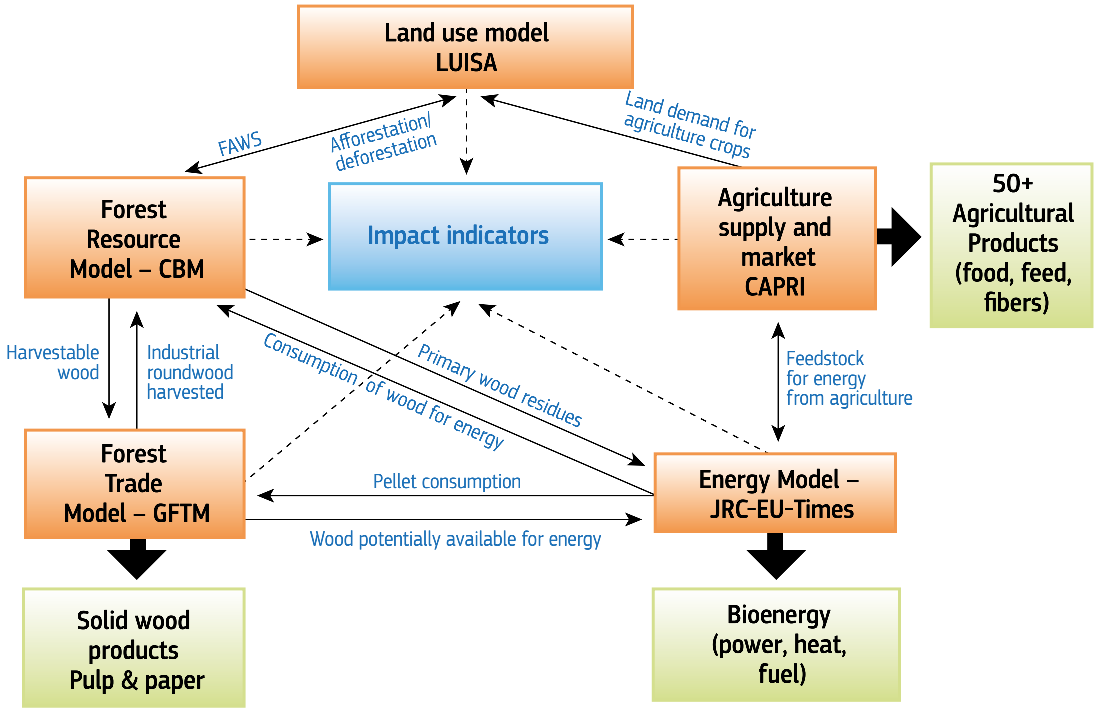



***Figure 20:***
*Schematic illustration of the IMF under development within the Biomass project*

study described in Section 4.2.3., forest logging residues are considered to have three possible fates: i) left on the forest floor; ii) burned on site; iii) harvested and used to produce domestic heating. The actual function of the residues is site-specific and driven by market forces; nonetheless, three systems can be designed and compared to assess the climate change mitigation potential of the bioenergy route.

Such an assessment introduces a higher degree of uncertainty and value judgements so that it is essential that results are considered on a relative basis (System 1 vs. System n) and an extensive sensitivity analysis is carried out.

When the goal is to evaluate the climate change mitigation potential of a system, it is important to use a dynamic inventory to capture dynamic phenomena and to use multiple climate metrics (e.g. global warming potential (GWP) ([21]) and global surface temperature change potential (GTP) ([22]) (Cherubini et al. 2016, Levasseur et al. 2016).

21 Capacity of a GHG to influence radiative forcing, expressed in terms of a reference substance (for example, $CO_2$-equivalent units) and specified time horizon (e.g. GWP 20, GWP 100 and GWP 500 for 20, 100, and 500 years respectively). It relates to the capacity to influence changes in the global average surface-air temperature and subsequent change in various climate parameters and their effects, such as storm frequency and intensity, rainfall intensity and frequency of flooding, etc.

22 Compared to the GWP, the GTP goes one step further down the cause–effect chain and is defined as the change in global mean surface temperature at a chosen point in time in response to an emission pulse – relative to that of $CO_2$. Whereas GWP is integrated in time, GTP is an end-point metric that is based on temperature change for a selected year: t. As for GWP, the impact from $CO_2$ is normally used as a reference, where a GTP is the absolute GTP giving temperature change per unit emission. Like GWP, the GTP values can be used for weighting the emissions to obtain '$CO_2$ equivalents'.

All these elements are highlighted in practice in the case study presented in Chapter 4.2.3.

### *4.1.4. Integrated modelling framework*

When the goal of the assessment is not to analyse a single product or value chain but rather to analyse the potential impacts of a policy choice or scenarios, then the proper approach is the C-LCA modelling.

This section describes the methodology being implemented for the impact assessment task within the JRC Biomass project. The work on the project was still ongoing at the time of writing.

The core pillar of the consequential modelling proposed within the Biomass project is the IMF, illustrated in Figure 20.

A list of impact indicators has been defined in order to characterise the impacts of any policy scenario modelled through the IMF in a synthetic and immediate way.

The DPSIR framework as described by the European Environment Agency was followed (Smeets et al. 1999). According to this framework, social and economic developments (**d**rivers) exert **p**ressure on the environment and, as a consequence, the **s**tate of the environment changes, such as the provision of adequate conditions for health, resources availability and biodiversity. Finally, this leads to impacts on human health, ecosystems and materials that may elicit a societal response that feeds back on the driving forces or on the state or impacts directly, through adaptation or curative action.

| Possible environmental indicators to consider (taken from existing literature) | | |
|---|---|---|
| Descriptive indicators | | |
| **Indicators of DRIVERS** | | |
| • GDP trend<br>• Population trend<br>• Overall level of consumption and production: <u>Biomass flows through sectors</u> | | |
| **Indicators of PRESSURES** | | |
| | **Land use change** | |
| **On biodiversity** | **On climate change** | **Land management intensification** |
| • Conversion/production on AoPs → world database on AoPs/ Natura 2000 areas<br>• Conversion/production on intact forest landscapes<br>• Conversion/production on peatlands<br>• Conversion/production on areas of high biodiversity value (including grassland and forests) | • Conversion/intensification of production on high carbon stock forests<br>• Conversion/intensification of production on wetlands<br>• Conversion/intensification of production on peatlands (histosoils)<br>• Conversion of abandoned/ marginal/fallow land<br>• Conversion of grassland to cropland<br>• Conversion of forest to cropland<br>• Deforestation/afforestation<br>• Carbon stocks in forests, wood products (and landfills) | • Intensification of agricultural management:<br>- index on agricultural inputs, e.g. total mineral fertilisation;<br>- agricultural residues management, increased removal of residues;<br>- area with conventional/ conservation agriculture.<br>• Intensification of forest management:<br>- rotation times;<br>- area under mineral fertilisation. |
| **Soil quality** | **Water use and quality** | **ILCD indicators and models at midpoint (24)** |
| • Biomass extraction on steep slopes<br>• Share of residues removed<br>• Extraction of biomass from soils defined as stony | • Biomass cultivation with irrigation in areas with a high level of water scarcity | • Climate change<br>• Ozone depletion<br>• Ecotoxicity for aquatic fresh water<br>• Human toxicity – cancer effects<br>• Human toxicity – non-cancer effects<br>• Particulate matter/respiratory inorganics<br>• Ionising radiation – human health effects<br>• Photochemical ozone formation<br>• Acidification<br>• Eutrophication – terrestrial<br>• Eutrophication – aquatic<br>• Resource depletion – water<br>• Resource depletion – mineral and fossil<br>• Land use |
| **Indicators of IMPACTS** | | |
| **ILCD indicators and models at endpoint (25)** | **Impacts on resource efficiency/ natural resources** | |
| | • Land take/Urbanisation<br>• Recycling rate/cascading indexes<br>• Carbon intensity of economy → GDP (or value added)/kg $CO_2$<br>• Energy intensity of economy → GDP (or value added)/mJ primary energy<br>• Freshwater extraction/consumption<br>• (Human appropriation of net primary production)<br>• (Transnational land acquisition) | |

23 It is proposed to apply default impact categories (with respective impact category indicators) and impact assessment models used for PEF studies.
24 ILCD recommendations exist for characterisation methods for evaluation of impacts (endpoint). However, given the uncertainties related to these methods, it is preferable to stop evaluating pressures at midpoint stage.

| Performance indicators | |
|---|---|
| **Carbon stocks and GHG emissions** | **EU 2030 targets** |
| • LULUCF ➔aggregation of various C-stock data to comply with accounting rules defined at EU level<br>• GHG emissions from the livestock sector<br>• GHG emissions from the energy sector<br>• Potential leakages (emissions outside EU borders associated with imported biomass and with indirect effects) | • GHG emission reduction as compared to EU targets for 2030<br>• Energy efficiency: primary energy consumption reduction<br>• Renewable energies (RES) share in final energy consumption<br>• RES share electricity generation<br>• RES in transport |

## Proposed social and economic indicators of the Biomass study

- Price and supply of national food basket
- Definition of an index to account for displacement of biomass between sectors: e.g. as proxy, stemwood/sawnlogs to bioenergy; agricultural land converted to energy crop
- Definition of a cascaded index of wood
- Energy security indexes: e.g. domestic biomass for bioenergy over imported biomass for bioenergy; domestic primary energy supply over imported primary energy
- Food security: domestic food/feed production over import
- Jobs created: estimate of jobs created per unit of residue delivered to the plant; employment indices in feedstock collection and in plant construction and operation
- Processing efficiencies by technology and feedstock
- Production costs
- Gross value added at factor cost and contribution to GDP
- Average production cost and share of cost of wood-based materials
- Imports and exports of wood and products derived from wood, and net trade
- Use of renewable and non-renewable materials, classified by virgin and recycled material
- Labour productivity
- Share of forests certified for sustainable management
- Consumption of wood per capita

#### *4.1.4.1. Initial considerations*

The calculation of impacts from the IMF is actually a more straightforward exercise compared to the A-LCA calculations. This is because there is no need for any special methodology to attribute specific impacts to a single product, but rather is a matter of properly 'accounting' all the flows and quantities produced by the IMF.

Ideally, all market sectors and all regions of the world would be included in the IMF and then the exercise would simply be to sum up the relevant flows.

However, in reality, the following limitations in the IMF need to be taken into account.

- Geographic scope: the IMF defined in the Biomass project is well defined for EU Member States but less so for the rest of the world (RoW). Thus, emissions and processes related to products and raw material imports will need to be added manually through the use of life cycle emission factors.
- Incomplete representation of the sectors of the economy: not all market sectors are depicted in the IMF, e.g. the construction and material sector (non-biogenic materials). Thus, the so-called substitution benefits of non-biogenic materials (concrete, fossil plastics, etc.) for wood products will need to be either quantified exogenously (again using life cycle factors) or evaluated qualitatively.
- Omission of some co-products in the modelled market sectors (e.g. products sold on the medicinal or cosmetic sector): in this case there will be a need to resolve the multifunctionality by either allocating emissions to the co-products or assigning credits.

#### *4.1.4.2. Definition of impact indicators*

Once the inventory is defined, these values will be filtered through an indicators formulation. This section presents a hypothetical list of indicators that could be calculated from the IMF. The current list is compiled to be comprehensive and takes stock of previous exercises of a similar nature to this one (Fritsche et al. 2012; ToSIA n.d.).

It is important to remember that each indicator $(I_j)$ will be calculated per each geographical unit *(g)* considered, per each policy scenario *(n)* and at each time step *(t)*.

All indicators from policy scenarios will be evaluated against a baseline (business as usual).

The classification of indicators reported by Smeets et al. (1999) were followed and divided in the following way.

- Descriptive indicators: *what is happening to the environment and to humans?*
- Performance indicators: *results weighted against specific policy targets.*

For each category, indicators for drivers, pressures and impacts on the areas of protection (AoP) were proposed. Indicators to assess economic and social impacts of each policy scenario were also proposed.

## 4.2. Results of available LCA studies

### *4.2.1. Exemplary environmental comparison between bio-based products and their fossil equivalents*

The bulk of publications comparing the environmental performance of bio-based products (excluding bioenergy) and their fossil references deal with bio-based polymers and composite materials. For the majority of bio-based chemicals and building blocks, this comparison is scarce.

In order to shed light on the subject, the JRC performed an A-LCA mapping of six chemical building blocks and three fossil-based polymers using the SimaPro v.8 (2014) and Ecoinvent v.3 (2014) databases. For the products where no data were found in Ecoinvent v.3, LCA data were collected from the BREW project report ([25]). For bio-based products, three types of feedstock (corn, sugar cane and lignocellulosic biomass) were compared (EC, 2015h). The majority of the impact categories reported in the tables are based on the impacts and LCA methods recommended by the PEF methodology.

Results showed a significant level of uncertainty over LCA figures, mainly due to poor uniformity in the methodological assumptions (i.e. system boundaries, allocation methods and functional units) and in the presentation of results (e.g. different terminologies for the same impact, non-reported life cycle data, etc.). Hence, their interpretation and comparison become rather challenging and should be carefully interpreted. Besides, when drawing conclusions regarding bio-based products, the high variability in nature and production systems of renewable feedstocks should also be taken into consideration.

According to this analysis, the bio-based products showed lower environmental loads in comparison to their fossil references for impact categories of climate change and non-renewable energy consumption. On the other hand, for impacts regarding eutrophication, acidification and land use, the bio-based products showed lower environmental performance, mainly due to the agricultural activities related to biomass production (i.e. use of fertilisers and pesticides) and lower efficiencies in the production processes (i.e. optimisation processes related to technology maturity in comparison to commercial-scale of fossil-based products). Within the bio-based products, for all impacts corn-based sugars lead to larger environmental loads than lignocellulosic biomass and sugar cane. The comparison for climate change is depicted in Figure 21 and Figure 22.

25 Medium- and long-term opportunities and risks of the biotechnological production of bulk chemicals from renewable resources (Copernicus Institute, n.d.).

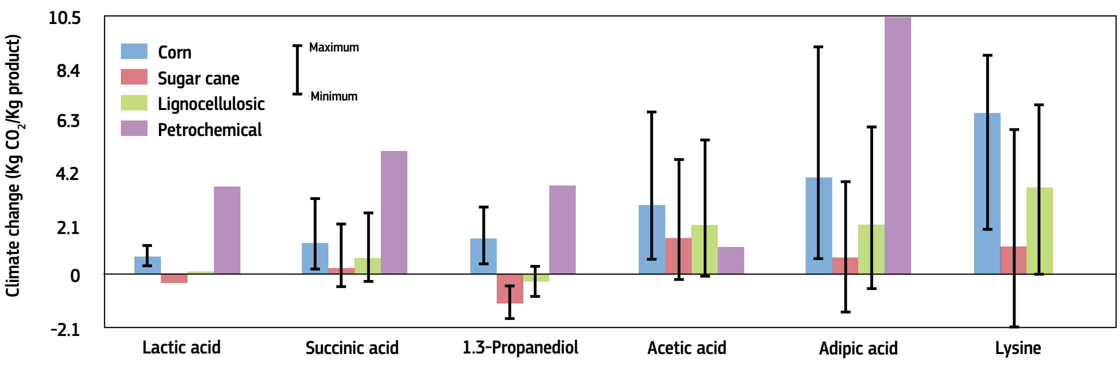



***Figure 21:***
*Climate change impacts of different chemical building blocks*

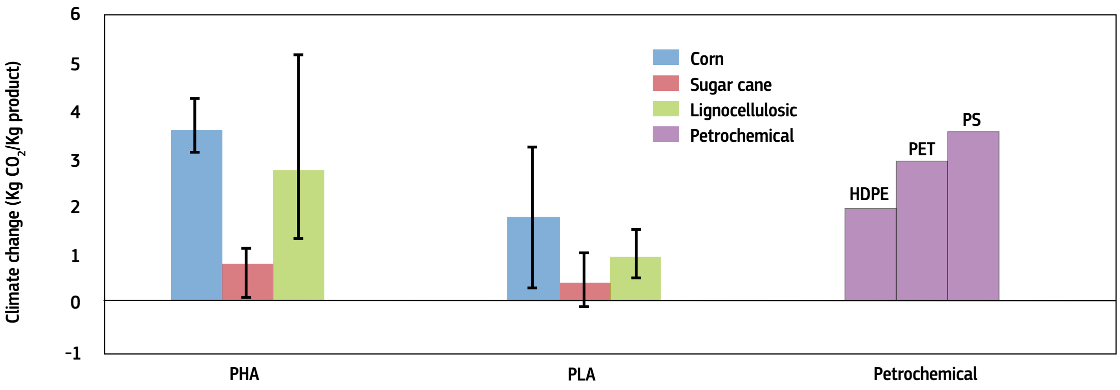



***Figure 22:***
*Climate change impacts of different polymers*

**PHA: polyhydroxyalkanoates; PLA: polylactic acid; HDPE: high-density polyethylene; PET: polyethylene terephthalate); PS: polystyrene.*

Some other general conclusions for the analysed bio-based products were found on the bases of the feedstock used:

- impacts on climate change and non-renewable energy demand from bio-based products obtained from sugar cane were lower in comparison to other feedstock due to the high productivity yields of the crop and the credits assigned to the process for the energy surplus generated from bagasse burn;
- when produced from lignocellulosic residues (e.g. corn stover), impacts on land use were significantly lower due to the economic allocation applied to the co-products;
- for climate change, the use and end-of-life phases of bio-based products are environmentally significant since the highest values were obtained from studies with a cradle-to-grave system boundaries approach;
- when lignin-rich wastes are co-produced from the hydrolysis of lignocellulosic materials, their use for heat and power helps to reduce impacts on non-renewable energy demand and climate change;
- in the processes where anaerobic fermentation is involved, continuous operation systems reduce the environmental loads for all impact categories as opposed to batch fermentation processes.

### *4.2.2. Environmental performance of three exemplary bioeconomy value chains*

In addition to the LCA mapping for the environmental comparison of bio-based products, the JRC (Cristobal et al. 2016) performed an LCA modelling for three exemplary case studies related to the use of sugar as feedstock for: sugar production (for the food and feed pillar); bioalcohols production via fermentation (for the bioenergy pillar); and PHA production (for the bio-based product pillar).

This assessment was conducted using the software package SimaPro v.8. The Ecoinvent v.3 database was mostly used for developing the life cycle inventories, and data gaps were filled with other bibliographic data.

Regarding sugar production, sugar beet and sugar cane grown in Germany and Brazil, respectively, were the two systems to be analysed. The functional unit chosen was 1 kg of extractable sugar produced. Results showed that the highest environmental impacts were mostly associated to sugar production from sugar cane, most importantly in the cases of freshwater eutrophication, ozone depletion and ionising radiation – human health effects. On the other hand, the sugar production from sugar beet resulted in higher environmental impacts for marine eutrophication, terrestrial eutrophication, acidification, climate change and human toxicity – non-cancer effects.

***Figure 23:*** *Normalised environmental impacts of sugar production ([27])*

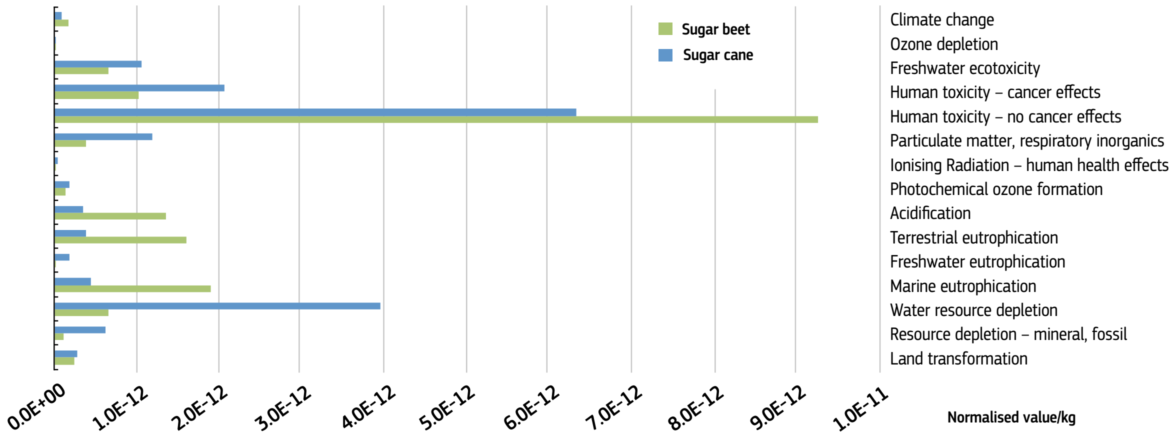



***Figure 24:*** *Normalised environmental impacts of bio-based ethanol production*

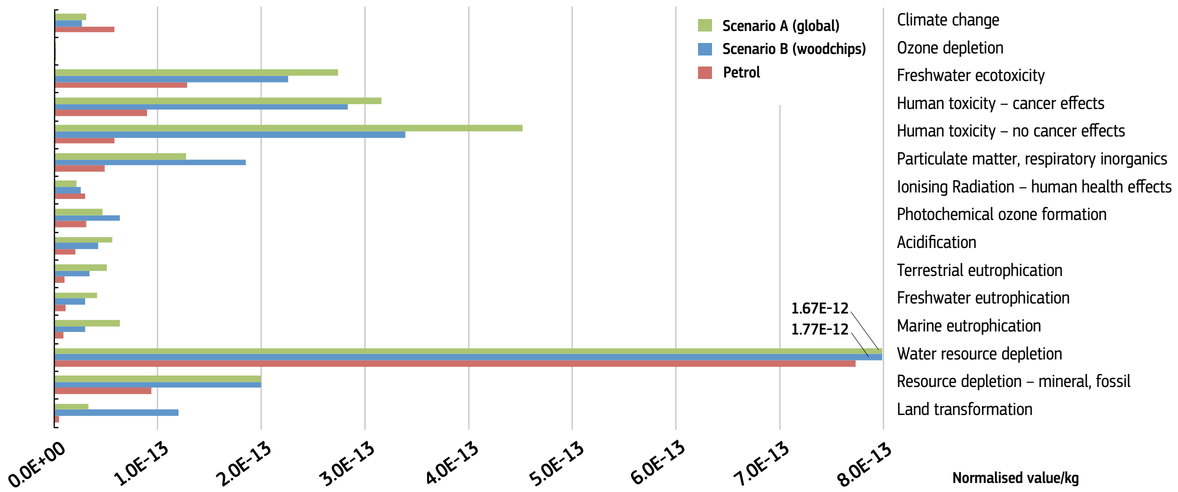
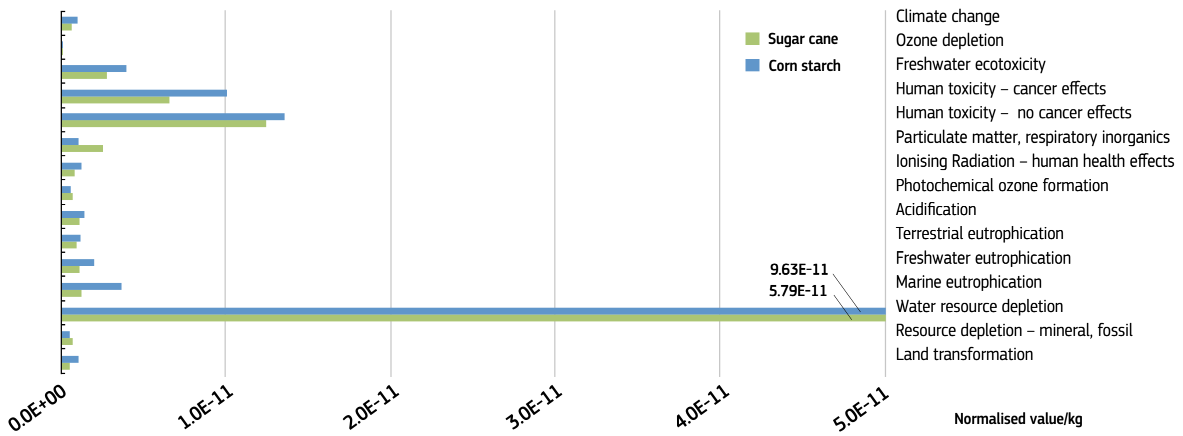



***Figure 25:*** *Normalised environmental impacts of polyhydroxyalkanoates production*




The calculated normalised values are depicted in Figure 23.

For the bioalcohols assessment, a well-to-wheel (i.e. cradle-to-grave) approach was considered for assessing two different systems: (i) ethanol produced from sugar cane and sugar beet grown in Brazil and the United States, respectively, and

26 Figure 23 presents the results of the ratio between the impact of 1 kg of a product, in this case sugar, and its overall impact on the environment on average in the EU-27 in 2010 for each category. For instance, the normalised value for sugar beet for the impact category of climate change is 1.65-13. This means that the production of 1 kg of sugar represents (contributes) 1.65-15 % of the total GHG emissions in the EU-27 (taking 2010 as reference).

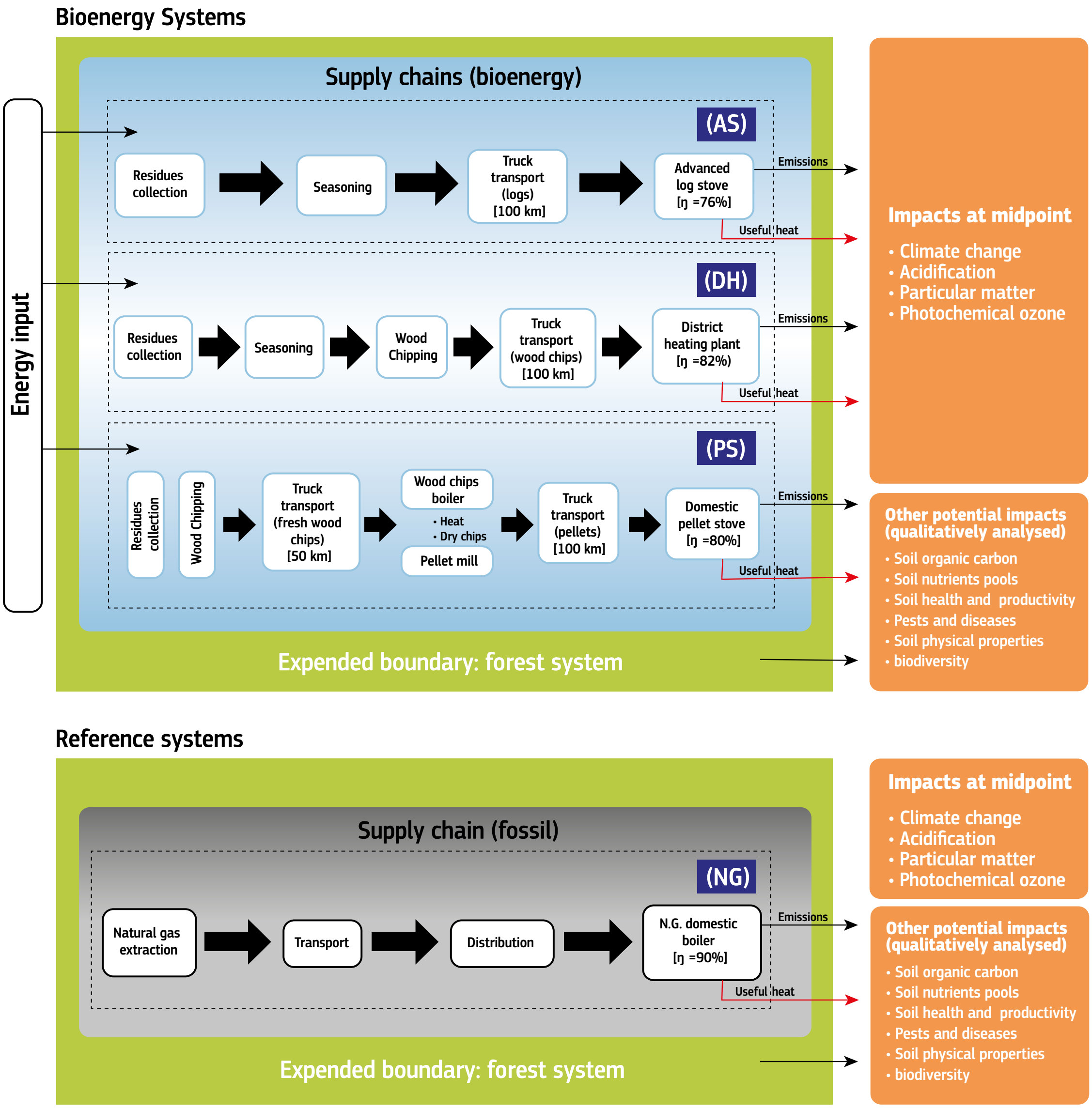



***Figure 26:***
*System boundaries definition for the advanced A-LCA case study*

*System boundaries for the bioenergy and reference systems, including supply chains and expanded boundary including the forest system. Environmental impacts quantified at midpoint ([28]) and additional environmental impacts analysed qualitatively are also shown.*

*AS = advanced stove; DH = district heating; PS = pellet stove; NG = natural gas boiler.*

then consumed in Europe, and (ii) ethanol from woodchips produced and consumed in Europe. The functional unit chosen was 1 km driven with a flexible fuel vehicle. Results showed that the production phase (including sugar production, fermentation and ethanol separation) contribute to most of the estimated environmental loads. According to the LCA, ethanol from woodchips had higher environmental performance for all impact categories, except from particulate matter, ionising radiation – human health effects, photochemical ozone formation and land transformation (Figure 24).

When it comes to PHAs, two different feedstocks were analysed, sugar from corn starch cultivated in Germany and sugar from sugar cane grown in Brazil. In this case, a cradle-to-gate approach was used. The functional unit chosen was 1 kg of polymer produced. The LCA results (Figure 25) showed that for most categories the system based on corn starch results in higher impacts than for sugar cane, mainly due to the lower agricultural efficiency of the corn system (crop yield). The main contributions to these environmental impacts are generated during agricultural production and by the energy consumed in the production process.

### *4.2.3. A case study: domestic heating from forest logging residues*

(Details in Giuntoli et al. 2015a)

Many of the methodological advancements described in Section 4.1.3. are applied in the case study presented here in order to provide a complete impact assessment of the environmental risks associated to the use of logging residues to produce domestic heating.

27 According to ISO 14044, the indicator of an impact category can be chosen anywhere along the impact pathway, which links inventory data to impacts on the AoP. Characterisation at the midpoint level models the impact using an indicator located somewhere along (but before the end of) the mechanism. Characterisation at the endpoint level requires modelling all the way to the impact on the entities described by the AoPs, i.e. on human health, on the natural environment and on natural resources (Hauschild et al. (eds.), 2011).

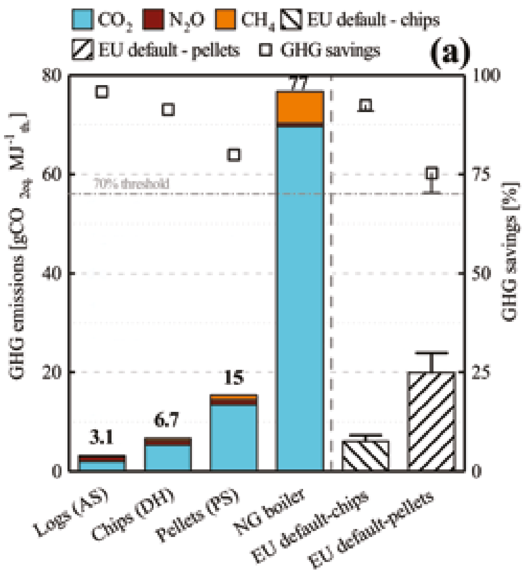



***Figure 27:***
*Supply chain GHG emissions for bioenergy and natural gas boiler*

*The functional unit considered is 1 mJ of useful heat. The bars are stacked based on the contributing gases. The total value is written on top of the bars. The square symbols represent GHG savings of bioenergy compared to the natural gas boiler (right y axis). Striped bars represent the typical and default (error bar) GHG emission values given in Giuntoli (2015b) and the associated GHG savings. Only well-mixed GHG (WMGHG) and no emissions from changes in forest carbon stock are considered.*

The dataset from the latest EC document on the sustainability of solid and gaseous biomass (SWD2014 259) were used, complementing those results by several additional steps, as explained in the following paragraphs.

### *A. Designing three pathways for domestic heat production using forest logging residues, with different combustion technologies*

For this case study, three pathways were designed representing three possible options for the production of domestic heat using forest logging residues, employing different combustion technologies (Figure 26) loose residues burned in a log stove; ii) a district heating plant utilising forest chips; and iii) a domestic stove fuelled with wood pellets. The functional unit considered is 1 mJ of useful thermal energy; this includes losses due to start-ups and shutdowns, partial loads, thermal inertia and losses in the heat-distribution system.

The term 'logging residues' in this context refers to the crown mass (tops and branches with leaves, also called slash) and stumps, produced as a result of commercial logging operations for the production of industrial wood (sawlogs and pulpwood). Logs from a thinning operation were not included.

Firstly, the supply-chains impacts with an A-LCA model, such as explained in the previous section, were calculated, applying the environmental impact models recommended by the International Life Cycle Data System (ILCD) (EC 2011e). Figure 27 illustrates the results for the climate change impact category, while results for other relevant impact categories quantified can be found in (Giuntoli et al. 2015b).

Supply-chain GHG savings of the three pathways analysed ranged between 80%-96% compared to a natural gas system above the 70% threshold suggested by the EU. However, as mentioned above, the climate impact of bioenergy should be assessed by also considering the non-bioenergy uses of the biomass and by including all climate forcers.

### *B. Expanding the analysis to include forest carbon stock development with and without bioenergy*

The system boundaries were then expanded to include the forest ecosystem. The reference (counterfactual) system assumes that the logging residues would be left on the forest floor to decompose in the absence of bioenergy demand.

Consequently, the net contribution of $CO_2$ to the atmosphere from the bioenergy system will be the result of the difference between instantaneous release of (biogenic) $CO_2$ by combustion of the wood and the slower release due to bacterial decay on the forest floor. This difference corresponds to additional emissions of $CO_2$ that need to be assigned to the bioenergy pathway. This creates a dynamic emission profile as represented in Figure 28.

### *C. Using absolute climate metrics to assess the surface temperature response by the end of the century to a bioenergy and a reference fossil system*

In order to properly capture the impacts of the dynamic phenomena considered, it is proposed to assess the climate impact of the systems calculating the surface temperature response (STR) of the planet to the systems studied, by 2100. The analysis is based on the absolute global surface temperature change potential (AGTP) metric (Myhre et al. 2013). Because of the uncertainties associated to the climate metric and to the LCI, the goal is not to quantify the magnitude of absolute temperature response but rather to assess the climate impact of the various systems relative to each other.

Many different metrics exist for the quantification of the impact of multiple gases on the Earth's climate system. The choice of metric goes hand in hand with the goal of the considered climate mitigation policy (Fuglestvedt, et al. 2003). Actually, as recently stated by Levasseur et al. (2016), a more complete impact assessment should present results obtained with multiple metrics, provided that the results are properly interpreted for the readers. In this analysis, results are reported which are explicit in time, to avoid prejudging the time horizon. The AGTP metric, both in its instantaneous and time-integrated formu-

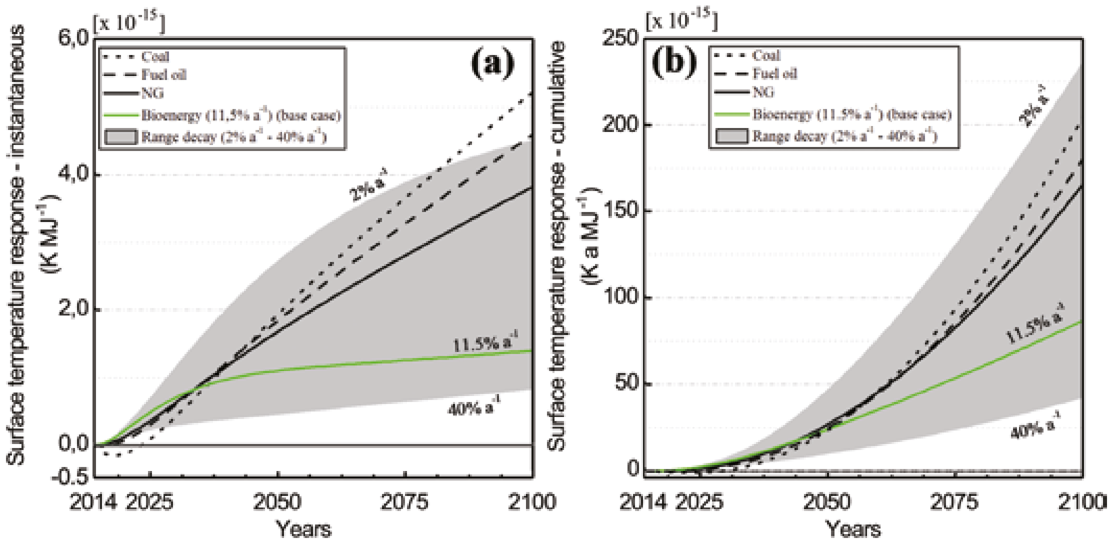



***Figure 28:***
*Climate change impact of bioenergy and fossil systems*

*Figure 28a represents the STR calculated with an instantaneous metric.*

*Figure 28b uses a time-integrated metric. Both figures consider a sustained production of 1 mJ of thermal energy per year.*

lation, is calculated (Giuntoli et al. 2015b). The two formulations can be associated to different impacts of climate change: instantaneous metrics are proxies of impacts linked to increasing surface temperature (e.g. heat waves and extreme weather events), while time-integrated metrics are better proxies of sea-level change (Giuntoli et al. 2016).

### D. Including multiple climate forcers (WMGHG, near-term climate forcers (NTCF) and biogeophysical forcers)

LCA studies usually consider only well-mixed GHG ($CO_2$, $CH_4$ and $N_2O$) for their impact on global warming. For these species, GWP factors are well established and updated in each Intergovernmental Panel for Climate Change (IPCC) assessment report. However, NTCF such as aerosols (e.g. $SO_2$, black carbon) and ozone precursors (e.g. NO, CO and NMVOC) and biogeophyisical forcers may also play a relevant role in the overall climate impact of bio-based value chains. NTCFs have a short lifetime in the atmosphere, rendering them subject to atmospheric transport phenomena and making their impact dependent on the point of emission. Nonetheless, scientific understanding is progressing and literature is available on the subject, including IPCC recommendations (Myhre et al. 2013; Collins et al. 2013).

Biogeophysical forcers, such as surface albedo change ([28]), from land area undergoing use or management change, i.e. clear-cut forest land in snow-covered boreal climates, may cause a relevant change in radiative forcing. Additionally, other non-radiative phenomena (e.g. evapo-transpiration) could contribute to the overall climate impact of bio-based value chains.

The case study indicates that surface albedo change, aerosols and ozone precursors' emissions play a limited role in the three bioenergy pathways analysed when compared with the magnitude of the warming impact due to WMGHG. Therefore, in the case of forest logging residues, analyses that focus solely on WMGHG, and $CO_2$ in particular, can deliver results, which are accurate enough for many applications.

While including all forcers provides a more complete impact assessment, when considering climate change mitigation options, the cooling contribution of local harmful pollutants such as NOx and SOx could be willingly excluded since mitigation options will never rely on increased emissions of these pollutants.

### E. Quantifying life cycle impacts on acidification, particulate matter emissions and photochemical ozone formation

The bioenergy systems analysed in this case study have higher environmental impacts associated with local pollution than the natural gas alternative (details in Giuntoli (2015a)).

Furthermore, several additional environmental risks are known to be associated with the removal and use of forest logging residues for bioenergy. These issues concern mostly biodiversity loss and, mainly for stumps removal, physical damage to forest soils. The results of a review of the literature on this topic are summarised in Giuntoli et al. (2015a).

28 Albedo is the fraction of solar radiation reflected by a surface or object, often expressed as a percentage. Snow-covered surfaces have a high albedo; the albedo of soils ranges from high to low; vegetation-covered surfaces and oceans have a low albedo. The Earth's albedo varies mainly through varying cloudiness, snow, ice, leaf area and land-cover changes.

All potential risks should be evaluated holistically for a complete impact assessment.

### *Overall results*

Supply-chain GHG savings of the three pathways analysed ranged between 80% and 96% compared to a natural gas system above the 70% threshold suggested within EU legislation. However, the climate impact of bioenergy should be assessed by also considering the counterfactual, non-energy uses of the biomass and by including all climate forcers.

Domestic heating from logging residues is generally beneficial to mitigate the surface temperature increase by 2100, compared to the use of natural gas and other fossil sources. As long as residues with a decay rate in the forest higher than 2.7% per year are considered as feedstock, investing now in the mobilisation of residues for heat production can reduce the temperature increase by 2100 compared to all the fossil sources analysed, both in case of bioenergy as a systemic change or in case of bioenergy as a transitory option. Forest logging residues are not free of environmental risks. Actions promoting their use should consider: (i) that climate change mitigation depends mainly on the decay rate of biomass under natural decomposition and time and rate of technology deployment; (ii) whether management guidelines aimed at protecting long-term forest productivity are in place; and (iii) whether proper actions for the management of adverse effects on local air pollution are in place.

# 5. Bioeconomy in sectors

# 5. Bioeconomy in sectors

The bioeconomy connects a wide range of sectors, which differ largely in their current nature, their relation to the bioeconomy and their potential development in the future. While Chapter 3 shows differences in the development in jobs and turnover for these sectors, Chapter 5 complements these findings by presenting the views of representatives of six relevant bioeconomy sectors: agriculture, food (security), forests and forest-based products, blue bioeconomy, bioenergy and bio-based industry. They present key challenges and opportunities that they have identified in their sectors, as well as how they see their sectors fit into the bioeconomy. Case studies provide hands-on examples of value chains that the authors find innovative and promising.

**DISCLAIMER**

The sections of this chapter have been prepared by external contributors. The texts do not represent the opinion of the European Commission or its Joint Research Centre.

## 5.1. Agriculture

*by Erik Mathijs, Katholieke Universiteit Leuven, Chair of the 4th Foresight Expert Group of the Standing Committee of Agricultural Research (SCAR)*



***Current technological development***

The bioeconomy concept is built on two premises. First, biomass is currently being underexploited, as many waste streams are not used in an optimal way. More materials and energy can be extracted from current biomass streams. Second, the biomass potential can be upgraded by increasing current yields through closing yield gaps, increasing the amount of productive land, introducing new or improved species that may or may not be generated by various biotechnological advances and introducing new and improved extraction and processing technologies. Two main developments leveraging agricultural output include advances in biotechnology and in precision farming.

In genomics, genotyping and high-throughput sequencing have generated an extensive and precise knowledge of the DNA and RNA. The cost of sequencing and the time needed for it have drastically decreased. In parallel, the rapid development of transcriptomics, metabolomics, proteomics and phenotyping enables the development of crops and animals with traits important for producers and consumers.

In addition, these advances also leverage precision farming and livestock rearing, the basic idea of which is to drastically increase resource efficiency by a more precise and targeted application of nutrients, pesticides, etc. These precision approaches are enhanced by developments in ICT, GPS-based technologies and sensor technologies. More recently, insight is emerging on the potential synergies between species, following the interaction between plants and between plants and soil microbiota, etc.

***Potentials in the relation to bioeconomy***

A higher utilisation of biomass use may create several societal benefits, when managed well. First, it may generate additional financial resources to support agriculture to develop sustainably. Second, increasing biomass-use efficiency may put less pressure on land and other resources. Third, using biomass, together with other renewable sources, may decrease our dependence on non-renewable resources.

***Most important interlinkages with other sectors of the bioeconomy***

Agricultural production provides the basic input for the food-processing sector but also recycles many by-products, not only from this sector but also from other sectors in the form of animal feed or nutrients applied to the soil. These inputs and their by-products are also important inputs for other, non-food industries to produce bioenergy, chemicals and materials.

***Challenges in the relation to bioeconomy***

In order for the benefits of the bioeconomy to flow back to a diversity of farmers and to avoid unintended consequences, its implementation needs to be carefully considered. Overexploitation of resources following an increased demand for biomass for non-food uses should be avoided by focusing on the by-products and waste streams of food production. The societal acceptance of new foodstuffs based on technological advances should be carefully prepared and monitored. Farmers should get a fair share from the value added through the bioeconomy by setting up appropriate governance mechanisms in biomass supply chains.

***Source***

Mathijs et al., 'Sustainable agriculture, forestry and fisheries in the bioeconomy – A challenge for Europe', report for the 4th SCAR foresight exercise, Publications Office of the European Union, Luxembourg, 2015.

***Key messages***

- Precision agriculture may drastically improve resource efficiency, particularly when combined with biotechnology advances.
- Increasing the utilisation of agricultural biomass has the potential to generate value added and save natural resources.
- The bioeconomy needs to be governed well in order for it to generate sustainable outcomes.

***Case study: grass refinery***

Bio-refineries have the ability to convert grass with much higher efficiencies than cows and to produce a much wider range of products, such as fertilisers, fibres, organic acids and biogas. Moreover, in some seasons the water content of grass is too high, resulting in an oversupply of grass that cannot be eaten by the cows. Several initiatives have developed grass bio-refinery concepts at different scales.

A Dutch initiative called Grassa! has designed a mobile grass refinery that became operational in 2011. It can process 500 kg of grass per hour, separating grass into fibres for the paper and pulp industry and proteins that can be used as animal feed.

The process first involves separating the fibres from protein-rich grass juice. The fibres can be used as roughage feed or as input in the pulp and paper industry. The grass juice is heated and enriched with lactic acid. The solid fraction is separated from the fluid fraction that is rich in sugars, phosphorus and potassium and can be used as a basis for fertiliser or feed. The solid protein fraction can be used to substitute imported soy or other protein sources, as it has a comparable amino acid composition.

As the Grassa! unit is a small bio-refinery, it saves on transportation costs and is affordable for farmers to use, such that they can capture the value added of the components themselves. To be economically efficient, farmers have to collaborate, as an economic exploitation requires an acreage of 500 ha to 1000 ha of grassland. Maize can also be refined to better extract and valorise its various components.

***Source***

www.grassa.nl, Sanders, J.P.M., Van Liere, J. and de Wilt, J.G., 'Geraffineerd voeren – Naar een sluitende mineralenkringloop door raffinage van lokaal geteeld veevoer', *Innovatie Agro & Natuur*, Report No. 16.2.337, Utrecht, 2016.

## 5.2. Food (security)

*by Olivier Dubois and Marta Gomez San Juan, Food and Agriculture Organization of the United Nations*



For food security objectives to be realised, the four internationally agreed dimensions of food security, i.e. availability, access, stability and utilisation, must be fulfilled simultaneously (FAO, 2001). These dimensions are related to several factors that matter to bioeconomy development. They include, inter alia, land use; land access; household income; access to energy; nutrition; and, last but not least, food supply and prices, which are in turn affected by a number of factors in addition to biomass production and use, such as the demand for food, feed and fibre, imports and exports of foodstuffs, weather conditions and the prices of energy and agricultural inputs. Food security is therefore a broad, multifaceted issue that has multiple economic, environmental and social dimensions. This has important implications regarding the links between food security and bioeconomy. In particular, at local level, food production should not necessarily have priority over other uses of biomass to ensure adequate food security. For instance, if a rural dweller prioritises the production of wood products to make enough money that allows him to buy food (i.e. the food access dimension), then this choice might enhance their food security. However, it is also true that the displacement of key staple crops for dedicated energy plantations can indeed be very detrimental to food security. Therefore it really depends on local circumstances and on the level that is under consideration.

In 2015, about 795 million people were undernourished globally, with 780 million in developing countries (FAO et al. 2015). For the developing regions as a whole, the share of undernourished people in the total population has decreased from around 23% in 1990-1992 to about 13% in 2015. Interestingly in relation to bioeconomy, the same report states that 'economic growth is a key success factor for reducing undernourishment, but it has to be inclusive and provide opportunities for improving the livelihoods of the poor. Enhancing the productivity and incomes of smallholder family farmers is key to progress.'

Food and feed are and will remain an important component of bioeconomy according to a recent study (Piotrowski et al. 2015).

In 2011, these sectors made up 72% of the global demand for bioeconomy products, and this proportion will range from 40% to 60% in 2050, depending on the progress in the production of non-food goods and the type of energy used to that effect (i.e. biomass or other types of renewables). At the same time, the global demand for all biomass-based products could increase by between 38% and more than 50% during the same period.

To supply the biomass to match this massive increase in demand in a sustainable way while ensuring the primacy of food security would require a combination of the following measures:

- at the supply level, including sustainable agriculture intensification, 'doing more with less' regarding biomass production, and the partial replacement of bioenergy by other types of renewable (e.g. solar, wind, hydro) energy in meeting global energy needs;
- at the demand level, significant improvement in biomass-use efficiency, including the reduction of food loss and waste, energy savings, managing competing uses of residues and, according to many, a reduction in global meat consumption.

***Key messages***

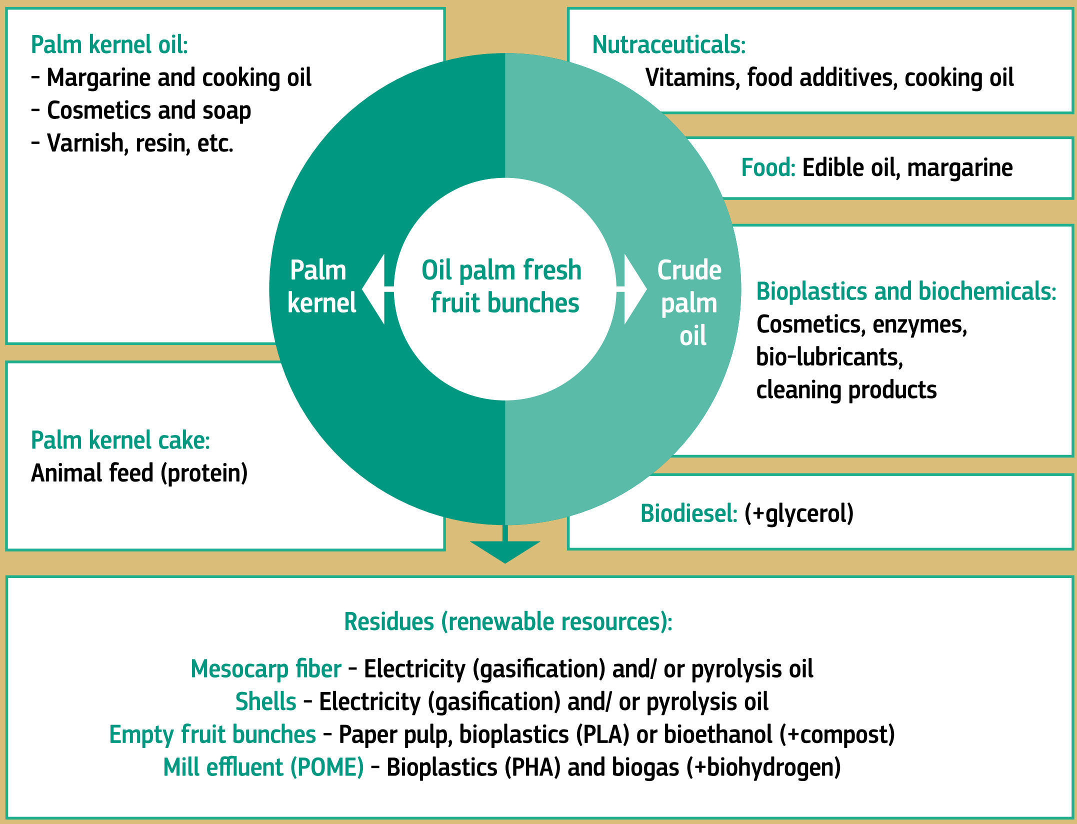
- The increase in bioeconomy development is welcome as it offers a unique opportunity to address, in a comprehensive way, interconnected societal challenges such as food security, natural resource scarcity, fossil resource dependence and climate change, while achieving sustainable economic growth.
- Bioeconomy will have a transformative role on agriculture in its broad sense – meaning crops, livestock, forestry and fisheries – because it will put a lot more pressure on renewable but finite biomass resources to produce a lot more non-food goods than today, while also fulfilling everybody's food needs.
- Bioeconomy development per se is not necessarily sustainable. Achieving sustainable bioeconomy faces major and simultaneous challenges, such as ensuring food security, addressing climate change and sustainably managing natural resources while guaranteeing that bioeconomy benefits everybody.
- While innovations are needed to address these challenges, at the same time we collectively already know many ways and have significant experience on how to advance bioeconomy in a sustainable and comprehensive way.

***Case study: food and non-food goods from palm oil***

In the extraction process of palm oil and palm kernel oil, at least one tone of by-products can be obtained for each tone of bio-oil (Elbersen, 2013). All these products are available for bioeconomy

*Multiple uses of palm oil-processed products from fresh fruit bunches*

*Source: Prepared by the authors, based on Alonso-Fradejas (2015), Elbersen (2013), Kamal (2015) and Hassan (2015)*




and provide added value. The uses of the different products coming from the fresh fruit bunches are summarised in the figure above. Other uses of the fronds and trunks include energy, timber, soil cover, feed, bio-materials, wine (from sap) or habitats.

***Ghana***

In the last 15 years the palm oil production in Ghana has grown exponentially, in part due to the programme included in the strategic national energy plan (Energy Commission of Ghana, 2006), which aims at introducing biofuels to help substitute energy imports. The imported palm oil was almost three times the exports in 2013 (Faostat, 2015).

Despite such growth, palm oil production was intended to meet food and energy needs. A recent study by Parbey et al. (2014) shows the possibility of producing bioethanol from the sap extraction instead of biodiesel from palm oil in order to increase food security. The sap is commonly called palm wine and is conventionally drunk in West Africa. When it ferments, its alcohol content increases, making it a good feedstock for bioethanol production (Parbey et al. 2014; Chandrasekher et al. 2012). With the increase in palm oil production and the technology of sap extraction, it will be possible to notably increase the supply of second-generation biofuels as well as to obtain biomaterials and by-products using bio-refinery processes and biotechnologies that do not hamper food security.

***Malaysia***

The production of palm oil in Malaysia has had a significant growth in the last 15 years, but it has become steady in the last four, around 20 M t. Half of this production comes from the states of Sarawak and Sabah. Two palm oil industrial clusters have been developed in the latter. They promote the creation of new industries that use biomass and bio-refinery by-products to obtain biomaterials (Kamal, 2015). According to Dr Mohd Nazlee Kamal (2015), CEO of BioeconomyCorp (ex BiotechCorp) in Malaysia, the palm oil industry generates yearly 100 M t of lignocellulosic biomass, which is left on the field as fertiliser as well as used for biofuel and biomaterials production that does not affect food security.

The majority of the biomass coming from palm oil is oil palm frond, and from its petiole a sugary juice can be extracted. This substance can be used to obtain bioethanol, high-value biomaterials such as polyhydroxybutyrate bioplastic, ruminant feed, bio-composites and bio-briquettes (Zahari et al. 2014). The same products can be obtained with empty fruit bunches residues from bio-refineries. Biogas and bioplastics can be also produced with mill effluent.

The bioeconomy transformation programme and BioeconomyCorp support the development of bio-industries that produce biochemical products from renewable resources, both on-farm and bio-refinery residues. Some bioeconomy products manufactured in the area are (Che Dir, 2014): renewable nylon fibre, resins and lubricants (Verdezyne and Bio-XCell Malaysia), biomedical products such as insulin (Biocon Ltd.), next-generation bio-manufacturing facility (Stelis Biopharma), bio-isobutanol production (Gevo Inc.) or the technology of catalytic metastasis for oil refinery, which has low energy consumption and GHG emissions in comparison with conventional technologies (POIC Genting Integrated Biorefinery).

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## 5.3. Forests and forest-based products

*by Marc Palahí and Lauri Hetemäki, European Forest Institute*



Forests, covering 40 % of the land in the EU, provide crucial ecosystem services to society including both supporting services that protect key resources like water, soil and biodiversity and provisioning services like renewable resources (wood and non-wood products) that can be transformed into bio-based products and bioenergy. Wood is the primary source of non-food and non-feed biomass, representing 25 % of the total biomass supply in the EU.

Advances in science and R&D as well as in forest management (e.g. genetic improvement, silviculture and afforestation measures) and modern bio-refineries (see bio-product mill below) open up significant opportunities for the forest-based sector in becoming a fundamental pillar of Europe's bioeconomy. A new generation of bio-based solutions: chemicals, food ingredients, bioplastics, composites, pharmaceuticals, textiles, construction products or bioenergy can now be produced from wood. A few examples:

- **nanocellullose**, an ultra-strong material that surpasses steel in strength, can be used to make products like flexible screens, printed electronics and batteries or high-resistant clothes;
- **carbon fibre** based on lignin offers great opportunities in the future to replace steel in industrial applications like the car industry;
- **wood-based dissolving pulp** can be used to produce environmentally friendly high-quality clothes to replace cotton, which has a high environmental footprint, or synthetic fabrics made from oil, such as polyester.

Moreover, one of the greatest impacts of using wood can be found in the construction sector. The construction sector in Europe represents 42 % of energy consumption, 50 % of material use, 33 % of waste and 35 % of $CO_2$ emissions. New wood engineering products (for example cross-laminated timber modules) allow the construction of **wood-frame buildings** of up to 40 storeys that can be created using industrial prefabrication methods. It is a new way of building that results in less use of materials and less waste gene-ration and allows moving from demolition to deconstruction once the life cycle of the building ends. Wood construction also has the greatest potential to reduce carbon emissions and primary energy use during the life cycle of the building.

***Key messages***

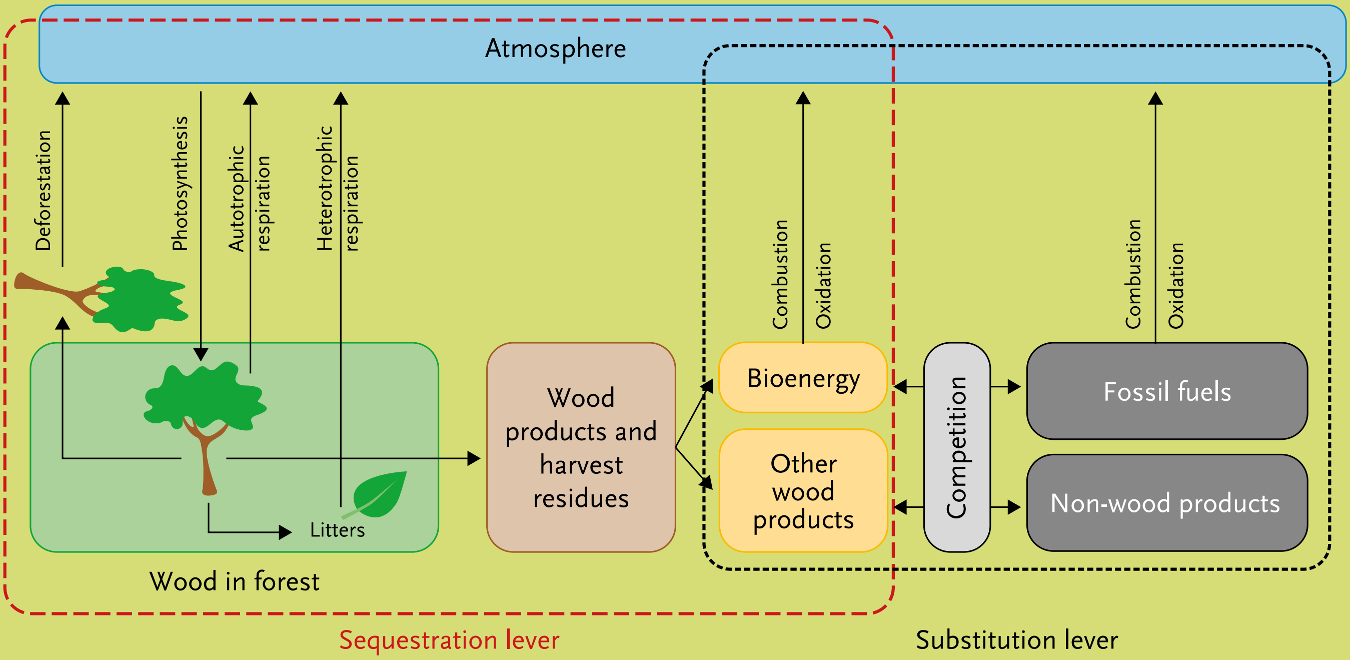
- Forests are the most important biological infrastructure and carbon sink of the European continent, capturing 10 % of the total current EU emissions.
- Producing 1 $m^3$ of wood stores 1 Tn of $CO_2$. Using wood products instead of fossil carbon products reduces $CO_2$ emissions and stores additional carbon.
- European forests and the forest-based bioeconomy could capture 25 % of the current $CO_2$ emissions within the coming two-three decades with the right policy incentives.

***The case of a forest-based bioproduct mill***

The three popular concepts of bioeconomy, circular economy and resource efficiency can be very much interconnected. This is especially the case in a modern forest-based bioproduct mill, which integrates the production of traditional forest products with chemicals, energy and wood products. The forest bioproduct mill is often a symbiosis or ecosystem of different companies working in the same mill site or region, where one producer's waste is the other producer's raw material. The necessary ingredients for such a concept to be successful are the region's raw material basis (forests), environmental sustainability, appropriate R&D and know-how infrastructure, cooperation between different companies and willingness to take risks with new concepts and technologies. The concept should in principle also be applicable in other regions in which these conditions are present.

Here we describe the Metsä Group Äänekoski bioproduct mill concept in Finland. Although the Äänekoski mill or 'bioindustry park' and region clearly has its specificities, the example is interesting in terms of describing the general trend towards which forest industry and bioeconomy is increasingly moving in other places in the EU as well. In line with the bioeconomy and circular economy concepts, the interest in the EU Member States is to process products as resource efficiently as possible and to maintain the value of products, materials and resources in the economy as long as possible while minimising waste generation.

Metsä Fibre, which is part of Metsä Group, is building a new bioproduct mill in Äänekoski in Central Finland, the operation of which will start in the third quarter of 2017. With a value of EUR 1.2 billion, the bioproduct mill is the largest investment in the history of the Finnish forest industry. At the heart of the mill or industry park is the production of high-quality pulps used as raw material for paper, tissue paper and paperboard, mainly for Chinese markets. But in the industry park around the pulp production

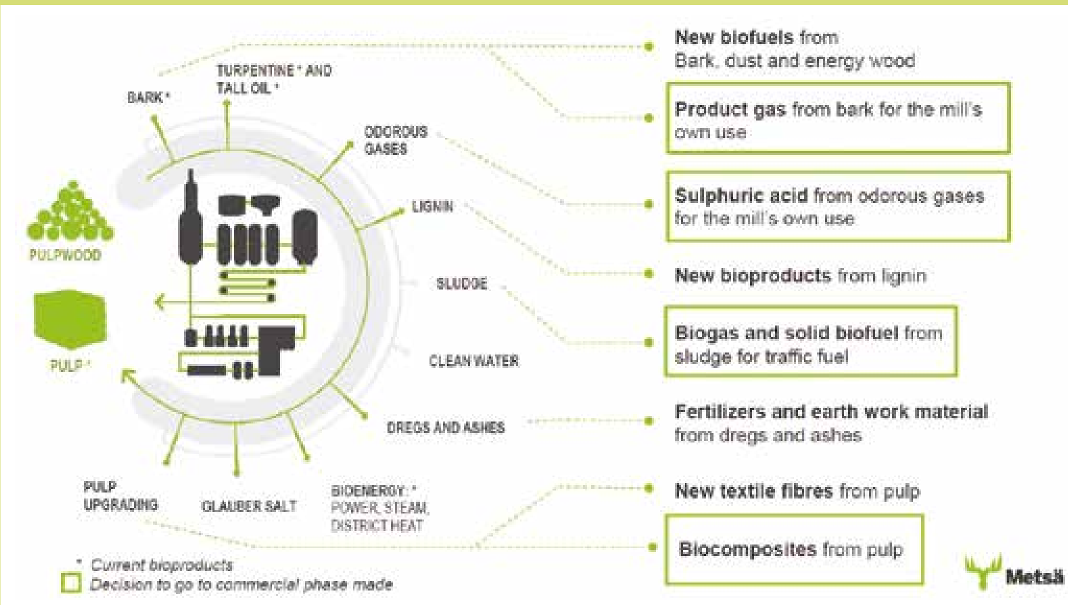



there is an ecosystem of Metsä Fibre and a number of other companies. In addition to pulp, the industry park also produces, for example, electricity, heat, steam, biogas for transportation, plywood for wood construction and for the transport industry, wood composite products and agri- and forest fertilisers. Moreover, the organic by-products, such as resulting from debarking of wood, will be used in gardening, for example. The other companies are using the side streams from the Metsä Fibre wood processing and pulping as raw materials for all these products. The mill processes are entirely based on renewables, and it is a net energy generator.

Such an ecosystem of companies, using the regional biomass and know-how strengths, will increasingly be the trend towards which the forest bioeconomy in the EU is likely to move.

*Simplified diagram of carbon stocks in reservoirs and flows between the atmosphere, biosphere and fossil reservoir. The two mitigation levers are depicted here (30)*






*Äänekoski bioproduct mill concept*



29 Source: Nabuurs, G.-J., Delacote, P., Ellison, D., Hanewinkel, M., Lindner, M., Nesbit, M., Ollikainen, M. and Savaresi, A. 2015. A new role for forests and the forest sector in the EU post-2020 climate targets, From Science to Policy 2, European Forest Institute.

## 5.4. Blue bioeconomy

*by Christina I. M. Abildgaard, Kristin E. Thorud and Kathrine Angell-Hansen, JPI Oceans*



### *Potentials*

The blue bioeconomy provides great potential for sustainable growth and jobs, responding to market needs for food and energy. Seafood is highly nutritious and rich in essential proteins, fatty acids, minerals and vitamins that contribute to balanced, healthy diets.

Seafood provides more than 3 billion people with almost 20% of their animal protein consumption. By being a rich source of high-quality proteins, essential fats (polyunsaturated fatty acids), vitamins (D, A and B) and minerals (selenium and iodine), seafood contributes to balanced, healthy diets.

Using new and existing marine bioresources in improved and new ways may generate a range of products used as foods, feed, pharmaceuticals, cosmetics, bioactive compounds, materials and bioenergy.

Aquaculture production has increased tremendously in past decades. Potential for growth is still substantial, for instance through novel ways of operation, e.g. offshore and integrated multitrophic aquaculture. Global fisheries have been relatively stable. However, there is a potential of increased marine biomass by harvesting at different trophic levels. Furthermore, there is potential in optimising production and processing including using waste streams.

### *Interlinkages*

Possibilities are numerous for synergies with land-based food, feed production and processing, production of bioenergy, chemicals and nutrients in a bioeconomy and circular bioeconomy perspective (see figure below).

Knowledge transfer across bio-sectors can improve feed, breeding and health regimes for biological production and food nutrition output. Waste streams from marine biomass may feed into terrestrial value chains and vice versa (see case study).

Joint technology development and transfer of knowledge between marine sectors like petroleum, maritime and renewable energy will also generate growth.

### *Technology*

There are potentials for synergy relating to food technology. Bio-refining technology demonstration/take-up may be accelerated by integration/interfacing with existing industrial operations. Developments within biotechnology and ICT already enable us to make use of a much broader spectre of renewable bioresources for applications in advanced products.

Technological advances will be a key driver in solving ocean-related environmental challenges and in fostering economic activities. Innovations in sensors, imaging, satellite technologies, automatisation, big data analytics, autonomous systems, offshore engineering and technology, advanced materials, manufacturing technologies, biotechno- logy and nanotechnology will enable growth.

### *Challenges*

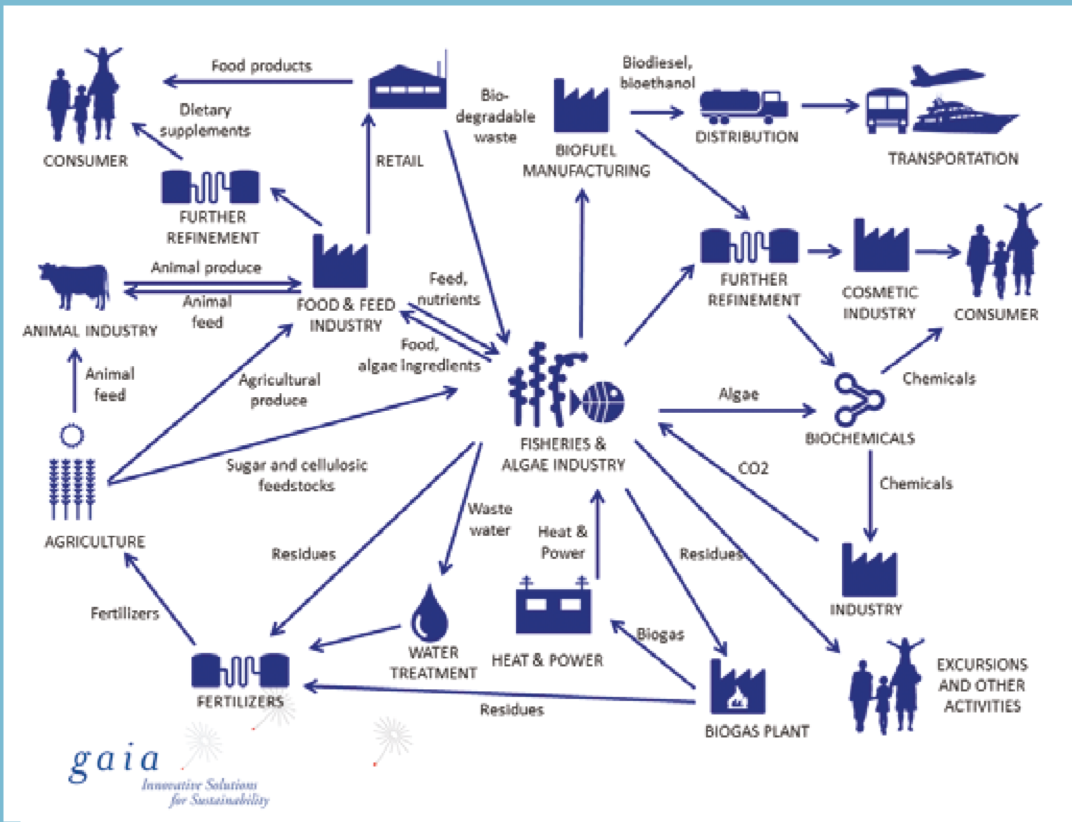
The ocean's health is under pressure from human activity through over-exploitation, pollution, declining biodiversity and climate change impacts. Blue growth may be hampered by competing access to space from different sectors, deficient management plans and regulations to support sound governance (such as spatial planning) and surveillance, lack of knowledge, innovativeness and cross-cutting approaches, as well as limited financial investments.

### *Messages*

- All areas above strongly rely on a sound scientific knowledgebase, requiring improved **education**, **research and innovation**, interdisciplinarity and collaboration across sectors.
- Fostering **ocean health** whilst stimulating **growth** in biomarine industries are key objectives.
- Enabling knowledge-based sustainable blue growth requires **integrated governance** regimes.

### *Case study: seaweed farming*

One innovative and promising area is the large-scale ocean farming of seaweed, being cultivated in a controlled manner. This has not been explored so far by JPI Oceans, although it is likely to be addressed in an action we are presently preparing. Most of the commercial production today occurs in Asia. In Europe some innovative and research-intensive industries have been established. Technological advances can replace high labour costs and help turn European seaweed cultivation into a viable commercial reality.




*The aquatic bio-refinery business ecosystem*

*© Nordic Innovation, 2014*
*Authors: Ida Rönnlund, Tiina Pursula, Mariaka Bröckl, Laura Hakala, Pävi Luoma, Maija Aho and Alina Pathan (Gaia Consulting Ltd.)*

The potential use of seaweed is broad, for instance as food supplement in a healthy diet. Growing food demand, awareness of diet – both in terms of health and traceability, a growing vegetarian population and a desire for specialty ingredients in the West provide opportunities. Seaweed can be used as animal feed, such as for finfish production, biochemicals, bioenergy, health products and cosmetics. Algae can also be used as fertiliser, bringing nitrogen and phosphorus back into the agricultural food chain. The latter is also important from a circular economy perspective.

**Environmental benefits are numerous.** Algae, including seaweed, are a renewable resource and highly efficient converters of solar energy. They are fast-growing and through large-scale cultivation the uptake and storage of $CO_2$ in seaweed farms may help to mitigate climate change and ocean acidification. The production does not require any use of freshwater or pesticides but rather assists in reducing coastal eutrophication and improves water quality, by consuming excessive amounts of nutrients and producing oxygen.

From a **production perspective**, seaweed farms provide a shelter and thereby attract fish. Increasing fish stocks has been observed in the vicinity of seaweed farms. Field trials have shown that macroalgae cultivated in close proximity to fish farms have higher growth rates compared to reference algae. Combining seaweed and aquaculture production through integrated multitrophic aquaculture (IMTA) contributes to cleaner waters and improved resource utilisation. IMTA systems also recycle/recover otherwise unexploited, valuable and limited minerals.

Finally, seaweed can be cultivated in a controlled manner at a large scale and can contribute to creating jobs and blue growth, but requires a close dialogue and cooperation between the industry, the research community and the regulatory authorities. Working with marine licensing authorities is important as they can contribute to raise awareness of the potential benefits of an IMTA system and act as a key driver for a wider adoption of the concept.

## 5.5. Bioenergy

*by Birger Kerckow, European Technology and Innovation Platform Bioenergy (ETIP Bioenergy)*



Bioenergy covers roughly two thirds of the RES in the EU. It provides the lion's share of renewable heat and transport fuels as well as a significant part of renewable electricity. Technologies are mature for heat, electricity from solid biomass as well as anaerobic digestion and first-generation biofuels. Key technology developments aim at improving sustainable biomass supply, commercialising advanced processes that produce high-value fuels and products from low-value biomass feedstocks, reducing conversion costs and improving their efficiency, and reducing emissions and making bioenergy production more flexible, which is crucial in an energy system with increasing but variable contributions of other renewable energy carriers.

### *Potentials*

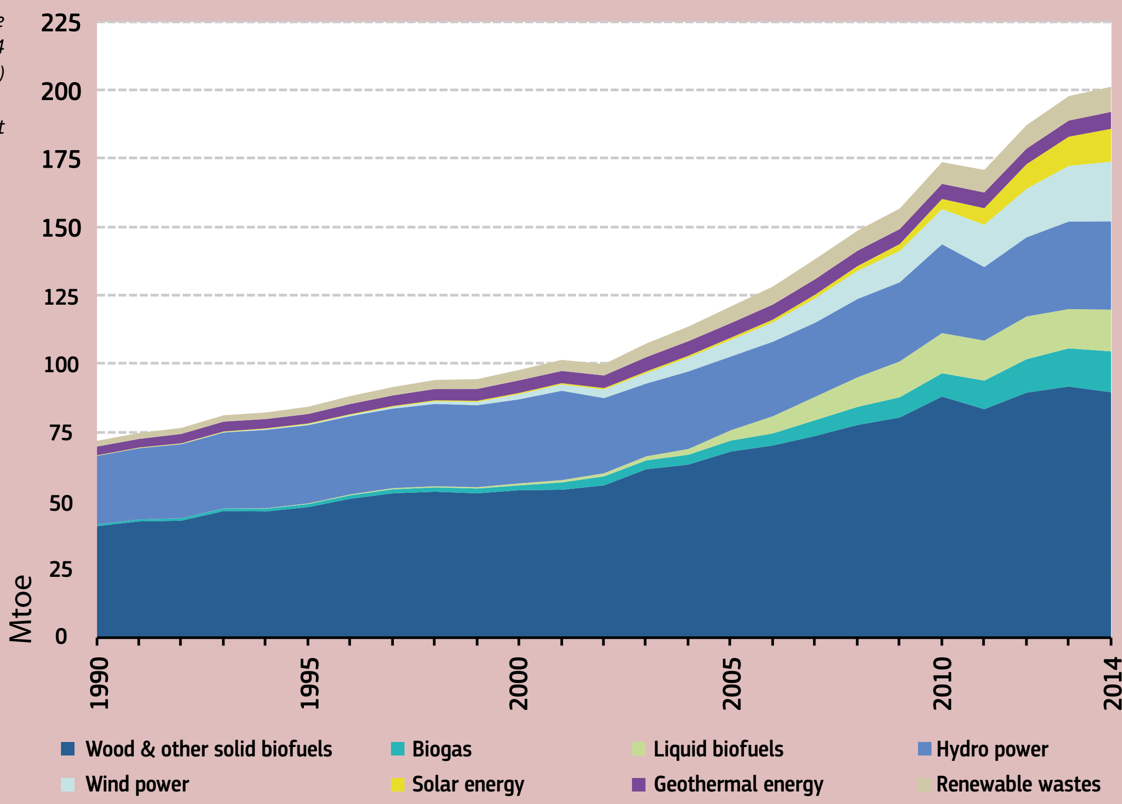
Key factors here are the availability of sustainable feedstocks and, for some applications, of advanced conversion processes. To a large extent the potential growth is determined by the availability of sustainable and resource-efficient feedstocks and cost reduction. Biomass potentials seem sufficient, but their mobilisation and market development require further attention. Bioenergy has been the frontrunner for sustainability requirements in the EU – since 2009 biofuels have to comply with mandatory sustainability requirements of the EU Renewable Energy Directive, which will be strengthened in the near future, e.g. with a view to GHG emissions. Bioenergy is storable and is the only short- and medium-term alternative for a number of applications, especially in transport, such as aviation, shipping and heavy-duty transport. For substantial growth of bio-based fuels, materials and chemicals, advanced (biochemical and thermochemical) conversion processes will need to be commercialised, stand-alone and in integrated biorefinery concepts.

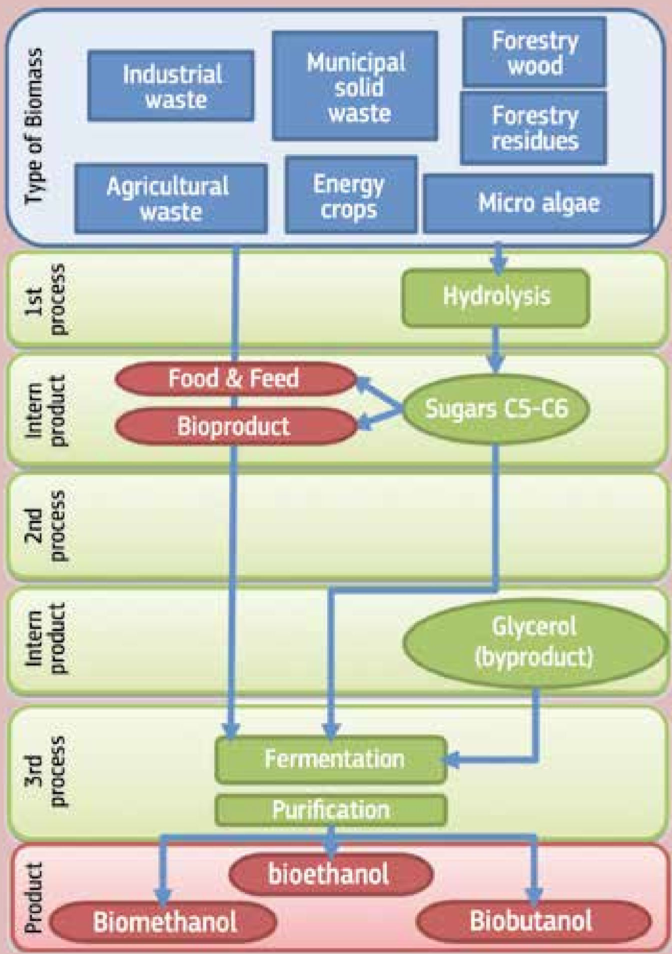
### *Most important interlinkages with other sectors*

Bioenergy is interlinked with other sectors for all steps of the production, processing and utilisation chain. It can use wastes and residues of other bioeconomy activities in a cascading approach, but it may also compete for feedstocks with other sectors. Many primary conversion technologies are identical, be they biochemical (e.g. fermentation) or thermochemical (e.g. gasification). Energy-driven bio-refineries will produce a range of products for different bioeconomy sectors, which complement each other and make the process environmentally sound and economically viable. Synthesis gas, bioethanol or biomethanol open up to a range of further chemical transformations

*Energy from renewable sources updated 2014 (EU 28)*

*Source: Eurostat*






*Generic flowsheet of fermentation process*

*Source: JRC, Environmental sustainability assessment of bioeconomy products and processes – Progress Report 1, Publications Office of the European Union, Luxembourg, 2015*

and products. Bioenergy may provide the economies of scale effects required for higher value added applications as well, e.g. enzymes will become cheaper if a large market demand can contribute to the development costs.

***Challenges in the relation to bioeconomy***

Key challenges are to define resource efficient and sustainable value chains, taking into account the use of co-products, in coherence with biomass supply demands of all bioeconomy sectors, to achieve cost reductions for supply and conversion technologies and to build a clear, stable, predictable and consistent legal framework.

***Key messages***

- Advanced bioenergy and biofuels will be a cornerstone of the European bioeconomy, as well as the energy system, during the coming decades.
- In a smart approach, different sectors of the bioeconomy make use of synergies and complementarities.
- Bioenergy and biofuels have been frontrunners for sustainability requirements. For the broad market rollout, a consistent approach for all bioeconomy sectors is required to facilitate understanding and reduce misconceptions and negative attitudes.

***Case study***

The Crescentino bio-refinery in Italy, owned by Beta Renewables and opened in October 2013, transforms cellulose into sugars and finally bioethanol. The feedstocks are agricultural residues such as wheat and rice straw, and lignocellulosic energy crops such as giant reed (*Arundo donax*). After a pre-treatment and viscosity-reduction step, hydrolysis and fermentation processes follow. The bioethanol, of which currently 40000 tonnes per year are produced, can be blended to gasoline but can also serve as a platform chemical for further upgrading to a broad range of chemical products. The plant itself is self-sufficient in terms of energy consumption, as the lignin from the process is used for electricity and steam production, and the plant does not release any wastewater.

Crescentino is a good example of the synergies between different bioeconomy sectors. The owners are rooted in the chemical and enzyme industry and have a natural interest in new market applications whenever economically viable. The chart above presents a broader picture of how fermentation processes can be integrated into different sectors of the bioeconomy, starting from the feedstocks and by-products, e.g. for animal feed, and up to the final products.

## 5.6. Bio-based industry

*by Flavio Benedito, SusChem*



The European chemical industry is gradually increasing its production, integrating bio-based processes and the conversion of renewable biological resources and associated waste streams. This marks a transition towards a more sustainable chemical industry. Advancements in industrial biotechnology allow the selective production of added- value small molecules used as building blocks for several applications of fine chemicals and pharmaceuticals. For instance, a large variety of goods, such as biofuels, plastics, paints, adhesives, lubricants, cosmetics, pharmaceuticals and many more, can be obtained using renewable resources.

Nevertheless, the main hurdle for the production of bio-based products is to guarantee a stable supply of sufficient amounts of feedstock that do not compete with food and feed production and are price competitive. To overcome this obstacle, the chemical industry is investing in several research projects focused on the use of alternative resources streams like municipal, forestry, agricultural wastes, recycled feedstock, algae or energy-related crops. Only the substitution of fossil-based resources to renewable ones in itself does not necessarily mean that the whole production process is more sustainable. In fact, the chemical industry needs to take into account the overall environmental, social and economic impact ($CO_2$ emissions, water use, energy efficiency, etc.) for crop seeding, fertiliser, harvesting, transport and conversion.

An integrated approach and cooperation among all players in the value chain is necessary to expand the bio-based industry in Europe, to generate new jobs and to open up the opportunity for new sustainable value chains and markets. There is a need to develop with academia an integrated research and innovation strategy that incorporates the key enabling technologies provided by the chemical sector1 to foster the growth and sustainable utilisation of biomass in Europe. Synergies among industrial players and the European authorities are crucial to assure an adequate set of policies that promote the bio-based industry, secure access to competitively priced renewable raw materials, enable investments in research and development, innovation, demonstration and production facilities, focus on tackling hurdles to market creation and allow market pull measures.

***Key messages***

- A structured R&I roadmap is key to boost bioeconomy.
- Sustainable supply and conversion of renewable biological resources is fundamental.
- Resource, energy efficiency and other sustainability aspects should be considered throughout the whole value chain.

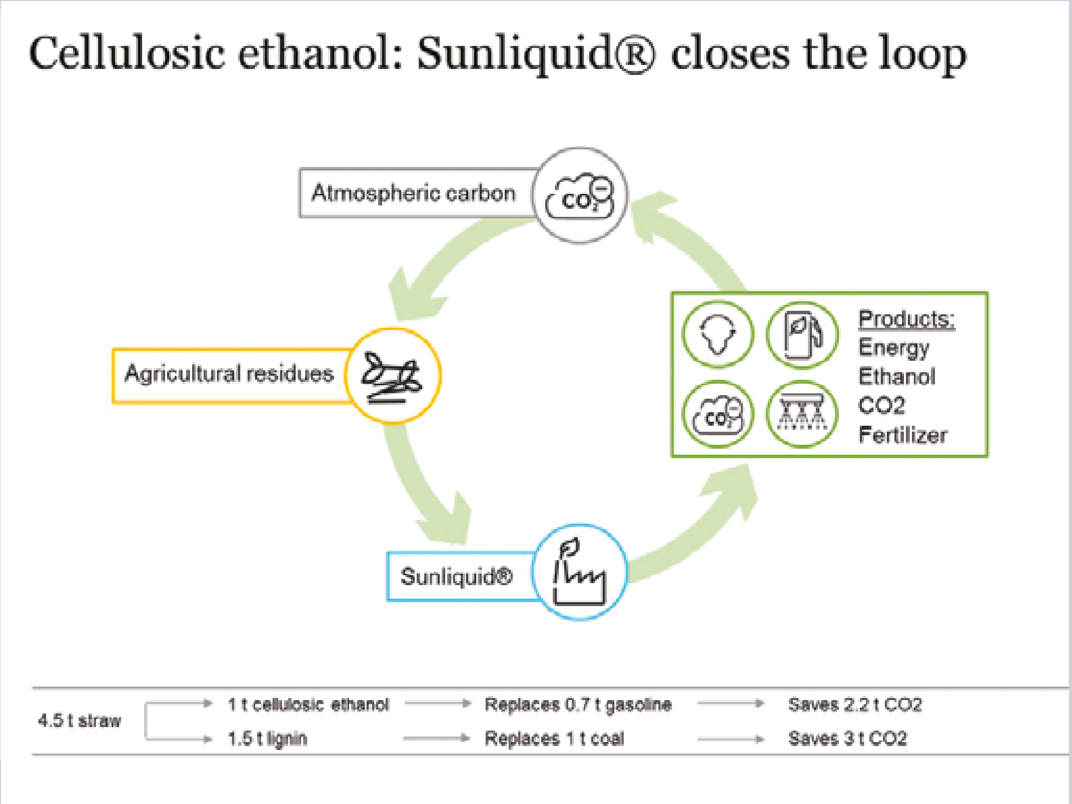
***Case study: Sunliquid® technology for cellulosic ethanol, commercialisation and application in biofuels and biochemicals***



More and more economies are looking at possibilities to substitute fossil resources by renewable ones, both to secure energy supply and to increase sustainability. The transport sector in particular will continue to be largely dependent on liquid energy sources and advanced biofuels are the preferred way to efficiently reach renewable substitution goals in the short to medium term. The chemical and materials industries also see an increased call for more sustainability and renewables in their products.

Lignocelluloses show a huge potential as a new feedstock for the production of advanced biofuels and bio-based chemicals globally. The key technical hurdle in the past has been how to access the sugars bound in the lignocellulosic material. In recent years a technological breakthrough has been achieved through a variety of technologies, in particular enzymatic conversion. The issue now is to validate production processes and optimise the efficiency for large-scale competitive production, in particular through high process yields combined with low operational and capital expenditure. The 'sunliquid®' enzymatic conversion technology overcomes these challenges through an integrated process design and technology features offering a flexible solution to convert different feedstock and adapt to various plant concepts. The production cost can compete with those of first-generation bioethanol and the GHG savings of this second-generation ethanol are 95 % compared to fossil fuels.

Since July 2012, realisation on an industrial scale has been tested in a pre-commercial plant in Straubing, Germany, with an annual capacity of 1000 tonnes (1.25 million litres, 330 000 gallons), converting approximately 4500 tonnes of lignocellulosic feedstock per year. Performance runs with




wheat straw, corn stover and sugarcane bagasse have shown very good results and further validated the technology confirming that it could be implemented worldwide. The process design used delivers a technological blueprint for commercial facilities between 50 kt and 150 kt (20-60 million gallons) of ethanol per year. In addition to the application in the transport sector, the technology offers a platform for conversion of agricultural residues into a range of chemicals for different industries and applications. In cooperation with another company, technologies have been integrated to convert bio-ethylene from cellulosic ethanol into derivatives such as ethylene oxide, bio-mono ethylene glycol and other bio-based products. Furthermore, the new enzymatic conversion technology offers access to low-cost cellulosic sugars for further conversion.

In collaboration with an automotive and a refining company, a new fuel based on enzymatic conversion was successfully tested. It is a premium-grade E20 blend that contains 20% cellulosic ethanol from the pre-commercial plant in a fleet test with vehicles. The fuel showed very good performance and sustainability properties: no increase in fuel demand compared to the E10 reference fuel and 50% reduction in particle emissions compared with gasoline and without being in competition with food and feed production.

# 6. Main findings and conclusions

## 6.1. EU policy framework relevant for the bioeconomy

Work towards a dedicated EU bioeconomy policy began about 10 years ago and led to the 2012 bioeconomy strategy and action plan. The strategy, as well as other bioeconomy relevant policies, supports four of the Europe 2020 flagship initiatives and three of the priorities of the Juncker Commission.

The EU bioeconomy policy framework is related to international treaties and the EU commitments therein, such as the Paris Agreement negotiated at the United Nations COP21 and the United Nations SDG. However, a more detailed presentation of this international dimension of the bioeconomy policy is beyond the scope of this report.

In addition to the bioeconomy strategy, the EU addresses the bioeconomy through relevant sectorial legislation. The CAP and CFP have a significant impact on biomass availability, price and price volatility. From the sectors using biomass, only the bioenergy sector is regulated by EU legislation promoting the use of biomass, which in turn can influence the availability and price of biomass for other sectors and uses such as food and bio-based chemicals and materials. Cross-cutting policies relevant for the bioeconomy, such as climate change policy, circular and blue economy and regional policy, can boost the bioeconomy. Further policies such as research and innovation, trade and internal market policies have a major impact on the bioeconomy.

EC research funding substantially supports the bioeconomy. Some 5.6% (EUR 4.2 billion) of the Horizon 2020 budget is dedicated to the bioeconomy. Management of the research budget is carried out by the EC in cooperation with and complemented by a high number of public–public and public–private structures and organisations. Horizon 2020 also provides public funds (approximately EUR 1 billion topped up by private funds to an overall budget of EUR 3.7 billion) for the BBI JU and financing tools for R&I actions (access to risk finance). The JRC, including its work on the bioeconomy, is also mainly financed by Horizon 2020 funds.

ESIF fund research and investment in the field of bioeconomy, especially in the context of rural development, cohesion, agriculture and fisheries. It is therefore relevant for boosting the introduction and development of the bioeconomy at regional level in the framework of smart specialisation. EFSI, as part of the Juncker investment plan, supports strategic investment projects which trigger substantial private funds.

Standards, labels and public procurement are instruments for boosting the market uptake of novel products. Standards (CEN and ISO) for bio-based products are being developed, and studies concerning bio-based labelling and procurement taking into account 'bio-based' as a criterion are being conducted.

This report provides an overview of policy instruments for the bioeconomy showing the high complexity of the issue. However, more research is needed for a fully fledged analysis of the impact of relevant policies. This could build, inter alia, on the exploratory assessment by Philippidis, M'Barek and Ferrari (Philippidis et al. 2016a; Philippidis et al. 2016b).

## 6.2. Quantifying indicators of the European bioeconomy

### *Employment*

The bioeconomy in the EU-28 employed around 18.6 million people in 2014, constituting about 8.5% of the jobs in all economic sectors. The agricultural sector (9.6 million jobs) and the manufacture of food, beverages and tobacco (4.5 million jobs) together provide three quarters of the total employment in the European bioeconomy. The other sectors of the bioeconomy contribute less than 9% each to the total number of people employed in the bioeconomy.

A slight decrease year to year in jobs resulted in approximately 2.2 million people less employed in the bioeconomy of the EU-28 in 2014 than in 2008. Job losses are mainly in the agricultural sector due to the ongoing restructuration of the European agricultural sector, but also in the manufacture of wood products and of wooden furniture, of bio-based textiles and of food, beverages and tobacco. Representing less than 1% of the bioeconomy workforce, the manufacture of bio-based pharmaceuticals employed 45000 additional people in 2014 compared to 2008. It is the bioeconomy sector shows the highest gain in the number of persons employed over the period.

The number of jobs in all economic sectors in the EU on the whole declined from 223 million to 218 million between 2008 and 2014. The share of jobs of the bioeconomy in overall jobs in the economy of the EU-28 decreased from 9.3% to 8.5%.

Due to very different natural resources endowment and different historical orientations of their domestic economy, the EU Member States present very different patterns of their bioeconomy. As far as employment is concerned, the location quotient is the indicator usually used to measure how 'concentrated' a sector is in a Member State compared to the EU, i.e. the share of Member State employment in the bioeconomy (or in a given sector of the bioeconomy) divided by the EU employment share in the bioeconomy (or in the same given sector).

In 2014, location quotients for the EU-28 ranged from 0.41 (indicating a relatively low concentration of bioeconomy employment for the United Kingdom) to 3.89 (for Romania). High to medium location quotients in Member States are usually driven by the high shares of agriculture in the national labour market. Member States with lower location quotients rely on more varied sectors, although some specific subsectors can show high location quotients. To mention just a few, the labour market in Greece is highly specialised in the fishing sector (including capture and aquaculture), while the Latvian bioeconomy workforce is concentrated in the forestry sector. The Estonian bioeconomy is concentrated in the forestry sector, in the manufacture of wood products and, to a lower extent, in the fisheries sector.

### *Turnover*

The bioeconomy in the EU-28 has generated approximately EUR 2.2 trillion in 2014, constituting about 9% of the turnover of the total economy according to a JRC study (Philippidis et al. 2016a). The agricultural sector (17%) and the manufacture of food, beverages and tobacco (more than 50%) together provided slightly more than two thirds of overall bioeconomy turnover.

Between 2008 and 2014, the turnover of the EU bioeconomy grew by approximately EUR 140 billion, accounting for a 7% rise. This trend is mainly driven by developments in the manufacture of food, beverages and tobacco products, and to a lesser extent by developments in agriculture and the manufacture of chemicals, pharmaceuticals, plastics and rubber. Turnovers of forestry, the manufacture of liquid biofuels and the manufacture of paper were also on the rise (with an additional EUR 5 billion to EUR 9 billion in 2014 compared to 2008). Comparable data showing the development of turnover in all economic sectors of the EU-28 between 2008 and 2014 are not available.

The analysis of turnover per person employed shows a wide range of results. At the high end are 'innovative' bio-based sectors that have seen much development and changes in recent years. In 2014, the production of electricity generated around EUR 820000 of turnover per person employed; electricity production is used as a reference for the production of bio-electricity in the absence of better estimates. The primary sectors are at the low end with, for instance, around EUR 40000 in turnover per person employed in 2014 in the agricultural sector. The combination of job reduction and turnover increase resulted in gains of turnover per person in almost all bioeconomy sectors over the 2008-2014 period.

Western and northern European Member States rank first with respect to the total bioeconomy turnover and sectorial turnovers. Total turnover in the bioeconomy ranged from EUR 407 billion in Germany to EUR 0.3 billion in Malta.

Just as for the EU on the whole, national bioeconomy turnovers rely mainly on two sectors: the manufacture of food, beverages and tobacco and agriculture. But also the specialisation in other sectors was observed, e.g. Nordic countries are usually specialised in the forestry sector and some of them in the manufacture of wood and wooden furniture and/or the manufacture of pulp and paper. Countries with relatively high shares in bio-based textiles are Italy and Portugal. Compared to the other EU Member States, Ireland's and Denmark's bioeconomy turnover is generated to a significant extent by the manufacture of bio-based chemicals, pharmaceuticals, plastics and rubber.

### *Overall*

Job and turnover estimates presented in this report come from a methodology that makes use of Eurostat statistics and expert opinion. Interviewed by the nova-Institute, experts were in charge of estimating the bio-based share of Eurostat sectors that produce both bio-based and fossil-based products. The methodology allows for using harmonised data across Member States and for an easy update when new Eurostat statistics become available. In the future the methodology will be complemented with the estimation of new indicators such as the value added of bioeconomy sectors. Nevertheless, the estimation of the labour productivity (in turnover per person employed) of mixed (i.e. bio-based and fossil-based) sectors remains a methodological challenge.

Despite this caveat, the analysis provides important insight into the size, impact and development of the EU bioeconomy, which makes up an important part of the total economy in the EU: around 8.5% of all sectors of the economy with regards to employment. The economic size (concerning jobs and turnover) of the bioeconomy sectors varies considerably across Member States. Agriculture and the manufacture of food, beverages and tobacco sectors together make up about three quarters of the overall bioeconomy with regards to employment and two thirds with regards to turnover.

Whereas the number of jobs in the EU bioeconomy decreased between 2008 and 2014, the turnover increased. Contributions of the different sectors to this development varied greatly.

Although the agricultural sector and the manufacture of food, beverages and tobacco are widely dominating, the EU Member States present very different patterns of their bioeconomy. An even more diverse picture could be expected for an analysis at regional level. On the one hand this shows that the bioeconomy concept, thanks to its versatility, can provide opportunities for many and possibly all of the Member States and their regions, independently of their very different natural resources endowment and different historical orientations of their domestic economy. On the other hand, such a diverse picture stresses the importance of cooperation within and between regions and Member States to exploit synergies between different sectors in the bioeconomy, as the size of these sectors can differ so much from one region and Member State to another.

### *Bio-based industries sector*

The survey on the bio-based industry summarised in this report was the first of its kind and scale carried out across the EU. It represents an important first step in a systematic approach to quantifying the EU bio-based economy. However, it is important to keep in mind that the survey is not able to provide a fully quantitative picture of the status and evolution of the EU bio-based industry. This is mainly due to the high number of products and their heterogeneity, the amount of data that needs to be collected and the difficulty for the respondents to assemble it, and the incomplete response rate.

At the same time, it is not possible to quantitatively compare the EU bio-based industry with important competing countries like the United States, China and Brazil due to the lack of harmonisation in the scope and methodologies between the existing country reports. Nevertheless, the survey is a good starting point for future surveys aiming to provide a more complete picture.

### *Biomass flow*

The JRC is compiling and harmonising data on the different sectors of production and use of biomass. Preliminary results are presented in this report, though the work will continue.

### *Multiplier analysis*

The JRC is preparing a new database which will allow to measure the bioeconomy through so-called economic and employment multipliers. These indicators will give an insight into the economic interlinkages of the bioeconomy sectors in EU Member States and their capacity to produce value added and create jobs.

## 6.3. (Potential) environmental impact on the bioeconomy

LCA has been integrated into EU legislation as a tool for informing about potential environmental impacts of products and commodities. A-LCA inventory modelling depicts the potential environmental impacts that can be attributed to a system (e.g. a product) over its life cycle, i.e. upstream along the supply chain and downstream following the system's use and end-of-life value chain. C-LCA inventory modelling aims at identifying the consequences that a decision in the foreground system has for other processes and systems of the economy, both in the analysed background system and on other systems outside the boundaries. Advanced A-LCA methodologies have recently been proposed, which apply elements of consequential thinking without properly being a C-LCA.

The JRC used A-LCA following the PEF methodology, which includes 14 impact categories, to analyse bioeconomy value chains from three groups: (1) food and feed, (2) bio-based products and (3) bioenergy including biofuels. The case studies presented in the report show that the bio-based products analysed produce lower environmental impacts in comparison to their fossil references for the impact categories of climate change and non-renewable energy consumption. On the other hand, for impacts regarding eutrophication, acidification and land use, the bio-based products may perform more poorly due to the agricultural activities related to biomass production (i.e. use of fertilisers and pesticides) and lower efficiencies in the production processes.

The report explains the methodological steps of an advanced A-LCA case study of the example of using forest logging residues for domestic heating. A comprehensive assessment of the environmental impacts associated to bioenergy should (i) consider a counterfactual, non-energy use of the biomass feedstock (in addition to the factual energy use); (ii) explicitly and dynamically account for all the flows of biogenic $CO_2$; (iii) apply multiple climate metrics; and (iv) include all relevant climate forcers and holistically assess all potential environmental impacts. This approach could be extended to all bio-based products when looking for the potential environmental risks of various alternative uses of biomass or land.

This case study reveals that the climate change mitigation potential of using forest logging residues for domestic heating depends strongly on the type of residue and on geographically specific conditions. For instance, the use of slow-decaying residues for domestic heating, as examined in this case study, would not contribute to climate change mitigation by the end of this century. Furthermore, the analysis shows that several environmental risks are associated with the removal and use of forest logging residues for bioenergy. These issues mostly concern local air pollution, biodiversity loss and, primarily for stumps removal, physical damage to forest soils.

Domestic heating from logging residues is generally beneficial to mitigate the surface temperature increase by 2100 compared to the use of natural gas and other fossil sources.

The JRC is also building up an IMF (C-LCA modelling) for analysing the potential impacts of a policy choice or scenarios; it will bring together several sectorial models. Ideally, all market sectors and all regions of the world would be included. However, in reality, limitations concerning the geographical scope and coverage of bioeconomy sectors and co-products need to be taken into account.

Overall, the discussion shows that choice and evaluation of data, the careful specification of the LCA models used and the system boundaries, as well as cautious interpretation are required to achieve reliable and useful results.

The development from A-LCA to advanced LCA and C-LCA including IMFs allow for taking into account relevant factors of the analysed system and of other systems outside the boundaries. Data gaps still need to be filled and concepts and methodology, including the integrated model for the environmental impact assessment, need to be further developed and implemented.

## 6.4. Bioeconomy in sectors

This chapter was written by experts from organisations representing the following sectors: agriculture, food (security), forestry, fisheries and aquaculture, bioenergy and bio-based industry. All experts stressed the high importance of the bioeconomy for their sector as well as the close interlinkages between their own and other sectors of the bioeconomy, and they discussed potentials and challenges.

In their key messages they explored important issues for their respective sectors such as the importance of forests as carbon sinks, the role of forerunners of bioenergy and biofuels for sustainability, the need to foster healthy oceans and the importance to improve agriculture through precision farming and other innovative measures.

Cross-sectorial issues are also of great importance. The experts stressed the role of the bioeconomy in addressing societal challenges such as food security, natural resource scarcity, dependence on fossil fuels and mitigating climate change. In addition they pointed out the key role of education, research and innovation; the need for transformative improvements of primary production of biomass to cope with increasing demand for renewable resources; the need for integrated and careful governance to reach sustainability; and the need to consider sustainability throughout the value chain from biomass cultivation, supply to conversation and use.

The sector representatives also provided a range of case studies, such as on using palm oil, seaweed or a grass refinery for innovative value chains. Furthermore, they presented the cases of a pre-commercial and a commercial plant for the production of ethanol from lignocellulosic sources and the construction of an innovative large-scale wood mill.

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# List of abbreviations

| | |
|---|---|
| A-LCA | attributional LCA |
| AoP | area of protection |
| BBI | bio-based industries |
| C-LCA | consequential LCA |
| CAP | common agricultural policy |
| CEN | European Committee for Standardisation |
| CF | Cohesion Fund |
| CFP | common fisheries policy |
| EC | European Commission |
| EAFRD | European Agricultural Fund for Rural Development |
| EAGF | European Agricultural Guarantee Fund |
| ECHA | European Chemicals Agency |
| EFSI | European Fund for Strategic Investments |
| EIB | European Investment Bank |
| EIF | European Investment Fund |
| EIP | European Innovation Partnership |
| EIP-AGRI | European Innovation Partnership for Agricultural Productivity and Sustainability |
| EIT | European Institute of Innovation and Technology |
| EMFF | European Maritime and Fisheries Fund |
| ERA | European Research Area |
| ERA-NET | European Research Area Networks |
| ESD | effort-sharing decision |
| ERDF | European Regional Development Fund |
| ESF | European Social Fund |
| ESIF | European Structural and Investment Funds |
| ETP | European technology platform |
| ETS | Emissions Trading System |
| EU | European Union |
| FP | framework programme |
| FQD | Fuel Quality Directive |
| GDP | gross domestic product |
| GHG | greenhouse gas |
| GTP | global surface temperature change potential |
| GWP | global warming potential |
| ILCD | International Life Cycle Data System |
| IMF | integrated modelling framework |
| IPCC | Intergovernmental Panel for Climate Change |
| ISO | International Organisation for Standardisation |

| | |
|---|---|
| JPI | joint programming initiative |
| JRC | Joint Research Centre |
| JTI | joint technology initiative |
| JU | joint undertaking |
| KBBE | knowledge-based bioeconomy |
| KET | key enabling technologies |
| KIC | Knowledge and Innovation Community |
| LCA | life cycle assessment |
| LCI | life cycle inventory |
| LEIT | leadership in enabling and industrial technologies |
| LMI | lead markets initiative |
| LULUCF | land use, land-use change and forestry |
| MAP | multiannual implementation plan |
| NTCF | near-term climate forcer |
| P2P | public–public partnership |
| PEF | product environmental footprint |
| PPP | public–private partnership |
| R&I | research and innovation |
| REA | Research Executive Agency |
| REACH | registration, evaluation, authorisation and restriction of chemicals |
| RED | Renewable Energy Directive |
| RIS3 | research and innovation strategies for smart specialisation |
| SC | societal challenge |
| SET-plan | strategic energy technology plan |
| SIRA | strategic innovation and research agenda |
| SME | small- and medium-sized enterprise |
| SRA | strategic research agendas |
| TFEU | Treaty on the Functioning of the European Union |
| TN | thematic networks |
| VC | value chain |
| WMGHG | well-mixed greenhouse gas |

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