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Bio-economy and sustainability: a potential contribution to the Bio-economy Observatory

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Contents

Abstract

In response to the need for further clarifications concerning the emerging concept of the "bio-economy", the present study scrutinizes this concept in order to better delineate its analytical scope. It also describes methodologies of potential relevance to evaluation and monitoring of the bio-economy. Although not directly intended to prepare the ground for the future EU Bio-economy Observatory (BISO), the material presented herein may also meaningfully inform the design of monitoring activities which will be undertaken within the BISO framework.

The introductory section sheds light on the bio-economy's multi-dimensional nature, scope, drivers, challenges and economic potential. In order to clearly distinguish between their specific features and coverage, a comparative description of eco-industries versus the bio-economy is included here.

The current EU policy approach to the bio-economy is sketched in the second section of this study.

With the purpose of defining the bio-economy's scope and its internal flows, the third section advances an integrated analytical perspective on the EU bio-economy. This perspective builds upon descriptions provided in the related Commission documents. Its potential use in support of the future Bio-economy Observatory is elaborated, together with several associated methodological aspects.

In the fourth section, the existing datasets, methods and models which could be used for measuring and monitoring the bio-economy's drivers, development and impact are identified and grouped into five interrelated methodological modules.

Further methodological clarification is provided as to i) the need for complementing a sectoral approach to the bio-economy with other perspectives, including the product-chain approach, and ii) the usefulness of inventory data from the European Commission's life-cycle based resource efficiency indicators. Other relevant data sources are also described. In addition, in light of the limited availability of statistical

data on new bio-based products and processes, the need for further disaggregated product-level statistics for bio-based products and company-level research is also discussed.

Current standardization and research activities on issues such as harmonization of sustainability certification systems for biomass production, conversion systems and trade, sustainability assessment of technologies, and environmental performance of products are reviewed in the fifth section.

Based on the observation that it would be impossible to obtain all required data for bio-economy monitoring from official statistical sources, we propose in the sixth section a general-purpose questionnaire which could serve as a basis for prospective surveys. It is intended to be further refined and adjusted, in collaboration with the sector-relevant European technology platforms and industry associations and other relevant stakeholders, according to the specific profile of each sector, product group or firm type to be included in any future surveys.

1. Setting the scene

The emerging bio-economy turns out to be a dynamic complex phenomenon[1]. Since the bio-economy is cross-sectoral in nature and influenced by a wide range of inter-connected global drivers and constraints, understanding and managing the bio-economy phenomenon requires an integrated multi-dimensional approach. Existence of interrelated, various-scale effects, feedback loops, limitations in estimating both the multiple relationships between the bio-economy sector and the rest of the economy and its overall impact call for an integrated assessment and monitoring of bio-economy development (e.g. Langeveld *et al.*, 2007). This must include analytical and methodological tools appropriate to comprehensively assessing and monitoring its development. As a prerequisite, it requires: i) identifying the applicable "type of knowledge" (Palmer, 2012); ii) defining its inherent uncertainty areas (e.g. unknown time-scale and space-scale implications of the bio-based transitions); and iii) avoiding misplaced objective evidence in choosing its variables.

Hence several questions are of immediate interest, including: i) how best to characterize bio-economy's structure, scope and relationships to the rest of the economy; ii) what data, methods and models are to be used for its measurement and modelling and what are their application limitations; iii) what is its (current and future) global impact on environmental and development processes - i.e. to some extent, similar to the debate on the effects of first generation biofuels production on food prices and indirect land use changes; and iv) what will be its long-term aggregated impacts on society? For answering these questions, applying the traditional fragmented perspectives (e.g. sectorial or disciplinary) must be subsequently complemented with practical trans-disciplinary assessment frames

[1] A detailed description of the sources of dynamic complexity and characteristics of complex dynamic systems is provided by Sterman (2001).

borrowed, for example, from complex system theory, systems thinking or post-normal science[2].

Today, transition from a fossil-based economy to bio-economy is justified by the need of an integrated response to several global mega-trends such as:

i) food security concerns induced by the fast-growing global population and higher life expectancy, and the consequent rise of food and feed production and demand (according to Food and Agriculture Organization, plus 70% by 2050);

ii) high dependence on fossil-based resources and need of strengthening energy security, which call for a more diversified supply option range;

iii) increasing demand of biological resources for bio-based products;

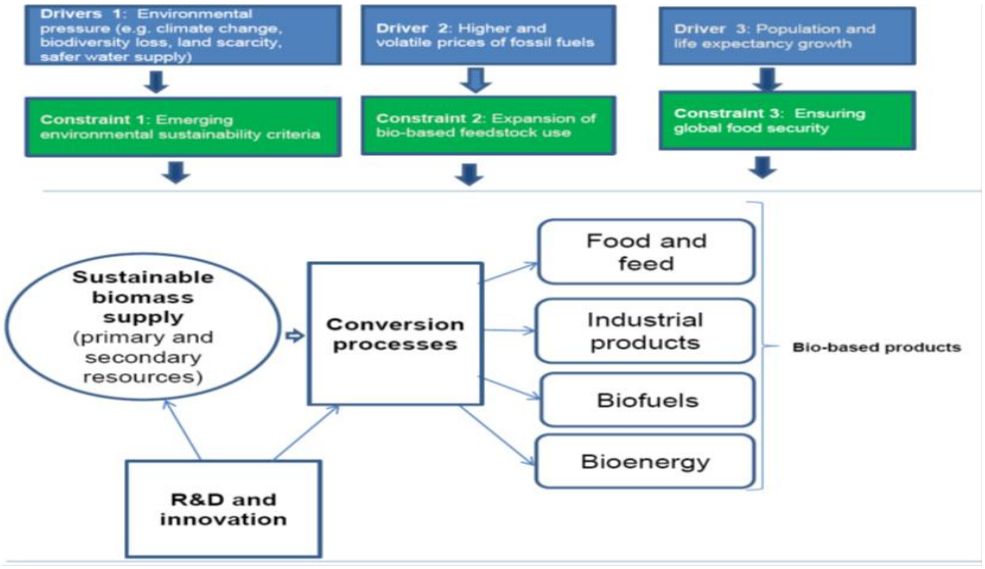
iv) increasing sustainability concerns (e.g. GHG emission reduction, moving towards a zero-waste society, environmental sustainability of primary production systems, increasing land use competition, etc.)[3].

In order to tackle all of these inter-connected global drivers and constraints (*Figure 1*), an integrated management of renewable biological resources in agriculture, food, bio-based and energy industries appears to be the most desirable.

[2] This will not be an unproblematic research endeavor. As Ravetz (2006) points out, "the systems approach provides a practical framework for comprehending how everything connects to everything. But at the same time, through its reminder of the incommensurability of various system levels (and also from one system to others), the systems approach explains how each part can seem totally alien to any other … Hence a problematic feature intruding from somewhere else in the total system is very easily ignored, suppressed or denied."

[3] In response, environmental, social and economic costs and benefits of bio-economy development (e.g. contribution to climate change and direct and indirect land use change; impact on food security; net return on investment) need continuous monitoring.

Figure 1: ***Global drivers and constraints conducive to bio-economy transition***



In order to clarify their specific meaning, features and coverage, a comparative description of eco-industries versus bio-economy is presented in *Table 1*.

Table 1: ***Comparative description of eco-industries versus bio-economy***

	Environmental industries	**Bio-economy**
Definition and coverage	"Eco-industries" cover a wide range of activities related to the measurement, prevention or minimization, and correction of environmental damage, ranging from equipment and services for pollution and waste management to the development and provision of better technologies. The scope of environmental goods and services sector (EGSS) is defined by OECD/Eurostat (1999) as including: "activities which produce goods and services to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems. This includes technologies, products, and services that reduce environmental risk and minimize pollution."	"The bio-economy provides a useful basis for such an approach, as it encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy". Bio-economy includes agriculture, forestry, fisheries, food, pulp and paper production, plastics, as well as parts of chemical, biotechnological and energy industries (EC's Bio-economy Strategy and its related Action Plan).
Relevant EU policy documents	- 2004 Environmental Technologies Action Plan; - Implementing the Community Lisbon Programme: A Policy Framework to Strengthen EU Manufacturing - towards a more integrated approach for Industrial Policy - COM(2005) 474; - Action Plan on Sustainable Consumption and Production and Sustainable Industrial Policy (SCP-SIP) COM(2008) 397 final; - Industrial Policy: Reinforcing competitiveness, COM(2011) 642 final; - "An industrial policy for the globalization era"	- EC's communication "Roadmap to a Resource Efficient Europe", COM(2011) 571 final; - EC's communication "Innovating for Sustainable Growth: a Bio-economy for Europe", COM(2012)60 (February 2012) and its accompanying Action Plan; - European Framework Programme for Research and Innovation "Horizon 2020" (2014-2020).

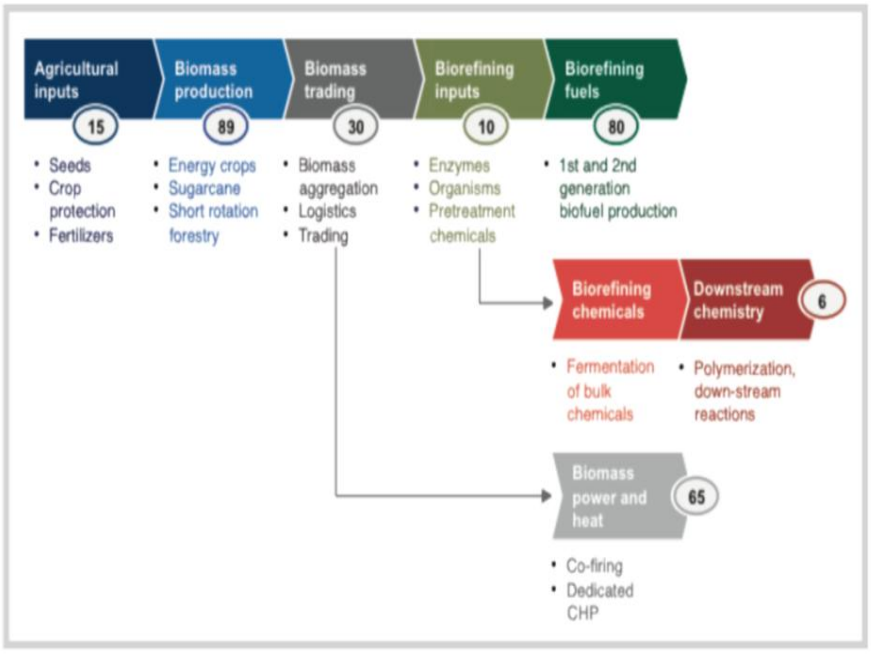
	- Waste Framework Directive - Roadmap to a Resource Efficient Europe, COM(2011) 571 final	
Key characteristics	- diversity of sectors, sub-sectors and activities; - include sectors/sub-sectors with different innovation and technological potential; - complexity of the interactions within and across the supply chains; - blurring boundaries between eco-industries and conventional industries and a strong interdependence between eco- and conventional manufacturing activities; - segmentation of activities.	- due to the bio-economy's cross-cutting nature, it entails addressing inter-connected socio-economic challenges – e.g. food security, natural resource scarcity, fossil resource dependence and climate change – in a comprehensive manner. - bio-economy covers multi-dimensional and potentially conflicting issues; it must therefore optimize resource allocation whilst simultaneously reconciling food security concerns with the sustainable use of renewable resources for industrial purposes and environmental protection; - research and innovation as the cornerstone of the bio-economy - its sectors have a strong innovation potential due to their use of a wide range of sciences (life sciences, agronomy, ecology, food science and social sciences), a wide range of technologies (biotechnology, nanotechnology, ICT, etc.); - diversity of sectors, sub-sectors and activities; - include sub-sectors with different innovation and technological potential; - complexity of the interactions within and across the supply chains; - blurring boundaries between bio-economy sectors and traditional ones;
Objectives	**Main goal**: Transition towards a sustainable, resource-efficient and low-carbon economy by greening existing industries. **Specific objectives**: - Improving the energy and raw material efficiency and pollution management of the industry (SCP-SIP); - To favor their uptake by traditional industries and thereby further the competitiveness of environmental industries; - Identifying regulatory barriers and market failures that hamper the competitiveness of environmental industries and their uptake by other sectors of the economy - Promoting eco-innovation and deployment of cleaner technologies along value chains for improving both the design of products and the efficiency of production processes, resulting in a decreasing environmental impact; - Promoting international trade and opening up new markets in environmentally friendly goods and services; - Creating new jobs in sectors linked to sustainable growth and with high potential for exports and value added;	**Main goals:** - reducing the dependency of EU's economy on fossil resources and mitigating climate change - satisfying Europe's need of renewable biological resources for secure and healthy food and feed, as well as for materials, energy, and other products; **Specific objectives:** - resource-efficient agriculture for sustainable production of renewable raw materials and alternative energy and carbon sources; - more sustainable industry and energy production;

Statistical scope	- The environmental industry sectors fall into two general categories, *pollution management* and *resource management*. They are distinct from the other groups of activities undertaken by enterprises engaged in environmental protection or resource management but whose activities cannot be regarded *in their entirety* as environmental protection or resource management. - OECD-Eurostat (1999) introduces a distinction between *core activity groups/eco-industries* and *connected activity groups/eco-industries* (eco-tourism, eco-construction, automotive, ICT, paper industry, chemicals). The core eco-industries (e.g. water supply; recycled materials; waste water treatment; solid waste treatment; soil & groundwater remediation; noise and vibration control; air pollution control; collection and treatment of waste and sewage (NACE 90); renewable energy; recycling/recycled materials (NACE 37); environmental equipment providers) are "those sectors within which the main – or a substantial part of – activities are undertaken with the *primary purpose of the production of goods and services* to measure, prevent, limit, minimize or correct environmental damage to water, air and soil, as well as problems related to waste, noise and eco-systems." - There are statistical and conceptual challenges, especially in relation to services and sectors not captured by existing classifications such as NACE. - On the other hand, according to Eurostat (2009), the environmental goods and services sector consists in a heterogeneous set of producers of technologies, goods and services that: i) measure, control, restore, prevent, treat, minimize, research and sensitize to environmental damages to air, water and soil as well as problems related to waste, noise, biodiversity and landscapes; this includes "cleaner" technologies, goods and services that prevent or minimize pollution; ii) measure, control, restore, prevent, minimize, research and sensitize to resources depletion; this results mainly in resource-efficient technologies, goods and services that minimize the use of natural resources. These technologies and goods and services must satisfy the *end purpose criterion*, i.e. they must have an environmental protection or resources management purpose (i.e. "environmental purpose") as their *prime* objective.	- The bio-economy encompasses: i) the production of renewable biological resources; ii) and their conversion into food, feed, bio-based products and bioenergy. - Bio-based products: "bio" refers to "renewable biological resources" and not to "biotechnology", i.e. to non-food products derived from biomass (plants, algae, crops, trees, marine organisms and biological waste from households, animals and food production). They exclude traditional bio-based products, such as pulp and paper, and wood products, and bio-mass as an energy source. - Bio-based products may range from high-value added fine chemicals such as pharmaceuticals, cosmetics, food additives, etc., to high volume materials such as general bio-polymers or chemical feed stocks. - As far as bio-fuels are concerned, it is essential to consider the linkages between the production of bio-fuels and bio-based products that could occur in "bio-refineries". The technologies to produce bio-fuels and bio-based products, or their intermediate chemical building blocks, follow the same principles. Bio-based products have the potential of reinforcing the economics and rapid introduction of bio-fuels and vice versa. Conventional paper and wood products are excluded even though these products are based on biomass, the reason being that for these products there are not the same kind of market failures that might be at hand for new bio-based products. However, wood based production is affected by the development of the bio-fuels demand and pulp and paper production plants have in principle the technical potential of becoming bio-refineries. The current forest-based industries can therefore be affected by the developments in lead markets for bio-based products. - Definition of „bio-based": 1. bio-based = derived from biomass; 2. biomass = material of biological origin excluding material embedded in geological formations and/or fossilized (DG Enterprise and Industry, Report on Mandate M/492). -Insofar as they have an explicit environmental purpose, bio-technologies can be classified as „integrated technologies"; -Insofar as they have an explicit environmental purpose (e.g. minimizing the use of non-

		renewable resources), bio-based products used as feedstock in industry, bio-energy and bio-fuel production can be classified as specific services, connected goods or „adapted goods". -Insofar as the purposes of the bio-based goods and services are to address societal challenges (e.g. health or food security) or opening new markets (e.g. food or pharmaceutics), the bio-based products do not fall into EGSS (Taskforce on Bio-based Products, 2007).
Importance	industrial value added; industrial competitiveness; eco-innovation and eco-efficiency; environmental protection; efficient resource management;	eco-)innovation; resource efficiency; competitiveness; food security; optimization of biomass production and use; supply diversification; environmental sustainability; rural development; job creation

According to the estimates of World Economic Forum (2010), i) biofuels markets are forecasted to more than triple by 2020; ii) combined US and EU27 demand for biomass in the fields of heat and power is expected to more than double by 2020; and iii) bio-based chemicals are expected increase their share in overall chemicals production to around 9% of all chemicals.

Figure 2: ***Estimated revenue potential of global biomass value chains by 2020 (US$ billions)***



Source: *WEF (2010)*

Currently, i) higher costs for and more complex value and production chains of bio-based products and ii) lack of clear environmental sustainability criteria and product quality standards for bio-based products limit their market uptake (Taskforce on Bio-based Products, 2007). Since the differences between costs of fossil-based feedstock and biomass in various applications are still significant (*Table 2*), putting bio-economy concept into practice requires, as called by Pontin (2012), a "convulsive collective effort". That means that more R&D investments, demonstration facilities and commercialization support for spurring alternative technologies helping biological resources compete with fossil-based raw materials must be complemented with solid institutions and regulation frameworks, public commitment and cooperation between policy makers, technology developers and business (Bio-based for Growth, 2012; Pontin, 2012).

Table 2: ***Comparative costs of fossil-based feedstock and biomass (€ per GJ end product)***

Product category	Fossil feedstock cost (€/GJ)	Biomass cost (€/GJ end product)
Heat	3 (coal)	4
Power	6 (coal)	22
Transport fuel	8 (oil)	10
Average bulk chemicals	30 (oil)	75

Source: *Langeveld et al. (2010)*

With an estimated annual turnover of about € 2 trillion and employing more than 22 million people and approximately 9% of the total EU workforce (DGRTD, 2012), the European bio-economy has a considerable economic significance (*Table 3* and *Table 4*).

Table 3: ***Estimated turnover and employment in EU bio-based industries***

Sector	Annual turnover (bil. €)	Employment (1000)
Forest	550-600*** (8% of GVA in manufacturing industry; 25-30% of world production of forest-based products)	3000-400 industrial jobs
Fisheries and aquaculture	32	500
Agriculture	168**** (1.6% of the total GVA)	12200**** (5.5 % of EU employment)
Food	965	4400
Pulp/Paper	375	1800
Starch	7.5	15.5
Sugar	14	28 employees; 161 beet growers
Bio-chemicals and bio-plastics	50*	150*
Enzymes	0.8* (64% of global production)	5*
Biofuels	6**	150
Total	**2078**	**22005**

Notes: *Estimation for Europe for 2009; **Estimation based on a production of 2.2 million tonnes bio-ethanol and 7.7 million tonnes of biodiesel at average market price in Europe; *** EU-25; **** in 2009.

Source: *DGRTD (2012)* and *Bio-based for growth (2012)*

Table 4: ***Estimated market capacity development for several bio-based products in Europe***

Bio-product category	Bio-products	Market volume "Bio" 2010 [1)]	Projected market volume "Bio" 2020 [1)] [2)]
Bio-based plastics (European Bioplastics)	Short-life/ disposable applications (PLA, PHA, Starch Blends, Cellulosics)	110.000	1.280.000
	Durable applications	150.000	
	Engineering Polymers		740.000
	Modified PLA, Cellulosics		
	Polyolefines (2012)		530.000
	Starch based alloys	not marketed	260.000
	TOTAL	**260.000**	**2.810.000**
Biodegradable and bio-based plastics (BASF SE)	Waste & shopping bags	30.000	260.000
	Tableware	3.000	33.000
	Bio mulch for agriculture	2.000	40.000
	TOTAL	**35.000**	**333.000**
Bio-lubricants (2008) (Fuchs Petrolub AG)	Hydraulic Fluids	68.000	230.000
	Chainsaw Lubricants	29.000	40.000
	Mould Release Agents	9.000	30.000
	Other oils	31.000	120.000
	TOTAL	**137.000**	**420.000**
Bio-composites (nova-Institut, 2012)	Compression moulding:		
	- with natural fibres	40.000	120.000
	- with cotton fibres	100.000	100.000
	- with wood fibres	50.000	150.000
	Extrusion and injection moulding		
	Wood Plastic Composites:	167.000	450.000
	- with natural fibres	5.000	100.000
	TOTAL	**372.000**	**920.000**
Bio-solvents [3)]	(2012)	**630.000**	[4)]
Bio-surfactants [3)]	(2012)	**1.520.000**	[4)]

1) In tons

2) All figures for 2020 are based on estimations

3) Figures by Industries & Agro-Ressources IAR

4) To be estimated by respective CEFIC sector groups

Source: *Busch & Wittmeyer, Current market situation 2010 and market forecast 2020.*

2. EU bio-economy policy context

Being an issue covering different EU policy areas, dealing with bio-economy policy calls for an integrated approach. In European Commission's perspective bio-economy's scope includes the production of biological resources (both from land and sea) and secondary biological resources (i.e. waste streams and by-products), and their conversion into value-added products, such as food, feed, bio-based products (e.g. bio-plastics and bioenergy (e.g. heating, cooling, power generation, biofuels). As far as the involved sectors are concerned, EU bio-economy encompasses agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries (DGRTD, 2012).

In the framework of the *EU 2020* Strategy for smart and green growth, in February 2012 the European Commission launched the Communication "*Innovating for Sustainable Growth: a Bio-economy for Europe*". This Communication presents a Bio-economy Strategy and an accompanying Action Plan for promoting a more sustainable use of renewable biological resources within the European economy. The aim of the strategy is to ensure continued supply of safe and healthy food and feed, as well as for materials, energy, and other products (DGRTD, 2012). Towards this end, management of the bio-economy would imply: i) optimizing resource allocation by addressing multi-dimensional and potentially conflicting issues (for example, the "food versus fuel" debate); ii) driving research and innovation in the primary production and processing sectors; iii) developing new industrial concepts and business models, and open new markets, iv) and the creation of new high-skill jobs.

EU bio-economy[4], having as driving forces research, development and innovation[5], is defined as all uses of biological renewable resources from land and sea as inputs to

[4] For a review of the preparatory steps leading to the final formulation of the EU Bio-economy Strategy, please see the Commission Staff Working Document accompanying the strategy (DGRTD, 2012).

the industry and energy sectors in the primary production[6] of renewable biological resources and the conversion of these resources into value added products, such as food, feed, bio-based products[7] and bioenergy. An integrated approach to managing the EU bio-economy is seen as essential to:

i) contributing to achieving the Europe 2020 objectives of smart and green growth;

ii) enhancement of EU economy's competitiveness by opening new or diversifying existing markets in food and other bio-based industries;

ii) reducing the EU economy's non-renewable resources dependence;

iii) increasing overall environmental sustainability in Europe, especially in the primary production sectors and industries based on biological feedstock;

iv) creating new high-skill jobs and enhancing welfare, especially in rural areas;

v) tackling societal challenges such as food security and health;

vi) reconciling the potential trade-offs between food and feed demand, and the industrial and energy uses of renewable biological resources (*Figure 3*);

vii) creating synergies with other EU policy areas, instruments and funding sources, such as the Common Agricultural and Fisheries Policies, the Integrated Maritime Policy, R&D, innovation, environmental, industrial, employment, energy and health policies;

viii) setting up a coherent framework for participative governance by bridging the information, knowledge and institutional gaps between science, policy, business environment and society.

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[5] EU's bio-economy scope is thus much more extended than that of bio-technology. According to Bio-economy Council Germany, bio-economy "encompasses precisely those areas which in English come under the headings of Food, Feed, Fibre and Fuel".

[6] Primary production sectors include agriculture, forestry, fisheries and aquaculture.

[7] Bio-based products are "non-food products derived from biomass (plants, algae, crops, trees, marine organisms and biological waste from households, animals and food production). Bio-based products may range from high-value added fine chemicals such as pharmaceuticals, cosmetics, food additives, etc., to high volume materials such as general bio-polymers or chemical feedstock. The concept excludes traditional bio- based products, such as pulp and paper, and wood products, and biomass as an energy source." They include: fibre-based materials; bio-plastics and other bio-polymers; surfactants; bio-solvents; bio-lubricants; ethanol and other chemicals and chemical building blocks; pharmaceutical products incl. vaccines; enzymes; cosmetics; etc. (Taskforce on Bio-based Products, 2007).

While having research and development at its core, EU bio-economy strategy aims also to reconcile sustainable agriculture, forestry and fisheries, food production and industrial use of biological feedstock. In addition, EU Bio-economy Strategy stresses the crucial importance of non-technological factors, such as wide stakeholder involvement and partnering [8], and the necessity of developing a coherently integrated EU policy framework for the bio-economy [9], including regional, agricultural[10], industrial, environmental and energy policy.

The Action Plan focuses on *three key pillars*:

i) Developing new technologies and processes for the bio-economy, by using R&D and innovation to produce renewable raw materials sustainably in agriculture, forestry, fisheries and aquaculture, and to process renewable raw materials into value-added products in the bio-based sectors.

ii) Developing markets and competitiveness in bio-based industries[11]. Concrete actions include support for: development of new markets and bio-based value chains, and commercialization of new bio-based products; demonstration plants and up-scaling facilities, and establishing R&D public-private partnerships[12].

iii) Collaboration between policymakers and stakeholders by means of a more co-ordinated bio-economy governance mechanism (i.e. including CAP, CFP; RTD and innovation; industrial policy and competitiveness; employment; energy and public

[8] That implies the involvement of all bio-economy-relevant technology platforms - http://cordis.europa.eu/technology-platforms/individual_en.html .

[9] That approach is made necessary by the fact that, as explicitly recognized in the Commission Staff Working Document accompanying the Bio-economy Strategy, "bio-economy encompasses sectors of the economy that are interrelated across the European geographical, economic, social, environment policy levels".

[10] As far as agriculture is concerned, in addition to decreasing productivity growth rates and meeting its own sustainability constraints, one of the intricacies needed to be resolved is to supply more feedstock for industry and energy feedstock without affecting the food and feed supply, while achieving other socio-economic objectives, e.g. rural development.

[11] Bio-based industries are industries, which either use renewable resources and/or apply bio-based processes (based on industrial biotechnology) in their production processes.

[12] *Copenhagen Declaration for a Bio-economy in Action*, March 2012.

health policies; EU environmental policies on: resource efficiency, sustainable use of natural resources and protection of biodiversity).

As explicitly stated in the European Commission's Bio-economy Strategy, it is necessary to "establish a Bio-economy Observatory in close collaboration with existing information systems that allows the Commission to regularly assess the progress and impact of the bio-economy and develop forward-looking and modelling tools" (DGRTD, 2012).

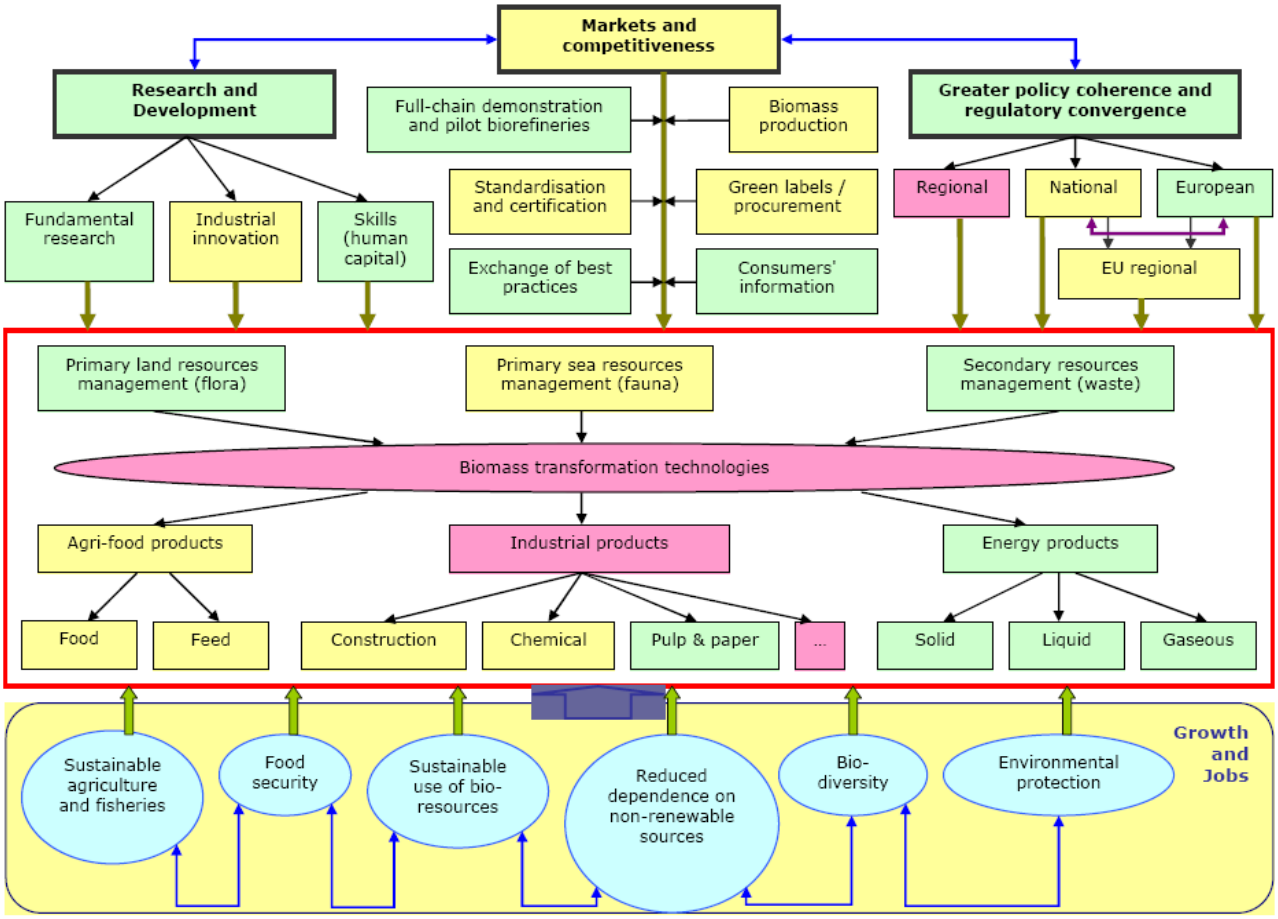
3. An analytical framework of the bio-economy

In order to monitor the EU bio-economy's progress, potential and impact, a structured, open-access data and information system is needed. It would bring together relevant data sets and information sources, and use assessment, modelling and forward-looking tools, in order to provide a coherent basis for establishing baselines, monitoring, and scenario modelling for the bio-economy as a whole.

The purpose of this section is to propose an analytical framework which could be used in the construction and subsequent monitoring activities of the future bio-economy data and information system. Based on a product-chain approach, the analytical framework put forward is intended to define the main bio-economy functional components and to elucidate the dynamic relationships between them. The main objective of the proposed analytical framework is to offer a coherent analytical informational basis for monitoring/evaluation the European bio-economy's potential, progress, and impact, as well as for developing appropriate indicators.

This analytical structure builds upon the description provided in the related Commission documents (DGRTD, 2012). As such, it aims to synthesize in a coherent framework, along with highlighting the links and interrelationship, the main points and priorities in the above-referenced policy documents. Depending on future policy developments and additional research work to be undertaken, this EU bio-economy concept will be further refined and complemented.

Figure 3: ***The proposed analytical framework of the EU Bio-economy***



The colour coding of the boxes in the middle and top sections of *Figure 3* (based on JRC expert judgment) indicates the likely level of difficulty in collecting data and/or information and/or making analyses. Specifically:

- Green - no major difficulties or challenges are likely;
- Yellow – difficulties or challenges are likely;
- Red – significant difficulties or challenges are likely.

The top section of *Figure 3* presents the priority elements as stated in the above Commission policy documents, where no formal description was provided in those documents. The aim of this section is to answer the question as to "what" the observatory should deal with. This question is directly connected to the following "where" question (explained above), at the same time being juxtaposed to the core

"why" milestones and benchmarks. The following interpretations have been made especially in the top part of the graph:

- Research and development: The original heading in the policy documents was "Technologies and processes", but we have amended it, in order to avoid confusion with the middle section technology components. Research and development was split into: longer-term, more academic fundamental research and shorter-term, more applied research that is close to market implementation (industrial innovation). Skills (human capital) were intentionally placed as a separate item, in order to highlight the importance of developing indigenous EU human research potential.

- Market and competitiveness. This has proven to be the most challenging component in the whole graph. We have shortlisted these six priority lines for action, based on the descriptions provided in the respective policy documents. Our understanding is that, while it is not allowed to directly intervene in the market, the Commission may provide targeted efforts and tools to trigger and promote the development of certain priorities, such as the bio-economy.

The middle part of the diagram summarizes the most important bio-economy flows.

The bottom section of *Figure 3* presents the main limiting and/or governing inter-related factors that underpin the bio-economy, encompassed by the overriding EU priority for growth and jobs. That part actually answers "why" we should look at the bio-economy, and provides the core milestones and benchmarks for evaluating its development.

3.1 A potential methodological approach to the EU Bio-economy Observatory

The Bio-economy Strategy calls for a more informed dialogue and better interaction and coordination across various policies in place at the EU and Member State level. This will provide a more coherent policy framework and encourage investment. Establishing a Bio-economy Observatory, in close collaboration with the existing

information systems that allows the Commission to regularly assess the progress and impact of the bio-economy and develop forward-looking and modeling tools, is one of the steps to achieve such a greater coherence.

In order to avoid possible confusions and misunderstandings, it is absolutely necessary to follow a single guiding principle when constructing the EU Bio-economy Observatory.

Amongst various possible options, the so-called "product chain" approach has been chosen owing to its objectivity, measurability and low political controversy. The product chain approach builds upon a single input-output principle along the whole biomass chain. As shown in the above diagram (*Figure 3*), it starts with biomass production and ends with the use/application of the final product. That's why intermediate sectors, such as forestry and enzymes production, do not appear at least in the current sketch. In the course of developing the Observatory, a significant further level of detail will be introduced in the middle-section boxes, in particular as regards biomass transformation technologies. There, for example, the production of enzymes and other industrial applications of biomass (further disaggregation is needed) will appear.

The alternative approaches that are sometimes suggested, such as "*sectoral approach*" or "*value chain*" approach, have been deemed more challenging and hence, they have been ruled out. Albeit the "sector approach" may appear as the most logical at first look, if undertaking this approach, one has to define straight in the beginning which sectors are parts of bio-economy and which sectors are outside the scope of bio-economy. In any case, the goal of the Bio-economy Observatory is presumably to systematically monitor the evolution of bio-economy markets and the impacts of policies and research and innovation actions, but it is not focused on particular sectors. The "value chain" approach seems less politically controversial than the "sector" one, but it may bring other challenging issues. A number of bio-economy products and markets are either still in a nutshell, or simply not existing

(*Figure 4*). Defining values for non-existing or little-known products, sometimes intended for still non-existing or little developed markets, may be misleading and even counterproductive from both economic and political point of view.

Figure 4: ***Uncertainty relations between new and existing products and markets***

↓ Products / Markets →	Existing	New
Existing	Low Uncertainty	Average Uncertainty
New	Average Uncertainty	Large Uncertainty

On the other hand, making a more sophisticated (higher) product does not necessarily mean that its (net added) value on the market will increase. The value will depend on the demand and hence, on the balance between price and cost. Thus, if there is no demand, or if the demand is insufficient, the added value may be negative (further technical discussion in the section 4.2).

We advanced *six inter-related methodological parts* strictly follow the priority topics which the pilot version of the EU Bio-economy Observatory should cover. The analyses to be performed under the components of the proposed structure of the Observatory (*Figure 3*) are consequently allocated to these priority topics, as follows:

MP1. ***Data on the bio-economy***, i.e. size of the bio-economy and its encompassing sectors, and performance indicators (e.g. economic and employment indicators, innovation indicators, productivity indicators such as unit labor cost, indicators of social well-being, indicators of environmental quality, etc.). MP1 will provide the static description and quantification of the middle section of *Figure 3* (i.e. the bio-economy product chains), as well as it will propose measurement indicators for that section.

MP2, ***"Technology watch" and "policy watch"***, will follow the development of science and technology as well of policies related to the bio-economy. MP2 will provide the dynamic characterization of the middle section of *Figure 3* (i.e. the bio-

economy product chains) in the short-term (2020) and medium term (2030). It will also include description and analyses of the most important, short- and medium-term technological solutions and policy steps that may foster the development of bio-economy product chains by components, jointly (as a system) and/or separately. The analysis will also identify possible technological or policy drawbacks that may significantly obstruct or delay the evolution of components of bio-economy product chains, jointly and/or separately, by 2020 and 2030.

MP3, *Mapping the EU bio-economy capacity,* will assess the bio-economy's research and development capacity in the EU, i.e. it will cover the first pillar "Research and development" from the top section of *Figure 3*. As shown in *Figure 3*, this assessment will be split in longer-term fundamental research and shorter-term, close-to-market industrial innovation, plus particular emphasis will be given to human capital (skills). In line with MP1 and MP2, the assessment will be spread in two layers – current status (related to MP2) and prospective situation (related to MP3), separately by 2020 (short-term) and 2030 (medium-term). The concluding outcome of this assessment will be a SWOT (Strengths/Weaknesses/Opportunities /Threats) snapshot of bio-economy research and development capacity of the EU today and the perspectives for 2020 and 2030. Totally 3 (three) snapshots could be provided – one per each component of the first pillar from the top section of Figure 1, i.e. longer-term fundamental research, close-to-market industrial innovation and human capital (skills).

MP4, *Mapping of market/regulation failures and needs for the bio-economy*. Exploiting the results of MP1 and MP2, MP4 will assess the other two pillars from the top part of *Figure 3*, i.e. "Market and competitiveness" and "Greater policy coherence and regulatory convergence". Similarly to MP3, the assessment will be spread in two layers – current status (related to MP1) and prospective situation (related to MP2), separately by 2020 (short-term) and 2030 (medium-term). The concluding outcomes of this assessment will be two separate categories of SWOT (Strengths, Weaknesses,

Opportunities and Threats) snapshots – one for the bio-economy market and competitiveness and the other one – for bio-economy policy coherence and policy convergence, each one presenting the situation today and the perspectives by 2020 and 2030, i.e. totally 6 (six) snapshots could be provided.

MP5, *Status of the implementation of the Bio-economy Action Plan*. Building upon the inputs from MP1-MP4, MP6 will assess the status of implementation of bio-economy action plan according to the so-defined milestones and against the governing and/or limiting inter-related factors that underpin bio-economy, encompassed by the overriding EU priority for growth and jobs. Thus, MP5 will deal with the bottom section of *Figure 3*, measuring the contribution of the Bio-economy Action Plan to the overall socio-economic system of the EU.

MP6. *Forward-looking analysis at EU and worldwide levels supported by appropriate new or existing indicators and models assessing the economic, social, environmental evolutions of the bio-economy*. Building upon the outcome of the preceding five MPs, MP6 will look into the longer-term future, beyond 2030, and will present alternative views and scenarios about the evolution of bio-economy in the EU and globally. As such, MP6 will aim to sketch how the whole bio-economy system (the middle section of *Figure 3*) may look like beyond 2030 under different assumptions or scenarios about research and technological progress, market development and policy and regulatory regimes (the upper section of *Figure 3*). These alternative "sketches", or rather - scenarios will then be evaluated vice-versa their enhanced contribution to the governing and/or limiting inter-related factors that underpin bio-economy, encompassed by the overriding EU priority for growth and jobs (the bottom section of *Figure 3*).

4. Data sources, methods and models

Due to its multi-dimension and cross-sector nature, measuring/monitoring the bio-economy will be challenging. Consequently, further research on the application of integrated methodological tools for evaluating the sustainable transition to a European bio-economy is needed.

For the time being, an important stage in this development is the identification of the most appropriate datasets, methods and models to be used for monitoring the bio-economy's drivers, development and impact.

4.1 Methodological modules for monitoring the EU bio-economy

This section proposes five methodological modules for grouping the future bio-economy-related monitoring and research activities.

i) *Socio-economic module*

i.1) Mapping and/or building relevant datasets of the existing economic, social and environmental statistical data, such as:

- "input" data on biological resource supplies;
- production data (e.g. bio-based output and value added, process innovation, etc.);
- investment data (e.g. R&D and innovation) ;

i.2) Scoping bio-economy relevant sectors (i.e. "agri-food" industries and other bio-based sectors, such as agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of the chemical, biotechnological and energy industries) at a disaggregated level.

i.3) Establishing assessment methodologies based upon a value-added analytical approach and developing key socio-economic indicators.

i.4) Collecting additional socio-economic data and information, in collaboration with relevant European stakeholders (e.g. sectoral business associations).

ii) *Environmental sustainability assessment module* could include activities such as:

ii.1) Developing relevant key environmental indicators concerning biomass production, logistics and use.

ii.2) Comparative life-cycle based assessment of example bio-based products and their supply chains, from the primary production of biological resources to end-of-life processes.

ii.3) Sustainability assessment:

- Designing minimum sustainability criteria for biomass production, mobilization and its industrial applications (e.g. in terms of resource efficiency, GHG emissions, land use change, forest exploitation, etc.);
- Elaboration/integration of comprehensive, multi-criteria sustainability assessment tools for both existing and emerging bio-products' (e.g. bio-based chemicals, bio-based plastics, enzymes, bio-based materials, biofuels)[13] performance, in terms of price, value-added, technical feasibility, utility and environmental impact;
- Developing methodological tools for tracing the bio-products' sustainability criteria compliance across the whole supply chain;
- Coping with the competing use options of both biomass and land in a multi-sector/multi-region approach
- Developing methodological tools for sustainability assessment of the existing and prospective technologies[14].

iii) *Forward-looking analyses*

iii.1) Building integrated scenarios concerning the EU bio-economy based on relevant modelling tools. An important task will be to identify, integrate and harmonize the existing modelling applications and foresight exercises for forward-looking analysis

[13] OECD (2010) can be used as a provisional methodological guide.
[14] E.g. building upon PROSUITE project - www.prosuite.org .

of policy options directly related to the EU bio-economy - e.g. integrated modeling platforms for specific sectors, such as food, materials, chemicals, energy etc.

iii.2) Specific foresight studies concerning: bio-economy-relevant R&D in production, conversion and use of biological resources.

- monitoring/building scenarios in relevant bio-economy areas such as food, energy, agriculture, biotechnology (i.e. traditional, emerging and future/potentially disruptive technologies) and biomass supply and use.

iv) *Market developments*

iv.1) Monitoring of:

- biomass supply chains (e.g. plant, animal and forestry-based) and use of bio-based resources;
- bio-based value chains and markets development;
- up-scaling and commercialization of new bio-based products (e.g. bio-based plastics, chemical building blocks, advanced biofuels, etc.).
- bio-refinery development and associated value chains within established bio-based industries (e.g. food; chemical industry; pulp and paper industry; starch industry).

v) *Policy and stakeholder networking*

v.1) Monitoring EU and national policies related to primary production of renewable biological resources (e.g. crops; residues from agriculture, forestry and fisheries; bio-waste), bio-based products and energy, standards and mandates.

v.2) Mapping the regulatory and financial incentives for R&D on new industrial application of biological resources, testing facilities and market uptake of final products;

v.3) Monitoring EU and national public-private partnerships in biomass supply chains (e.g. farmers, foresters, waste managers, etc.) and bio-based industries (e.g. food and feed; production of bio-based energy, chemicals and materials).

4.2 Further methodological clarification

Due to the large number of sectors covered by the bio-economy (i.e. agriculture, forestry, fisheries, food and pulp and paper production, chemistry, etc.), a preliminary sectoral analysis can be helpful in the first instance. Already JRC-IPTS successfully used this approach for monitoring agri-food sectors and some other sector linked to them, and released the report "*An approach to describe the agri-food and other bio-based sectors in the European Union*" in September 2012 (Cardenete et al., 2012). The analytical methods used in this report are suitable for analyzing several aggregated bio-economy sectors (such as agriculture and food industry and other closely related sectors - e.g. pulp and paper, energy, etc.). The input-output tables, disaggregated AgriSAMs[15] were able to estimate the contribution and potential of these sectors in terms of value added and job creation, as well as their economic linkages.

As far as its relevance to the bio-economy is concerned, what turns out to be insufficient in this study is the treatment of several sectors such as chemistry, rubber and plastic products, energy and biotechnology. More specifically, as no method of discriminating between the traditional industrial and energy products and the bio-based ones is put forward, the contribution and potential of the bio-based share of these sectors remains undefined. Moreover, the disaggregated sectoral approach seems capable of capturing and assessing the primary production-conversion-use chains of biological resources in the traditional sectors only, above all in the food industry. However, the contribution of the agri-food and other traditional bio-based sectors (i.e. conventional and non-food crops, agricultural waste residues and organic waste) to energy and industrial feedstock remains unresolved. Thus, this sectoral approach needs further disaggregation and also to be complemented with other methodologies.

[15] AgriSAM stands for "Social Accounting Matrix with a Disaggregated Agricultural Sector".

First, in order to identify the bio-based products and monitor the evolution of their value chains and trade flows, separate and disaggregated product-level statistics (e.g. CN[16] and PRODCOM[17]) are needed. In this direction, the introduction of new PRODCOM and CN codes for bio-based products will be essential.

Second, in order to support the process of gathering data and information (for example: company' share of bio-based production and potential; R&D, biotechnology, production facilities, and other investments directed to bio-based activities; biological resource use, etc.), additional product- and company-level research is needed.

Third, due to the importance of environmental sustainability criteria that are applicable to bio-based products, special emphasis should be placed to the development and application of life-cycle-based methods. Towards this end, life-cycle data inventory, resource-efficiency and life-cycle indicators already developed by the JRC can be useful.

4.3. Use of data inventory of life-cycle based resource efficiency indicators

In response to policy needs of the Roadmap to a Resource Efficient Europe (EC, 2011), JRC-IES[18] has developed a set of life-cycle based resource efficiency indicators, with the aim to quantify the overall environmental impact potential of production and consumption in the EU-27 (taking into account internationally traded commodities). This indicator set provides an overall indicator of potential environmental impacts, by normalizing and weighting across multiple environmental

[16] The Combined Nomenclature (CN) provides the rules for the classification of imported and exported goods to an eight-digit level.

[17] Eurostat's PRODCOM database provides statistics on the production of manufactured goods to an eight-digit level. Most product codes correspond to one or more Combined Nomenclature (CN) codes, but some (mostly industrial services) do not.
http://epp.eurostat.ec.europa.eu/portal/page/portal/prodcom/introduction

[18] Joint Research Centre, Institute for Environment and Sustainability.

criteria such as climate change, acidification, toxicity and energy resource depletion potentials.

The methodology builds on pilot case studies recently developed by JRC for life cycle indicators (EC, 2012a and 2012b) and will combine territorial emissions and resource extractions for each of the Member States and the EU27 in total with those related to imported and exported products, consistently to the requirements of the International Reference Life Cycle Data system (ILCD) (EC, 2010 and 2012c). This framework will also allow to cover the environmental impacts related to import and export activities, allowing to capture the environmental impact occurring outside the territory of the EU.

The project outcomes will allow monitoring over time of overall consumption-related environmental impacts. The results will represent the actual pressures on the natural environment, human health and the availability of material, biomass, energy, water and land resources exerted by the European society.

4.3.1 Domestic inventory datasets relevant to the bio-economy

Anthropogenic resource consumption and emissions occurring within EU countries have to be quantified in order to monitor resource efficiency indicators. Data gathering activities have been recently initiated with the aim of developing a “domestic inventory" of emissions and resources extracted within the national boundaries of EU countries. This dataset, which will cover the highest number of member states and the longest time series so far as possible, will be used as the quantitative basis for monitoring resource use performance. The dataset will also create the basis from which to assess the environmental impacts associated to the production of goods, the use of goods by consumers, the provision of services, the end-of-life management of goods, and other anthropogenic emissions and resource use, at the Member State level.

Statistics on biomass, in terms of both land use dedicated to agriculture and forestry and biomass production quantities, could be included within the domestic inventory for monitoring land use, land use change and biomass extraction. The data source which has been identified as the most suitable for this purpose is the Faostat dataset[19], developed by the Food and Agriculture Organization of the United Nations (FAO) statistics division. Of particular interest are the Faostat datasets on Production, Trade, Forestry and Fisheries, which will be used for quantifying the domestic production of the following biomass resources: i) primary crops, including cereals, roots, sugar crops, pulses, nuts, oil bearing crops, vegetables, fruits, fibers, tobacco, rubber and other crops; ii) crop residues (used), fodder crops and grazed biomass; iii) wood; iv) fish catches and seaweeds. The future use of this dataset for monitoring biomass extraction would be an advantage since it is internationally relevant and statistically sound. Yet, this dataset is based on a production perspective rather than on consumption perspective and thus it cannot be used for inferring on bio-based product consumption. Moreover, information on by-products, co-products and residues are generally not reported or difficult to find (e.g. straw quantities are taken from the Faostat-Trade database, since they are not reported in the Faostat-Production database). *Annex 2* presents an example of the FAO dataset for the EU-27, as elaborated within the life cycle indicators framework (EC, 2012a). Data refers to the production quantities within the EU27, and serves the purpose of monitoring the domestic production of the European Union. As the domestic inventory has a production perspective structure, information on bio-based products are not accounted for. In order to comprehensively monitor resources flow among economic sectors or along product supply chains, the dataset on biomass production should be complemented with other data sources.

In the context of the bio-economy research and monitoring activities, the dataset can serve the purpose of assessing extracted biomass for commercial use. By coupling

[19] http://faostat.fao.org/

this dataset with land use statistics (Faostat), spatially resolved datasets ((e.g. Corine Land Cover, Eurostat), and biomass production data, it could be possible to quantify unused biomass reserves, production hot spots, as well as land use change issues driven by food and non-food production.

A set of life cycle-based indicators for *waste management* was recently developed within JRC-IES for the purpose of assessing the potential environmental impacts caused by waste production and management within the EU-27. These indicators are based on available European and national statistics and could be used for assessing bio-waste flows. In particular, the following Eurostat datasets on waste statistics may be of interest: i) waste stream 7.2 paper & cardboard wastes; ii) waste stream 7.5 wood wastes; iii) waste stream 10.1 household and similar wastes (e.g. this category includes both bio and non-bio wastes). Data on separate collection of bio-waste from households are lacking, as are estimates for agricultural residues. Moreover, available data are few and there are consistency issues. However, by making general assumptions on waste composition, the impacts related to the management of bio-wastes can be quantified, as well as the benefits arising from their re-use or transformation into bio-fuels through the appropriate technology (e.g. pyrolysis/anaerobic digestion/etc. of household wastes – wet fraction).

4.4 Other relevant data sources and models

Depending on the scope of the bio-economy-related monitoring and research activities which are to be undertaken, the following information and data sources, and modelling frameworks could be used.

I. *JRC INTERNAL SOURCES*:

1. AGRI4CAST model: Crop monitoring and forecasting at EU level in support to the Common Agricultural Policy:

http://ies.jrc.ec.europa.eu/the-institute/units/monitoring-agricultural-resources-unit/agri4cast-action.html

2. AGRI-ENV: Integration of Environment Concerns into Agriculture: http://ies.jrc.ec.europa.eu/index.php?page=79

3. AGRITECH: New Technologies in Agriculture – their agronomic and socio-economic impact: http://agrilife.jrc.ec.europa.eu/agritech.html

4. AGRITRADE: Support to Agricultural Trade and Market Policies: http://agrilife.jrc.ec.europa.eu/agritrade.html

5. Biofuels Coordinating Action: http://iet.jrc.ec.europa.eu/bf-ca/

6. Common Agricultural Policy Regionalised Impact (CAPRI) model (JRC-IPTS): www.capri-model.org

7. Integrated Modelling Platform for Agro-economic Commodity and Policy Analysis (iMAP), JRC-IPTS: http://ftp.jrc.es/EURdoc/JRC69667.pdf

8. INTEgrated Sustainability Assessment: scenarios, platform and indicators: http://ies.jrc.ec.europa.eu/the-institute/units/sustainability-assessment-unit/intesa-action.html

9. Land Use Modelling Platform (LUMP) (JRC-IES): http://moland.jrc.ec.europa.eu/index.htm

10. - Monitoring the forests in Europe (FOREST): http://ies.jrc.ec.europa.eu/index.php?page=92

11. Sustainable Agriculture and Rural Development (SUSTAG): http://agrilife.jrc.ec.europa.eu/s_home.html

12. Sustainability of Bioenergy (BioS): http://re.jrc.ec.europa.eu/biof/

II. *OTHER EU DATA SOURCES*:

1. *Eurostat*. Eurostat provides regular data on: agriculture and agri-environmental indicators; forestry; fisheries; aquaculture; food production and consumption; energy; environmental accounts and waste; land cover and use (LUCAS); research and development; science, technology and innovation; rural development.

- Farm Structure Survey (FSS) statistics, which provide data on: number of agricultural holdings; land use and area (crops); livestock; main crops; farm labour force (age, gender, etc.); system of farming; machinery; organic farming.
- EU-Statistics on Income and Living Conditions (EU-SILC), which collects micro-data on: income; poverty; labour; education; health.
- Geographical information and maps on: agriculture, forestry and fisheries; food; environment and energy; science, technology and innovation;
- Manufactured goods (PRODCOM).

2. *Corine Land Cover* (European Environment Agency):

http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2006-clc2006-100-m-version-12-2009

3. *European Technological Platforms*.

iii.1 *Data and information on primary production*:

- Plants for the Future - http://www.plantetp.org/
- Forest-based Sector - http://www.forestplatform.org/
- European Aquaculture Initiative - http://eatpnet.org/default.php

iii.2 *Data and information on industrial processing*:

- Food for Life - http://etp.ciaa.be/asp/index.asp
- Sustainable Chemistry - http://www.suschem.org/

iii.3 Data and information on research & development:

- *European Biofuels Technology Platforms*: studies, research and demonstration projects on biofuels; data and information on biomass feedstock and conversion;

biofuel production and uses; biofuel markets; sustainability; national biofuel technological platforms; policy and R&D; monitoring etc. http://www.biofuelstp.eu/

4. *European Marine Observation and Data Network* (EMODnet). https://webgate.ec.europa.eu/maritimeforum/category/160

5. *Relevant FP7 research projects* – e.g. *Global-Bio-Pact* (http://www.globalbiopact.eu/), *PROSUITE* (www.prosuite.org), *LCA to go* (www.lca2go.eu/).

6. Nova Institute, Cologne:
http://www.nova-institut.de/bio/index.php?tpl=startlist&lng=en
Data and information on:
- World, EU and Germany bio-based polymers and plastics market data;
- Information directory of the suppliers, clusters and R&D companies in bio-plastic products sector;
- News portal for bio-based economy, Biomaterials and Industrial Biotechnology; http://www.nachwachsende-rohstoffe.info/
- Studies on feedstock and production of industrial bio-products;
http://www.bio-based.eu/en/index.html
- Environmental assessment of bio-plastics and bio-polymers (http://www.bio-based.eu/ecology/en/index.php)

III. EXTRA-EU DATA SOURCES:

1. *FAOSTAT*. Data on: agriculture, forestry and food industry. http://faostat3.fao.org/home/index.html#HOME
2. *OECD statistics and analyses*. Data on: agricultural production; agriculture and environment (land use; irrigation; manpower; machines; energy; fertilizers; pesticides; livestock; agricultural production); energy.
http://www.oecd.org/document/0,3746,en_2649_201185_46462759_1_1_1_1,00.html
3. *Biofuels Digest* (policy, producer and research news on biofuels).

http://www.biofuelsdigest.com/

4. *Bio-based Digest* (policy, producer and research news on bio-based products). http://biobased.biofuelsdigest.com/

5. Standardization and monitoring of bio-based products

Current limited availability of statistical data on new bio-based products and processes [20] and differences in bio-based product definitions and statistical classification references[21] make it still difficult to comprehensively estimate their corresponding markets. Consequently, a more suitable methodological approach would be to focus on the most promising (both economically and environmentally) supply chains where bio-based products can substitute the traditional ones.

The lack of clear information concerning the technical standards concerning the bio-based content and environmental impact of bio-based products[22] turns out to be an obstacle to their market uptake (CSES, 2011; *Table 5*).

Table 5: *Estimated development of the market and employment for bio-based products in the period 2006 - 2020*

	2006	**2010**	**2020**	**Growth in volume 2006 - 2020**
Market volume (mil. Euro)	19,000	28,000	57,000	38,000
Job creation (thousand jobs)	120		380	260

Source: *CSES (2011)*

Due to the lack of European standards for bio-based products (i.e. for the determination of their bio-based content, technical performance, life-cycle environmental impact, biodegradability, etc.), the European Commission, in the

[20] Zika *et al*. (2007).

[21] Use of NACE and PRODCOM codes proves to be inappropriate as they cover much more products that the bio-based ones (for a detailed discussion, CSES (2011).

[22] Bio-based products encompasses intermediate products, product components and end products such as: amino- and organic acids, bio-fibers for textiles, bio-lubricants; bio-plastics and other biopolymers; bio-solvents; cosmetics; enzymes; ethanol, other chemicals and chemical building blocks; materials for the construction sector or car industry; pharmaceutical products including vaccines; surfactants (European Commission, 2007 and CSES, 2011).

framework of the Lead Market Initiative, appointed an Ad-hoc Advisory Group for Bio-based Products. It has elaborated new European product performance standards, and issued, since 2008, several mandates for bio-based products:

i) Mandate M/429 for the programming of standards for all types of bio-based products.

ii) Mandate M/430 for the rapid elaboration of pre-standards for bio-based lubricants and bio-polymers, covering the following aspects: biodegradability (for bio-lubricants only), product functionality, impact on greenhouse gas emissions and raw material consumption, measurement methods, test methods, and Life Cycle Analysis Assessment procedures. The standardization documents CEN/TR 15932 "Plastics - Recommendation for terminology and characterization of biopolymers and bio-plastics" and "Bio-Lubricants" are already available. Two others are in the issuing process ("Plastics - Determination of the bio-based carbon content" and "Plastics - Declaration of the bio-based carbon content").

iii) CEN/TR16208, Bio-based products - Overview of standards.

iv) Mandate M/491 on the development for bio-based surfactants and solvents of European standards.

v) Mandate M/492 on the development of various horizontal standards and other standardization deliverables for bio-based products[23].

Several criteria and thresholds have been or are to be established for bio-lubricants bio-plastics/bio-polymers, bio-surfactants, bio-solvents, chemical building blocks and enzymes (i.e. technical, food and animal feed enzymes). A specialized CEN working

[23] European Commission, DG Enterprise and Industry, Lead Market Initiative – Bio-based Products, http://ec.europa.eu/enterprise/policies/innovation/policy/lead-market-initiative/biobased-products/index_en.htm

group, CEN/TC 411/WG 4, was established for sustainability criteria and life-cycle analysis[24].

Further research has been or is being conducted on issues such as harmonization of sustainability certification systems for biomass production, conversion systems and trade[25], sustainability assessment of technologies, including bio-refineries[26], and environmental performance of products[27].

In order to monitor the technological and commercial market developments related to the most innovative and competitive bio-products (e.g. bio-based plastics, bio-lubricants, bio-base solvents, bio-based surfactants, bio-composites and bio-based platform and fine chemicals), new technical standards (e.g. carbon content derived from renewable raw materials) and separate statistical codes should be assigned to them, in addition to the existing ones[28] in official goods classification (i.e. the CN and PRODCOM) and trade statistics. DG Enterprise has already proposed CN codes for several products (i.e. bio-based lubricants, succinic acid and 1,4-butandiol), together with the technical verification methods for bio-based renewable content.

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[24] European Committee for Standardization, Technical Committee 411, *Bio-based products* - http://www.cen.eu/cen/Sectors/TechnicalCommitteesWorkshops/CENTechnicalCommittees/Pages/TCStruc.aspx?param=874780&title=Bio-based%20products

[25] *Global-Bio-Pact* research project, http://www.globalbiopact.eu/ .

[26] *PROSUITE* research project, www.prosuite.org .

[27] "LCA to go" research project, http://www.lca2go.eu/ .

[28] The already existing CN and PRODCOM codes are: bio-based glycerol; enzymes; ethanol; polylactic acid; natural polymers and modified natural polymers in primary form; ethanol; other butanols; butan-1-ol; polyacetals including other polyethers and epoxy resins, in primary forms, polycarbonates, alkyl resins, polyallyl esters and other polyesters, in primary forms-others, others; other plates, sheets, film, foil and strip, of plastics, non-cellular and not reinforced, laminated, supported or similarly combined with other materials, -of cellulose or its chemical derivatives, -of regenerated cellulose; other – acyclic polycarboxcylic acid, their anhydrides, halides, peroxides, peroxyacids and their halogenated, sulphonated, nitrated or nitrosated derivatives; wholesale of solid, liquid and gaseous fuels and related products - wholesale of fuels, greases, lubricants, oils.

6. General questionnaire for collecting additional data and information

Conducting additional qualitative research on various bio-economy-related issues is justified by the current impossibility of obtaining all statistical data from official sources. A detailed gap analysis between the future specific needs and the available data will be needed beforehand.

To this end, we propose a general-purpose questionnaire, divided into six modules, which could serve as a basis for prospective surveys. It is intended to be further refined and adjusted, in collaboration with the sector-relevant European technology platforms and industry associations[29] and other relevant stakeholders, according to the specific profile of each sector, product group or firm types to be included in the surveys.

[29] European technology platforms: Forest-based Sector TP; Plants for Future; European Algae Biomass Association; Manufuture; ETP FoodforLife; SusChem; European Biofuels TP; Construction ETP; European Innovation Platform on Sustainable Agriculture; Industry associations: ERRMA - European Renewable Resources and Materials Association; AAF - the trade association for the starch industry at European and international level; COPA-COGECA; CEPI; European Association for Bio-industries European Bioplastics (EuropaBio); Fediol; PlasticsEurope; ERRMA; European Bio-plastics; FoodDrinkEurope; CEFIC.

I. Socio-economic assessment module.

Q1. *What was your company's production corresponding to the bio-based activities*[30] *in the last three years (disaggregated according to NACE)*?

	2010	2011	2012
Overall turnover			
Bio-based production, out of which:			
Activity 1/ NACE code			
Activity 2/ NACE code			
…			
Bio-product 1/ PRODCOM 8-level			
Bio-product 2/ PRODCOM 8-level			
…			

Q2. *Please list the main bio-based products (e.g. biofuels, bio-based polymers, lubricants, etc.) sold by your company and, if possible, their corresponding turnover share*.

Product	Turnover share 2010	Turnover share 2011	Turnover share 2012
P1			
P2			
…			

Q3. What was your company's number of employees in the last three years?

	2010	2011	2012
Total employees, out of which:			
1. Directly involved in bio-based activities, broken down by occupational category (ISCE), out of which:			
2. Newly created, broken down by occupational category (ISCE)			
2.1. Newly created in rural areas, out of which:			
1. Directly created			
2. Indirectly created			

[30] 1) *Bio-based* = derived from biomass. 2) *Biomass* = material of biological origin excluding material embedded in geological formations and/or fossilized. (*Note*: This definition refers to the well-known short-cycle of carbon, i.e. the life cycle of biological materials (e.g. plants, algae, marine organisms, forestry, micro-organisms, animals, and biological waste from households, agriculture, animals and food/feed production). 3) *Bio-based product* = product wholly or partly bio-based. (*Note*: The bio-based product is normally characterized by the bio-based content.)

Q4. *What were the main risks/challenges related to operating bio-based activities and products your company faced in the last three years? Please rank them on a scale from 0 to 5 (e.g. 0 means no risk)*[31].

	2010	**2011**	**2012**
Secure access and stability of biomass supply			
Financial risks (e.g. return on investment)			
Policy risks			
Environmental compliance			
Technical risks (e.g. regulation and standards)			
Public acceptance			
Demand related risks (e.g. creating new markets)			
Lack of financial support for production upscaling			
Lack of effective coordination between governments, business associations and companies			

Q5. *What were the main drivers of your company's developing bio-based activities and bio-based products in the last three years? Please rank them on a scale from 0 to 5 (e.g. 0 means no risk).*

	2010	**2011**	**2012**
1.			
2.			
3.			
…			
…			

[31] The prospective respondents will be asked to specify those risks and challenges that are specific to the biotic nature of the activity.

II. R&D, technology and innovation.

Q1. What were your R&D expenditure and technology adoption investments related to your bio-based activities in the last three years?

	2010		2011		2012	
	In EU-27	Extra EU-27	In EU-27	Extra EU-27	In EU-27	Extra EU-27
Total R&D expenditure, out of which:						
- related to the bio-based activities						
Total technology investment, out of which:						
- related to the bio-based activities						

Q2. What types of technological change and/or innovation investments related to your bio-based activities your company made in the last three years?

	2010		**2011**		**2012**	
	In EU-27	Extra EU-27	In EU-27	Extra EU-27	In EU-27	Extra EU-27
New bio-based facilities (including integrated and diversified bio-refinery)						
Developing competence center in a specific technology field						
Development new, improvement of existing and mix of different technologies for entry into the existing value chains						
Adoption of technologies for new bio-based activities						
Replacing or supplementing non-renewable raw materials						
Improving resource efficiency of the existing bio-based activities						
For increasing economic performance of the existing products (e.g. resource efficiency)						
For increasing environmental performance of the existing products						
Replacing processing applications based on non-renewable resources						

Integrating new bio-based applications into the existing ones based on non-renewable resources						
Replacing non-renewable-based products by bio-based ones						
Producing bio-based products in addition to the existing ones based on non-renewable resources[32]						

Q3. What is your company's estimated budget for investments in R&D, technology and/or innovation related to your bio-based activities in the next three years?

	2013		**2014**		**2014**	
	In EU-27	Extra EU-27	In EU-27	Extra EU-27	In EU-27	Extra EU-27
R&D related to the bio-based activities						
Technological investment related to the bio-based activities						
Competence center in a specific biorefinery technology						
New bio-based facilities						
Technology adoption for new bio-based activities						
Substitution of non-renewable raw materials						
Improving resource efficiency of the existing bio-based activities						
Increasing economic and environmental performance of the existing bio-based products						
Replacing fossil-based processing applications by bio-based ones						
Integrating bio-processing applications into the existing						

[32] A wide range of non-renewable raw materials would be considered – i.e. not only those for energy or chemical industries but also other non-renewable raw materials like metals, concrete, glass, etc.

fossil-based ones						
Replacing fossil-based products by bio-based ones						
Producing products that are partly bio-based and partly fossil-based						
Producing bio-based products in addition to the existing non-renewable-based ones						

Q4. Was your company involved in R&D and technology transfer networks in the last three years?

	2010	**2011**	**2012**
EU/national/regional technology platforms			
R&D and technology networks between small businesses (SMEs) across the supply chain			
Cooperation with research centers, universities and technological poles			

Q5. How many R&D spin-offs and start-ups for advanced technologies and/or specific bio-based products split off from your company in the last three years?

	2010		**2011**		**2012**	
	In EU-27	Extra EU-27	In EU-27	Extra EU-27	In EU-27	Extra EU-27
Start-ups						
Spin-offs						

Q6. What are the main risks, uncertainties and obstacles which hinder your company's investments in R&D, technologies and product innovation related to the bio-based activities in the last three years?

	2010	**2011**	**2012**
Unclear business framework conditions			
Feedstock availability, price and supply stability			
Lack of qualified labour force			

Technical standards and sustainability requirements related to bio-based products			
Lack of support for establishing large-scale pilot and demonstration plants			
Technical product capabilities requirements that are not met			
Uncertain return on investment			
Unsecure demand/markets			

Q7. What are your company's main drivers for investing in R&D, technologies and innovation related to the bio-based activities in the last three years?

	2010	**2011**	**2012**
New markets and/or new market opportunities			
Environmental regulation compliance			
…			

III. Feedstock supply

Q1. What was the amount of bio-based feedstock used in your EU bio-based activities, by category, in the last three years (wet or dry tons; carbon or energy content)/year?

	2010	**2011**	**2012**
Cereals and other starch rich crops			
Sugars			
Oil crops			
Wood			
Municipal waste			
Industrial waste			
Residues			
Aquatic materials			
Straw			
Animal manure and sewage sludge			
Other: ….			

Q2. What was the share of your required bio-based feedstock sourced from EU-27 countries, by category, in the last three years (%)?

	2010	**2011**	**2012**
Cereals and other starch rich crops			
Sugars			
Oil crops			
Wood			
Municipal waste			
Industrial waste			
Residues			
Aquatic materials			
Straw			
Animal manure and sewage sludge			
Other: …..			

Q3. What were the main risks and challenges related to bio-based feedstock supply faced by your company in the last three years?

	2010	**2011**	**2012**
Availability			
Stability			
Quality-related			
Cost related			
Technical specifications			
Sustainability requirements			
Long-distance supply			

IV. Environmental sustainability

Q1. Please indicate what were your company's specific environmental sustainability concerns in the last three years?

	2010	**2011**	**2012**
Resource efficiency			
GHG emissions			
Energy use			
Water use			
Land use			

Q2. Did the existing standards and sustainability criteria on bio-based products impact on your company activity in the last three years? If so, please indicate how.

Q3. What potential sustainability criteria (e.g. related to feedstock, processing, technologies, products, etc.) would influence your current bio-based business activities? If so, please indicate how and to what extent.

V. Policy support

Q1. What EU, national and regional policies, programmes and regulation influence mostly your company's bio-based business activities? Please specify.

	Details
EU policies	
EU programmes	
EU regulation	
National policies, programmes and regulation	
Regional policies, programmes and regulation	

VI. New products and markets

Q1. What are the main obstacles to the integration of your bio-based products into the existing industrial supply chains and markets?

Conclusions

The emerging bio-economy is a dynamic complex phenomenon influenced by various global mega-trends. Understanding the roots of this complexity and identifying tools appropriate to its evaluation is hence prerequisite to effective policy formulation. The following three questions are of immediate interest:

i) how to best characterize the bio-economy's structure, scope and relationships to the rest of the economy;

ii) how to comprehensively integrate and effectively manage the existing fragmented analytical frames, data sets and methodological approaches;

iii) how to determine its long-term aggregated impact on the broader economy, society and the environment.

Following from the first question, a comparative description of the specific features and coverage of both eco-industries and the bio-economy underscores major differences between these two concepts. Notably, although they refer to an apparently similar subset of economic sectors, they address fundamentally different objectives. Whereas eco-industries are defined according to their capacity to lower their negative impact on the environment, the bio-economy concept focuses instead on innovation, and on maximizing both the efficient use and the value-added of bio-resources.

The drivers for the processes behind the bio-economy are environmental (pressures), economic (e.g. e.g. price signals induced by resource scarcity) and social (e.g. population growth and consumption patterns) in nature. These drivers influence the flows of biomass, the inputs requested for biomass production and the output and allocation of its uses. For this reason, research foci and policy decisions should necessarily be attentive to the market potential of biomass value chains, obstacles to

the market uptake of bio-based products, and potential consequences of policy measures. In order to address the multi-dimensional feedbacks and synergies of the bio-economy, a coordinated management of renewable biological resources in agriculture, food production, bio-based industries, climate change and rural development appears to be the most suitable policy approach.

For the purpose of defining the bio-economy's scope and capturing its internal flows and functional components, we proposed a comprehensive analytical framework based on a product-chain approach. We further described the potential use of this framework in the context of the future Bio-economy Observatory, and detailed the six inter-related methodological components of which it is comprised. We conclude that this proposed analytical framework offers a coherent basis for monitoring of the European bio-economy's potential, progress, and impact, as well as for developing appropriate indicators. An additional important contribution of this study was the identification of several key datasets (including the data inventory for the life-cycle based resource efficiency indicators) and models relevant to bio-economy-related research and monitoring activities. These were grouped into five methodological modules; socio-economic; environmental sustainability; forward-looking analyses; market monitoring; policy and stakeholder networking.

We emphasize, however, that further research will be necessary in order to determine the completeness, suitability, and integrability of the identified data sets, including those related to biomass flows and waste management. In addition, due to the current limited availability of statistical data on new bio-based products, further disaggregated product-level statistics for bio-based products and company-level research is needed. Conducting additional qualitative research on various bio-economy-related issues is warranted given that it is presently not possible to obtain the necessary statistical data from official sources. Accordingly, we designed a general-purpose questionnaire, divided into six modules, which could serve as a basis for prospective surveys. It is intended to be further refined and developed, in

collaboration with the sector-relevant European technology platforms and industry associations and other stakeholders, according to the specific profile of each sector, product group or firm types to be included in the surveys.

As far as the identified data sources and models are concerned, further research is needed for evaluating and bridging the existing data gaps, investigating the usefulness of additional data sets, and linking modeling frameworks into a integrative modelling platform for sustainability assessment of the bio-economy.

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Annexes

Annex 1: *Global market projections for platform and fine chemicals*[1)]

Product category	Products	Market volume "Bio" 2010[2)]	Projected market volume "Bio" 2020[2)]
Succinic acid	Polymers, sweetener	2.500	>> 1.000.000
1.4-Butanediol	Polyesters, Polyurethanes	<100	> 200.000
1.3-Propanediol	Polyesters	45.000[3)]	1.400.000
Epichlorohydrin	Epoxy Resins	10.000	300.000
Acrylic acid	Polyacrylates	pilot quantities	450.000
Isoprene	Elastomers	pilot quantities	50.000
Ethanol	Chemicals	n.a.	430.000
Lactic acid	Monomeric acid	280.0003)	500.000
	Polylactic acid (PLA)	140.000[3)]	1.200.000
Sorbitol	Surfactants, Polyethers, Isosorbide	140.000	300.000
	Others	1.100.000	1.340.000

[1)] Figures from Novamont SpA, Valbiom, NNFCC, Roquette Frères S.A.
[2)] In tonnes
[3)] Mostly outside of Europe

Source: *Busch & Wittmeyer, Current market situation 2010 and market forecast 2020.*

Annex 2: *Domestic extraction used in EU-27 (metric tons except for whales, seals and walruses, which are in numbers)*

	2004	**2005**	**2006**	**2007**
A.1 Biomass	1.812.154.589	1.743.274.205	1.655.757.567	1.680.957.500
A.1.1 Primary crops				
A.1.1.1 Cereals				
Barley	64.298.408	54.822.771	56.035.741	57.976.450
Buckwheat	229.238	226.723	160.086	237.104
Canary Seed	20.894	13.694	10.214	6.742
Cereals nes	363.456	348.940	346.137	409.273
Fonio				
Maize	71.995.783	63.239.735	55.966.123	48.873.302
Millet	73.123	69.329	74.495	75.155
Mixed Grain	5.131.006	4.608.314	4.062.846	4.883.586

Oats	9.309.551	7.930.351	7.766.782	8.767.917
Pop Corn				
Quinoa				
Rice, Paddy	2.902.023	2.671.974	2.610.857	2.770.763
Rye	10.022.776	7.688.524	6.550.479	7.636.507
Sorghum	543.803	490.745	566.739	521.452
Triticale	11.149.431	10.458.192	8.799.999	9.602.216
Wheat	149.395.121	135.427.382	126.735.011	120.263.628
A.1.1.2 Roots, tubers				
Cassava				
Potatoes	71.113.005	62.469.380	56.986.365	63.753.411
Roots and Tubers nes	13.689	11.130	11.472	13.446
Sweet Potatoes	79.788	73.153	72.726	59.867
Taro (Coco Yam)	2.091	2.342	2.300	2.284
Yams	2.100	2.100	2.500	2.650
Yautia (Cocoyam)				
A.1.1.3 Sugar crops				
SUGAR BEET	132.763.500	135.453.780	110.838.838	114.470.236
SUGAR CANE	70.810	47.405	21.425	5.622
SUGAR CROPS NES				
A.1.1.4 Pulses				
Bambara Beans				
Beans, Dry	193.121	176.722	146.515	135.721
Broad Beans, Dry	728.793	699.241	663.988	618.376
Chick-Peas	75.809	29.429	30.921	42.139
Cow Peas, Dry	143	157	133	145
Lentils	41.857	29.395	32.653	30.357
Lupins	149.669	169.378	151.302	153.968
Peas, Dry	3.208.084	2.499.835	2.112.063	1.451.777
Pigeon Peas				
Pulses nes	865.524	825.279	728.468	677.663
Vetches	154.761	80.706	69.516	62.124
A.1.1.5 Nuts				
ALMONDS	257.568	401.842	491.486	359.738
ARECA NUTS, betel nut				
BRAZIL NUTS, Para or cream nut				
CASHEW NUTS				
CHESTNUTS	122.355	110.800	121.822	111.041
HAZELNUTS (FILBERTS)	182.316	120.877	178.007	155.362
KOLA NUTS				
NUTS	29.350	9.288	10.655	9.655
PISTACHIOS	10.331	11.581	9.269	10.955
WALNUTS	152.129	186.547	193.783	170.528

A.1.1.6 Oil bearing crops				
Castor Beans				
Coconuts				
Cottonseed				
Groundnuts in Shell	10.223	10.243	9.961	9.534
Hempseed	6.548	6.078	6.078	6.078
Jojoba Seeds				
Kapok Fruit				
Karite Nuts (Sheanuts)				
Linseed	186.532	237.650	164.446	102.053
Melonseed	5.000	5.000	5.000	6.000
Mustard Seed	81.592	42.991	33.705	29.812
Oil of Palm				
Oil Palm Fruit				
Oilseeds nes	222.850	217.500	232.428	144.267
Olives	12.296.059	10.632.776	11.936.933	11.953.334
Palm Kernels				
Poppy Seed	44.655	58.115	48.086	53.388
Rapeseed	15.461.818	15.649.381	16.112.867	18.421.055
Safflower Seed	741	306	306	107
Seed Cotton	1.527.174	1.576.705	1.186.596	1.168.208
Sesame Seed	1.811	1.354	1.276	1.141
Soybeans	1.105.478	1.192.773	1.215.110	765.162
Sunflower Seed	6.829.806	6.021.632	6.814.883	4.831.704
Tallowtree Seeds				
Tung Nuts				
A.1.1.7 Vegetables				
Artichokes	883.641	753.446	783.977	781.324
Asparagus	260.682	250.942	260.617	256.348
Beans, Green	969.147	912.538	914.883	884.533
Broad Beans, Green				
Cabbages	5.894.874	5.795.353	5.578.933	5.433.201
Carrots	5.970.083	5.883.553	5.502.169	5.337.886
Cassava Leaves				
Cauliflower	2.341.674	2.242.272	2.179.893	2.254.646
Chillies&Peppers, Green	2.464.328	2.377.190	2.684.447	2.323.068
Cucumbers and Gherkins	2.713.415	2.575.302	2.765.005	2.634.612
Eggplants	879.522	780.823	810.439	778.183
Garlic	336.840	308.180	304.059	289.181
Green Corn (Maize)	1.055.321	879.457	1.008.164	1.093.418
Leeks and Oth.Alliac.Veg	823.521	829.087	848.102	881.365
Lettuce	3.451.095	3.369.863	3.363.728	3.158.200
Mushrooms	1.103.412	1.048.312	1.040.678	1.100.386
Okra	1.644	1.788	2.245	1.947

Onions, Dry	6.001.902	5.473.456	5.091.866	5.331.545
Onions+Shallots, Green	164.819	161.970	216.813	218.858
Peas, Green	1.266.029	1.154.569	1.179.521	1.098.562
Pumpkins, Squash, Gourds	1.508.002	1.231.562	1.379.729	1.440.271
Spinach	535.337	566.229	562.507	587.275
String Beans	416.501	424.501	403.913	402.589
Tomatoes	19.806.171	18.424.947	16.585.275	16.886.138
Vegetables Fresh nes	7.859.554	7.420.869	7.259.461	6.935.615
A.1.1.8 Fruits				
Apples	12.976.418	11.825.734	11.883.137	10.658.520
Apricots	713.873	740.762	762.139	599.394
Avocados	92.095	90.763	97.485	100.799
Bananas	459.657	386.555	391.419	399.263
Berries nes	99.495	147.669	132.914	135.835
Blueberries	31.533	27.122	30.351	28.636
Cantaloupes&oth Melons	2.213.314	2.281.935	2.275.225	2.296.091
Carobs	151.304	133.322	124.366	127.723
Cashewapple				
Cherries	538.068	584.945	584.502	487.517
Citrus Fruit nes	42.852	45.000	60.419	31.004
Cranberries	3.450	2.600	2.700	2.500
Currants	453.664	442.214	289.011	218.050
Dates	4.273	4.360	4.622	5.000
Figs	105.726	100.318	94.915	86.052
Fruit Fresh nes	334.685	405.668	415.871	418.790
Fruit Tropical Fresh nes	35.100	34.100	34.100	34.100
Gooseberries	104.433	64.236	64.995	62.884
Grapefruit and Pomelos	86.474	84.031	93.665	87.239
Grapes	29.909.855	26.838.728	27.502.402	25.100.291
Kiwi Fruit	586.233	584.444	628.709	583.979
Lemons and Limes	1.497.053	1.665.308	1.567.939	1.176.231
Mangoes				
Oranges	5.868.997	5.842.820	6.925.367	5.997.633
Papayas				
Peaches and Nectarines	4.203.500	4.411.815	4.269.366	4.192.649
Pears	2.867.929	2.795.163	2.858.768	2.744.490
Persimmons	57.635	51.831	53.498	53.038
Pineapples	2.000	2.000	2.500	3.000
Plantains				
Plums	1.535.670	1.603.534	1.574.956	1.301.630
Pome Fruit nes, Fresh				
Quinces	39.770	41.127	36.232	34.170
Raspberries	119.367	109.071	112.104	111.078
Sour Cherries	367.416	254.063	338.535	222.264

Stone Fruit nes, Fresh	43.495	40.120	42.602	45.306
Strawberries	1.100.903	1.112.991	1.166.578	1.087.283
Tang.Mand.Clement.Satsma	3.287.593	2.820.158	3.434.334	2.810.857
Watermelons	3.260.791	2.941.513	2.850.510	2.576.972
A.1.1.9 Fibres				
Abaca (Manila Hemp)				
Agave Fibres nes				
Cotton Lint				
Fibre Crops nes				
Flax Fibre and Tow	181.563	168.897	142.659	134.182
Hemp Fibre and Tow				
Jute				
Jute-Like Fibres				
Kapok Fruit				
Ramie				
Seed Cotton				
Sisal				
A.1.1.10 Other crops (Spices Stimulant crops, Tobacco, Rubber and other crops)				
ANISE, BADIAN, FENNEL	49.671	36.387	40.526	35.530
ARABIC GUM				
CAROBS (Ceratonia siliqua) Carob-tree, locust bean				
CHICORY ROOTS	985.098	867.357	565.781	536.388
CINNAMON (CANELLA)				
CLOVES				
COCOA BEANS				
COFFEE, GREEN				
GINGER				
HOPS	50.948	54.693	44.263	49.448
MATE				
NATURAL GUMS				
NATURAL RUBBER				
NUTMEG, MACE, CARDAMONS				
OTHER RESINS				
PEPPER black, white pepper; long pepper	97.873	93.167	75.424	56.093
PEPPERMINT, SPEARMINT	600	550	550	600
PIMENTO				
PYRETHRUM, DRIED FLOWERS	300	300	300	300
SPICES NES	4.892	4.678	5.409	4.573
TEA	125	112	115	115
TEA NES				

TOBACCO LEAVES	454.062	428.467	291.086	282.352
VANILLA				
A.1.2 Crop residues (used), fodder crops and grazed biomass				
A.1.2.1 Crop residues (used)				
A.1.2.1.1 Straw	147.997.000	132.714.000	117.022.000	114.844.000
A.1.2.1.2 Other crop residues (sugar and fodder beet leaves, other)	34.607.000	32.722.000	27.226.000	26.559.000
A.1.2.2 Fodder crops and grazed biomass				
A.1.2.2.1 Fodder crops (incl. biomass harvest from grassland)				
Fodder crops (cropland)				
ALFALFA FOR FORAGE Medicago sativa	67.498.810	68.322.876	69.262.656	63.982.738
BEETS FOR FODDER beet, beetroot, mangold (Beta vulgaris)	6.298.568	6.025.662	5.877.025	5.834.803
CABBAGE FOR FODDER Brassica chinensis; B. oleracea	1.615.849	1.528.315	1.507.000	1.502.000
CARROTS FOR FODDER Daucus carota	9.518	9.896	9.082	8.739
CLOVER FOR FORAGE Trifolium spp.	10.742.824	12.667.391	12.809.308	13.220.013
GRASSES NES FOR FORAGE	24.047.366	22.828.235	22.248.728	22.424.685
GREEN OILSEEDS FOR SILAGE	17.781.560	17.736.333	17.717.550	17.717.550
Hay (Clover, Lucerne, etc.)				
LEGUMES FOR SILAGE	16.385.711	16.503.161	16.449.960	16.449.960
MAIZE FOR FORAGE	185.098.094	183.668.750	173.011.864	167.824.676
PUMPKINS FOR FODDER	96.776.353	92.533.244	92.499.404	93.550.501
RYE GRASS FOR FORAGE	26.703.004	26.028.708	26.066.464	26.907.636
SORGHUM FOR FORAGE	1.270.585	1.163.388	1.195.977	1.216.688
SWEDES FOR FODDER	1.300.000	1.500.000	1.800.000	1.800.000
TURNIPS FOR FODDER	1.257.146	1.258.995	1.233.954	1.238.427
VEGETABLES, ROOTS FODDER NES	4.661.835	4.374.516	3.986.643	3.971.532
Fodder (grassland)				
Hay, Non-Leguminous				
Hay nes				
Grazed biomass	248.188.000	239.437.000	244.080.000	269.476.000
RANGE PASTURES				
IMPROVED PASTURES				
A.1.3 Wood				
A.1.3.1 Timber (Industrial				

roundwood)				
Pulpwood,Round&Split(C)	42.315.347	46.700.873	42.180.407	48.785.603
Pulpwood,Round&Split(NC)	19.298.796	19.200.779	18.858.870	19.109.150
Other Indust Roundwd(C)	4.025.167	3.980.620	3.651.220	3.720.140
Other Indust Roundwd(NC)	3.097.237	2.899.892	3.019.969	2.297.881
Sawlogs+Veneer Logs (C)	77.943.873	89.311.958	79.513.425	92.563.620
Sawlogs+Veneer Logs (NC)	14.398.464	13.461.313	13.424.149	13.916.347
A.1.3.2 Wood fuel and other extraction				
Wood Fuel(C)	10.441.303	11.299.466	11.833.286	11.572.331
Wood Fuel(NC)	27.189.210	29.410.253	30.536.178	28.276.468
M.1.3 Memorandum item: Net increment of timber stock				
A.1.4 Fish catch and other aquatic plants/animals				
A.1.4.1 Fish catch				
Inland waters				
Crustaceans				
Freshwater fishes				
Diadromous fishes				
Marine areas				
Abalones, winkles, conchs	38.711	30.613	38.372	37.566
Clams, cockles, arkshells	80.139	58.919	64.350	68.033
Cods, hakes, haddocks	868.563	914.394	919.073	751.202
Crabs, sea-spiders	51.775	37.927	54.287	60.486
Flounders, halibuts, soles	222.792	212.169	202.934	194.277
Freshwater crustaceans	3	3	0	0
Herrings, sardines, anchovies	1.876.181	2.019.732	1.762.012	1.585.449
King crabs, squat-lobsters	187	83	71	77
Krill, planktonic crustaceans	8.983	4.335	6.415	7.414
Lobsters, spiny-rock lobsters	58.343	58.224	72.365	77.801
Marine fishes not identified	47.956	65.409	70.867	73.225
Miscellaneous aquatic invertebrates	14	15	4	10
Miscellaneous coastal fishes	424.301	263.804	394.478	279.951
Miscellaneous demersal fishes	179.278	162.345	177.790	202.281
Miscellaneous diadromous fishes	55	52	56	42
Miscellaneous marine crustaceans	9.392	8.660	8.861	9.685
Miscellaneous marine molluscs	5.947	3.464	1.511	1.158
Miscellaneous pelagic fishes	769.913	706.804	684.584	791.196
Mussels	148.659	90.802	72.305	66.670
Oysters	2.787	1.809	2.240	3.099

River eels	1.785	1.489	1.613	1.519
Salmons, trouts, smelts	7.685	6.665	6.543	6.413
Scallops, pectens	55.855	57.329	60.005	64.075
Shads	2.683	2.026	2.687	3.087
Sharks, rays, chimaeras	117.059	102.112	102.073	109.405
Shrimps, prawns	97.209	109.439	97.765	98.634
Squids, cuttlefishes, octopuses	112.659	121.509	125.769	135.180
Sturgeons, paddlefishes	15	8	0	0
Tunas, bonitos, billfishes	520.321	520.905	544.273	387.150
A.1.4.2 All other aquatic animals and plants				
Inland waters				
Miscellaneous aquatic animals				
Whales, seals and other aquatic mammals				
Marine areas				
Brown seaweeds	102.518	100.758	108.606	103.069
Corals	17	16	20	24
Green seaweeds	1.333	1.364	1.343	1.329
Miscellaneous aquatic plants	2	3	10	0
Pearls, mother-of-pearl, shells	0	0	0	1
Red seaweeds	18.265	17.798	3.506	3.971
Sea-squirts and other tunicates	30	76	78	77
Sea-urchins and other echinoderms	517	431	794	223
Sponges	15	9	5	5
Blue-whales, fin-whales	7	1	2	3
Eared seals, hair seals, walruses	30	90	130	233
Sperm-whales, pilot-whales	4.535	4.174	431	594

Sources: *FAOSTAT data*

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Abstract

In order to prepare the ground for creation of the future EU Bio-economy Observatory, which is intended for monitoring of implementation of the EU Bio-economy Strategy, this study advances an integrated analytical perspective on the EU bio-economy, discusses the data sets, methods and modeling frames of potential relevance to its evaluation, and proposes a general-purpose questionnaire which could serve as a basis for prospective surveys.

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