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A global view of bio-based industries: benchmarking and monitoring their economic importance and future developments

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Towards a benchmark of bio-based industries in the EU, Brazil, Canada and USA

Abstract
This report describes the strategies that are in place in the EU, Brazil, US and Canada about the nascent Bioeconomy. It also focuses on the comparison of the initiatives taken so far to measure the innovative bio-based industrial sector.

Contents

Acknowledgments

We would like to acknowledge contributions made by all participants to the workshop (a complete list is included in Annex I), including their detailed presentation, their consent to share their knowledge and ideas, and their availability to revise the text of these Proceedings. We thank all contributing and participating colleagues from the European Commission, in particular Emilio Rodríguez-Cerezo from the JRC for being co-organiser and chairman of the event and for revising the final document, Xavier Vanden Bosch from DG-RTD and Emanuele Ferrari and Robert M'Barek from the JRC. We also would like to thank the participants from the Brazilian delegation: Luiz Henrique Mourão do Canto Pereira, Geraldo B. Martha Jr and Bernardo Silva, and all following invited external experts for their nice contribution to the success of the workshop: Marie Wheat, Samuel Bonti-Ankomah, Michael Carus, Dietrich Wittmeyer, Tilman Benzing, Dirk Carrez, Kees Kwant, Hans van Maijl, Justus Wesseler and Peter Schintlmeister. Finally, we also would like to thank the staff involved in the organisational arrangements, in particular Leonor Rueda.

Executive Summary

The workshop entitled 'A global view of bio-based industries: benchmarking and monitoring their economic importance and future developments', organised in the framework of the EU–Brazil Sector Dialogues, brought together relevant experts from the EU, the USA, Canada and Brazil, to describe the strategies that are in place in their own countries to foster the bioeconomy and the initiatives taken to date to measure this sector and understand its relevance. A specific focus of the workshop concerned the most innovative bio-based industries and the emerging issues for their precise measurement and analysis. The workshop provided a forum for the exchange of information about different scopes within the broad concept of the bioeconomy and to discuss different needs for specific data and indicators, and different methodologies that have been developed to address these needs.

Different bioeconomy policy settings

In the EU, the bioeconomy is defined as the use of biomass in food and animal feed, bio-based products and bioenergy, independently of the processing technologies that have been employed in its production. A strategy that was dedicated specifically to the bioeconomy was established in 2012 (EC, 2012) and is currently being revised. The main objectives and drivers of the growing bioeconomy in Europe are environmental sustainability, climate change and reduction of dependence on fossil resources. The strategy aims to improve investments in research and innovation (R&I), reinforce policy interaction and stakeholder engagement, and enhance the market and competitiveness in the bioeconomy sectors. Because of its innate diversity, the EU bioeconomy strategies adopted by different Member States (MSs) are quite heterogeneous, but the common purpose is to reach policy coherence in this sector and in bioeconomy-related policies.

The US definition of the bioeconomy includes both the replacement of fossil resources by biomass-based feedstock sources and the use of biotechnology tools (in both industrial and medical fields) in the manufacturing process, independently of the feedstock used. The 2012 National Bioeconomy Blueprint (White House, 2012) describes five strategic objectives: to support research and development (R&D) investments, to facilitate the transition of bioinventions from research lab to market, to develop and reform regulations to reduce barriers, to update training programmes and to identify and support opportunities for the development of public–private partnerships and precompetitive collaborations. Specifically for bio-based products, the BioPreferred program was developed in 2002 with the aim of identifying new markets for bio-based products and is characterised by two major elements: Mandatory Federal Purchasing and the Voluntary Labelling Program.

Canada defines the bioeconomy as the economic activity associated with the invention, development, production and use of products and processes that are based primarily on biological resources and is a multidisciplinary field that cuts across the health, energy, agriculture, chemicals and materials industries. Therefore, the scope of the Canadian national bioeconomy is broader than that of the EU and appears to be more in line with that of the USA. However, Canada has not yet adopted a federal bioeconomy strategy but did adopt a strategy for renewable energy in 2006 and an agricultural strategy ('Growing Forward') in 2013 (Bioökonomierat, 2015).

Brazil has based its definition of the bioeconomy on the application of biotechnology in different sectors, not only in the agricultural and industrial fields, but also in the health

sector. Brazil has not put in place a specific strategy for the bioeconomy, but is constantly updating its legal framework on biotechnology, which includes different policies for product development and R&D incentives. A specific Observatory for Innovation and Biotechnology (OIB) was created in 2014 by the Ministry of Science, Technology and Innovation (MCTI) with the aims of exploring opportunities and mapping challenges for technological development in biotechnology, conducting international benchmarking of technologies of interest, evaluating the market potential of developed (and developing) technologies and identifying bottlenecks and opportunities to minimise the risks associated with the innovation in biotechnology (http://sectordialogues.org/en/acao-apoiada/establishment-biotechnology-innovation-observatory-brazil-and-its-interaction-european).

Data collection and analysis on the bio-based industry

Despite the different scopes, a clear common interest emerged in measuring and monitoring the bioeconomy sector during the workshop. A common issue that emerged for all countries is the lack of data for the most innovative sectors of the bioeconomy, such as bio-based chemicals and composites. The reasons for the data gap are related to the recent development of most relevant products, for example new products or those that are more commonly obtained from fossil resources. They are also related to the fact that no specific codes have been developed for these bio-based products in official statistics yet (i.e. no Statistical Classification of Economic Activities (NACE) codes in the EU or North American Industry Classification System (NAICS) codes in the USA). Additionally, bio-based chemicals and composites are produced in very complex value chains and the product categories include hundreds of different products when intermediates and final products are included. Therefore, it would represent a huge bureaucratic burden to create specific codes for each product.

EU data collection and analysis on the bio-based industry

The nova-Institute (Hürth, Germany) researched the biomass transformation pathways within the European biomaterial industry to represent the different routes to the final bio-based products. In cooperation with the Joint Research Centre (JRC), the nova-Institute has also estimated turnovers and employment levels in the different sectors of the European bioeconomy, including bio-based chemicals and plastics. According to the nova-Institute´s data, the total turnover of the EU bioeconomy is EUR 2.1 trillion, which is derived mainly from food and food products (44 %), with 5 % from chemicals and plastics and 1 % from biofuels. The EU bioeconomy employs 18.3 million people, mainly in raw materials production (57 %), with only 1 % of these employed in chemicals and plastics and 0.2 % in biofuels. The methodology applied, which was based on Eurostat data, seems to fit the desired purpose, but results in rough estimates in the absence of ad hoc statistics. Further refinements are required to obtain more precise data at product level.

In 2015, specifically for the EU bio-based industry sector, the JRC conducted a survey of EU companies producing bio-based chemicals and composites. The final population that was identified included 133 EU companies, operating at more than 200 facilities in the EU, 50 of which provided data to the survey. This represented a response rate of 38 % and was a very heterogeneous sample. The main findings show a growing sector with its main constraints related to feedstock price and availability.

The Renewable Raw Materials (RRM) group, established in 2001 by the European Commission, works in cooperation with industry partners and is collecting data to analyse the value chain for bio-based products. Generally, the collected data indicates aslight increasing trend in the market for bio-based products in the coming years and, consequently, in the consumption of biomass feedstock for industrial use.

The estimation of the use of raw renewable materials by the EU chemical industry was also analysed by the European Chemical Industry Council (CEFIC), which established its own methodology to obtain baseline information concerning the present situation and to be able to monitor the evolution of this area in the future. According to CEFIC 2014 data, the total raw materials used in the organic chemical industry amounted to 78.8 Mt, of which 70.9 Mt was fossil-derived materials and 7.8 Mt (10 % of the total) was from renewable sources. However, the emerged uncertainties in the data collection mean that the resulting data requires careful interpretation, particularly when analysing future developments.

A few projects of the European Seventh Framework Programme (FP7) are also dedicated to the collection of data that describe the status of the bio-based industry in the EU. In the framework of the FP7 European-funded BIO-TIC project, the nova-Institute estimated that 2 Mt of starch and sugar and 1.2 Mt of vegetable oil are used for chemical production in the EU. New Horizon 2020 projects are also being planned to continue this type of data collection.

Data collection concerning the bio-based industry sector is also being carried out at MS level. The Netherlands Enterprise Agency is currently developing a methodology to monitor the bio-based economy in the Netherlands. This methodology focuses on the economic added value, the flow of bio-based materials and innovation, together with the regions, but still needs to be further developed, particularly for the bio-based chemical and material sectors. According to the main findings, the chemical sector has the highest economic added value per biomass tonne, but there is a need for market development in this sector, for example through more procurements for bio-based products.

Measuring the socio-economic impacts of the EU bioeconomy

An integrated assessment is required to monitor and evaluate the bioeconomy in terms of the main societal challenges and policy targets. The computable general equilibrium (CGE) model 'Modular Applied General Equilibrium Tool' (MAGNET) is employed by the JRC and the Agricultural Economics Institute of Wageningen University (LEI) to describe the inter-sectoral linkages and indirect effects for the entire bioeconomy, in combination with partial equilibrium (PE) models to obtain a more detailed description of certain bio-based sectors. The main challenge for MAGNET is that data on cost structure, sales, trade patterns and future developments of innovative bio-based sectors are not explicitly represented. Therefore, the LEI has recently integrated four bio-based categories into MAGNET: biomass supply, electricity, transport fuels and chemicals.

Through the use of MAGNET, the LEI finalised the FP7 project 'Systems Analysis Tools Framework for the EU Bio-based Economy Strategy' (SAT BBE) in 2015 to provide analytical tools for monitoring and the evaluation of the implementation of the EU Bioeconomy Strategy. The LEI was also involved in impact assessments of Brazilian biofuels production and use with respect to land use and agricultural dynamics from a Brazilian and global perspective, by combining various modelling approaches. Recently, the LEI performed an assessment of the impact of the bioeconomy in the Netherlands by implementing four possible scenarios.

In 2016, the JRC finalised a study using MAGNET to provide a systematic and connected view of the sectors that define the bioeconomy, in particular agriculture and the food industry, with the inclusion of less traditional sectors in 2030 and the creation of two scenarios based on pure research needs.

Wageningen University (WUR) has also developed methods to measure the size of the EU bioeconomy and estimated data on turnover and employment in the different sectors of the bioeconomy. Regarding sustainability-related irreversibility effects, WUR has developed an indicator, called 'Maximum Incremental Social Tolerable Irreversible Costs', to deal with uncertainties and integrate them into the economic assessment. WUR is also planning a study to perform an appropriate analysis of the bioeconomy, based on a homogeneous panel data set and, ideally, through a plurality of models addressing specific questions.

As reflected in the modelling analysis, the bioeconomy consists of various complex and interlinked sectors that are driven by technological change and open markets and can contribute to the societal challenges of the EU. The macro-economic impacts of the bioeconomy depend on the competitiveness of biotechnologies and fossil energy prices. Possible future developments include running some realistic and more detailed scenarios that would reflect specific policy questions. Data will be continuously updated, new modules will be included and more specific data on the less traditional bio-based sectors will be integrated.

Data collection and analysis in partner countries: USA and Canada

The US Department of Agriculture (USDA) study 'An Economic Impact Analysis of the US Biobased Products Industry' defines the US bio-based industry as encompassing the agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest products and textiles sectors, and reports on innovative products carrying the USDA's BioPreferred® label. The approach taken to carry out the study was threefold: the collection of statistics; interviews with experts; and modelling analysis using IMpact analysis for PLANning data and software (IMPLAN). According to the main findings of the study, the US bio-based products industry contributed USD 369 billion and four million jobs to the American economy; each job in the bio-based products industry is responsible for generating 1.64 jobs in other sectors of the economy. Additionally, the use of biomass feedstock by this industry is displacing the use of approximately 300 million gallons of petroleum each year. An update of the study will soon be publicly available. Similarly to the studies based on Eurostat data for the EU, many information gaps were detected in the US study, in particular related to the fact that there are no specific NAICS codes for bio-based products.

In Canada, several government institutions conducted survey studies within the framework of the bioeconomy, with a focus on non-conventional industrial bioproducts, which include biofuels, bioenergy, biochemical and biomaterials. Statistics Canada carried out three surveys between 2003 and 2009 on bioproduct activities in Canada, led by Agriculture and Agri-food Canada (AAFC). Each of the three surveys used different definitions and scopes, as a result of the dynamic evolution of the industry and the required updates. Therefore, the obtained results are difficult to compare between surveys. A new survey on bioproducts production and development is planned to be carried out for 2015 data with new, updated definitions that have been agreed with the help of industry representatives and other stakeholders.

Generally, the differences in the scopes and strategies described in the four countries described above mean that it is very difficult to compare the available data that describe the bioeconomy. For a benchmarking activity, a harmonisation of the scope and methodologies for data collection would be desirable. However, these differences are probably based on differences in political priorities in each country and therefore harmonisation could be less beneficial.

The way forward: how to ensure the progress of the bioeconomy and the bio-based industry

Two relevant organisations are very active in the general area of future developments in the bioeconomy at European and international level. The EU Bio-based Industries Consortium (BIC) is a multi-sector organisation that was established in 2012 to represent the private sector in the public–private partnership (PPP) for the Bio-based Joint Undertaking (BBI JU) and is focused on the support and development of innovative bio-based value chains at the EU level to ensure the establishment of ideal market conditions for the bio-based sector. The focus of the BBI JU is on the entire value chain of the bio-based industries. The BBI-JU 2016 call, officially published in April 2016, focuses particularly on food waste valorisation and on the production of innovative chemical building blocks and advanced materials.

The Organisation for Economic Co-operation and Development (OECD) is giving support to the analysis of the opportunities and progress of the bioeconomy in several countries. Currently, the OECD is particularly focused on work streams related to sustainability, which have been at the forefront of the discussion for a few years. Within the framework of the bioeconomy, one work stream relates to biomass sustainability and the aim of reconciling food security with industrial uses. An OECD platform for biomass sustainability is currently being planned. Another relevant work stream in the context of the bioeconomy concerns biorefinery models and policy, and financing biorefineries for second-generation fuels and materials employing alternative feedstock sources, for example bio-waste. Finally, developing industrial biotechnology and, in particular, developing the support to empower policies related to bio-based materials are also a main focuses for the OECD.

Conclusions

In general, despite the differences in policy interests (e.g. policy in the USA is driven by the requests of Congress, while in the EU it is driven by the Commission), there are certainly common elements among the studies conducted in the various countries, as presented at the workshop. The methodologies described for the analysis and monitoring of the bioeconomy in all participating countries include collections of official statistics, industry surveys and modelling work. Certain indicators related to bio-based production, for example market size (in terms of sales or turnover) and, in particular, job creation, are certainly of common interest. If we could come to a harmonised definition of the scope of the studies, these indicators would facilitate benchmarking activity. In conclusion, the relevance of the workshop as starting point for international communication in the area of bio-based products was highly appreciated.

Introductory Session: Policy Setting

The use of bio-based feedstock in the production of industrial materials and products (non-food/non-energy) represents an emerging industry with great economic and environmental potential in several countries of the world. However, the data measuring the importance and volume of bio-based feedstock use is still difficult to retrieve.

This workshop was organised by the Joint Research Centre (JRC) of the European Commission in cooperation with the Brazilian Ministry of Science, Technology and Innovation (MCTI), in the framework of the EU–Brazil Sector Dialogues (http://sectordialogues.org/). The workshop aimed to gather representatives of the European Union (EU) Member States (MSs), Brazil, USA and Canada to exchange information and knowledge of the current status of their national bio-based industries (benchmark) and future developments.

The introductory session provides an overview of the current status of the bioeconomy and the policy strategies in place in the EU and in Brazil. The main differences between the two approaches are illustrated, in particular in the adopted definition of the bioeconomy and the boundaries of each concept. The Brazilian Observatory for Innovation in Biotechnology and the European Bioeconomy Observatory will benefit from a mutual cooperation in the framework of the EU–Brazil Sector Dialogues and from cooperation with several other international partners, towards the harmonisation of definitions and methodologies.

IS-1: The Bioeconomy Strategy in the European Union

Xavier Vanden Bosch, *European Commission – Directorate-General for Research & Innovation (DG-RTD)*

The European Bioeconomy Strategy

The European Bioeconomy Strategy was defined in 2012 in the Communication of the European Commission 'Innovating for Sustainable Growth: A Bioeconomy for Europe' (EC, 2012), prepared under the lead of the Commissioner for Research and Innovation. Rooted in a holistic approach, the bioeconomy strategy pursues the broad objective of 'pav[ing] the way to a more innovative, resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources for industrial purposes, while ensuring environmental protection'. The strategy is intended to be multi-sectoral, encompassing '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'. It therefore includes 'agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries' (EC, 2012).

The main objectives and drivers of the growing bioeconomy in Europe are environmental sustainability, climate change and reduction of dependence on fossil resources, demonstrating an evolution of the European themes towards sustainable development, including food security, jobs and competitiveness, which are also based on the new uses of biomass. On the basis of this, the aim of the European Commission is to reach policy coherence on these themes; the green economy and circular economy should also be harmonised with the concept of the bioeconomy, which is very broad and requires further efforts.

The bioeconomy strategy priorities defined in the Bioeconomy Action Plan

Rather than defining a precise policy, the holistic and multi-sectoral European bioeconomy strategy put particular emphasis on research and innovation (R&I), policy coherence at the European and MS level and the development of new bio-based value chains. These focuses are clearly defined in the accompanying Action Plan, which includes several actions on three themes:

- investment in research, innovation and skills to promote public and private research activities, strengthen the coherence between the public programmes in MSs, increase the proportion of multi-disciplinary approaches in research and promote the uptake and dissemination of innovation;
- reinforcement of policy interaction and stakeholder engagement, including several aims, for example the creation of the Bioeconomy Observatory (https://biobs.jrc.ec.europa.eu/) and the Bioeconomy Panel (http://ec.europa.eu/research/bioeconomy/index.cfm?pg=policy&lib=panel), and support for regional strategies and international cooperation;
- enhancement of markets and competitiveness in bioeconomy sectors, including a better understanding of biomass availability, support to markets through standardisation, labelling, public procurements and the provision of better information to consumers.

The Bioeconomy Strategy and Action Plan will play a key role in achieving the goals of the Europe 2020 strategy (EC, 2010), its 'Innovation Union and Resource Efficient Europe' flagship initiative and in tackling the predicted societal challenges.

The planned review and updating of the Bioeconomy Strategy by 2017 will assess the achievements of the strategy by building on a variety of inputs, including expert review and stakeholders' and civil society's engagement, with the aim of providing a major opportunity for new political impetus and orientation. It can already be observed that the research aspect has predominated during the first years of implementation of the Bioeconomy Strategy (2012–2015), while the policy and legislation aspects still need stronger support.

The bioeconomy: an emerging and widespread concept calling for new data and indicators

The main research question in the context of the bioeconomy is how to sustainably produce and use biomass, and several research groups are working on this subject. Currently, there is a lack of data regarding the use of biomass beyond the traditional sectors (food and animal feed, energy, textiles, etc.) and on the potential of waste as biomass source. The assessment of sustainability is very complex, even if it is limited to environmental sustainability. In the short term, the aim is to guarantee that the Bioeconomy Strategy is contributing to the societal challenges described in the Europe 2020 Strategy, while creating coherence in biomass-related policies is the long term objective.

As a result of the widespread bioeconomy concept, there is an emerging need to collect data to analyse and monitor its current and predicted evolution in the EU. In particular, there is a lack of reliable quantitative data on the biomass entering the various bioeconomy value chains, which are needed to assess biomass availability and guarantee its sustainable use. For this reason, the JRC, in collaboration with the nova-Institute, has prepared a preliminary description of the biomass flow that describes the European bioeconomy (Ronzon *et al.*, 2015), illustrated in Figure 1, and their work is currently being updated to refine the data and include all relevant flows (e.g. waste). Individual MSs are undertaking similar exercises.

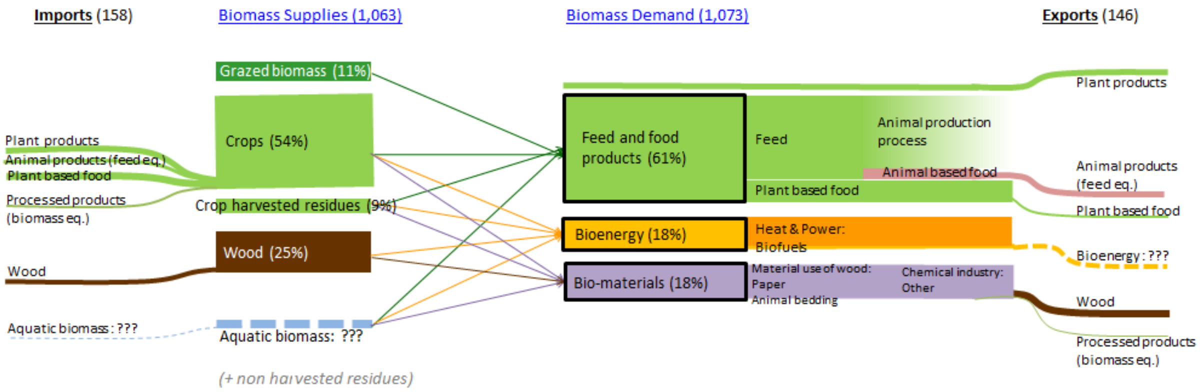

Figure 1. European biomass flows.

The bioeconomy strategy: a multi-objective strategy calling for integration at Member State level

Currently, only six EU MSs have a dedicated national bioeconomy strategy in place, while one country (the UK) has a partial strategy and five countries are still developing their strategy. The MSs' strategies differ in definitions and approaches according to their endowment of natural resources and the characteristics of their industry. For example, Finland's bioeconomy refers mainly to its broad forestry sector, while those of the Netherlands and Flanders build on the transformation of their strong petrochemical sector into bio-based industries. The Bioeconomy Strategy of the European Commission is a supporting document to help EU MSs work towards integrated bioeconomy strategies with the common focus of moving from the fossil economy to a bioeconomy to reach sustainable development.

International cooperation predicted to strengthen the development of the bioeconomy

Bioeconomy has also become a national priority in many non-EU countries. Different bioeconomy Strategies are being adopted at international level by several countries and regions. Therefore, the EU is planning future actions for international cooperation and integration, consisting, in particular, of maintaining a continuous dialogue with partner countries in existing fora and introducing an international element into the review of the European Strategy by 2017.

The launch of an informal International Bioeconomy Forum (IBF) in October 2016 aimed at improving alignment of research agendas in Europe and foster multilateral cooperation. This forum would provide an informal multilateral network for the countries that are actively engaged in the bioeconomy, a framework for reinforced, strategic programme-level R&I cooperation, an area for policy/knowledge-related discussions and a platform for working on concrete actions.

IS-2: Bioeconomy in Brazil: an Overview

Luiz Henrique M. do Canto Pereira, *Ministry of Science, Technology and Innovation of Brazil*

Brazil is a relevant country in the global market and in the bioeconomy sector. Brazil is the seventh largest consumer market in the world and, in the last decade, 30 million of its population became middle class. It has a 7 400 km coastline that provides privileged access to North America, Europe and Asia and it shares borders with 10 countries in South America. Fifteen million companies are based in Brazil, 93 % of which are small businesses, and the country represents the second largest trade flow in Latin America, reaching USD 454 billion in 2014 (National Confederation of Industry Brazil (CNI), 2016).

Brazil is also the world's largest exporter of meat, coffee and sugar, and the second largest exporter of soybeans, following the USA (data from the National Confederation of Industry Brazil (CNI), 2014). In 2015, Brazil reached a record in agricultural production: 209.5 million tonnes of cereals, legumes and oilseeds (data from the IBGE-Pintec database: http://www.pintec.ibge.gov.br). Brazil is also very active in the innovation aspect of the bioeconomy; the first commercial-scale cellulosic ethanol factory in the southern hemisphere (and one of the largest in the world) was recently established in north-east Brazil, in the state of Alagoas. It has the capacity to produce 82 million litres of biofuel per year (http://www.granbio.com.br/en/blog/granbio-begins-producing-second-generation-ethanol/).

A biotechnological approach to the bioeconomy in Brazil

The concept of the bioeconomy in Brazil is not completely aligned with the European definition described above. In line with definitions from the Organisation for Economic Co-operation and Development (OECD, 2009) and the USA (White House, 2012), the Brazilian bioeconomy focuses mainly on biotechnology as common ground and embraces three different spheres:

- Industrial biotechnology:
  - processing and production: chemicals, plastics, enzymes;
  - environmental applications: bioremediation, biosensors, methods for reducing environmental impacts;
  - production of biofuels;
- Primary production (agribusiness):
  - plant and animal breeding;
  - veterinary applications;
- Human health (particularly medical (red) biotechnology):
  - new diagnostic and therapeutic procedures;
  - pharmacogenetics;
  - functional foodstuffs;
  - medical equipment.

The Brazilian Biotechnology landscape is a promising profitable sector, particularly in the areas of health (red biotech) and agribusiness (green biotech). In summary, the main goal of the Brazilian bioeconomy is to create added value in the value chains and in

Brazilian exports, starting with the products with higher value added, for example healthcare products, followed by nutrition and fertiliser products, industrial chemicals and material products, and then low-value, high-volume products, for example biofuels (HBR Brazil, 2011).

The development of the bioeconomy in Brazil is rooted in the modernisation of the legal framework and R&D policies

Brazil did not establish a national strategy that was specifically dedicated to the bioeconomy as established by the EU, but encouraged the development of the bioeconomy through legal and policy reforms. The 2005 innovation law (or 'lei do Bem', C/ Lumbreras) already considered the bioeconomy as a strategic area. A second push was given in 2007 with the launch of the national legal framework for biotechnology development, the Federal Decree 6.041-2007 (President of Brazil, 2007), which included the creation of the National Committee on Biotechnology (CNB, Comitê Nacional de Biotecnologia).

This committee is composed of several ministries and agencies (for example the National Council for Scientific and Technological Development of Brazil (CNPq), the Brazilian Innovation Agency (FINEP) and the Brazilian Development Bank (BNDES)). It is the main organisation dealing with policy formulation and evaluation on biotechnology in Brazil. It also established structural actions in all biotech sectors. The National Committee works in cooperation with a constellation of stakeholders, ranging from academics, small and medium-sized enterprises (SMEs), industrial associations' representatives and colleagues from federal and state-level government. This framework was completed in 2011 along with the industrial policy 'Brasil Maior' (http://www.abdi.com.br/paginas/pdp.aspx) that acknowledges a predominant role of the biotechnology sector.

Currently, the national policy for biotechnology development is in the process of being further modernised. A new legal framework for research and development (R&D) activities was released in early 2016 with the aim of facilitating research activities, in both the public and private sectors. The aim is also to benefit partner countries through enhanced international cooperation (HBR Brazil, 2011). In parallel, the National Strategy for Science, Technology and Innovation (MCTI, 2011), released in 2012, is being revisited with the aim of implementing a new strategy by the second quarter of 2016, through the Legal Framework for Science, Technology and Innovation (law 13.243/2016, http://www.planalto.gov.br/ccivil_03/_ato2015–2018/2016/lei/l13243.htm), launched in January 2016. The purpose is to facilitate R&D activities in Brazil, both in public and private sectors and as public–private partnerships, and to obtain funds from abroad. Within this national strategy, 12 sectors are established as a priority for the country, of which six are particularly relevant for the Brazilian bioeconomy (including biotechnology and nanotechnology, biofuels, agribusiness and biodiversity).

Brazil has become a global player in biotechnology applied to biofuels and agribusiness

Biotech companies in Brazil already numbered 1 820 in 2011 (PINTEC, 2011). The strongest segments of the Brazilian biotech market are human health (33 % of the market), agribusiness (31 %) and industrial biotech (30 %), while environmental biotech represents 6 % of the market. At a global level, Brazil is a major player in agriculture and biofuels production, but is also aiming to be a global player in the health sector. Brazil is making a large contribution to biotechnology at an international level, particularly thanks to progress in genome sequencing, which is of both medical and agricultural interest.

By analysing the assignment of R&D fellowships in the field of biotechnology, as shown in Figure 2, Brazil shows a clear increase between 2001 (approximately BRL 500 million) and 2014 (approximately BRL 2.7 billion), including both internal and foreign funds, while 2015 (and probably 2016) shows a drawback that was a result of the Brazilian economic situation. The expectation for 2017 is that the funds can be recovered by regulating federal investments.

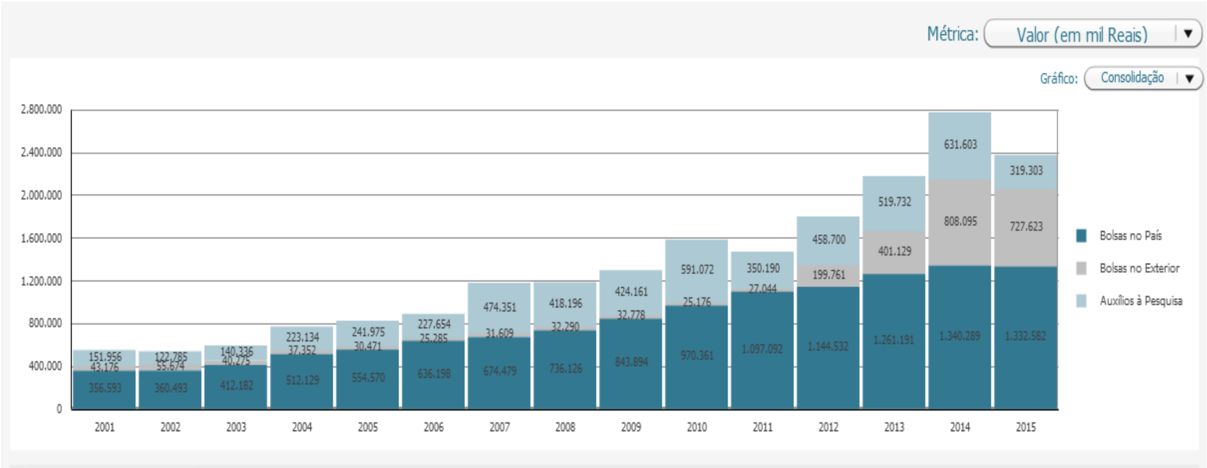

Figure 2. Assignment of R&D fellowships in Brazil in the field of biotechnology for 2001–2015. Source: CNPq (http://www.cnpq.br/painel-de-investimentos).

The establishment in Brazil of the Observatory for Innovation in Biotechnology is one of the main strategies associated with the goal of developing innovative biotechnologies that add value, promote the sustainable use of biodiversity and integrate new technologies. The Brazilian Biotechnology Observatory is dedicated to several aspects of biotechnology development, focusing on research and also on commercial activity and strong communication with the private sector. The Brazilian Observatory and the European Bioeconomy Observatory will benefit from mutual cooperation in the framework of the EU-Brazil Sector Dialogues and from cooperation with several other international partners, including the European Union as a whole, specific European countries, North American countries and Mercosur countries, among others.

Session 1: Data Collection and Analysis on the EU Bio-based Industry

This session is dedicated to the activities carried out so far in the EU to develop proper methodologies and collect data to measure the current status and evolution of the bioeconomy. A specific focus is put on the more innovative sectors, such as the production of bio-based products, (chemicals, plastics and composites among others).

S1–1: Quantifying the European Bioeconomy

Michael Carus, *nova-Institute (Germany)*

The nova-Institute (www.nova-institut.de) provides consultancy services in the field of the bioeconomy, in particular on the study of the link between agriculture and the chemical industry (e.g. techno-economic and environmental evaluations, market research and strategic consulting).

In line with the EC definition of the bioeconomy, the nova-Institute further details bioeconomy value chains, such as the use and transformation of biomass from the feedstock (including sugar, starch, lignocellulose, oils and fats, proteins and waste, among others) through different processes (physical-mechanical, chemical, thermochemical, biotechnology and anaerobic digestion, among others) to the manufacturing of bio-based products, such as food and feed, wood-based materials, pulp and paper, platform and fine chemicals, fibres, pharmaceuticals, composites, surfactants, lubricants, polymers, bioenergy and biofuels.

This definition is not linear, since a given biomass transformation process can combine different technologies, for example the physical, chemical and biotech transformations used for the poly-lactic acid (PLA) production. The nova-Institute estimates that, in the EU, biotechnology is involved in approximately 5–10 % of the techniques for biomass transformation

The complexity of industrial bio-based material production processes

In 'material use', biomass serves as a raw material for the production of all kinds of goods, as well as being used directly in products. This distinguishes it from energy use, when biomass serves purely as an energy source, and use for food and feed purposes (Carus *et al.*, 2010). This characteristic is very well illustrated in the nova-Institute's schematic overview of biomass transformation pathways within the European biomaterial industry, in which the arrows represent hundreds (or possibly thousands) of different routes from biomass feedstock to the final bio-based products (see Figure 3). In particular, the sector of bio-based chemicals and composites is highly complex and therefore difficult to analyse, compared with, for example, biodiesel and bioethanol production.

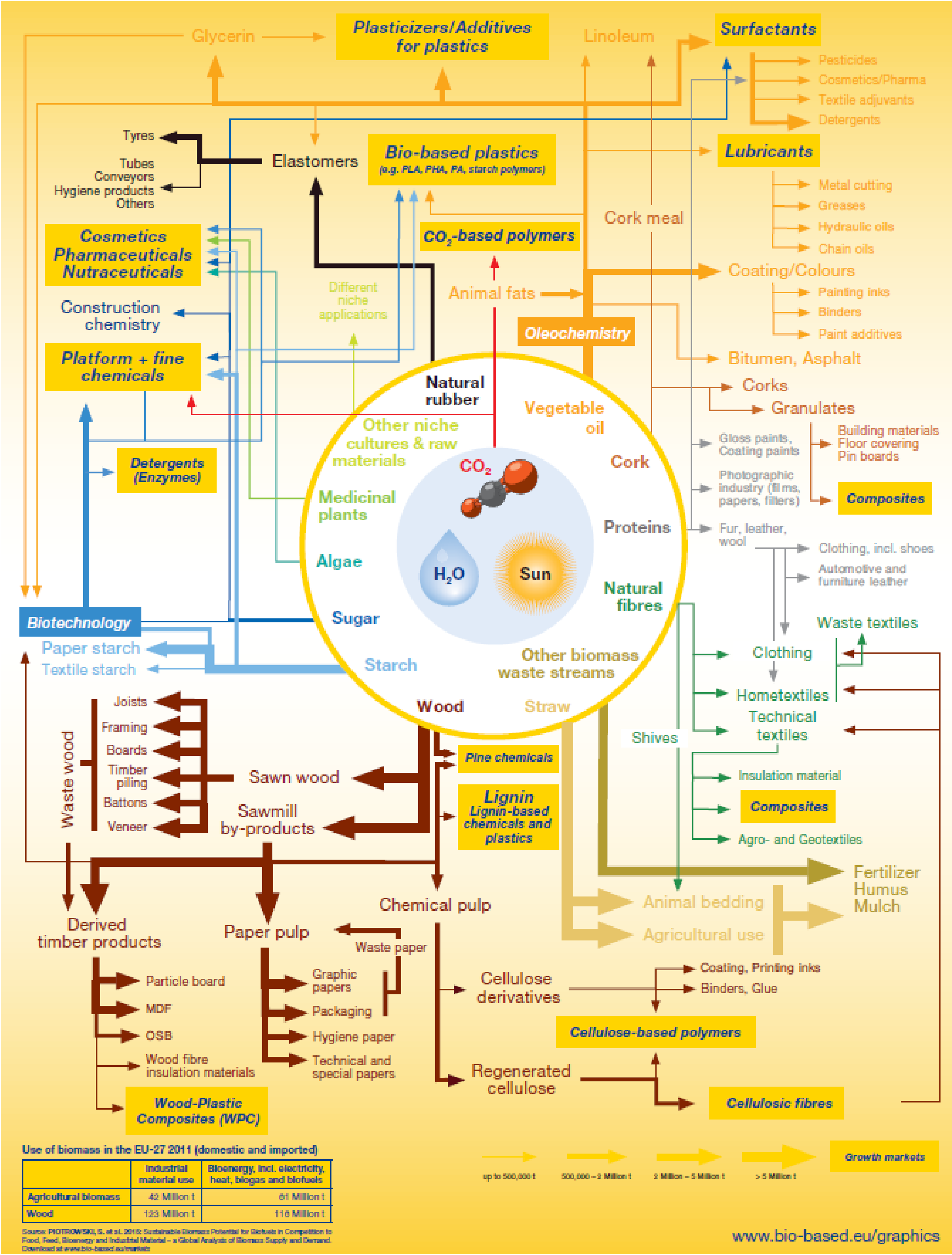

Figure 3. Industrial material use of biomass in Europe (2015). Source: © nova-Institut GmbH 2015.

Within the BIO-TIC project (see section S1–6 by Kees Kwant in this report), the nova-Institute addressed this complexity in the fields of the material use of starch and sugar and of vegetable oil. In these two sectors, European domestic production, trade and transformation routes have been quantified based on 2013 Eurostat data (in quantity) complemented by data from surveys and from industry associations (BIO-TIC, 2015c, b).

According to these estimates, 2 Mt of starch and sugar and 1.2 Mt of vegetable oil are used for chemical production in the EU in 2013. The main difficulty of this project was to link the production and trade of raw materials (i.e. agricultural commodities) with their miscellaneous applications and the products made from them.

Estimating the turnover and employment generated by the European bioeconomy

The nova-Institute has estimated the turnover and number of people employed in the different sectors of the European bioeconomy. The methodology and results have been elaborated and updated over different projects in collaboration with the JRC, the BBI-JU and some Framework Programme (FP) projects on biotechnology. The methodology used consisted of compiling Eurostat statistics for the sectors that can be fully attributed to the bioeconomy (i.e. the sectors producing products that are completely derived from biomass) and applying bio-based shares to the sectors that produce only partly bio-based products. These bio-based shares were estimated by experts according to the Eurostat–Prodcom classification of products. Forty-three Prodcom groups were identified as fully bio-based products (e.g. tall oil, casein glues) and 53 groups as partly bio-based products (e.g. citric acid, acetic acid, epoxide resins).

This methodology results in rough estimates in the absence of *ad hoc* statistics. Progress is expected by 2017, with the data release for the three new Combined Nomenclature (CN) codes of bio-based products introduced in 2015: succinic acid (CN 29.17.19.20; Prodcom 20.14.33.82), 1,4-butanediol (CN 29.05.39.26; Prodcom 20.14.23.38) and bio-based lubricants (CN 34.03.19.20; Prodcom 20.59.41.59). However, bio-based chemicals number in the hundreds, and the introduction of new codes is unlikely in the coming years, unless certain bio-based products reach relevant trade volumes.

According to the data collected, in the EU-28 the overall proportion of biomass in chemical products is slightly higher than 5 % and showed an increase between 2008 and 2013. The proportion is 5 % with respect to the whole raw material, but it is approximately 11 % when considering only the organic part, since the chemical industry consists of approximately 50 % organic and 50 % inorganic materials (which includes minerals and metals). The 11 % is in line with the estimate provided by the European Chemical Industry Council (CEFIC) of the proportion of biomass in the EU organic chemical industry (see section S1–4 by Tilman Benzing from CEFIC in this report).

For most EU countries, the proportion of biomass also increased between 2008 and 2013. While most countries showed a biomass of approximately 5 % or less, a few MSs showed a much higher share, for example Denmark with almost 40 % in 2013, followed by Latvia, Sweden and Finland. Denmark does not have a large chemical industry and the enzyme-producing company Novazyme is a very big player, which explains the high share.

The total turnover of the EU bioeconomy is EUR 2.1 trillion. Food and food products represent the highest share (44 %), followed by agriculture with 19 %, which is much higher than forestry with only 2 %, according to the estimates. Bioenergy (7 %) is only a small part, followed by chemicals and plastics at 5 %, while the turnover share of turnover attributable to biofuels is only 1 %. Altogether, the primary sectors and the food and feed industry generate approximately EUR 1.5 trillion of turnover (i.e. EUR 0.4 trillion and EUR 1.1 trillion, respectively). Thus, the total turnover of the EU bio-based economy (i.e. excluding agriculture, forestry, fishery and the food and feed sector from the previous numbers) is estimated as EUR 600 billion, 8 % of which comes from the manufacturing of bio-based chemicals and 2 % from the manufacturing of biofuels.

The EU bioeconomy employs 18.3 million people, of whom 10.6 million work in the primary sectors and 4.5 million in the food, beverage and tobacco industry. Therefore, the bio-based economy employs approximately 3.2 million people. It is noteworthy that raw materials production (e.g. agriculture and forestry) contributes much more to the total employment in the EU bioeconomy than the further processing steps.

The top three MSs in terms of bio-based economy turnover are France, Germany and Italy and France, while the top three in terms of employment are Germany, Italy and Poland (agriculture is particularly important in Poland).

Sectoral employment effects

When attributing the employment generated by the production of raw materials to the downstream sectors, according to their relative use of raw materials, bioenergy (excluding liquid biofuels) and the pulp and paper industry rank as the highest sectors because of their high use of raw materials. The chemical industry is intermediate, with the highest share determined by the manufacturing process. The lowest employment figures are, again, in the bioethanol sector.

The picture is slightly different when comparing sectors according to the ratio of employment to turnover; textile products have the highest employment effect per unit of turnover, while the smallest employment effect is observed in bioenergy and biofuels. Chemicals and plastics present an intermediate value. These results are in line with data from the USA (Golden *et al.*, 2015), in spite of some methodological differences. The general trends are likely to be also reflected in Brazilian data (not yet collected).

The employment effect can also be measured per unit of feedstock used in the sector, to establish in which sector the same unit of biomass creates the highest employment. By collecting this type of data, the plastic and chemical sectors show the highest numbers, while the lowest effect is in wood-based products, pulp and paper and bioenergy from solid biomass. Generally, the impact on employment, in terms of total number employed per unit biomass, is much higher for all agriculture products than in the forest sector.

Finally, bioplastic production capacities in the EU are relatively low compared with Asia, Brazil or the USA, limiting the employment effect in this sector. Most of the employment is in the conversion of plastic into end products, which process employs many more people than the other parts of the bioplastic value chain.

In conclusion, the methodology applied by the nova-Institute for the analysis of the bio-based sectors in the EU seems to fit the purpose and also reflect the results of other previous studies, with the new advantage of being able to update the data every year and for each MS. The main research areas for further refinement of methodology and results are the estimation of bio-based share at product level (for which hundreds of chemicals would have to be analysed) and further improved estimates of employment generated in agriculture and forestry in the EU for the production of bio-based chemicals, plastics and bioenergy. So far, for most sectors, 50 % domestic biomass and 50 % imported biomass is calculated, although there could be differences that are not yet taken into account.

S1–2: The 2015 Survey of the EU Bio-based Industry

Emilio Rodriguez-Cerezo, *Joint Research Centre – Seville (Spain)*

In the EU, the bioeconomy sectors of primary production, that is agriculture and forestry, marine and livestock, are well covered in terms of the many statistical databases available (e.g. Eurostat) and therefore their impact on the overall economy can be well understood. In contrast, the industrial sectors of bio-based chemicals and materials are poorly defined, because they are characterised by a wide diversity of products, a complex supply chain and, therefore, by lack of data (Dammer *et al.*, 2014). The survey of the EU bio-based industry, conducted in 2015 by the JRC, is meant to fill this data gap in the bioeconomy context. The scope, methodology and results of the survey are illustrated in detail in the JRC report of Nattrass *et al*. (2016).

Elaboration of the questionnaire: definition of the scope and validation process

The scope of the survey includes EU companies, defined as those producing a turnover or employing labour in the EU and that may have production facilities not only in the EU but also elsewhere. The targets of the survey are companies producing bio-based chemicals and composites from a list agreed with experts during several consultations. Traditional and mature industries (pulp and paper, traditional textiles, etc.), liquid biofuels, energy and power, pharmaceuticals, food and feed additives and finished goods derived from the bio-based products are outside of the scope of the survey.

The methodology followed for the execution of the survey included the following steps:

- definition of a list of relevant bio-based products within the scope of the study, validated through expert consultation;
- definition and identification of the target population (EU companies) representing the universe of the study;
- preparation of a structured questionnaire, validated through several rounds of expert consultation, including a dedicated workshop (Brussels, September 2014);
- pilot survey of approximately the 10 % of the target population and validation through questions and answers (between November 2014 and January 2015);
- final survey to all relevant bio-based companies (between March and May 2015).

Response rate and sample composition

The final identified population included 133 EU companies, operating at more than 200 facilities in the EU, 50 of which provided data to the survey, producing a response rate of 38 %, and were a very heterogeneous sample in terms of geographic coverage, company size, the bio-based products manufactured and biomass feedstock used.

The great majority of participants indicated that they produced more than one product from the provided list and several respondents identified additional products that were within the scope of the survey but were not included in the initial list. The bio-based products identified by the largest number of participants belonged to the category of organic acids, followed by polymers (from monomers) and surfactants. Several of the identified bio-based products were not yet in production but were planned to be produced by 2020 (e.g. polybutylene succinate, hydroxymethylfurfural, *n*-butanol and propylene glycol, among others), meaning that the number of products and producers is predicted to increase by 2020.

The geographic distribution of the production facilities of the initial target population of the 133 bio-based companies shows a clear correspondence with the location of the main EU chemical clusters, as illustrated in Figure 4, with a few exceptions. Most respondents Italy, Germany and France as the location of their facilities in the EU, and Asian and North American countries were identified locations outside the EU. According to respondents, the main reasons for choosing the location of the facilities (within or outside the EU) were feedstock availability, proximity to existing commercial activities and proximity to R&D activities.

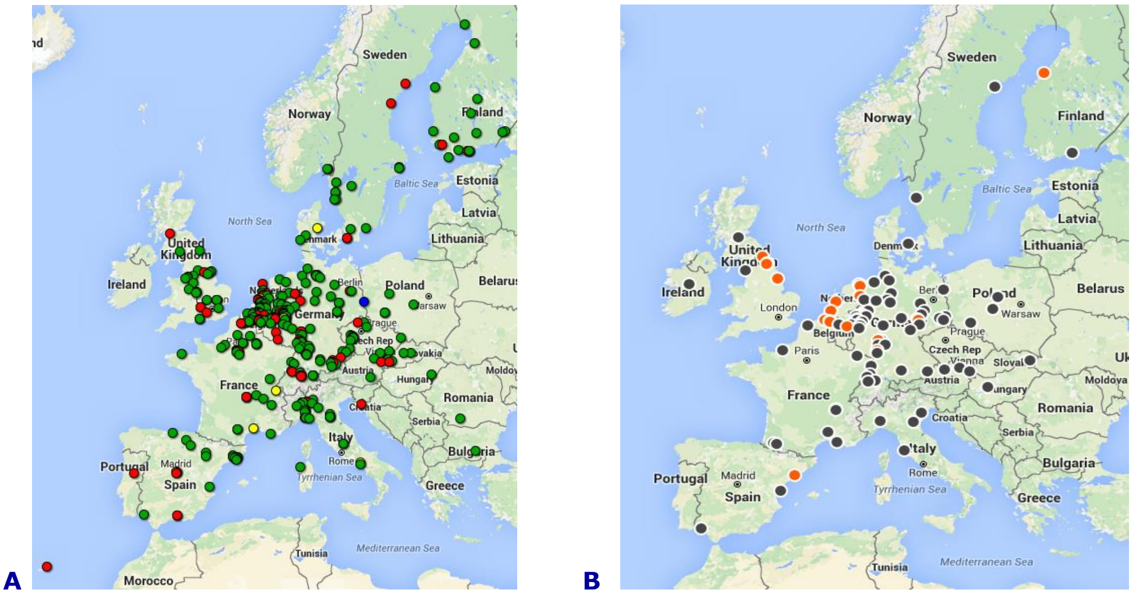

Figure 4. (A) Location of the target population premises within the EU, showing headquarters (red), R&D sites (yellow), demonstration plants (blue) and production plants (green). (B) Location of major chemical parks in Europe: grey, no European Chemical Site Promotion Platform (ECSPP) members on park; orange, ECSPP members on park (source: ECSPP).

Identified trends according to the production size of the company surveyed

Survey participants were asked to indicate the value of annual output, the annual turnover, the total number of employees and the number of R&D-involved employees relevant to their bio-based production for a time series of four years, between 2010 and 2013. Since not all participants provided data, it was not possible to obtain precise numbers, therefore the four-year trends were analysed. For all indicators, small and medium companies with an annual production of bio-based products of less than 50 000 tonnes showed an increase in output, turnover and number of employees in these four years, while larger companies (with production between 50 001 and 5 000 000 tonnes) remained more stable (or even slightly decreased) in the four-year period.

Generally, the majority of respondents expect these indicators to increase in the EU by 2020. Therefore, the size of the EU bio-based industry is expected to increase by 2020 in terms of number of companies, number of products, type of products, feedstock use, share of the total feedstock and bio-based products sold.

While biomass feedstock costs are identified as a constraint, the use of biomass would be on the rise

Participants of the survey were also requested to indicate the contribution of various cost categories to bio-based production. The obtained data illustrate that the largest determinants of the overall production costs is the biomass feedstock, in line with previous analysis of constraints to the development of bio-based products. However, there are large variations between companies, and these figures have to be considered cautiously.

Participants were also asked to provide data concerning the type and origin of the biomass feedstock used in the bio-based production. According to the results, for 75 % companies the biomass feedstock represents more than 50 % of the total feedstock used while 68 % of respondents predicted that the proportion of bio-based feedstock of the total feedstock would increase by 2020. The sources of feedstock identified by most respondents were first-generation feedstock biomass and, in particular, vegetable oils, starch and alcohols (particularly ethanol and glycerol), of which in average by respondent, 70 % was sourced within the EU.

Drivers and constraints for the bio-based development in the EU

According to the results of the survey, the main drivers for the development of bio-based products are improved profitability, improved product competitiveness and potential for the development of innovative products with improved properties or performance. Among the constraints for the bio-based development, those identified by most respondents were higher production costs compared with existing fossil-based alternatives, increased or variable feedstock costs and the availability of funds to invest in production capacity.

S1–3: Measuring the Bio-based Products Value Chain: Available Data

Dietrich Wittmeyer, *Renewable Raw Materials Group (RRM)*

The Renewable Raw Materials (RRM) group was established in 2001 by the European Commission (DG Enterprise & Industry) as a working group with the objective of making the expertise of the EU industry available on a range of issues arising from the wider use of renewable raw materials (RRM group, 2002). The RRM group works in cooperation with partners from the whole bio-based value chain: industry, industry associations, research institutes, universities, national agencies and agriculture bodies.

Defining and reporting on the value chain of bio-based products

The RRM group is collecting data, particularly on production, consumption and trade, to analyse the value chain of bio-based products, which can be divided into the following steps:

- feedstock: sugar crops, starch crops, wood, oil seeds, animals, flax, hemp, etc.;
- raw materials: sugar, starch, cellulose, oils, fats, fibres;
- intermediates: hydrolysate, fatty acids, fatty alcohols, glycerine, etc.;
- platform chemicals: lactic acid, butanediol, propanediol, succinic acid, ethanol, ethylacetate, isosorbide, etc.;
- materials/products: poly lactic acid, polyurethanes, polyesters, surfactants, composites;

- market products: packaging, adhesives, paints and inks, lubricants, solvents, durable plastics, biodegradable plastics, detergents.

Regarding data availability throughout the value chains of bio-based products, the first steps (feedstock, raw material and intermediates) are quite well covered by many national or European statistics, while the more advanced steps (platform chemicals, materials/products and market products) are very poorly described.

Main trends in the production and use of raw materials in the EU bio-based products' value chain

According to the data collected within the RRM group, the production of pulp from wood in Europe was relatively stable between 2010 and 2014 (with a slight decrease of 5.6 % over the five years) and the trade balance was negative, that is pulp imports in the EU were higher than exports. Regarding the consumption of mechanical and chemical pulp from wood per sector, as expected, nearly all of it went to the paper and board industry, while for dissolving pulp (pulp with a much higher purity, obtained from wood chips through chemical processes, for example the sulphite process), half was used in the fibres industry and half in the chemical industry (in 2013), including imported and exported pulp.

The production of starch and sweeteners in the EU was nearly stable from 2010 to 2014, with only a slight increase (4 %) in the five-year period studied. There was a large trade surplus of starch in the EU (1 541 tonnes exported in 2013, compared with 313 tonnes imported), meaning that starch availability in the EU was very high. Most starch is consumed by the food and feed sector, followed by the industrial sectors of paper and board, with 2 100 tonnes in 2014), adhesives (500 tonnes), chemical industry (400 tonnes) and non-food and textiles (with 400 tonnes).

Vegetable oil production in the EU is mainly derived from rapeseed, sunflower and soybean. The oils produced from these crops are those that have the highest levels of consumption in Europe, together with palm oil. Regarding oil consumption per sector, the main consumer is the food and feed sector, followed by the energy sector, which includes electricity, blended fuel and biodiesel. However, blended fuel and biodiesel sectors showed a decrease in vegetable oils consumption between 2010 and 2014, whereas consumption in the electricity sector increased. Other industrial uses, including the production of bio-based chemicals, consumed a smaller proportion of vegetable oil production, which was nearly stable in the five years analysed. Regarding the European trade balance of vegetable oils, unlike the starch sector, there is a large trade deficit. The amount of imported oil (18 081 tonnes in 2014) was double that of the exports (9 584 tonnes). This is very relevant for the chemical sector, which uses oils and fats with specific chemical structure characteristics that can be found mainly in imported oils, for example tropical oils (palm and palm kernel oil).

Platform chemicals, bio-based products and markets in the EU bio-based products' value chain

According to the data collected within the RRM group for bio-based products market, the largest global production capacity for platform chemicals is for lactic acid (724 000 tonnes in 2013), followed by epichlorohydrin (395 000 tonnes) and monoethylene glycol (275 000 tonnes) (Aeschelmann *et al.*, 2015). Regarding the production capacities of bio-based polymers, a sharp increase between 2011 and 2014 should be highlighted for epoxy resins (from 135 080 tonnes in 2011 to 1 520 00 tonnes in 2014) and for polyurethanes (from 1 000 000 to 1 400 000 tonnes), which are, among others, very important materials for the chemical industry (Aeschelmann *et al.*, 2015).

The data collection within the RRM group was focused on the markets for lubricants, surfactants and composites. Normally, the bio-based fraction of bio-lubricants is estimated at 30 %. Bio-based lubricants represent a relatively small sector in the EU, with an estimated market volume of 137 000 tonnes in 2008. But it is foreseen to increase to 800 000 tonnes in 2030, particularly for hydraulic fluids, if the Lead Market Initiative (LMI) recommendations for bio-based products are realised in the coming years (EC, 2011). The reason for this expected increase is related to the standardisation of the EU Ecolabel and the anticipation of a growing market among consumers. The consumption of bio-based surfactants is estimated at 1 089 000 tonnes in 2012 and is expected to increase modestly in the EU, Norway and Switzerland at a rate of 1 % per year until 2020; however, in this product family, the calculated bio-based fraction is on average higher than in bio-based lubricants (approximately 50 %). The market volume of bio-based composites in the EU is estimated at 315 000 tonnes in 2008 and is predicted to reach 830 000 tonnes in 2020, although this growth is also a function of LMI implementation (Carus *et al.*, 2015).

The success story of the succinic acid

Succinic acid is an interesting case of a joint undertaking between the companies Roquette and DSM (called Reverdia), which obtain the product ‘Biosuccinum’ from sugars. The high-quality, low-pH yeast technology employed (see Figure 5) enables economic commercial production and is very positive in terms of sustainability and reduction of the carbon footprint. The market of Biosuccinum is very wide; the top four segments are bio-polymers, polyurethanes, butanediol (BDO) and plasticisers, but the market also includes pharmaceutical and cosmetic applications, solvents, food, flavour and fragrances, among other products. Bio-succinic acid, therefore, represents a large market opportunity and its market is expected to grow from 40 kt in 2015 to 700 kt in 2025. Key growth drivers are an improved cost position compared with existing petrochemical routes and the use of a green feedstock, which is particularly appreciated at consumer level. The success of bio-polymers is supported by upcoming regulations and brand owners’ drive for sustainability.

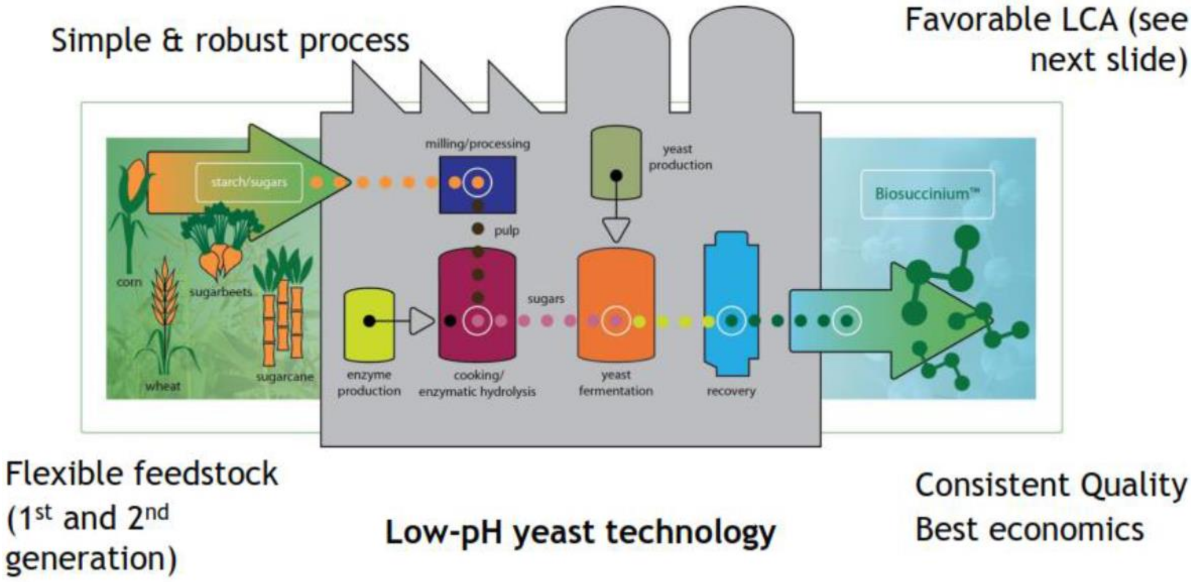

Figure 5 Reverdia technology for bio-succinic acid

Source: Reverdia – Selected process and market info – Jan 28th 2016

In conclusion, the EU has a positive approach in terms of the availability of carbohydrates, while the vegetable oil sector is more dependent on imports from other countries. The present bio-based market is still very modest, particularly in terms of biomass share in content, but the market volume of bio-based products overall is expected to increase, thanks to the recommendations of the LMI for bio-based products.

S1–4: Measuring Bio-based Raw Materials Use in the EU Chemical Industry

Tilman Benzing, *European Chemical Industry Council (CEFIC)*

The estimated use of raw renewable materials by the EU chemical industry is of great interest for the analysis and monitoring of the EU bioeconomy. A few years ago Tilman Benzing and other colleagues from the German Chemical Industry Association (VCI) set up a methodology that was applied to the German industry. This methodology was recently used by the European Chemical Industry Council (CEFIC), with the cooperation of various private companies, to make this estimate at a European level. The purpose was to obtain baseline information concerning the present situation to be able to monitor its evolution in the future. Many sources of data are still rough estimates, but work is ongoing to obtain more exact data. The scope and methodology of the exercise are illustrated in Figure 6 and described in the following paragraphs.

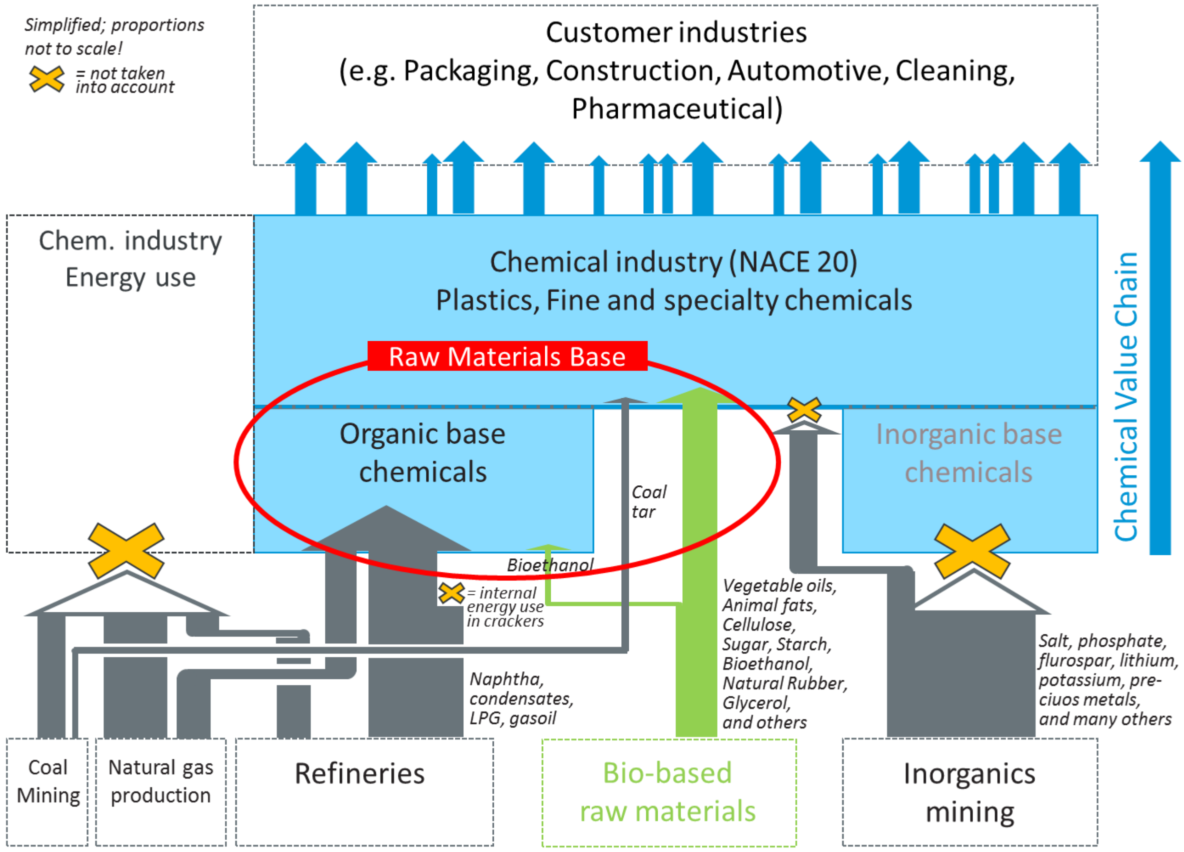

Figure 6. Description of scope of the exercise for the estimation of the use of raw renewable materials by the EU chemical industry. Source: CEFIC.

The raw material consumption by the bio-based chemical industries as a starting point for the quantification

The focus of the exercise is at the level of raw materials that enter the chemical industry, since it would be extremely complicated to quantify the volume of the products of the chemical industry, because of the very complex and interconnected value chains. Additionally, a very important assumption is to establish which materials are bio-based and which are not, and this is easier at raw material level. However, the estimation of value could be feasible with a broader study. The scope of the exercise is defined by organic raw materials, divided between fossil-based and renewable material. The sector of the chemical industry employing inorganic raw material (for example salts and metals) is excluded, since no clear statistics are available and therefore it is currently not quantifiable. Additionally, renewables cannot replace inorganic materials; therefore, the data are not very relevant to the monitoring of the bio-based economy.

The chemical industry is statistically described by the Statistical Classification of Economic Activities (NACE) Code 20 and includes polymers and fine and speciality chemicals produced from the base chemicals, which are derived from various raw materials. It should be noted that a portion of the fossil organic raw materials of the chemical industry is used for energy production, which should be distinguished from feedstock used for the production of chemical products and is excluded from the scope of the study.

When analysing raw materials in the chemical industry, there are still several sources of difficulties. The first is formulating a clear description of the value chain. Several different chemical companies use each specific raw material. These companies are often interconnected, so that the products of one company serve as raw materials for the next company in the value chain. Additionally, this interrelation is not linear, but is usually branched and can even go backward in certain cases, for example when additives are manufactured as speciality chemicals but are used for the production of base chemicals. This is the reason why only the input of raw materials into the chemical industry is taken into account in the study.

Renewables summing up 10 % of the raw materials used by the European chemical industry

The first results obtained in this study are presented in a document published by CEFIC (Benzing and Mosquera, 2014) for 2011 and were recently updated with 2014 data and with some conversion factors updated (e.g. compared with 2011 data, the amount of natural gas is lower because of a correction of the conversion factor of energy units to volumes to weight) and sources of information (e.g. compared with 2011 data, the amount of chemical pulp is lower because updated data are from Eurostat while previous data were from Food and Agriculture Organization of the United Nations (FAO)). According to the updated study, the total raw materials of the organic chemical industry amount to 78.8 Mt, of which 70.9 Mt is fossil materials and 7.8 Mt (10 % of the total) renewables. Fossil materials include 73 % mineral oil derivatives (CEFIC data from Petrochemicals Europe), 16 % natural gas and 1 % coal (Eurostat energy data). If the data also included the mineral oil that is used in the crackers as energy source, the sum would be larger, but this use was excluded from the scope of the study to obtain a clearer picture.

Data on renewable feedstocks derive from three main sources: (1) associations' statistics for vegetable oils (European Vegetable Oil & Proteinmeal Industry (FEDIOL)) and animal fats (European Oleochemicals and Allied Products Group (APAG)); (2) expert estimates for starch and sugar and for ethanol used for ETBE production (biofuel component); and (3) Eurostat statistics on production and import/export for materials exclusively used by the chemical industry and not in other areas (e.g. chemical pulp, natural rubber and glycerol). Among the renewable components, the most relevant are bioethanol with 1.64 Mt (if combining EBTE and bioethanol for industrial use) and starch and sugar with 1.56 Mt (18 % of the total renewables), followed by vegetable oils (1.42 Mt) and natural rubber (1.19 Mt).

In conclusion, the study shows some limitations, in particular in the definition of the methodology and scope and in the varying quality of data and in the estimates from different sources, but CEFIC has chosen a relatively coherent approach. The results are an important step towards a baseline for monitoring the future development of bio-based chemical production, but should not be seen as definitive. Changes in scope and methodology, as well as changes in data sources and estimates, could lead to structural changes in the data, limiting the validity of future monitoring. These uncertainties mean that careful interpretation of the resulting data is required, particularly when analysing future developments.

The way forward is to update the study regularly and to screen data sources regularly to improve data quality. Estimates should be replaced by systematically and regularly updated statistics, where possible.

S1–5: Biotechnology Challenges in Terms of Technology, Regulation and Market Development in the Context of the European Bioeconomy

Dirk Carrez, *Bio-based Industry Consortium (BIC)*

BIO-TIC is a European Seventh Framework Programme (FP7), European-funded project concerning Industrial Biotechnology and the relative challenges in terms of technology, regulation and market development. The BIO-TIC project has the objective of driving technological innovation and building solid foundations for a growing industrial biotechnology sector in the EU. Several participants are involved in the project: associations such as EuropaBio, CEFIC and DECHEMA, organisations such as IAR and KTN UK and consultants, such as TNO, the nova-Institute, Pöyry and Cleverconsult.

Defining roadmaps for the industrial biotechnology sector

Within the framework of the project, data were collected through an initial literature search and by interviewing several stakeholders, particularly from the industrial biotechnology sector. In addition, specific workshops were organised all over Europe, at regional level and by product groups, that is chemical building blocks, bioplastics, advanced biofuels and biolubricants.

From all the inputs and feedbacks received, three specific roadmaps related to industrial biotechnology were developed and are available on the project website (http://www.industrialbiotech-europe.eu/), including:

- a market roadmap (BIO-TIC, 2015d);
- a research & innovation (R&I) roadmap (BIO-TIC, 2015e);
- a policy and regulatory roadmap (Bio-TIC, 2015f).

Each document describes hurdles and gaps, and potential ways to overcome them. In 2015, a summary report was published with the final integrated roadmap and an action plan for industrial biotechnology in Europe (BIO-TIC, 2015a). The report provides ten key recommendations for developing a vibrant industrial biotechnology sector in Europe:

1) improve opportunities for feedstock producers within the bioeconomy;
2) investigate the scope for using novel biomass;
3) develop a workforce that can maintain Europe's competitiveness in industrial biotechnology;
4) introduce a long-term, stable and transparent policy and incentive framework to promote the bioeconomy;
5) improve public perception and awareness of industrial biotechnology and bio-based products;
6) identify, provide leverage and build upon EU capabilities for pilot and demonstration facilities
7) promote the use of co-products;
8) improve the bioconversion and downstream processing steps;
9) improve access to financing for large-scale biorefinery projects
10) develop stronger relationships between conventional and non-conventional players in the value chain.

While hurdles are clearly identified, stakeholders acknowledge a significant development potential of industrial biotechnology

In regards to the markets, inputs were requested from stakeholders concerning products that can be obtained through industrial biotechnology, though not for the whole bioeconomy. According to the feedback, there is huge potential for industrial biotechnology products and bio-based products. The EU market for these products could double in the next 15 years, if certain hurdles were overcome, for example the oil price will have a direct and indirect impact on this development. The bio-based product categories, where the highest growth is expected in the EU, are plastics, ethanol and chemical building blocks.

According to the stakeholders' contributions, the main hurdles identified for technology, regulation and market development of industrial biotechnology in the EU are mainly in line with the findings of the JRC survey study of the bio-based industry (see section S1–2 by Emilio Rodríguez-Cerezo (JRC) in this report). The main hurdle identified was feedstock supply, related, in particular, to the cost of feedstock, infrastructure logistics and transport, trade barriers (e.g. for importing feedstock for ethanol), seasonality of feedstock production and quality of the raw material.

The second group of hurdles identified is related to production, mainly focusing on the need to increase yield productivity and robustness, the need to find properties of some bio-based products that fit the consumers, for example speciality products and the possibilities of scale-up. The third group of hurdles focuses on the market at the end of the value chain. In this respect, it is also considered crucial to have stable, long-term regulatory and policy strategies. In addition, market penetration and consumer awareness were identified as crucial to develop the market. In this respect, brand owners (e.g. Coca-Cola, Ikea, Lego, etc.) play an important role in the marketing activities.

The last group of hurdles that were identified concerns innovation. Here, the major hurdle is access to finance, particularly for upscaling (i.e. from pilot to 'demo' plants) to demonstrate the proof of concept in order to capture the interest of investors, and also for new production plants. The cost of patents and intellectual property legislation, demo and flagship support, collaboration between industry and academia and training were also included in this last group of hurdles that are related to innovation.

Market development could also bring new opportunities and new collaborations

Many steps are already in progress to overcome the identified challenges. Regarding feedstock, new opportunities will be created for producers in 2017. For example, with the termination of the sugar quota, new opportunities for sugar beet producers will arise, not only for food and feed applications, but also for the chemical and the fermentation industry. Pulp and paper companies are also reacting to the new markets: EU paper production is decreasing, with these companies becoming pulp producers with flexible outputs that include paper, bioenergy and chemicals. These changes are bringing stronger relationships and collaborations between conventional and non-conventional players.

Regarding the search for new sources of biomass, there is currently a strong focus on waste. For example, the food industry is diverting its attention towards the opportunity of giving added value to its waste or side streams. In parallel, the chemical industry is gaining interest in food waste as potential constant supply of cheap biomass. Therefore, there is room for possible collaborations between the two industries and some joint ventures have already started. Algae, particularly seaweeds, are been explored in the EU as potential alternative feedstock. The importance of other types of waste is also growing in the EU.

Research and development (R&D) funding and stable policies, the other two drivers of industrial biotechnology

Regarding research and innovation, a climate of investment and access to funding is a key issue for the European Commission, as stated in the Bioeconomy Strategy (EC, 2012). Access to financing has improved in recent years, for instance through the European Investment Bank. In addition, more awareness has been created at regional level, since regions support the local bioeconomy through the European Structural and Investment Funds (ESIFs) and the Rural Development Funds. Additionally, more funds are available for pilot and demo plants through new initiatives, such as the Bio-based Industries Joint Undertaking (BBI-JU), which is attracting new kinds of ventures and projects to Europe (see section S4–1 by Dirk Carrez in this report).

In the area of production, increasing yields and lowering production costs are still major issues. Improving bioconversion technologies and the efficiency in the processing steps can also reduce production costs. Finally, when looking into market and policy, stable policies are important to attract investments for the longer term and public perception should be improved by involving brand-owners.

In addition to the roadmaps, other studies are also included within the BIO-TIC project and are available through the BIO-TIC project website. Among them, the nova-Institute is performing the assessment of the amount of biomass used for bio-based industrial applications in the EU, with a focus on starch, sugar and plant oil and linked to the activities performed for the Bioeconomy Observatory (BIO-TIC, 2015c, b). The sustainability of different bio-based products is also assessed within BIO-TIC, coordinated by the nova-Institute and a database of approximately 50 products is available through the website (http://bio-based.eu/biotic). Finally, a database was created to identify who is who in the European bioeconomy and this is used to develop different events in the field, for example webinars. Although the BIO-TIC project was already finalised, this database is being further used and can constitute a useful basis for the development of new European projects, for example the BioLinX project (http://www.biolinx-project.eu/about).

S1–6: Monitoring the Bio-based Economy in the Netherlands

Kees Kwant, *Netherlands Enterprise Agency*

According to the Netherlands Strategic Vision made public in January 2016 (https://www.rijksoverheid.nl/documenten/kamerstukken/2016/01/27/kamerbrief-over-strategische-visie-inzet-biomassa), sustainable biomass is an important resource for green growth in the country. The best way of exploiting this resource by valorising the biomass and obtain the highest value from it is through an integrated approach for food and feed, materials and energy. Ideally, biomass should be processed in biorefineries that apply a cascading approach where high-value products are extracted first, followed by less-valuable products, in a very effective way, ending with high-volume low-value products (e.g. fuels). More possibilities should be explored to increase biomass availability, while guaranteeing sustainability. The green growth can then be realised by stimulating higher CO_2 prices (through ETS (emissions trading systems) or other solutions), improved regulations, research & innovation (R&I) activities and by establishing partnership between government of the Netherlands and other EU players.

In this framework, the Netherlands Enterprise Agency is currently developing a methodology to monitor the bio-based economy in the Netherlands, which is still an ongoing work with certain questions still to be addressed.

Defining the scope of the bio-based economy and the pilot sectors

The study of the Netherlands Enterprise Agency focuses on the bio-based economy (i.e. excluding the food and feed sector but keeping the bioenergy sector) rather than on the whole bioeconomy, since the Netherlands have a strong chemical industry with a strong interest in replacing fossil resources with biomass resources. Therefore, the sectors that define the bio-based economy include the bio-based chemical sector and the bioenergy sector, but also more traditional sectors, such as wood, paper and board.

The methodology developed is focused on the economic added value, the bio-based materials flow and the innovation, together with the regions. The starting point for this exercise was the renewable energy sector, with the idea of applying the developed method to the other sectors. However, while renewable energy is measured as final energy consumption and not as fossil fuel substitution, renewable materials are measured as consumption of biomass in each sector and in terms of fossil fuels replaced.

Bioenergy includes biofuels, co-firing, bio-CHP (combined heat and power), biogas and bio-heat. In the Netherlands, there was a clear increase in the use of biomass for bioenergy between 1990 and 2014, as measured in units of pentajoules (PJ). However, it should be taken into account that the energy efficiency of each application shows a large variation and therefore the numbers should be interpreted cautiously.

Bio-based material and energy flows in the Netherlands

Biomass flows comprise the biomass input from forestry and agriculture production in the Netherlands, biomass imports and exports with other countries, and the biomass uses, which are estimated for each sector. The energy use of biomass, including the production of biofuels for the transport sector, is quite well understood and good statistics are available for energy consumption in the Netherlands. However, it is much more complicated to estimate how much biomass is used by the chemical and material sector, since this sector includes a complex mixture of different products. For this reason, the input for the bio-based chemical and material sector is measured in terms of replacement of fossil resources. However, there are still difficulties in achieving a good balance between the different sectors of application of the same biomass source, for example soybean is used for the transport sector (for biodiesel production), in the chemical sector and as feed for livestock; therefore, not all of soybean use can be calculated as replacement of the fossil resources in the chemical and material industry.

By analysing the flows of oils and fats as an example of the applied method (see Figure 7), it can be observed that most biomass is imported from other countries. The Netherlands grows only a very small amount of rapeseed, while imported soybean and palm oil represent very relevant flows to the industry. Each of these sources is used in different industrial sectors. Soybeans are used in biodiesel factories and for animal feed. Palm oil goes to biodiesel production but also partly to the chemical industry to produce various products, for example detergents. Used cooking oil (UCO) and animal fats have also been taking into account in the monitoring exercise. By comparing 2013 and 2014 data, there is an increase of the use of UCO for biodiesel production compared with pure palm oil.

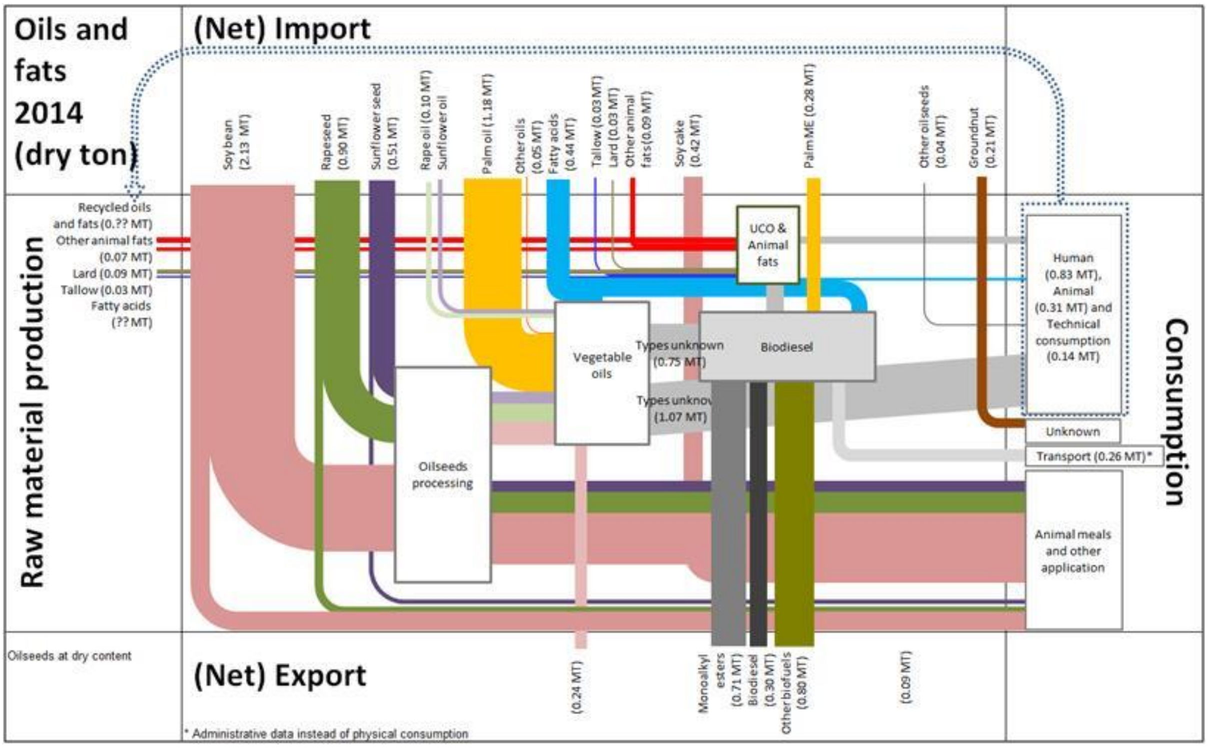

Figure 7. Bio-based and energy flows from oils and fats in the Netherlands (tonnes dry mass, 2014). Source: The Netherlands Enterprise Agency (Goh *et al.*, 2015).

According to the estimates obtained with the described method, the biomass used in the Netherlands for energy (power, heat, biofuels and other bioenergy sources) and material use (mainly wood and paper) was 14.2 Mt in 2014 and has increased by approximately 3 % per year since 2010. By looking at single sectors, it can be observed that the use of wood is decreasing; the use of wood as material could be decreasing because of the economic crisis and the construction of fewer houses. Wood is also used less for power and heat, since there is less co-firing in the country. In contrast, biofuels production (particularly in the Rotterdam harbour), export and consumption are increasing and are driving the bio-based economy in the Netherlands.

Jobs and growth in the Dutch bio-based economy

Another objective of the applied methodology is to establish the economic added value of the use of biomass in the different sectors, including production of the resources, material use of the biomass, chemicals and bioenergy production, and how this relates to the employment created. Most of the jobs identified that are related to biomass use are in material production and are related to chemicals that show the highest added value (calculated in euros/job).

A further aspect that would be of great interest to explore in the monitoring of the bio-based economy is the CO_2 reduction from all applications and the estimated cost of the avoided greenhouse gas (GHG) emissions.

A dynamic research and development (R&D) in the Dutch bio-based economy

The Netherlands is very active in R&D on the bio-based applications and many different activities are in place in different regions. The so-called Bio-based Delta, in the south-west of the country, encompasses all the harbours and has a high concentration of chemical industries; the south-east hosts the large chemical company DSM, which is also very active in bio-based R&D and creates extensive cooperation with the border regions, such as Flanders and North Rhine-Westphalia in Germany. Other regions in the north of the country are more dedicated to agriculture but are also involved in energy production.

In the Netherlands, R&D is supported through the top sector approach, in which the investments to move from research to the market are in the hands of the industry, while a regional support is predicted, based on specific regional strengths. In total, approximately EUR 500 million is available each year for R&D activities and support from regions and government by subsidies, fiscal support, loans, etc., amounts to approximately EUR 120.

In the Netherlands, many initiatives are taking place in terms of R&D. In order to monitor R&D in the bio-based sector, the Netherlands Enterprise Agency has analysed the different Technology Readiness Levels (TRLs) from basic research (TRL = 1) to implementation in the market (TRL = 9). The TRL analysis shows that there are ongoing activities covering all nine TRLs; however, most of them are currently concentrated in applied research and product development, while there is not much activity at the demonstration or market level.

In conclusion, the methodology developed to monitor the bio-based economy in the Netherlands is of intense interest but still needs to be developed further. The chemical sector has the highest economic added value per biomass tonne, but there is a need for market development in this sector, for example through more procurement for bio-based products. The extension of this methodological approach to other countries is recommended, as well as the analysis of GHG emission reductions as a result of bio-based production, particularly taking into account the Paris agreement. There is a need to develop a method to calculate GHG reduction for material use of biomass.

Session 2: Benchmarking with Non-EU Data Collection Activities

This session is meant to illustrate the approaches taken by the other countries, such as the USA, Canada and Brazil, in defining the bioeconomy, establishing specific policies to regulate or promote its development, and implementing methodologies for specific data collection, particularly in the most innovative sectors.

S2–1: The US Department of Agriculture BioPreferred Program: an Economic Impact Analysis of the US Bio-based Industry

Marie Wheat, *US Department of Agriculture (USDA)*

The BioPreferred program (www.biopreferred.gov) of the US Department of Agriculture (USDA) was developed by Congress, initially within the 2002 Farm Bill, and further expanded in the 2008 and 2014 Farm Bills. The aim of the programme is to identify and seek new markets for bio-based products, from intermediate products and platform chemicals, all the way to final products (e.g. cleaning products). Companies participating to the programme are therefore very heterogeneous and may include small businesses of two or three employees as well as large companies, for example Procter & Gamble.

Two major elements of the BioPreferred program: the Mandatory Federal Purchasing Requirements for Bio-based Products and the Voluntary Labelling Program

The Mandatory Federal Purchasing requirements for bio-based products are part of the USDA procurement division and stipulate that Federal agencies and contractors must by law purchase bio-based products in 'designated categories' of which there are currently 97. Currently, the USDA is also working on regulations to automatically designate products derived from designated intermediates.

Since 2011, vendors and manufacturers of bio-based products may apply for certification following testing by a third-party laboratory (using the ASTM International D6866 test method) for their eligibility to display the USDA 'Certified Biobased Product' label. Over 2 500 consumer products are currently certified to carry this USDA label (https://www.biopreferred.gov).

Labelled products that display the 'FP' symbol qualify for Mandatory Federal Purchasing. However, Mandatory Federal Purchasing and the USDA 'Certified Biobased Product' label are currently not interchangeable, that is some products are only included in one programme. There are over 15 000 products in the programme catalogue that fall within a product category designated for Mandatory Federal Purchasing. There is an ongoing work to bring the two programmes together and to avoid confusion (i.e. if a company is certified it would also be designated for federal purchase). In total, the BioPreferred catalogue includes approximately 25 000 products, which are mostly intermediates, as can be seen at the BioPreferred website (www.biopreferred.gov), which also reports data on companies and on sustainability, and displays an interactive map.

The definition of bioeconomy and the bio-based products industry in the USA

In the USA, the bioeconomy is defined as the global industrial transition to sustainably utilising renewable aquatic and terrestrial resources in energy, intermediates and final products for economic, environmental, social and national security benefits. For example, pharmaceuticals or other products of red biotechnology are not included in the definition (unlike in Brazil), since they are regulated by the Food and Drug Administration (FDA). Food and food products are also not included in the definition.

The USDA study *An Economic Impact Analysis of the US Biobased Products Industry* (Golden *et al.*, 2015)[1] defines the US bio-based industry as encompassing the following sectors: agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest products and textiles. Biofuels are not included in the scope of the study, since several previous studies were already dedicated to biofuels and this study is meant to promote and bring a different approach to the bio-based products industry. Biorefineries are included in the scope of the study though with a specific focus on those primarily producing bio-based products. Pharmaceuticals and food and feed products are also excluded from the scope.

The 2015 economic impact analysis of the US bio-based products industry

Mandated by the 2014 Farm Bill, the USDA study (Golden *et al.*, 2015) examined and quantified the effect of the US bio-based products industry from an economic and jobs perspective, as well as from the environmental point of view of sustainability and climate change mitigation.

The approach taken to carry out the study was threefold, encompassing the collection of statistics, interviews with experts and modelling analysis using IMpact analysis for PLANning data and software (IMPLAN). Statistics were collected from government agencies (including state agencies where possible) and published literature on bio-based products, economics and jobs. As in the case of the work of Eurostat in the EU, many information gaps were detected, in particular those related to the lack of specific North American Industry Classification System (NAICS) codes for bio-based products. The list of codes to be included in the study has been defined thanks to experts' interviews with representatives from the government, different industries and trade associations.[2] This list will be subject to updates and adjustments to reflect the constant changes within the industry. Finally, the authors conducted an extensive modelling analysis using the input–output IMPLAN model to analyse and trace spending through the US economy and measure the multiplier effects of this spending to determine how economic growth in a certain sector and in a certain region of the USA would affect other parts of the economy in the USA.

According to the key findings of the study, the total contribution of the bio-based products industry to the US economy in 2013 was USD 369 billion of added value and the employment of four million workers, including direct, indirect and induced effects. The jobs multiplier for the bio-based products industry is estimated at 1.64, meaning that each job in the bio-based industry was responsible for generating 1.64 jobs in other sectors of the economy. In more detail, the 1.5 million jobs directly supporting the bio-based industry resulted in the formation of 1.1 million indirect jobs in related industries and another 1.4 million induced jobs produced from the purchase of goods and services

[1] The primary authors are from Duke University's Center for Sustainability & Commerce and from North Carolina State University's Poole College of Management.

[2] Based on the interviews carried out within the study, the authors believe a conservative estimate is that there is a minimum of 40 000 bio-based products currently on the market that could potentially complement the 15 000 already integrated in the USDA programme.

generated by the direct and indirect jobs. Similarly, the USD 126 billion in direct sales by the bio-based products industry generated another USD 126 billion in indirect sales and USD 117 billion in induced sales. Additionally, according to IMPLAN forecasting, the estimated number of jobs in the US bio-based products sector (excluding enzymes) will increase from 2015 to 2020 and reach more than 5.3 million jobs.

The study also included an analysis of the relative employment contribution of the bioeconomy at the state level to its contribution to the US economy, that is the per cent of state employment in an industry divided by the per cent employment in the same industry in the USA. This measure is called a location quotient (LQ) and, if it is greater than 1.0, it means that the state is more specialised in the bio-based products industry relative to the USA. An LQ of less than 1.0 means the state is less specialised. The results (illustrated in Figure 8) show that the bio-based products industry in the USA is developing in all 50 states and is growing. States with the greatest concentrations of bio-based products industrial activities are Mississippi, Oregon, Maine, Wisconsin, Idaho, Alabama, North Carolina, Arkansas and South Dakota.

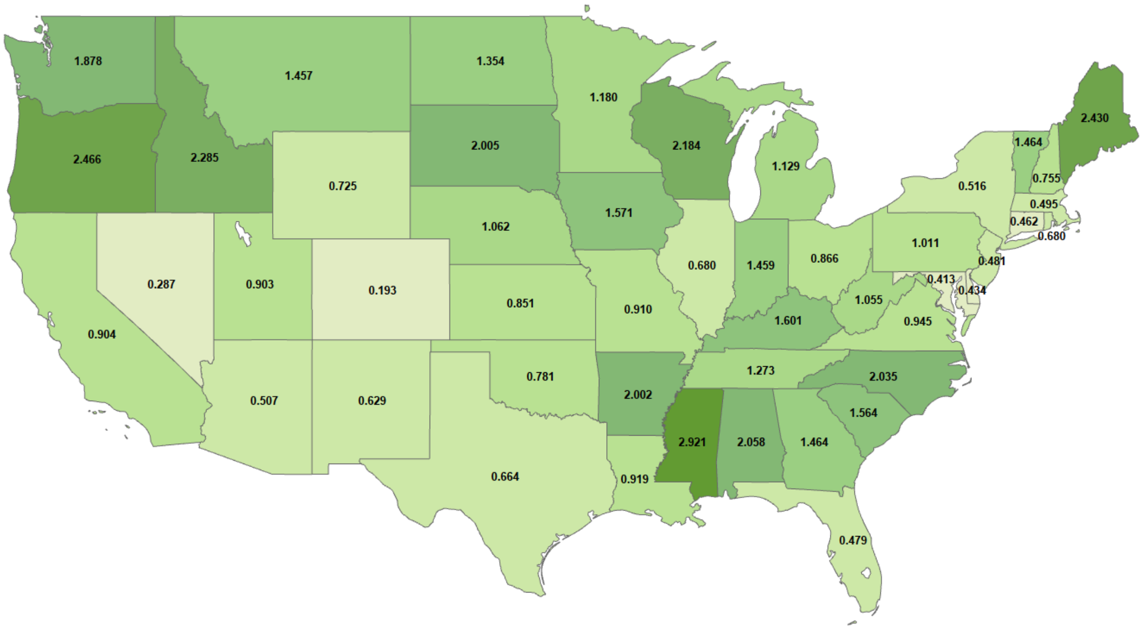

Figure 8. Location quotients for the total bio-based products industry 2013. Source: Golden *et al.*, 2015.

With regards to the environmental impact of the development of bio-based products in the USA, a minimum of 300 million gallons of petroleum are replaced annually as a result of the use of bio-based products, which is the equivalent of taking 200 000 cars off the road each year. More detailed studies on the environmental impact are predicted for the future.

Emerging trends and recommendations for the development of the US bio-based products industry

According to the findings of the study, particularly those based on experts' interviews, the main emerging trends in the bio-based products industry are the following:

1. New venture capital investment has slowed in recent years, but shows promise of increasing by 5–10 % in the next five years, provided that the right conditions are in place.
2. New technologies will be tied to readily available feedstocks, which could be in short supply in the future.
3. Successful technology development must be based on solid execution and business fundamentals.
4. Selection of the right supply chain technology partners is key, along with understanding the right market requirements for success.
5. Easy venture capital funding is no longer a reality, so long-term partnerships and alternative sources of funding are needed.

The authors also added many recommendations for the steps that should be taken to aid the development of the bio-based products industry, as summarised in the following:

- increase government purchasing and tracking;
- increase the visibility of the USDA 'Certified Biobased Product' label;
- develop NAICS codes for bio-based products;
- support production credits, tax incentives, and specific investment incentives;
- appropriate funding for the BioPreferred program;
- continue support for the USDA Biorefinery Assistance Programme and Biomass Crop Assistance Programme;
- promote and increase both government and private sector purchasing of bio-based products;
- incentivise renewable/'green' chemistry in TOSCA reform legislation;
- legislation to improve logistics infrastructure to support bio-based production;

Regarding the third point, the USDA is planning a long-term project concerning the development of the next NAICS codes for bio-based products. This development would tend to enable the huge data gaps in this sector to be filled, thanks to regular industry surveys and trend analysis to monitor the precise development of the sector. An important lesson learnt in the course of the study was that communication is fundamental to engage the public and policy makers in the effort to promote the bio-based industry as a key element of economic growth. In particular, the seven case studies presenting the replacement of fossil-based feedstock by biomass feedstock in daily products resulted in very useful for communication in practical terms.

S2–2: Canadian Industrial Bioproducts Production and Development Survey

Samuel Bonti-Ankomah, *Agriculture and Agri-Food Canada (AAFC)*

Industrial bioproducts have recently been the focus of the Canadian government for several reasons: they open new agricultural markets, provide opportunities to add value to commodity production, provide the potential of diversifying operations to increase revenues, offer new opportunities for the management of resources (e.g. livestock waste as a revenue stream), provide alternatives to finite petroleum-based resources for environmental benefits (e.g. biofuel mandate) and provide economic opportunities for rural communities. For Canadian agriculture, the development of bioproducts can present significant opportunities in the use of traditional crops (e.g. wheat, oats, flax, potatoes) for existing and new products (e.g. fuels, fibres and chemicals), as well as in the use of new crops, for example crops for dedicated energy production (e.g. switchgrass) and crops with higher levels of beneficial oils, etc. (e.g. high-oleic canola). Plants, such as tobacco and safflower, which are used as factories for industrial enzymes or compounds are also taken into consideration. Finally, bioproduct development also considers the new uses of livestock wastes (e.g. for heating and electricity).

Non-conventional bioproducts, the focus of the Canadian bioeconomy

The focus of the studies conducted in Canada in the framework of the bioeconomy is on non-conventional industrial bioproducts, defined as products made from renewable biological inputs (biomass) but excluding food, nutraceuticals, feed (livestock and pet food), medicines and forestry-based products produced in a traditional way (e.g. lumber and paper). Biomass sources include agricultural crops and other products (e.g. milk), trees, agricultural and forestry residues, livestock wastes, municipal wastes, biological materials from marine and aquaculture sources, which are converted into valuable bioproducts through different processing, including biocatalysis, fermentation, extraction, gasification, combustion and co-firing. The bioproducts obtained in this way include biofuels, bioenergy, biochemical and biomaterials.

The reason of focusing only on non-conventional products is to fill the current data gaps in surveys and data collection in general in Canada, which are similar to those in the EU and the USA, since, as previously illustrated, bioproducts are not described in specific NACE or NAICS codes. Regarding forestry products, specific surveys have already been conducted by industries and by Natural Resource Canada (Natural Resources Canada, 2015), so this exercise was not repeated in the context of bioproducts.

Within the Canadian government, several institutions are interested in the data collection for bioproducts: (1) Agriculture and Agri-food Canada (AAFC) for programme and policy development and for the development of indicators for the Departmental Performance Reports; (2) other governmental departments for example Natural Resources Canada, Global Affairs Canada, Environment and Climate Change Canada, Innovation, Science and Economic Development Canada and (3) provincial governments for policy, programme development and regulatory issues. Academics are involved in the research of new industrial uses of agricultural products and industries. Non-governmental organisations (NGOs) and commodity groups are also following the development of bioproducts very closely.

The 'Canadian industrial bioproducts production and development surveys'

Statistics Canada carried out three surveys from 2003 to 2009 (Rothwell *et al.*, 2011) with the aim of capturing manufacturing firms' bioproducts activities in Canada, under the lead of AAFC and jointly with other government departments, particularly to come up with common definitions of terms and to establish the type of information needed. These surveys targeted all firms using biomass to produce and/or develop industrial bioproducts: 232 firms in 2003, 239 in 2006 and 208 in 2009, indicating that the whole population was not very large, since the focus is on non-conventional bioproducts. Each one of the three surveys followed different definitions and scope (see Table 1), because of the dynamic evolution of the industry and the required updates. Therefore, the obtained results are difficult to compare between surveys.

According to the main findings of the 2009 survey, Canada's bioproducts firms are regionally dispersed and employ in total 3 020 employees in bioproduct-related activities; 54 % of the firms are located in Ontario (33 %) and Quebec (25 %). These two areas employs nearly two-thirds of the sector's employees. A further 38 % of firms are located in the west of the country, and account for 29 % of total employment. Finally, the Atlantic region has 8 % of firms and 7 % of employment.

A new survey on bioproducts production and development is planned to be carried out for 2015 data (http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5073). The objective is to collect information on the characteristics and activities of all establishments in Canada that use biomass to develop and/or produce bioproducts or that are engaged in the improvement of post-harvest biomass for the production and/or development of bioproducts (e.g. aggregate, bail, clean, dry, modify, refine, etc.). Again, the industry has evolved and become more complex since the last survey of 2009; therefore new, updated definitions were agreed with the help of industry representatives and other stakeholders to give a common understanding and a clear distinction between conventional and non-conventional products (see Table 1).

Regarding the structure of the 2015 survey, the questions are based on the questionnaire of 2009 survey, with the relevant updates, after an extensive review carried out by Statistics Canada and AAFC to ensure the clarity and alignment of the concepts and with the intention of maximizing the final response rate. The novelty of the 2015 survey, compared with the previous survey, lies in the use of an electronic questionnaire, which will be available when the full survey is released in 2016, to retrieve 2015 data (http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5073) and the outcome should be made publicly available by the end of 2016.

The target population of the 2015 survey was constructed from a number of sources including a list of businesses provided by AAFC based on consultation with several stakeholders and existing survey databases of Statistics Canada, integrated with an online research. A pre-contact pilot phase was established in 2015 by telephone to determine which institutions are within the scope of the study and to identify an appropriate contact for the final survey. Screening questions are used to confirm if the establishment uses biomass to develop and/or produce bioproducts and/or improve biomass. The number of in-scope units identified for the survey was 599.

The reasons behind performing this type of survey are to collect information to understand who the producers are, where they are located across the country, which products are being produced and how important these products are to the economy. Very little analysis has been performed to date. Similarly to EU analyses, it is of crucial importance for Canada to understand how much biomass is being used in the bioproducts industry and where it is coming from, to determine its relevance for Canadian farmers and other players in the value chain. Biomass conversion is, therefore, also included in the survey to understand which technologies are available and the challenges they present, although the whole bioproducts value chain is not covered by the survey because of its high complexity. Finally, the survey intends to identify the challenges faced by producers, to developing programmes and policies to help stakeholders in the development of this industry.

Table 1. Comparison of bioproduct categories in 2003, 2006, 2009 and 2015 surveys. Source: AAFC *Characteristics of the survey 2015*

2003	2006	2009	2015
Biofuels (methane, ethanol, biodiesel) **Bioenergy (heating and electricity)** **Biosensors** **Biocatalysts** **Biochemicals** (e.g. biosolvents, bioadhesives, biosurfactants, biolubricants, fine chemicals, etc.) **Bioplastics** **Biopesticides/biofungicides/bioherbicides** **Fibre composites** **Fibreboard/agri-fibre panels** **Other bioproducts or biomaterials, (specify)**	**Liquid fuels (biodiesel, ethanol)** **Gaseous fuels (methane)** **Solid fuels (paper sludge, wood)** **Biochemicals** (biosolvents, bioadhesives, biosurfactants, biolubricants, fine chemicals, etc.) **Bioplastics** **Biocontrol agents** (biopesticides, biofungicides, bioherbicides) **Fibre composites** **Fibreboard/agri-fibre panels** **Biocatalysts** **Other bioproducts or biomaterials**	**Liquid fuels:** ethanol (for fuel), biodiesel (for fuel), other liquid fuels (e.g. methanol, butanol, etc.), gaseous fuels (e.g. biogas, syngas, hydrogen, etc.), solid fuels (e.g. agri-straw pellets, agri-wood pellets, etc.), bioenergy (e.g. electricity, heat, co-generation, etc.) **Organic chemicals:** lubricants and greases, polymers, adhesives, fine chemicals, solvents, other organic chemicals, biopesticides (e.g. insecticides), biocatalysts and bioenzymes **Materials and composites:** Composites, fibreboard/agri-fibre panels, materials (e.g. foam, insulation, masonry, road materials, cement, geofibres, geotextiles, etc.), other bioproducts	**Biofuel and bioenergy:** ethanol (for fuel), biodiesel (for fuel), renewable diesel (e.g. hydrogenation derived renewable diesel), pyrolysis oil, other liquid fuels (e.g. methanol, butanol, etc.), gaseous fuels (e.g. biogas, syngas, hydrogen, etc.), black pellets (steam exploded pellets/terrified pellets), biochar, other solid fuels (e.g. straw pellets, agri-wood pellets, etc.), bioenergy (e.g. electricity, heat, co-generation) **Organic chemicals:** lubricants and greases, adhesives, fine chemicals, solvents, industrial alcohols, industrial oils (e.g. HEAR flax), other organic chemicals **Materials and composites:** composites, bioplastics, agri-based/wood composites, cross laminated timber, textiles and geo-textiles, other materials (e.g. foam, insulation, masonry, road materials, cement) **Intermediary biochemicals and biomaterials (include if only produced/made in a non-conventional manner):** cellulose filaments, lignin hemicellulose, C5 sugars, C6 sugars, polymer, bio-based platform chemicals (e.g. succinic acid, aspartic acid) **Other bioproducts:** biopesticides and biostimulants (e.g. insecticides, fungicides, herbicides), biocatalysts and bioenzymes, others

S2–3: Brazil – Building a Leader of the Bioeconomy – Industrial Biotechnology as a Vector of Sustainable Development

Bernardo Silva, *Brazilian Industrial Biotechnology Association (ABBI)*

Created in 2014, the Brazilian Industrial Biotechnology Association (ABBI) represents the Brazilian associations of Industrial Biotechnology and aims to establish a vibrant biotechnology sector in Brazil. It organises events and discussion forums with experts, with the Brazilian government and with other stakeholders, specifically to promote better regulations, to modernise the infrastructures in Brazil, to contribute to the development of new technologies with Brazilian resources and to place Brazil in the forefront of the global bioeconomy. Currently, ABBI is made up of 13 companies from Brazil, Europe and the USA, all of which are well established as global leaders in the bioeconomy. Although the focus of these companies is mainly on biofuels, biochemicals and biomass conversions, ABBI is open to expand its membership to other sectors, for example the paper and pulp industry, the mining industry and any industry that utilises industrial biotechnology in its business model.

ABBI defines industrial biotechnology as the use of agricultural residues, biomass and the implementation of enzymes, microorganisms and biomass conversion technologies to produce second-generation biofuels and biochemicals. ABBI focuses on four themes: (1) engaging stakeholders; (2) communicating the benefits of industrial biotechnology; (3) incentivising investments, R&D and production and demand of industrial biotech; and (4) regulating the sector. Three themes are the most critical in these activities: industrial property, biosafety, and biological diversity.

Multiple national assets for a strong Brazilian bioeconomy

Brazil is reaching several milestones to position itself in the international bioeconomy, including the largest supply and lowest cost of non-food biomass worldwide, climate change commitments that favour the transition to a low-carbon industrial matrix, the opportunities for rural employment and gross domestic product (GDP) development, solid experience, infrastructure and technology base in advanced biofuels and the world's greatest biological diversity. The starting point for the development of the Brazilian bioeconomy was the PRO-ALCOOL programme (http://projects.wri.org/sd-pams-database/brazil/national-alcohol-program-proalcool), which was established in the mid-1970s and promoted the ambitious goal of using biofuels in Brazil's energy and fuels matrix.

Although implementation of the advanced bioeconomy and the application of industrial biotechnology in Brazil started approximately 10–15 years ago, with the consolidation of first-generation ethanol in Brazil back in 2000 and the advent of the flex fuel car in 2003, it was the launch of the PAISS programme (http://www.bndes.gov.br/SiteBNDES/bndes/bndes_pt/Areas_de_Atuacao/Inovacao/paiss.html) and other policies, including the biosafety law and the national biotech policy, that allowed the industrial biotechnology and the bio-based industry to flourish.

Another important milestone was the first commercial plant for second-generation biofuels (the Crescentino plant: http://www.betarenewables.com/crescentino/green-revolution), launched in Italy in 2013 by the company BetaRenewables, which also has manufacturing assets in Brazil. It created awareness of the pre-commercial availability of second-generation biofuels. The establishment of ABBI in 2014 also helped the industry to organize itself, mapping the major challenges and opportunities and building communication with the government to enable it to understand industrial biotechnology and the bioeconomy.

The launch of GranBio in 2014 (http://www.biofuelsdigest.com/bdigest/2014/09/24/granbio-starts-cellulosic-ethanol-production-at-21-mgy-plant-in-brazil), the first stand-alone plant for second-generation biofuels in the north-east of Brazil, put Brazil at the forefront of bioeconomy development. The energy company Raízen followed that example by launching the first integrated first-generation/second-generation biofuel plant in 2015. The two plants have been developed thanks to important programmes to incentivise the development of the fuel industry in Brazil, in partnership with the Brazilian development Bank (BNDES) and the Brazilian Innovation Agency (FINEP). Over the past few years, more companies, such as Solvay, Dow, DuPont and others, have launched R&D centres exclusively for industrial biotechnology in Brazil. The general purpose is to look at the national resources, biomass availability and biodiversity, to develop technologies that can be implemented in Brazil.

The Brazilian bioeconomy geared towards the second generation of biofuels and biomaterials

Another important aspect that could represent a big push towards bioeconomy development, particularly for Brazil, is the United Nations Climate Change Conference in 2015 (COP 21). ABBI worked with the Brazilian government to have second-generation biofuels in Brazil recognised as an Intended Nationally Determined Contribution (INDC), a mechanism to reduce Brazil's emissions of CO_2. One of the justifications was that Brazil has the potential to produce 10 billion litres of biofuels annually by 2025 by replacing gasoline with second-generation ethanol and can thereby reduce CO_2 emissions by approximately 60 million tonnes of CO_2 equivalents/year[3] (data from the National Technology Centre for Bioethanol, 2015). However, it is estimated that with proper regulations and more efficient technologies, almost 13 billion litres of cellulosic fuels could be produced (mainly cellulosic ethanol from sugarcane residues), that is approximately half of Brazilian production of first-generation ethanol.

Additional actions can also potentially contribute to the increase in bioethanol production in Brazil. First, Brazil has over 400 sugar and ethanol plants in the country, most of which use outdated, inefficient systems. Investment in modernising these facilities could nearly double production in the coming decade. Second, approximately 10 more second-generation ethanol plants are expected to come online in the coming decade, which, according to a recent study by the Brazilian Development Bank (BNDES) and the Brazilian Bioethanol Technology Centre (CTBE) (Milanez *et al.*, 2015), will have the effect of increasing annual production to 5 billion litres. According to the same study, the second-generation biofuels would be more competitive than the first generation over the short, medium and long term, even at an oil price of USD 40 per barrel. And, third, technological development, such as the optimisation of the use of microorganisms and technology efficiency, coupled with the consolidation of energy cane as feedstock, could also potentially triple current ethanol productivity in Brazil, reaching approximately almost 25 000 litres per hectare of first-generation biofuels integrated with second-generation biofuels.

The second generation of biofuels as a driver for the development of bio-based chemicals in Brazil?

ABBI believes that the cellulosic biofuels industry in Brazil will serve as platform for bio-based chemicals. A study carried out in conjunction with the BNDES (Bain & Company, 2014) investigates options for diversifying the Brazilian chemical industry by introducing new products and focusing on bio-based chemicals. The study illustrates the bio-based products with the highest opportunities in the Brazilian market, for example cosmetics, feed, vitamins and other chemical products, which will receive the support needed from the government to develop R&D.

In December 2015, the BNDES, in partnership with FINEP, launched the PADIQ programme (Bernardo, 2016), which is similar to the one carried out in the cellulosic industry (PAISS), but focuses on bio-based chemicals. The aim of the programme is to

[3] According to life cycle assessment data showcased during the United Nations Climate Change Conference in 2015 (COP 21) by the President of the Brazilian Development Bank.

provide nearly BRL 2 billion (approximately EUR 0.5 billion) for funding R&D and innovation in the chemical industry sector.

The ABBI action plan for industrial biotechnology

ABBI worked intensively with the Brazilian industries to establish the steps that are required for industrial biotechnology to develop (see Figure 9). A national strategy was proposed, with clear action plans and up-to-date regulations in the medium and long term to create the incentives for the industrial development. The USA was taken as model of policy initiatives, in particular the BioPreferred program and certain state or national mandates, for example the fuels standards in California (the California Low Carbon Fuel Standard Program (LCFS)) and the Renewable Fuels Standard (RFS). ABBI is also working together with the Brazilian patent agency (the Brazilian National Institute of Intellectual Property (INPI)), which is putting forward directives and programmes to fast track the patenting process of green technologies, although many issues are still to be addressed. Other mechanisms proposed for industry development are the capital expenditure (CAPEX) reduction (which will encourage investments in capital for R&D and commercial facilities), levelling fossil subsidies vis-à-vis bio-based industry in Brazil and, finally, communicating the benefits of biotechnology in the bioeconomy, not only to government, but also to major stakeholders.

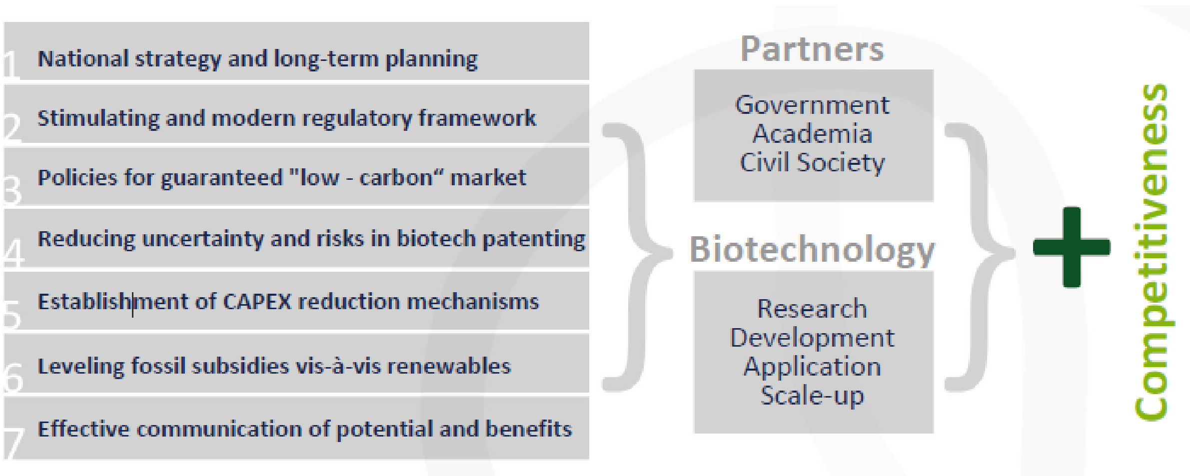

Figure 9. Seven steps to the forefront of the global economy. Source: ABBI.

Compared with other countries and regions, the levels of R&D and production activities are not yet competitive in Brazil, despite the fact that important policies are in place, for example biofuel mandates. Financing and incentives are in place, but costs are still very high compared with other countries. This is balanced by the cost and availability of biomass in Brazil, which make Brazil one of the most competitive countries for the implementation of the bioeconomy and industrial biotechnology.

S2–4: Biotechnology and Agricultural Value Chain in Brazil: Development and Future Prospects

Geraldo B. Martha Jr, *Brazilian Agricultural Research Corporation (Embrapa), Labex-USA*

Determining the future of agriculture's competitiveness and sustainability and defining which areas of knowledge and technology should be pursued by research systems to fuel the innovation process. Therefore, the interactions between public and private agricultural research organisations cannot be restricted to those within a country's borders. International partnerships are necessary for rapid advances in the generation of basic and applied knowledge and technologies to support to the innovation process.

Embrapa is the research arm of the Brazilian Ministry of Agriculture, Livestock and Food Supply. It has approximately 10 000 employees, of whom approximately 4 000 are scientists. In the mid-1990s, Embrapa made a strategic decision to foster international scientific cooperation by establishing the Embrapa Labex Programme – Embrapa's Virtual Laboratory Abroad. The Labex mission is to promote and develop international scientific cooperation opportunities at the frontier of knowledge in strategic areas and themes, and to monitor science, innovative technologies and innovation in agriculture, anticipating potential risks and opportunities. Within Labex, there are opportunities to exchange knowledge and engage senior scientists, allowing them to collaborate on mutually beneficial research in priority areas. Among other things, this strategy has been shown to reduce time and cost in research development. Labex-USA was the first programme to be established. The Agricultural Research Services (ARS) of the USDA hosts Labex-USA in the USA since its inception in 1998.

The modernisation of the Brazilian agriculture, cornerstone in the development of the Brazilian bioeconomy

Agriculture and biotechnology represent core areas of the Brazilian bioeconomy. According to the most recent data (up to 2015), the agricultural value chain in Brazil has a total value of BRL 1 267 241 million (corresponding to approximately EUR 360 000 million) distributed between input supply (11.9 %), agricultural production (29.8 %), agricultural industry (27.4 %) and distribution (the remaining 30.8 %) (data from USP/ESALQ/Cepea: http://cepea.esalq.usp.br/pib). Between 1995 and 2015 the agricultural value chain grew by 50 %, mainly as a result of growth in the input supply and in agricultural production. These data reflect the fact that Brazilian farmers are increasingly adopting technology that, according to studies by Embrapa, currently produces 68 % of the Brazilian agricultural product (Alves, 2013). Furthermore, agricultural value chains accounted for 21.5 % of the Brazilian GDP in 2015. Therefore, the Brazilian bioeconomy may represent at least 21.5 % of the Brazilian economy.

From a technological perspective, the transformation of Brazilian agriculture from 'traditional agriculture' to an approach strongly based on science was key to the observed success. Despite the possibility of expanding agricultural area, Brazil has focused on incorporating technology into production systems as a mean of increasing overall production. From 1950 to the mid-1970s, the average yield growth for the main crops in Brazil was only 4 kg/ha per year. Since the mid-1970s, with increased technology adoption, yield growth rates showed an increase, reaching over 60 kg/ha per year (data from G.B. Martha using the IBGE database, available online: http://www.pintec.ibge.gov.br). Approximately 40–50 % of the yield increases came from progress in plant genetics (Albuquerque and Silva, 2008).

When the total factor productivity (TFP) is considered, for example the combined effect of the productivities of land, capital and labour, Brazilian agriculture is also outstanding. Brazil's national average farm TFP growth increased at an annual rate of 2.55 %

between 1985 and 2006. For the most efficient farms, the progress was even more impressive, at an annual rate of 4.4 % (Rada and Valdes, 2012).

From an environmental perspective, the huge land-saving effects arising from continued productivity gains, coupled with better governance and improved relative prices, has allowed for a sizable reduction in deforestation rates, markedly benefiting the preservation of Brazilian biomes. Data from the Brazilian Government indicates that approximately 62 % of the Brazilian biomes are covered with native vegetation (data from MMA, Ministério do Meio Ambiente, Unidades de Conservação: http://www.mma.gov.br/governanca-ambiental/geoprocessamento and from IBAMA (Brazilian Institute of Environment and Renewable Natural Resources), Projeto de monitoramento do desmatamento dos biomas brasileiros por satélite: http://siscom.ibama.gov.br/monitora_biomas/), an outstanding achievement not observed in other important agricultural country or region in the world.

Finally, from a socio-economic perspective, Brazilian agricultural value chains have strongly contributed to overall Brazilian economy. From 1989 to 2015, this was, by far, the main sector responsible for a positive trade balance (exports–imports) (data from AgroStat Brasil, Balança do agronegócio: http://www.agricultura.gov.br/internacional/indicadores-e-estatisticas/balanca-comercial). Furthermore, by analysing the historical trends in Brazilian consumer prices over the same timescale, the 1970s also brought the largest decrease in prices of agricultural products (data from Dieese, Departamento Intersindical de Estatística e Estudos Socioeconômicos, Cesta Básica de Alimentos: https://www.dieese.org.br/cesta). Today, Brazilian consumers are paying approximately half the inflation-discounted price of 40 years ago. This steep decline of real prices to consumer has alleviated inflationary pressures and generated an 'income effect' that has mainly benefited the poor.

The incentives to agriculture have been low in Brazil compared with other major countries. The OECD's Producers Support Estimates (PSE) to Brazilian farmers averaged 1.6 % of total farm receipts from 1995 to 2014. The corresponding values for farmers in the USA and the EU farmers were 13.5 % and 28.3 %, respectively (data from OECD, Producer and Consumer Support Estimates database: http://www.oecd.org/tad/agricultural-policies/producerandconsumersupportestimatesdatabase.htm). Brazilian farmers are moving forward based on efficiency and competitiveness.

Agricultural biotechnology, a strong asset of Brazilian agricultural value chains

The size of the global biotechnology market (including applications in agriculture, pharmaceuticals, industry and other services) was estimated at USD 270 billion in 2013, of which approximately 8 % was represented by agricultural biotechnology (Grand View Research, 2015). Experts predict that this market will reach over USD 600 billion by 2020, with the pharmaceutical sector representing the largest proportion.

The main characteristic of the agricultural biotechnology market is the presence of large companies that usually produce both seeds and chemical products for crop protection (Phillips McDougall, 2011). The reason behind the predominance of big players in the agro-biotech market is related to the high costs of bringing a new trait to the market, which is estimated at approximately USD 136 million, and bringing a new plant protection product to the market, estimated at almost USD 256 million (Phillips

McDougall, 2011). The presence of this hurdle may encourage the creation of public–private partnerships to share the advantages of both sectors in terms of research and capital.

The global area planted with genetically modified (GM) crops was estimated at 181.5 million hectares in 2014, of which Brazil accounts for 42.2 million hectares (the second largest area after the USA, with 73.1 million hectares) (James, 2014). There is a high level of penetration of biotechnology in Brazilian agriculture, in particular in soybean (93.5 % is GM) and maize (82.7 %). The adoption of agro-biotech in the last decade was extremely fast, particularly driven by soybean, followed by maize and cotton. Most GM crops in Brazil possess the traits of herbicide tolerance, followed by insect resistance or both traits together (Céleres, 2015). More quality traits (related to crop composition) are envisaged for the future (Parisi *et al.*, 2016).

The way forward: between productivity gains and product differentiation

As a result of the high relevance of the agricultural sector and associated value chains in Brazil, it is fundamental to consider the different strategies for increasing the value added in the agricultural value chain. When commodities are considered, the inherent lack of differentiation opportunities determines strategies, focusing on increased scale of production, reduction of production costs and losses (data from G.B. Martha, unpublished report to Embrapa's Strategy Management Committee, 2015). One of the alternatives to achieve these goals is through better systems management, for example by adopting 'digital farming' technologies (Phillips McDougall, 2011).

When product differentiation is feasible, adding value can be achieved in terms of quality (if the product meets customer expectations), functionality (if the product provides the needed function), form, place, time and the ease with which it can be obtained by the consumer (Anderson and Hanselka, 2009). Overall strategies may consider, among other things, certification or geographic indication, strengthening of the brand and increased product variety to target specific segments and regions (data from G.B. Martha, unpublished report to Embrapa's Strategy Management Committee, 2015). New traits, for example salt stress, temperature and water stress, would also contribute to product differentiation.

Red (medical) and yellow (insect) biotechnology can present some useful examples of opportunities for product differentiation. Exciting examples are identified in the collaboration between the USDA-ARS and Embrapa. One example is the genetic study of the cattle pest *Boophilus microplus* and the development of a vaccine for cattle using one of its proteins (Guerrero *et al.*, 2014). Another example is the use of gene silencing approaches as a defence against target organisms, for example the bacteria causing citrus greening (Hunter and Andrade, 2014). Finally, another collaborative project between teams from the Center for Cancer Research (at the US National Cancer Institute and the US National Institutes of Health (NIH) and Embrapa) concerns the production of medicines in plants (De Oliveira, 2013), for example substances produced in soybeans to treat HIV infection, which could represent a big opportunity to increase small and medium farmers' income in the future.

Red and white (industrial) biotech can also contribute to product differentiation and, consequently, to the value added in the agricultural value chain. Their contributions can be in the development of functional foods, medicinal plants, biopesticides, fragrances and cosmetics, phytotherapeutic compounds and other bioactive molecules. White biotech can contribute valuable molecules, for example renewable chemicals, food additives, aromas and fragrances (Bain & Company, 2014). Brazil, with its high land area and more than 60 % of natural vegetation cover, offers a high degree of biodiversity and a significant opportunity for new biomass and compound sources. As already illustrated in previous sections, the basic idea behind the exploitation of biomass is to apply a cascading approach, in which highest value products are produced first.

Regarding biotechnology adoption in Brazilian firms, in spite of the 56 % increase in biotech activity over 2006–2008, R&D efforts still need to be substantially increased. Large firms are showing substantially more biotech activity than medium and small firms. Most of the firms using biotechnology are final users or intermediate users (data from IBGE-Pintec database: http://www.pintec.ibge.gov.br).

Exploratory scenarios in Brazilian bioeconomy

Embrapa (with its strategic intelligence system, Agropensa) and the Strategic Affairs Secretariat of the Brazilian Presidency Office (SAE-PR), partnered to build exploratory scenarios for the technological development of Brazilian agriculture (Martha *et al.*, 2015). In this project, four possible scenarios were built along two axes (as shown in Figure 10): a vertical axis consisting of a bioeconomy era compared with an era trapped by commodities and a horizontal axis based on well-developed national RD&I capabilities compared with a high dependence on foreign research, development and innovation (for example from regions such as the USA or the EU). Ideally, Brazil could pursue the 'top of the world' scenario, boosted by a bioeconomy orientation and a national leadership in R&D (although with strong international partnership). In the worst-case scenario, Brazil would move towards the 'shoemaker's son always goes barefoot' scenario, represented by a situation in which the country is 'trapped by commodities', is unable to progress R&D efforts and depends on game-changing technologies generated abroad. The two additional scenarios represent the intermediate options. Fortunately, times in Brazil have changed compared with 50 years ago and the country is developing the multi-functionality that can be added to agriculture.

Finally, Brazilian agriculture has pursued a science-oriented path over the four decades. Based on the Agricultural Science and Technology Indicators (ASTI) database (https://www.asti.cgiar.org) for agricultural R&D investments in Brazil, it is possible to calculate that the R&D intensity averaged 1.2 % of Brazilian agricultural GDP in the 1980s. However, over the past 25 years, R&D intensity ranged from 1.8 % to 1.9 %. To reach the 'top of the world' scenario described above, it will probably be necessary to almost double the R&D intensity in Brazilian agriculture. To that end, it will be increasingly necessary to get the private sector engaged in R&D activities in Brazil (Martha *et al.*, 2015).

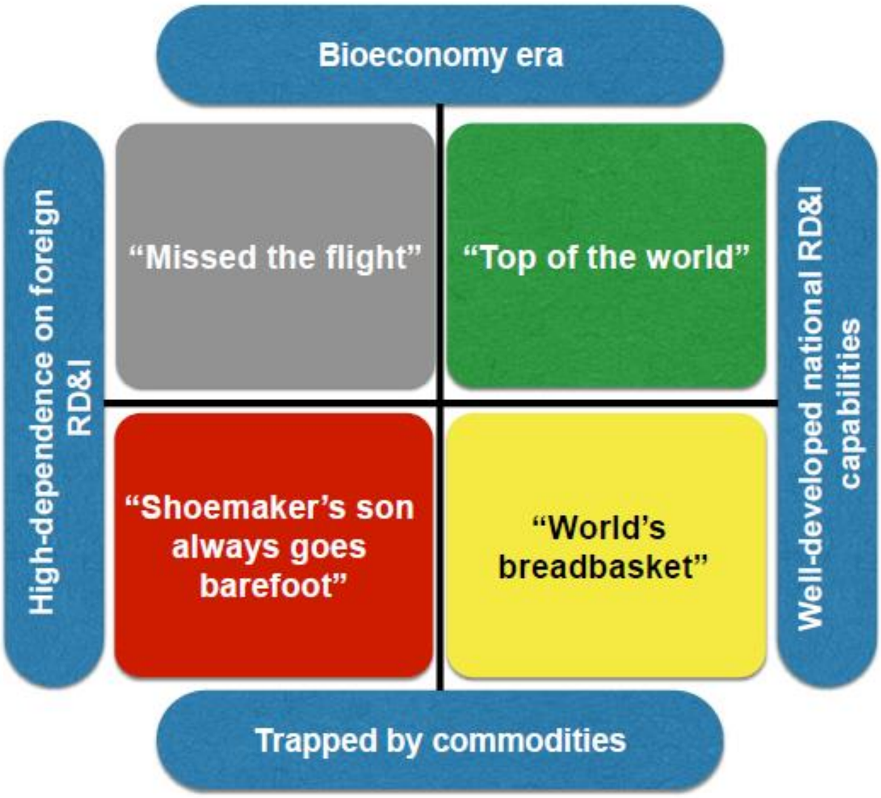

Figure 10 Exploratory scenarios for technological development of Brazilian agriculture (2034). Source: Empraba Agropensa and SAE-PR (2015)

Session 3: Socio-economic Impacts of the EU Bioeconomy

This session illustrates current activities to develop and fine-tune appropriate methodologies for impact analysis of the bioeconomy in the EU with the help of economic models. The bioeconomy is broadly defined (including food and feed, energy and industrial material production), but it is fundamental for an appropriate analysis to also maintain a focus on the most innovative sectors. A key limitation is, again, the availability of data.

S3–1: Modelling Bio-based Sectors in the Computable General Equilibrium Model 'MAGNET'

Hans van Meijl, *LEI – Wageningen University (the Netherlands)*

The development of a Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy

An integrated assessment is needed to monitor and evaluate the bioeconomy with respect to the main societal challenges and policy targets. A computable general equilibrium (CGE) model, such as the Modular Applied General Equilibrium Tool (MAGNET), can contribute by describing the inter-sectoral linkages and the indirect effects in the whole bioeconomy. Furthermore, MAGNET can be combined with partial equilibrium models to obtain a more detailed description of certain bio-based sectors. Complementary analysis can take into account non-economic impacts (e.g. life cycle analysis (LCA) analysis for environmental impacts). Such a complete and integrated framework is a scientific and technical challenge.

The FP7 project 'Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy' (SAT BBE), led by the LEI Institute of Wageningen University, was finalised in 2015. Publications of the SAT-BBE project are available on the website (http://www3.lei.wur.nl/satbbe/). The objective of the project was to provide analytical tools for monitoring and evaluation of the implementation of the EU Bioeconomy Strategy.

In the conceptual systems analysis framework established for SAT BBE, food and feed, energy and materials represent the nucleus of the analysis, including interactions with various policy domains and supply and demand correlations. This framework also takes into consideration the multiple drivers and constraints of these sectors, with the final objective of measuring the impact of potential developments of the bioeconomy on societal challenges (see Figure 11).

MAGNET as a tool to simulate the development of the bioeconomy and analyse impacts

MAGNET is a CGE model that includes 113 regions of the world and covers the entire global economy (standard 57 sectors), including factor markets. MAGNET fits in the SAT-BBE framework, since it captures the linkages between the bioeconomy and the rest of the economy (e.g. with the fossil-based sectors), while taking into account the various drivers and constraints described in Figure 11. However, data on cost structure, sales, trade patterns and future developments of innovative bio-based sectors are not explicitly represented in MAGNET (e.g. second-generation biofuels and bio-based chemicals). In addition, uncertainties concerning future policy measures[4] (e.g. energy, agricultural and climate polices) and the development of fossil energy prices add difficulty to modelling the impact and development of the bioeconomy. Simulating land market dynamics (i.e. how much land is potentially available and can be brought to production), physical balances (in hectares or energy units) and food and nutrition security impacts represent other methodological challenges.

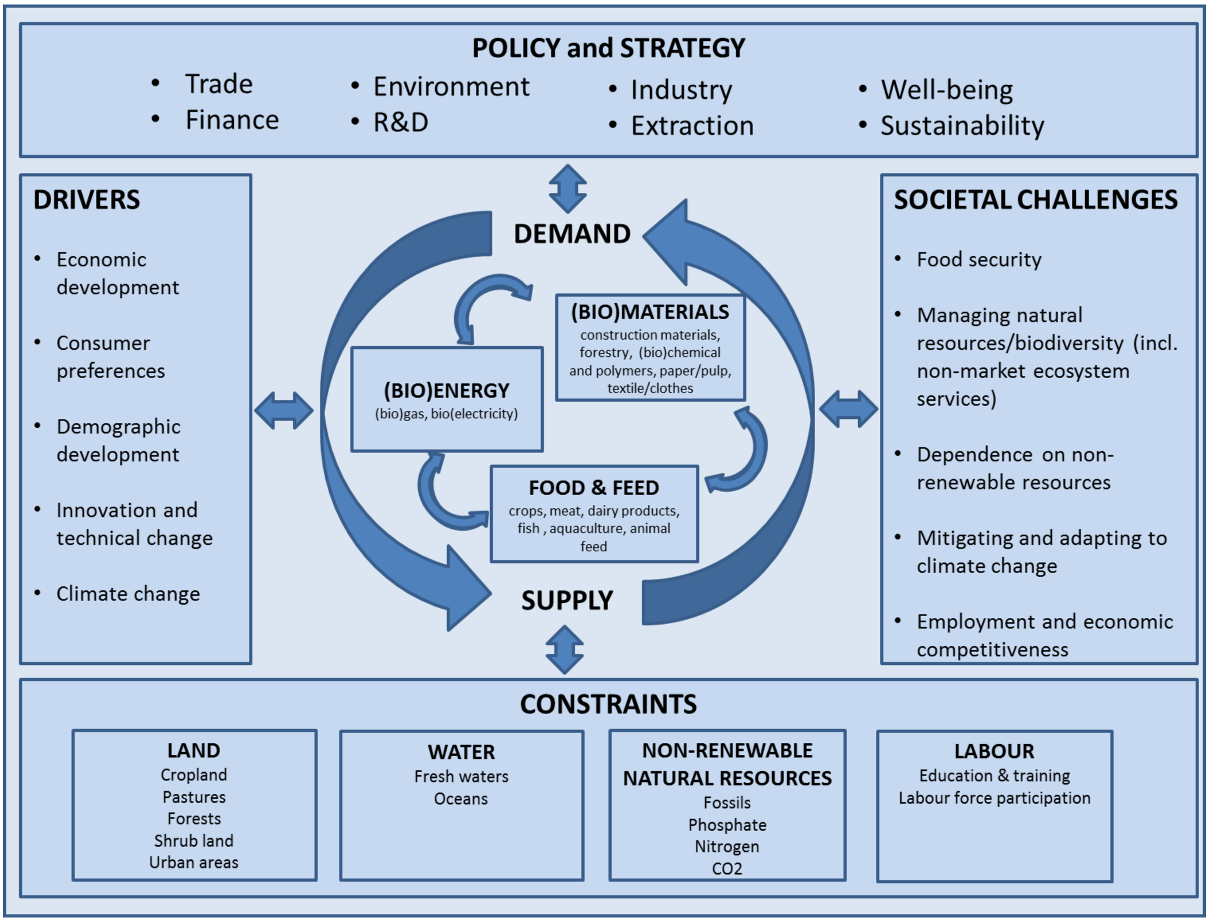

Figure 11. The conceptual systems analysis framework of the bioeconomy in the Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy (SAT BBE) project. Source: SAT BBE.

MAGNET has recently been integrated with four bio-based categories: biomass supply, electricity, transport fuels and chemicals. Biomass supply includes residues, which were taken into consideration in this study because of their relevance in the bioeconomy and the circular economy, and for applications in other sectors (bioelectricity and second-generation biofuels and biochemicals). Dedicated plantations and pellets (i.e. biomass traded across the world) were also introduced into MAGNET as part of the biomass supply. Electricity includes six sources: coal, gas, nuclear, wind and solar, hydro and electricity from biomass. Transport fuels include conventional, petrol-based fuels, first-generation bioethanol and biodiesel and second-generation biofuels (bioethanol and Fischer Tropsch biodiesel). It is important to note that second-generation biofuels often do not exist or are currently produced at a very small scale and therefore represent very small sectors that may or may not grow, depending on the rate of technological development, the prices of biomass and oil, and on energy and climate policies.

[4] Policies are crucial to determine the scenarios, in particular the 10 % biofuel mandate (EC, 2009), the GHG emissions reduction of 40 % in 2030 and the agricultural policy.

The chemical sector constitutes a significant challenge because of the complexity of the value chains. To represent it in the study, a few main routes were developed, for example the production of the main bio-based polymers, polylactic acid (PLA) and polyethylene (PE), which represent the sugars that are used for ethanol production for chemical use. Overall, the bio-based chemical sector represented in MAGNET includes PLA, PE, lignocellulosic sugar and mixed bio/fossil chemicals. The introduction of new bio-based sectors in MAGNET is carried out in collaboration with Utrecht University, based on detailed analyses using the MARKAL partial equilibrium model of the energy and chemicals sector.

Various other modules were added to MAGNET, including food security module, renewable energy policy module, biofuels module, residue supply module and GHG emissions module, among others. The various modules can be connected to evaluate, for example, the impact of biofuel production on food security (as carried out in the FP7 project FoodSecure: http://www.foodsecure.eu).

MAGNET as tool for the modelling of the Brazilian bioethanol case

LEI Wageningen UR was also involved in impact assessments of Brazilian biofuels production and their use for the analysis of land use and agricultural dynamics from a Brazilian and global perspective. This involved combining various modelling approaches. First, the global general equilibrium model MAGNET and the partial equilibrium model BLUM (Brazilian Land Use Model) were combined by the LEI and the Institute for International Trade Negotiations from Brazil (ICONE). The second approach involved the combination of MAGNET with the spatially explicit land use model PLUC (PCRaster Land Use Change model), which was performed by the LEI and Utrecht University.

The integration of MAGNET with BLUM involved a regional disaggregation of agricultural production and land use by including regional land markets that contains all the transitions of land from one type of use to another. The development of the productivity of crop sectors is further improved by considering multi-cropping, which is becoming increasingly important. In addition, the development of the intensification of various livestock production systems is a key factor that was considered. Finally, the integration of various models also involved the consideration of biofuel use and biofuel policies, international trade patterns and effects and calibration of land use and agricultural production.

The preliminary results of the study predicted an increase in bioethanol exports by Brazil by 2030 of between 3.6 billion litres (relative to the baseline) and 9.0 billion litres. Intensification of livestock production reduces the land use change (LUC) effects of ethanol production to less than one fifth of the direct land use change (DLUC). MAGNET predicts substantially higher land use change effects compared with BLUM when the trade of agricultural commodities is fixed. However, the global indirect land use change (ILUC) effects of ethanol production in Brazil are similar (limited) as identified by Laborde *et al*. (2014). Comparison of results shows the (uncertain) role of managed plantations on total net global ILUC effect.

MAGNET as a tool for the modelling of the renewable energy sector in the Netherlands

LEI Wageningen UR has recently performed an assessment of the impact of the bioeconomy in the Netherlands "MEV-II Macro-economic outlook of sustainable energy and biorenewables innovations" (van Meijl *et al.*, 2016). This study was commissioned by the Dutch government to establish if the it should invest in emerging technologies for bio-based energy and chemicals.

Using, as a starting point, the study of Kwant *et al*. (2015), bio-based shares were estimated for the year 2013 from the Dutch agricultural input–output (IO) table. The findings show that the agriculture and food sectors are the most important sectors of the bioeconomy in the Netherlands. Wood is also a large sector, while biochemistry makes up 4.7 % of the bioeconomy.

In order to analyse possible developments of the Dutch bioeconomy by 2030, four scenarios were implemented, according to two axes: one axis represents low compared with high technological development and the other axis represents globalisation compared with regionalisation of the bioenergy trade.

According to the analysis using these scenarios, energy (electricity, heat and fuels) and chemicals would consume at least 50 % more biomass by 2030 compared with 2013 (233 PJ in the low-tech/regional scenario (RegLowTech). The development of second-generation biofuels and second-generation bio-based chemicals increases the use of biomass even further. In the high-tech/global scenario (GlobHighTech), forestry products and residues, and wood from short-rotation forestry supply more than 50 % of the total biomass consumed, which is imported partly as wood pellets from outside the EU-28. In the latter scenario, two large second-generation biorefineries will be built by 2030 in the Rotterdam harbour area. A large amount of biomass needs to be imported, while second-generation products are exported (van Meijl *et al.*, 2016).

Regarding the effects on GDP, the difference between the RegLowTech and GlobHighTech scenarios is EUR 1 billion in 2030 in favour of GlobHighTech, demonstrating that the bioeconomy creates significant macro-economic benefits. However, the Renewable Energy Directive (RED) has a negative effect, from a GDP perspective, up to 2020, since efficient fossil technologies are replaced by inefficient bio-based technologies and this has a negative effect on GDP of approximately EUR 800 million. In the GlobHighTech scenario, cheaper biomass can be bought from all over the world, lowering the costs of the RED in terms of GDP in the Netherlands. The GDP impact becomes more positive in the next period (from 2020 to 2030) when the technological progress is introduced, but is clearly much lower in the RegLowTech scenario.

According to the main findings of the study, the value added of the new bio-based sectors (biofuels, bio-based chemical, bioenergy) increases in both technological scenarios, but at a higher growth rate in the GlobHighTech scenario. This is particularly relevant for the contribution of the bio-based chemical sector. The value added of agriculture is currently declining in the Netherlands. The value added is predicted to decline slightly in the two low-tech scenarios (both regional and global) and increase slightly in the high-tech scenarios, particularly in the regional scenario. These results demonstrate that the bioeconomy can confer a higher value added to agricultural resources.

The new bio-based sectors are too small to have a large impact on greenhouse gas emissions. If CO_2 taxes are maintained at a moderate level, as in the current situation, then the emissions are predicted to stabilise at 2010 levels. This is far below the 2030 40 % reduction target. CO_2 taxes need to be much higher to reach the 40 % reduction target. High levels of technological development and open trade to improve biomass availability are predicted to reduce GHG emission by 0.5 %.

In conclusion, the bioeconomy consists of various complex and interlinked sectors and can contribute to the societal challenges of the EU. The macro-economic impacts of the bioeconomy depend on the competitiveness of biotechnology and fossil energy prices (fossil energy prices, biomass prices, technological change and energy policies). The bioeconomy is driven by technological change and open markets can contribute to reduce mitigation costs of achieving GHG target reductions (as specified in the United Nations Climate Change Conference in 2015 (COP 21)) and reduce costs with low energy prices.

S3–2: Drivers of the European Bioeconomy in Transition

Emanuele Ferrari, *Joint Research Centre – Seville (Spain)*

A model-based assessment of the current status and expected evolution of the bioeconomy in the EU

In April 2016, the JRC published the report *Drivers of the European Bioeconomy in Transition* (Philippidis *et al.*, 2016), which presents an exploratory, model-based assessment of the current status and expected evolution of the bioeconomy in the EU. The analysis was performed employing the CGE model MAGNET. Although MAGNET is a global model, the focus of the analysis was specifically on the EU. The main objective of the study was to provide a systematic and connected view of the sectors that define the bioeconomy, in particular agriculture and food industry, with the inclusion of the less-traditional sectors in 2030.

The reason for performing the study was primarily to create a reference, called the baseline or outlook, to describe what the situation in will be 2030 for the bioeconomy sectors. This obtained baseline can be then used for policy analysis by introducing new policy shocks and testing to see how the system reacts. This study involved several sectors that are interlinked in the bioeconomy and, consequently, involved several different policies, in a similar way to the study described in section S3–1 by Hans van Meijl in this report. Therefore, the main aim of the study was to analyse how all these policies interact with each other and to determine if there is coherence among them, and to analyse the creation of possible trade-offs.

As in the study previously described, the tool employed in the JRC study is the MAGNET model (Figure 12). With the help of the LEI and with internal input, the starting database (from the Global Trade Analysis Project (GTAP)) was disaggregated to add the most relevant bio-based sectors for the analysis. In terms of data, one of the main differences compared with the previously described study is that all the electricity and energy sectors are not included in the JRC study. Energy markets were not within the scope of this JRC study, because the main focus is agriculture and everything that proceeds from it.

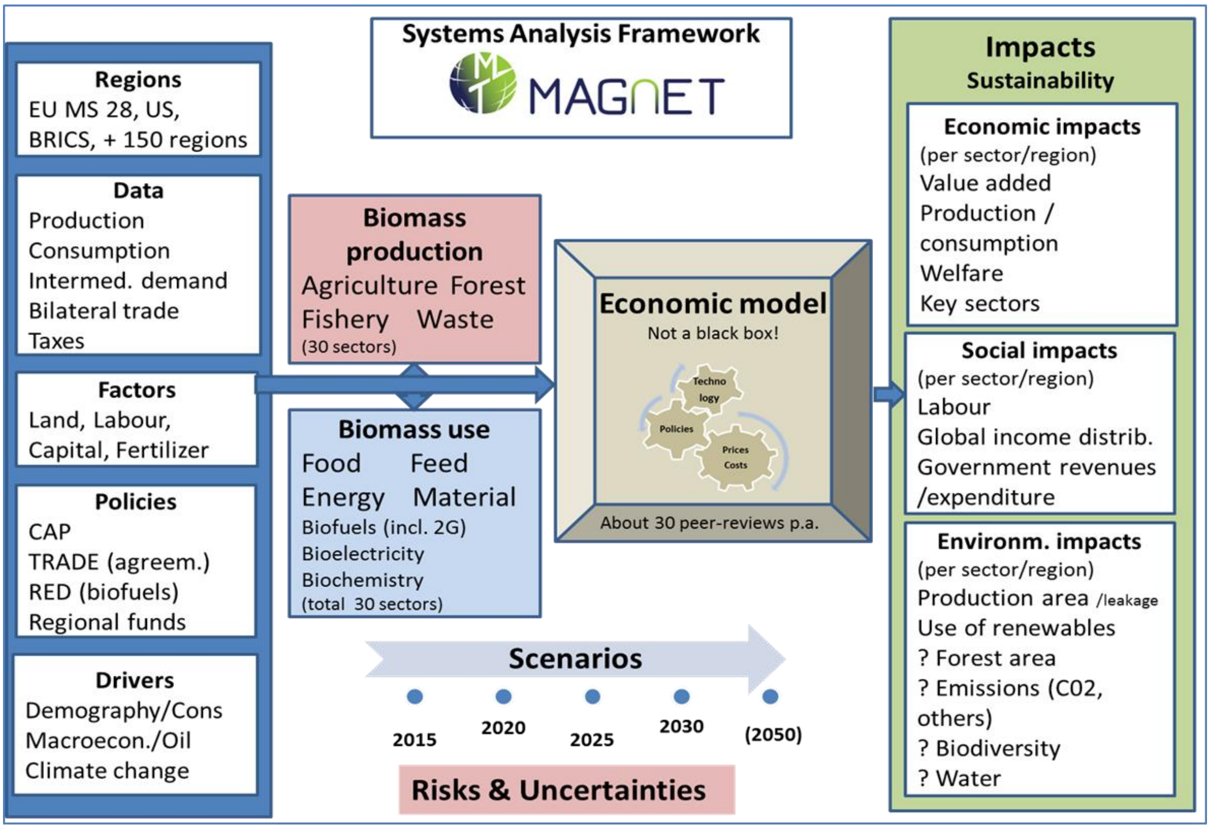

Figure 12. The MAGNET model applied to the bioeconomy analysis, a graphical overview.

Economic and policy assumptions for the establishment of the baseline

The baseline to 2030 presented in the study was created through a series of assumptions regarding macroeconomic development (mainly GDP and population) and productivity drivers (in particular on land), based on the Shared Socioeconomic Pathway 2 (SSP2). In addition to this, data on GHG emissions were derived from the European Commission (Labat *et al.*, 2015).

When looking at the EU, one of the main characteristics of these drivers is that the EU shows much slower macroeconomic and productivity growth than most of its competitor countries.

The estimates concerning global fossil fuel prices (for coal, crude oil and gas) were taken from the World Bank (2015). It must be kept in mind that these prices are generally very volatile and that no precise estimate can be predicted for the future. In fact, a few years ago, nobody would have predicted that the crude oil price would reach USD 30/barrel. Therefore, uncertainties must always be acknowledged and explained, to improve the understanding the outcome of the study and the possible variations.

In addition to the macroeconomic drivers, four main policies are modelled within the study:

- the Common Agricultural Policy (CAP), considering the newest developments in particular, for example 'greening';
- Bio-fuel policies, in particular the blending mandate;
- greenhouse gas emissions policies;

- trade policies, including, in particular, free trade agreements (FTAs), at both regional and global levels.

The baseline adopts policies that are currently in place in the EU (i.e. those already signed). Most of the current policies have a 2020 horizon; therefore, for the remaining 10 years until 2030, it was assumed that there will be no changes and that the same policies will continue to be implemented. Around these four policies, two possible scenarios were built to assess how the policies would interact and to create two possible different futures.

Identified diverging trends in the different sectors of the bioeconomy in the EU

According to main findings of the study, which are described in detail in the published report (Philippidis *et al.*, 2016), the evolution of the baseline shows diverging trends in output in the EU in the different sectors of the bioeconomy. Sectors that are more exposed to international competition, such as textiles, clothes and leather products, or are strongly affected by GHG emissions' reduction, for example the fertilizers sector, show a decrease of production in the periods 2013–2020 and 2013–2030, while most of the other bioeconomy sectors show increases. The less-traditional bio-based sectors, that is bioenergy, biochemicals and biosupply (the sum of residues, pellets and energy crops), show impressive growth rates until 2030; however, the starting proportion of these sectors within the EU is very small, therefore, the growth is actually small in absolute terms.

In order to obtain data on the effects on employment in the EU bioeconomy, the MAGNET database was parameterised, with jobs data produced in cooperation with the nova-Institute by the Bioeconomy Observatory. Some employment trends are very well known; for example, the agricultural sector shows job losses and this trend is consistent with historical data. Regarding the less-traditional bio-based sectors, the trend on employment is similar to the output trend: there would be high percentages of growth for very small initial numbers. Overall, these advanced sectors would not be able to counteract the trend towards loss of jobs within the bioeconomy as a whole.

The study also provides an analysis of the output changes in the EU-28 bioeconomy sectors between 2013 and 2030. Additionally, using a specific modelling technique, all the resulting endogenous changes within the model were decomposed into the part-worth that corresponds to a specific exogenous shock. For example, the macroeconomic projections in terms of GDP and population would cause the EU agricultural sector to increase by 5 %. However, the GHG policy, that is the commitment of the EU to decrease the production of GHG emissions between now and 2030, would have the impact of decreasing the agricultural output by 3.6 %. Therefore, the final output would be an increase of only 1 %. This analysis is focused only on economic effects and does not include the measure of the benefits expected to arise from the reduction in GHG emissions. To obtain a complete picture, a climate module should be implemented within the model.

From the policy point of view, it can be observed that the CAP, as it is currently designed, does not result in significant effects in most of the analysed sectors. Trade policies included in the baseline are only those that are already signed and, therefore, include only a few regional agreements that are not particularly relevant for the EU and show a very small impact on output growth. Biofuels policies (the blending mandate) have a small impact for most of the described sectors, but have a substantial impact for the non-traditional bio-based sectors, causing a huge increase in biosupply and bioenergy production. The blending mandate forces the use of biomass for bioenergy production, thus displacing it from chemical production, which means that its effect on the biochemical sector is very negative.

Additional observations that should be added to the analysis are that the Malthusian fears of population growth and resulting increasing prices and food shortages are not really substantiated by the findings of the study. Another observation is that there are some bottlenecks, in particular in the small-scale infant bio-based industries and particularly in the second-generation biofuels sector, which will result in a huge increase in price.

Analysis of two potential scenarios in the future bioeconomy development

In addition to the baseline scenario, two additional scenarios are created in the study: an inward-looking and an outward-looking one. In the inward-looking scenario narrative, the EU adopts a 'tried and tested' approach towards employment and growth, with greater emphasis on the promotion of existing carbon technologies, while bio-based activity is no longer afforded any policy dispensation: the biofuel mandate is not renewed, the GHG emissions policy is not further pushed in terms of increasing reduction and, with respect to trade, there are more regional agreements instead of global agreements. In the outward-looking scenario, the EU takes the lead on the world stage with a more altruistic approach. The EU policy actively pursues a prototype model of employment and growth that actively promotes the concept of the bioeconomy, with more multilateral trade agreements and the environmental policy pushed even further (an additional 20 % reduction of GHG), following some global mitigation scenarios (Labat *et al.*, 2015).

From the analysis of the two scenarios, it was observed that reductions in GHG emissions create a loss in real GDP and reduce EU agricultural and food sector output. An increase in the EU biofuel mandate generates additional loss in real GDP, since it forces an increase in production in an infant industry and thereby creates inefficiency in the system. This result would support the recent initiatives of abandoning single-objective policies, such as mandates, and initiatives to link biofuel usage with lower GHG emissions. According to the outcomes of these scenarios, multilateral trades can improve poverty reduction and reduce the EU's traditional bioeconomy sector growth in agriculture, food, textiles, wearing apparel and leather. More market orientation, for example removing CAP pillar 1 payments and biofuel mandates and implementing multilateral trade deals, would reduce employment in bio-based sectors compared with the baseline.

The final observations were that macroeconomic issues are by far the main determinants of future developments in the EU bioeconomy, compared with the policies, but are also the elements with most uncertainties, since it is not possible to precisely forecast GDP and oil prices for 2030. Technological changes that affect productivity are game changers, but most technological changes are not endogenously determined by the model. Therefore, it also would be fundamental to obtain more data on future technological advance in terms of R&D investments to improve the reliability of the study. The ambitious GHG emission reduction plan has wide-ranging effects, in particular for high emission sectors. Policies stimulate the development of the (still infant) innovative bio-based industries, as seen through biofuel mandate, but this can have welfare costs through non-optimal allocation of resources.

The bioeconomy is a complex and highly interlinked system that needs an integrated assessment. This study represents a 'state-of-the art' analysis for modelling and data development, with the creation of two scenarios based on pure research needs. The predicted future developments in the context of this study are to run some realistic and more detailed scenarios that would reflect specific policy questions. Data are continuously being updated and more specific data on the less traditional bio-based sectors will be integrated. New modules, such as those on climate change, should also to be included in the model to obtain a more complete picture of the situation, and the incorporation of endogenous technological change mechanisms will also be considered. Finally, a systematic sensitivity analysis will be explored further to improve how possible uncertainties can be viewed.

S3–3: Measuring the EU Bio-based Economy: Some Methodological Issues

Justus Wesseler, *Wageningen University (The Netherlands)*

As a contribution to the debate concerning the actual size of the bioeconomy, Wageningen University (WUR) has developed methods to measure the size of the EU bioeconomy (Wesseler, 2015; Heijman, 2016). Similarly to the nova-Institute (see section S1–1 by Michael Carus in this report), WUR collected data on turnover and employment in the different sectors of the bioeconomy that, based on the European Commission's definition (EC, 2012), involve approximately 9 % of EU workforce and 80 % of land use (see Figure 13).

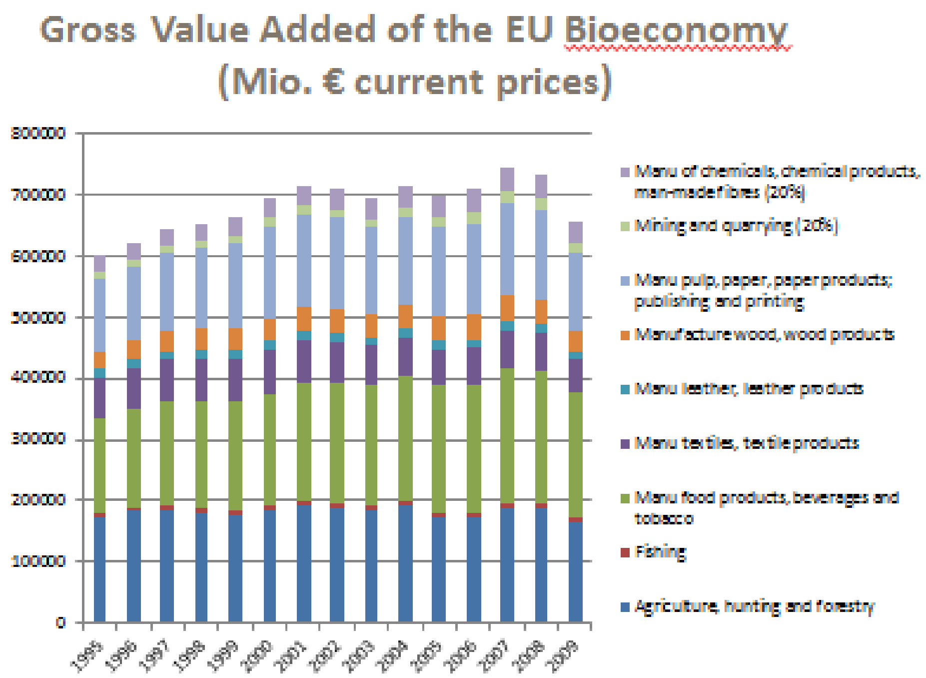

Figure 13. Size of the EU bioeconomy 2009. (Source: Wesseler, 2015).

An everyday, more connected and integrated bioeconomy

The bioeconomy is not a new concept and it could have been measured a few decades ago; however, in the meantime, several advances have been made. First, in the biological sciences, there are now more inter-linkages between different sectors of the bioeconomy. Another important aspect is the observed increase in horizontal and vertical integration in all our economies, for example large biotech companies that are growing through mergers and acquisition of other companies and markets that develop through strong vertical integrations in the supply chain (e.g. GM-free market in Germany). Globalisation has also brought to an increase in inter- and intra-industry trade, for example in agricultural products (Wesseler, 2015).

Another important area that has shown impressive development in the last decades is information and communication technologies (ICT), which now cover the whole world and must be taken into consideration in the description of the bioeconomy. One example of the power of ICT was demonstrated in 2011, with the EHEC (enterohaemorrhagic *Escherichia coli*) crisis and the rapid spread of news concerning all possible causes until its final discovery.

The bioeconomy in the sustainable development framework

The bioeconomy introduces some scientific challenges and elements of societal relevance, which are included in the agenda of the EU and of other countries, for example the USA and Brazil, and contribute to sustainable development:

- contributions to food security;
- sustainable management of natural resources;
- reducing dependence on non-renewable resources;
- mitigating and adapting to climate change;
- creating jobs;
- maintaining competitiveness.

A very important question is how sustainable development can be properly measured. Several methodological approaches have been illustrated in the economic literature, including the ecological footprint, Bhutan's Gross National Happiness Index and the United Nations (UN) Human Development Index. The World Bank also developed two indicators: Genuine Savings, which deducts other expenditures, for example the depreciation of natural resources, from the gross national saving and Genuine Investment, that is the change in the economy's set of capital assets weighted at shadow prices. Important aspects that need to be added to these indicators are what is captured under the shadow prices and externality effects, for example the results of air pollution, forest death and climate change. Another important aspect that should be considered in the analysis is the internalisation of external effects, that is the effects of externalities on our economies, as well as the effects of the policies that address these externalities. These effects must be included in the overall assessment. Currently, the standard recommendation made to take externalities into account is to introduce a Pigouvian tax to charge extra costs to those that are producing a specific product, to internalise the externalities and thereby reach an optimal social level of production. This approach has, however, a number of limitations (Wesseler and Drabik, 2016).

Internalising externalities with or without policies?

Several policies already in place in the EU, the USA and Brazil have internalised many of these externality effects; therefore, many externality costs are already included at market level. The ideal starting point to perform an appropriate policy analysis with a CGE model would be to describe a scenario without any policy and compare it with scenarios with policies added, ideally one by one, so that the most appropriate one could be selected. Unfortunately, this type of analysis is practically impossible and the current approach is to compare the current situation with a set of policies and select the policies that can improve the current situation.

There are several examples in which the private sector has internalised a number of externalities without policies, for example the Round Table for Responsible Soy (RTRS, 2016); therefore, it must be considered that the private sector could have incentives that are in line with sustainability requirements and policies should be safeguarding also this aspect.

How to take into account possible but uncertain irreversible effects?

Regarding sustainability-related irreversibility effects, a very relevant concept to be taken into account is the precautionary approach, defined in the Rio declaration on environment and development:

'In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation′ (United Nations, 1999).

However, this does not result is a logical way of assessing uncertainties, because of the lack of precise information. To deal with these types of uncertainty and integrate them into the economic assessment, the WUR has developed an indicator called Maximum Incremental Social Tolerable Irreversible Costs (MISTIC or $I*$), with the formula:

$$I^{*} = W/\left(\frac{\beta - 1}{\beta}\right) + R$$

where *W* is the social incremental reversible benefits, that is the welfare effects, and can be assessed with general or partial equilibrium models; *R* is the social incremental irreversible benefits, for example the reduction of pesticide use to reduce the probability of farmer death, vaccination campaign, etc.; and β/(β −1′ represents the measure of uncertainty and flexibility, for example with respect to the introduction of new technologies (Wesseler *et al.*, 2007; Benjamin and Wesseler, 2016). As long as the indication of damages is clearly larger than $I*$, the action should be postponed to wait for additional information. If there are sufficient indications that the results (the right-hand side of the equation) are below $I*$, the new technology can be introduced.

One example of the application of this principle is the Amflora potato, the genetically modified starch-enhanced potato that gave rise to several concerns related to the introduction of genetic modification technology a few years ago and did not reach the market. The dynamics of the introduction of a new technology are also important aspects to analyse. Technologies that work very well, for example technologies to control specific pests in agriculture, can have limited efficiency because of the appearance of pest resistance; however, they can become effective again in time, once pest susceptibility is restored. This aspect can be modelled in the economic assessment.

The value of a new technology versus investment costs

Another important issue to consider when looking at new technologies that reach the market is the value of opportunities. Investment costs are covered by the value of the technology, so if the value of the technology rises, so do profits. In case of uncertainty by the industry concerning the possibility of investing in a new technology, companies need an empirical demonstration of the value of the technology for them to maximise their option value.

In certain cases, the introduction of regulatory policies implies an increase in investment costs. For example, when introducing a new GM crops into the EU market, several regulatory requirements must be complied with, which affect investment costs and the optimal timing to reach the market (Smart *et al.*, 2016). The fact that the industry is affected by these regulatory hurdles is demonstrated by the decreasing number of biotechnology patents filed in the EU since 2000 (OECD, 2016), which also affects the bio-based economy. Certain standard models do not consider these elements of uncertainty and irreversibility, and therefore underestimate the implications of this type of regulation on the investment behaviour of the industry. The option value model takes these elements into consideration, with the effect of increasing costs. Compared with the intrinsic value alone, the option value allows to optimally assessing the value of new technologies (Wesseler, 2015).

In conclusion, to perform an appropriate analysis of the bioeconomy, there is a clear need for sectoral data (e.g. from National Statistics), though this is not sufficient. For a proper assessment, and to identify the option value, we need a homogeneous panel data set, similar to the EU Farm Accounting Data Network (FADN) (http://ec.europa.eu/agriculture/rica/concept_en.cfm). A similar study is currently planned for the bioeconomy, but would require concerted effort at EU level. Ideally, a plurality of models should be employed, where each one could address a specific question. Finally, there is a need for more data on innovation, for example on R&D expenditure and patent data, to understand whether the industry is really moving forward or not. This is necessary to assess wider implications of the bioeconomy.

Session 4: The Way Forward: How to Measure the Progress of the Bioeconomy

This final session brings together the representatives of two relevant organisations in the panorama of the future developments of the bioeconomy at European and international level. The Bio-based Industries Initiative is focused on the support and development of innovative bio-based value chains at EU level to ensure the settlement of the ideal market conditions for the bio-based sector. The OECD is giving support to the analysis of the opportunities and progress of the bioeconomy in several countries.

S4–1: The European Bio-based Industries Initiative – Public–Private Partnership: New Business Models to Create Impact in the Bio-based Industries

Dirk Carrez, *Bio-based Industries Consortium (BIC)*

The EU Bio-based Industries Consortium (BIC) was established in 2012 to represent the private sector in the public–private partnership (PPP) on the Bio-based Joint Undertaking (BBI JU), in which the European Commission represents the public sector. The main tasks of the BIC are to define the BBI's Strategic Innovation and Research Agenda, to lead the drafting of the annual BBI Work Plans and Call for Proposals topics, to improve the conditions for the 'Access to finance' in Europe and to mobilise stakeholders: industry (large, SMEs, SME Clusters), research organisations, universities, regions and all other relevant stakeholders across Europe.

The BIC is a multi-sector organisation, which includes more than 200 members among large industries, SMEs, regional clusters, universities, technology platforms and other stakeholders, from different sectors of the bio-based economy, for example agriculture, agro-food, forestry and pulp and paper, chemical industry and energy, including technology providers and end-users, and is still growing.

A public–private partnership aimed at 'de-risking' the emerging bio-based industry

The main reason to create a PPP between the European Commission and BIC is to 'de-risk' the emerging bio-based industry and, in particular, to provide a clear framework that brings clarity for activities and investments, long term stability and predictability, a joint approach across sectors and across nations, joint financial commitment and a jointly defined programme. The BIC's programme seeks to unite parties that would otherwise find these activities too risky for an individual institution. The BBI JU is industry driven and therefore result- and market-oriented. It should leverage further investments and help to create new value chains in Europe involving different industrial sectors.

The main specific objectives of BIC for 2016 are to attract new sectors, in particular the food industry (valorisation of waste and by-products) among other sectors, to expand the use of biomass to new sources, for example algae and municipal solid waste (MSW) and, finally, to attract brand owners. In fact, the greening of brand owners, such as IKEA and LEGO (with plastic components to be made using renewable material by 2020 and

2030, respectively), Coca-Cola and Danone (with bio-based bottles) is driving innovation in bio-based materials.

The budget of the BBI PPP is EUR 3.7 billion; EUR 1 billion is public funding from the European Commission that is balanced by another EUR 1 billion from the BIC. Additionally, almost EUR 1.8 billion should be added to the total: these are investments by the industry for additional activities that are not reimbursed by the BBI JU. They include, for example investments in infrastructure within demonstration or new flagship projects. The Regions, the European Investment Bank and the MSs can also fund a non-reimbursed part of the BBI projects.

The value-chain approach applied to the Bio-based Industries Joint Undertaking

The focus of the BBI JU is on the entire value chain of the bio-based industries (see Figure 14); this starts at feedstock phase by fostering a sustainable biomass supply and building new value chains and new feedstock sources, with particular emphasis on waste and residues, for example from industrial side stream and MSW. The focus then changes to cover the processing phase by optimising efficient processing through R&D and upscaling in large-scale demo/flagship biorefineries. Finally, the focus is transferred to the market phase by developing markets for (new) bio-based products and optimising policy frameworks.

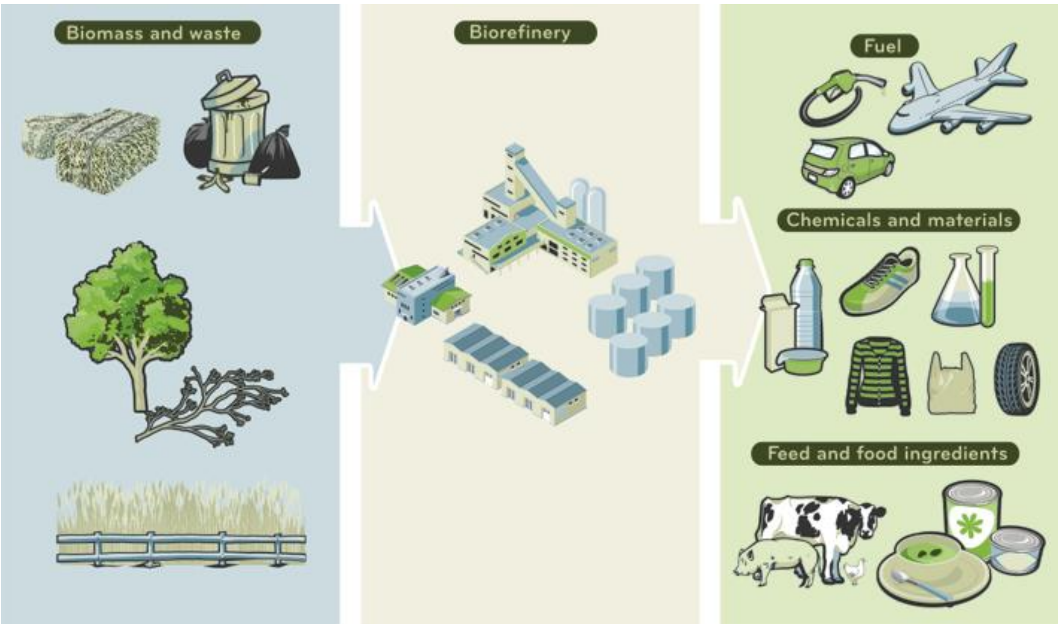

Figure 14. Bio-based industrial value chains. Source: BIC.

Particular emphasis was put on five value chains in the strategic innovation and research agenda of BIC, as defined in 2013: (1) the conversion of lignocellulosic feedstock to advanced biofuels, bio-based chemicals and biomaterials; (2) next-generation forest-based value chains; (3) next-generation agro-based value chains; (4) new value chains from (organic) waste; and (5) integrated energy, pulp and chemicals biorefineries that can realise sustainable bio-energy production by backwards integration with biorefinery operations that can isolate higher-added-value components

BIC started a process, together with the European Commission and the BBI, to revise and update the strategic innovation and research agenda. BIC will extend the scope of existing value chains and will create new ones that can use broader feedstock diversity.

BIC will also improve the visibility of 'demand-pull', rather than just suggesting 'feedstock-push'.

From strategy to support: the projects funded by the BBI

The BBI launched the first (small) call for proposals with EUR 50 million from public funding in 2014 (http://www.bbi-europe.eu/participate/calls-proposals-2014), which resulted in 10 projects:

- seven funded research projects tackling specific value chain challenges, such as sustainability, technology and competitiveness;
- two demonstration projects that will demonstrate the technological and economic viability of biorefinery systems and processes for making chemicals from wood, and for making high-value products for detergents, personal care, paints and coatings and composites from sugar beet pulp;
- one industrial scale flagship project that will make use of cardoon, an under-utilised oil crop grown on arid and marginal lands, to extract vegetable oils to be further converted into bio-based products (bio-lubricants, cosmetics, bio-plastics); by- and co-products from the process will also be valorised for energy, feed for animals and added value chemical production.

On top of the EUR 50 million public funding, there was EUR 70 million of investment by industry.

Demonstration and flagship projects always have to cover the entire value chain. Demonstration projects are small-scale production plants designed to obtain proof of concept before taking the risk of progressing to a commercial production plant. Flagship projects are new, first of their kind, innovative production plants. The objective of research projects is, in particular, to cover the weakest technological point in innovative value chains, so that a specific process can go on to demonstration stage. It is the first time in Europe that this kind of funding is also available also for demo and flagship plants. It is fundamental that all the possible partners that are active in the value chain are integrated in the project, so that they can build mutual trust and make joint investments at a later stage.

The BBI 2015 call was the largest to date (http://www.bbi-europe.eu/participate/calls-proposals-2015), containing additional topics compared to the previous, and was published in two steps:

1. First call 2015: a budget of EUR 100 million was allocated, specifically for flagship projects; the topics were:
   - BBI.VC1.F1: from lignocellulosic feedstock to advanced bio-based chemicals, materials or ethanol;
   - BBI.VC2.F2: valorisation of cellulose into new added value products; and
   - BBI.VC4.F3: innovative processes for sugar recovery and conversion from Municipal Solid Waste (MSW).

2. Second call 2015: a budget of EUR 106 million was allocated for research and demo projects:
   - EUR 28 million for Research and Innovation (R&I) Actions
   - EUR 12 million for innovative and efficient biorefinery technologies
   - EUR 64 million, to be allocated for Demonstration Actions

- EUR 2 million for Coordination and Support Actions

Thanks to the gained experience of the BBI and of the potential participants to the call, a large number of proposals were received. An overview of the projects that have started is available online (http://www.bbi-europe.eu/projects).

The 2016 call was officially published in April 2016 (http://www.bbi-europe.eu/participate/calls-proposals-2016). The deadline for the calls was September 2016 and the evaluation should be finalised by the beginning of 2017. It is, again, an important call, with EUR 188.65 million of public funding, twelve topics for research (EUR 50 million indicative budget), nine topics for demonstration projects (EUR 70.2 million) and two flagship topics (EUR 65 million). The flagship projects will focus particularly on food waste valorisation, in which there is quite a lot of interest, particularly from food companies that started collaborations as joint ventures with chemical industry and related to the production of innovative chemical building blocks and advanced materials. Compared with the previous calls, the 2016 call is more focused on new products and new applications and, for the first time, includes new kinds of feedstock, for example seaweeds/algae.

S4–2: Bioeconomy in the OECD

Peter Schintlmeister, *Federal Ministry of Science, Research and Economy of Austria, and OECD Working Party on Bio-, Nano- and Converging Technologies (BNCT)*

The Organisation for Economic Co-operation and Development (OECD) is an international economic organisation founded in 1961, in the aftermath of the European recovery from the Second World War, to stimulate economic progress and world trade in 20 MSs at that time. The OECD is a unique forum for governments to work together to address the economic, social and environmental challenges of globalisation. The mission of the OECD is to promote policies that will improve the economic and social well-being of people around the world. Today, 34 countries are members of the OECD, while many other countries, such as Brazil, China, India and South Africa, are strengthening their cooperation with the OECD through a process of enhanced engagement.

The bioeconomy, a well-spread concept within the OECD

At the OECD, the bioeconomy is the remit of several different groups. Under the Council of Ministries, there are approximately 25 committees and beneath them several working groups. Currently, the Working Party on Bio-, Nano- and Converging Technologies (BNCT) is working under the Committee for Scientific and Technological Policy (CSTP) and the Joint Working Party on Agriculture and the Environment (JWPAE) is working under the Committee for Agriculture (COAG). The Working Group for the Harmonisation of Regulatory Oversight in Biotechnology (WGHROB) also takes an interest in the bioeconomy, but from a regulatory point of view.

The CSTP was recently restructured. Until the end of 2014, it included the Global Science Forum (GSF), the Working Party of National Experts on Science and Technology Indicators (NESTI), the Working Party on Innovation and Technology Policy (TIP), the Working Party on Research Infrastructures and Human Resources (RIHR), the Working

Party on Biotechnology (WPB) and the Working Party on Nanotechnology (WPN). Two task forces were installed under the aegis of the WPB: the Task Force Industrial Biotechnology (TFIB) and the Task Force Biotechnology in Health (TFBIH).

With the 2015 restructuring, the RIHR was abandoned and its tasks transferred to the TIP and the parent committee. WPB and WPN were merged into the Working Party on Bio-, Nano- and Converging Technologies (BNCT). The task forces TFIB and TFBIH were also drawn into the BNCT, providing a simpler structure and with the aim of easier governance. The BNCT does not oversee any sub-groups but conducts projects, and so bioeconomy activities shifted from an institutional to a project base. The new structure brought increased flexibility and the possibility of dealing with resources more easily, which is a fundamental issue at the OECD; it has 2 500 people in the Secretariat and approximately 40 000 experts and delegates that are only partly financed by the membership fees. On the downside, it caused a loss of visibility within the bioeconomy community.

The bioeconomy in OECD: policy recommendations and scientific events

The BNCT had its inaugural meeting in May 2015. The remit of the group is focused on policy issues in emerging technology fields related to bio-, nano- and converging technologies. Its aim is to contribute original policy analysis and messages to the global community and to make ground-breaking proposals to policy makers, enabling the OECD to act as a think tank and provide policy recommendations. Its recommendations are not legally binding, but if the recommendations are adopted, there is some sort of general consensus to implement them, so they are considered to be ‘soft law’.

The OECD itself does not normally have the resources to carry out original research, but it produces reports from desk research, including scientific events such as workshops, to aggregate available advanced information; it undertakes collation and distribution, and disseminates the information to policy makers.

The BNCT’s most recent activities that are related to the bioeconomy included participation to the following scientific events:

- the workshop on Present and Future Policy for Bio-Based Production (Turin, October 2014);
- the Workshop on Biowaste Biorefineries (Ecomondo, Rimini, November 2015), which included the presentation of pilot projects;
- the Workshop on Bioeconomy Policy Analysis (in the framework of the Global Bioeconomy Summit, Berlin, November 2015) (Schintlmeister, 2015);

The Berlin workshop included a session on international policy comparison, bringing new, particularly interesting insights from countries that are not normally around the table, for example Thailand and Kenya, that can bring new visions of the bioeconomy. Brazil participated actively, describing its prospective bioeconomy and, in particular, the role of industrial biotechnology, as the most promising vector for Brazil’s reindustrialisation. Various reports were prepared on current work streams and the Secretariat is currently collating the results of these workshops and preparing them for declassification (planned by the second half of 2016). All the resulting publications will be available at the OECD webpage (http://www.oecd-ilibrary.org); this includes both technical publications, for example on synthetic biology, and more policy-related reports, for example on bioeconomy policies (OECD, 2013, 2014b, a).

Sustainability and biotechnology: highly relevant to the bioeconomy agenda of the OECD

Currently, the OECD is very focused on work streams that are related to sustainability; this has already been at the forefront of the discussion for a couple of years, particularly as there is still no internationally agreed definition of sustainability. In the framework of the bioeconomy, one work stream concerns biomass sustainability and the purpose of reconciling food security with industrial uses. An OECD platform for biomass sustainability is currently being planned. Another relevant work stream in the context of the bioeconomy concerns Biorefinery Models and Policy and relates to financing biorefineries that employ alternative feedstock sources (e.g. bio-waste) for second-generation fuels and materials. Finally, another relevant work stream concerns industrial biotechnology, and, in particular, support to enable bio-based materials policy, convergence of industrial biotechnology with green chemistry and education, training and capacity building in industrial biotechnology.

The OECD works in biannual work plans and, at the time of the workshop, the planning for the 2017–2018 projects was ongoing. One relevant topic proposed for the new biennium concerns achieving sustainable growth in the bioeconomy, through standardising sustainability in bio-based products, challenges and opportunities of using gene editing (CRISPR/Cas9) for a sustainable bioeconomy and building up the OECD Biomass Sustainability Platform. Another important topic concerns harnessing converging technologies for the next production revolution, by integrating sustainability into policy assessment frameworks. Topics and budget are to be approved by CSTP as the parent committee and the Budget Committee during 2016.

From a more general point of view, within the scope of the bioeconomy, certain policy issues are recurrently debated in the OECD, including the definitions of sustainability, the public notion of bio-based versus biodegradable products, the innovative use of renewable resources ('replacing the oil-barrel'), (financial) incentives for innovative bio-refineries, particularly pilot and demonstration plants, possible measures to overcome regulatory obstacles and hurdles stifling innovation, necessary economic viability of bio-based products in relation to the oil price, inherent competition of material versus energetic use of biomass, competition for high-quality waste and public acceptance of innovative products.

Conclusions of the Workshop

The workshop entitled 'A global view of bio-based industries: benchmarking and monitoring their economic importance and future developments', organised in the framework of the EU–Brazil Sector Dialogues, brought together relevant experts from the EU, the USA, Canada and Brazil to describe the strategies that are in place in their own countries concerning the bioeconomy and the initiatives taken so far to measure this sector and understand its socio-economic relevance. The specific focus was on the most innovative bio-based industry and the emerging issues for its precise measurement and analysis. The workshop provided a forum for the exchange of information about different scopes within the broad concept of the bioeconomy, different needs for specific data and indicators and different methodologies developed to address needs.

Different national strategies of bioeconomy…

In the EU, the definition of the bioeconomy refers to the use of biomass in the food, feed, bio-based products and bioenergy sectors, independently of the processing technologies employed in production. A strategy that was specifically dedicated to the bioeconomy was established in 2012 (EC, 2012) and is currently being revised. The main objectives and drivers of the growing bioeconomy in Europe are environmental sustainability, climate change and reduction of dependence on fossil resources. The strategy aims to improve investments in research and innovation (R&I), reinforce policy interaction and stakeholder engagement and enhance the market and competitiveness in the bioeconomy sectors. Because of the diversity of the bioeconomy, the EU bioeconomy strategies that have been adopted by different MSs are still quite heterogeneous, though their common purpose is to reach policy coherence in this sector between bioeconomy-related policies.

The US definition of bioeconomy includes both the replacement of fossil resources by biomass-based feedstock sources and the use of biotechnology tools (both in industrial and medical fields) in the manufacturing process, independently of the feedstock used. The 2012 National Bioeconomy Blueprint (White House, 2012) describes five strategic objectives: support R&D investments, facilitate the transition of bioinventions from the research lab to the market, develop and reform regulations to reduce barriers, update training programmes, and identify and support opportunities for the development of public–private partnerships and precompetitive collaborations. Specifically for bio-based products, the BioPreferred program was developed in 2002 with the aim of identifying new markets for bio-based products and it is characterised by two major elements: the Mandatory Federal Purchasing and the Voluntary Labelling Program.

Canada defines the bioeconomy as the economic activity associated with the invention, development, production and use of products and processes that are based primarily on biological resources and it is a multidisciplinary field that cuts across health, energy, agriculture, chemicals and materials industries. Therefore, the scope of the national bioeconomy is broader that in the EU and is apparently more in line with the USA. However, Canada has not yet adopted a federal bioeconomy strategy, although it has a strategy for renewable energy in 2006 and an agricultural strategy ('growing forward') for 2013 (Bioökonomierat, 2015).

Brazil has based its definition of the bioeconomy on the application of biotechnology within different sectors, not only in the agricultural and industrial fields, but also in the health sector. Brazil has not put in place a specific strategy for the bioeconomy, but is constantly updating its legal framework on biotechnology, which includes different policies for product development and R&D incentives. A specific Observatory for Innovation and Biotechnology (OIB) was created in 2014 by the Ministry of Science, Technology and Innovation (MCTI) with the aims of exploring opportunities and mapping challenges for technological development in biotechnology, conducting the international benchmarking of technologies of interest, evaluating the market potential of developed (and developing) technologies and identifying bottlenecks and opportunities to minimise the risks associated with innovation in biotechnology (http://sectordialogues.org/en/acao-apoiada/establishment-biotechnology-innovation-observatory-brazil-and-its-interaction-european).

The differences in the scopes and strategies described for each country make it more complex to compare the data available that describe the bioeconomy. For benchmarking activity, a harmonisation in scope and methodologies for data collection would be desirable. However, these differences are based on differences in political priorities in each country and therefore a direct comparison of bioeconomy sectors is difficult because of the different definitions and scope.

… but a common interest in measuring the bioeconomy…

Despite the different scopes, a clear common interest emerged during the workshop related to measuring and monitoring the bioeconomy sector. Several organisations in each country are in charge of developing the appropriate tools for this objective. In the EU, the Bioeconomy Observatory, composed of members of the JRC (https://biobs.jrc.ec.europa.eu), is collecting reference data and analyses related to the bioeconomy to supply policy makers and stakeholders. In parallel, other EU groups are also collecting data on the bioeconomy and, in particular, on the bio-based material sector. These groups include the European Commission itself, the RRM, the BBI-JU, industry associations (such as CEFIC), consultancy groups (such as the nova-Institute), universities (such as WUR) and organisations at MS level (such as the Netherlands Enterprise Agency). As reported during the workshop, the USDA is collecting data for the US Congress on the bio-based products industry, and AAFC and Statistic Canada are collecting data on bioproducts for the Canadian government. In Brazil, the recently created Observatory on Biotechnology will soon start to collect data, in cooperation with the EU Bioeconomy Observatory.

A common issue that emerged in all countries is the lack of data for the most innovative sectors of the bioeconomy, which are bio-based chemicals and composites. The reasons for the data gap are related to the recent development in most products, including new products and those that are more normally obtained from fossil resources, and therefore the fact that no specific codes have yet been developed for bio-based products in official statistics (i.e. no NACE codes in the EU or NAICS codes in the USA). Additionally, bio-based chemicals and composites are produced in very complex value chains with product categories that can include hundreds of different products, from intermediates and final products. Therefore, it would represent a huge bureaucratic burden to create specific codes for each product.

In the EU, estimates are being collected by experts from the industrial sectors involved. The first concrete step towards specific data collection in the sector of bio-based chemicals and composites was represented by the survey conducted in 2015 by the JRC in the framework of the Bioeconomy Observatory (Nattrass *et al.*, 2016). Canada has taken a similar approach by conducting industry surveys on bioproducts with a three-year interval between surveys since 2003. However, each year has presented different challenges in terms of definitions and scope and the rate of evolution of the industry has meant that the methodology has been modified for each survey, rendering the data comparison among years also complicated. Brazil is planning to run the Bioeconomy Observatory on biotechnology and conduct similar exploratory work, although this is not yet in place.

The USA performed a study mandated by the 2014 Farm Bill to analyse the economic impact of the US bio-based products industry. The study examined and quantified the effect of the US bio-based products industry from economic and jobs perspectives and focused on agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest products and textiles. The approach taken to carry out the study was mainly threefold: collection of statistics, expert interviews and modelling analysis with IMPLAN.

… ideally with comparable indicators and reference data

In general, despite the differences in policy interests (for example the USA is driven by the requests of Congress and the EU is driven by the Commission), there are certainly common elements among the studies that have been conducted in the different countries, as presented at the workshop. The described methodologies for the analysis and monitoring of the bioeconomy in all participating countries include the collection of official statistics, industry surveys and modelling work. Certain indicators related to bio-based production, such as market size (in terms of sales or turnover) and, in particular, job creation, are certainly of common interest. If we could come to a harmonised definition of the scope of the studies, these indicators would allow benchmarking activity.

In contrast, the EU, compared with other countries, seems to have a stronger focus on certain elements, such as the analysis of the specific type of bio-based products produced, the type of feedstock used, its origin and the land area to produce it, which seems to be less problematic in the USA and Canada, and less of an issue in Brazil because of the size of the available areas.

Workshop participants also agreed on certain needs for the future studies in the bio-based sector. The sources of data should be improved to obtain indicators and data that are more precise; for example, specific official databases or codes would be a move in the right direction. In the meantime, it would be desirable to have a reference set of data, at least in the EU, to which everybody would refer, with the aim of avoiding the proliferation of different parallel studies with similar, overlapping scopes. Finally, in terms of the need for more data, the potential for innovation should be better characterised, both in term of technological potential (i.e. through patent analysis) and in terms of possible investments in R&D, from both the private and public side.

In conclusion, the relevance of the workshop as starting point for international communication on the topic of bio-based products was highly appreciated. Unifying principles for a global bioeconomy should be put in place by international policy bodies (El-Chichakli *et al.*, 2016). The event confirmed the usefulness of a structured dialogue between countries and the need for continuing with this type of initiative, for example through the proposed International Bioeconomy Forum (IBF).

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List of Abbreviations

AAFC	Agriculture and Agri-food Canada
ABBI	Brazilian Industrial Biotechnology Association
APAG	European Oleochemicals and Allied Products Group
ASTI	Agricultural Science and Technology Indicators
BBI-JU	Bio-based Industries Joint Undertaking
BDO	Butanediol
BIC	Bio-based Industries Consortium
BIO-TIC	FP7 European-funded project on Industrial Biotechnology
BLUM	Brazilian Land Use Model
BNCT	OECD Working Party on Bio-, Nano- and Converging Technologies
BNDES	Brazilian Development Bank
CAP	Common Agricultural Policy
CAPEX	Capital expenditure
CEFIC	European Chemical Industry Council
CEN	European Committee for Standardization
Cepea	Brazilian Center for Advanced Studies on Applied Economics
CGE	Computable general equilibrium
CHP	Combined heat and power
CNB	National Committee on Biotechnology of Brazil
CNI	National Confederation of Industry Brazil
CNPq	National Council for Scientific and Technological Development of Brazil
COAG	Committee for Agriculture
COP 21	2015 United Nations Climate Change Conference
CSTP	Committee for Scientific and Technological Policy
CTBE	Brazilian Bioethanol Technology Centre
DG-RTD	Directorate-General for Research & Innovation of the European Commission
Dieese	Brazilian Inter-Union Department of Statistics and Socio-Economic Studies
DLUC	Direct land use change
EC	European Commission
ECSPP	European Chemical Site Promotion Platform
EHEC	Enterohaemorrhagic Escherichia coli
Embrapa	Brazilian Agricultural Research Corporation
ESALQ	College of Agriculture "Luiz de Queiroz" of USP
ESIFs	European Structural and Investment Funds
ETS	Emissions Trading System
EU	European Union
FADN	Farm Accounting Data Network
FAO	Food and Agriculture Organization of the United Nations
INPI	Brazilian national institute of intellectual property
JRC	Joint Research Centre
JWPAE	Joint Working Party on Agriculture and the Environment
LCA	Life Cycle Assessment
LCFS	California Low Carbon Fuel Standard Program
LEI	Agricultural Economics Institute of WUR
LMI	Lead Market Initiative
LQ	Location quotient
LUC	Land use change
MAGNET	Modular Applied General Equilibrium Tool
MCTI	Brazilian Ministry of Science, Technology and Innovation
MISTIC	Maximum Incremental Social Tolerable Irreversible Costs
MMA	Brazilian Ministry of the Environment
MS	European Member State
MSW	Municipal solid waste
NACE	Statistical classification of economic activities in the European Community
NAICS	North American Industry Classification System
NESTI	Working Party of National Experts on Science and Technology Indicators
NGO	Non-governmental organization
NIH	US National Institutes of Health
OECD	Organisation for Economic Co-operation and Development
OIB	Brazilian Observatory for Innovation and Biotechnology
PE	Partial equilibrium
PE	Polyethylene
PJ	Petajoule
PLA	Poly-lactic acid
PLUC	PCRaster Land Use Change model
PPP	Public-Private Partnership
Prodcom	Eurostat database of statistics on the production of manufactured goods
PSE	OECD's Producers Support Estimates
R&D	Research & Development
R&I	Research & Innovation
RED	Renewable energy directive
RFS	Renewable Fuels Standard
RIHR	Working Party on Research Infrastructures and Human Resources
RRM group	Renewable Raw Materials group
RTRS	Round Table for Responsible Soy
SAE-PR	Strategic Affairs Secretariat, of the Brazilian Presidency Office

FDA	Food and Drug Administration	SAT BBE	Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy
FEDIOL	European Vegetable Oil & Proteinmeal Industry	SME	Small and medium-sized enterprises
FINEP	Brazilian Innovation Agency	TFBIH	Task Force Biotechnology in Health
FP	Federal Purchasing	TFIB	Task Force on Industrial Biotechnology
FP7	Seventh Framework Programme	TFP	Total factor productivity
FTA	Free trade agreement	TIP	Working Party on Innovation and Technology Policy
GDP	Gross domestic product	TRL	Technology Readiness Level
GHG	Greenhouse gas	UCO	Used cooking oil
GM	Genetically modified	UK	United Kingdom
GSF	Global Science Forum	UN	United Nations
GTAP	Global Trade Analysis Project	US	United States of America
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources	USD	US Dollars
IBF	International Bioeconomy Forum	USDA	US Department of Agriculture
IBGE	Brazilian Institute of Geography and Statistics	USP	São Paulo University
ICONE	Institute for International Trade Negotiations from Brazil	VCI	German Chemical Industry Association
ICT	Information and Communication Technologies	WGHROB	Working Group for the Harmonization of Regulatory Oversight in Biotechnology
ILUC	Indirect land use change	WPB	Working Party on Biotechnology
IMPLAN	IMpact analysis for PLANning data and software	WPN	Working Party on Nanotechnology
INDC	Intended Nationally Determined Contribution	WUR	Wageningen University and Research Centre

Annexes

Annex I – List of participants to the Workshop

Non-EU participants		
Participant	**Country**	**Affiliation**
Luiz Henrique Mourão do Canto Pereira	Brazil	MCTI - Ministério da Ciência, Tecnologia e Inovação
Maguida Silva	Brazil	MCTI - Ministério da Ciência, Tecnologia e Inovação
Geraldo B. Martha Jr	Brazil	Embrapa - Brazilian Agricultural Research Corporation
Bernardo Silva	Brazil	ABBI - Brazilian Industrial Biotechnology Association
Cecília Oliveira	Brazil	IBICT - Brazilian Institute for Information in Science and Technology
Samuel Bonti-Ankomah	Canada	AAFC - Agriculture and Agri-Food Canada
Marie Wheat	US	USDA - US Department of Agriculture
EU participants		
Peter Schintlmeister	Austria	Federal Ministry of Science, Research and Economy of Austria
Servet Goren	Belgium	CEFIC - European Chemical Industry Council
Dirk Carrez	Belgium	BBI - Bio Based Industries Consortium
Christophe Luguel	France	Pôle Industries & Agro-Ressources
Michael Carus	Germany	Nova-Institut
Dietrich Wittmeyer	Germany	ERRMA - European Renewable Resources and Materials Association
Tilman Benzing	Germany	VCI - German Chemical Industry Association
Daniela Thrän	Germany	German Bioeconomy Council
Claudia Parisi	Italy	Expert
Kees W. Kwant	The Netherlands	Netherlands Enterprise Agency
Hans van Meijl	The Netherlands	LEI Wageningen UR
Justus Wesseler	The Netherlands	LEI Wageningen UR
EC participants		
Xavier Vanden Bosch	DG-RTD	
Tomasz Calikowski	DG-RTD	
Michael Klinkenberg	JRC.H.6	
Leticia Landa	JRC.H.6	
Candela Vidal Abarca Garrido	JRC-IPTS	

Emanuele Ferrari	JRC-IPTS
Emilio Rodríguez-Cerezo	JRC-IPTS
Mauro Cordella	JRC-IPTS
Renata Kaps	JRC-IPTS
Robert M'Barek	JRC-IPTS
Tevecia Ronzon	JRC-IPTS
Oliver Wolf	JRC-IPTS

Annex II - Agenda of the Workshop

EU-Brazil Sector Dialogues Workshop

"A global view of bio-based industries: benchmarking and monitoring their economic importance and future developments"

18–19 February 2016

European Commission (EC), Joint Research Centre (JRC)
Institute for Prospective Technological Studies (IPTS)
Unit "Agriculture and Life Sciences in the Economy" (AGRILIFE)

Venue: JRC-IPTS, Isla de la Cartuja, Edificio Expo, 1st floor, Room A30, c/ Inca Garcilaso 3, Seville, Spain

AGENDA

DAY 1: 18 FEBRUARY 2016		
INTRODUCTORY SESSION: POLICY SETTING		
14:00 – 14:20	Welcome address & Tour de Table	**Emilio Rodríguez-Cerezo** European Commission JRC-IPTS
14:20 – 14:40	The Bioeconomy Strategy in the EU	**Xavier Vanden Bosch** European Commission DG-RTD
14:40 – 15:00	Bioeconomy in Brazil: An overview	**Luiz Henrique M. do Canto Pereira** Ministry of Science, Technology and Innovation of Brazil (MCTI)
15:00 – 15:30	**Coffee Break**	
SESSION 1: DATA COLLECTION AND ANALYSIS ON THE EU BIO-BASED INDUSTRY *Chair: Emilio Rodriguez-Cerezo; European Commission JRC-IPTS*		
15:30 – 16:00	Quantifying the European Bioeconomy	**Michael Carus** Nova-Institute (Germany)
16:00 – 16:25	The 2015 Survey of the EU Bio-Based Industry	**Emilio Rodríguez Cerezo** European Commission JRC-IPTS

16:25 – 16:50	Measuring the Bio-Based Products Value Chain: Available Data	**Dietrich Wittmeyer** Renewable Raw Materials Group (RRM)
16:50 – 17:05	Measuring Bio-Based raw materials use in the EU chemical industry	**Tilman Benzing** European Chemical Industry Council (CEFIC)
17:05 – 17:20	Biotechnology Challenges in Terms of Technology, Regulation and Market Development in the Context of the European Bioeconomy	**Dirk Carrez** Bio-based Industries Consortium (BBI)
17:20 – 17:35	Monitoring the Bio-based Economy in the Netherlands	**Kees W. Kwant** Netherlands Enterprise Agency
17:35 – 18:00	**General Discussion**	
18:00 – 18:15	**Closing of day 1 and announcements**	
20:30	**Departure to dinner from Hotel NH Plaza de Armas (lobby)**	

DAY 2: 19 FEBRUARY 2016

SESSION 2: BENCHMARKING WITH NON-EU DATA COLLECTION ACTIVITIES

Chair: Geraldo B. Martha Jr , EMBRAPA, Brazil

	Activities on data collection and analysis on the bio-based industry sector outside the EU	
09:00 – 09:20	The USDA BioPreferred Program: an economic impact analysis of the US bio-based industry	**Marie Wheat** US Department of Agriculture (USDA)
09:20 – 09:40	Canadian industrial bioproducts production and development survey	**Samuel Bonti-Ankomah** Agriculture and Agri-Food Canada (AAFC)
09:40 – 10:00	Brazil – Building a leader of the Bioeconomy – Industrial Biotechnology as a vector of sustainable development	**Bernardo Silva** Brazilian Industrial Biotechnology Association (ABBI)
10:00 – 10:20	Biotechnology and agricultural value chain in Brazil: Development and future prospects	**Geraldo B. Martha Jr** Brazilian Agricultural Research Corporation (Embrapa)
10:20 – 11:00	**General Discussion**	
11:00 – 11:30	**Coffee Break**	

SESSION 3: SOCIO-ECONOMIC IMPACTS OF EU BIOECONOMY *Chair: Robert M'Barek; European Commission JRC-IPTS*		
11:30 – 11:50	Modelling bio-based sectors in the global CGE model "MAGNET"	**Hans van Meijl** LEI Institute Wageningen University (The Netherlands)
11:50 – 12:10	Drivers of the European Bioeconomy in Transition	**Emanuele Ferrari** European Commission JRC-IPTS
12:10 – 12:30	Measuring the EU Bio-based Economy: some methodological issues	**Justus Wesseler** Wageningen Univeristy (The Netherlands)
12:30 – 13:00	**General Discussion**	
13:00 – 14:00	**Lunch break**	
SESSION 4: THE WAY FORWARD: HOW TO MEASURE PROGRESS OF THE BIOECONOMY *Chair: MCIT*		
14:00 – 14:30	The European Bio-based Industries Initiative - Public-Private Partnership: new business models to create impact in the bio-based industries	**Dirk Carrez** Bio Based Industries Consortium (BIC)
14:30 – 14:50	Bioeconomy in the OECD	**Peter Schintlmeister** Federal Ministry of Science, Research and Economy of Austria
14:50 – 15:10	**General Discussion**	
CLOSING OF WORKSHOP		
15:10 – 16:00	**Closing of the workshop** - Next steps - Final word	**Emilio Rodríguez-Cerezo** European Commission JRC – IPTS **Luiz Henrique do Canto** Ministry of Science, Technology and Innovation of Brazil (MCTI)
16:00 – 16:30	**Final Coffee**	

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