

Overview of the Systems Analysis Framework for the EU Bioeconomy

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Overview of WP1 in the EU FP 7 SAT-BBE project:
Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy

Report for public dissemination

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Preface

This document is based on the contribution of all project partners (see box below). It especially builds forward on the three interim project deliverables. Hans van Meijl, Myrna van Leeuwen and Edward Smeets of LEI part of Wageningen UR are the editors of this report. Researchers who contributed are Peter Verburg and Marleen Schouten (VUA), Stefan Bringezu and Meghan O' Brien (WI), Hannes Böttcher and Hugo Valin (IIASA), Yannis Tsiropoulos and Martin Patel (UU), Lauri Hetemäki, Marcus Lindner and Alexander Moiseyev (EFI), Franziska Junker and Ralf Döring (TI), and Siwa Msangi (IFPRI).

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1. Introduction

1.1 Motivation for SAT-BBE project

In 2012, the European Commission (EC) launched a new strategy on the Bioeconomy¹, consisting of a Bioeconomy Strategy and an Action Plan. Both have the objective to establish a resource efficient and competitive society that reconciles food security with the sustainable use of renewable resources. The focus of the Action Plan is on 1) investing in research, innovation and skills; 2) reinforcing policy interaction and stakeholder engagement; and 3) enhancing markets and competitiveness in the bioeconomy. The Bioeconomy Strategy is aimed at five societal challenges relevant for the bioeconomy:

1. ensuring food security;
2. managing natural resources sustainably;
3. reducing dependence on non-renewable resources;
4. mitigating and adapting to climate change; and
5. creating jobs and maintaining European competitiveness.

To promote and monitor the development of the EU bioeconomy, the EC launched two projects. In November 2012 the Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy project (SAT-BBE) was launched with the purpose to design an analysis tool useful to monitoring the evolution and impacts of the bioeconomy. In February 2013, the Bioeconomy Information System Observatory project (BISO) started with the objective to set up a Bioeconomy Observatory. That observatory must bring together relevant data sets and information sources, and use various models and tools to provide a coherent basis for establishing baselines, monitoring, and scenario modelling for the bioeconomy.

SAT-BBE and BISO are complementary projects. SAT-BBE develops a Systems Analysis Framework for the Bioeconomy to assess and address the short and long term challenges for an effective and sustainable EU strategy. Among other it develops a conceptual analysis tool for monitoring the evolution of the bioeconomy and could thus advise the BISO project on the types and sources of data and tools that need to be taken into account. Also, BISO assemble and implements the data and tools that lie beyond the conceptual framework to be designed in SAT-BBE into an information system. Similarly, SAT-BBE could benefit from the BISO project in the sense that the latter is providing a comprehensive insight in the availability of data and tools that could be helpful when developing the conceptual analysis framework of the bioeconomy.

More precisely, the purpose of SAT-BBE is to develop a system analysis tool for monitoring and assessing the evolution of the bioeconomy based on both quantitative and qualitative analytical models and tools. The toolbox enables to assess and address the impact of drives and various policies on the evolution of the bioeconomy and the implication on people, planet and profit indicators. The focus is thereby not only on economic aspects, but also on other effects, e.g. land use, food security, biodiversity and greenhouse gas emissions. A systems analysis tools framework has the purpose to understand the functional requirements of a bio-based economy and to measure the necessary extent for transformation of the economy as a whole to a bio-based foundation. Systems analysis implies the capacity to understand relations between parts, and the nature of both the parts and their relationships. Tools are modelling and non-modelling analytical methods, organised in evaluation (and, by extension, monitoring) methodologies. Currently, there is no aggregate 'super model' that provides a meaningful description of the functioning of the bioeconomy in relation to the rest of the economy. Even if such a super model would exist it probably would be insufficiently detailed and have insufficient flexibility and legitimacy across the disciplines to address the rapidly evolving questions in this field. Moreover, there are already many models and tools that can be used to evaluate certain aspects of the bioeconomy, although they were not specifically designed for this purpose. This shows the need to categorise and link these models and tools regarding and the complementary need is to find either mathematical algorithms or purely conceptual constructs that allow quantitative model outcomes to be interpreted relative to one another, in order to have more balanced outcomes in terms of forecasting, foresight elaboration or impact assessment.

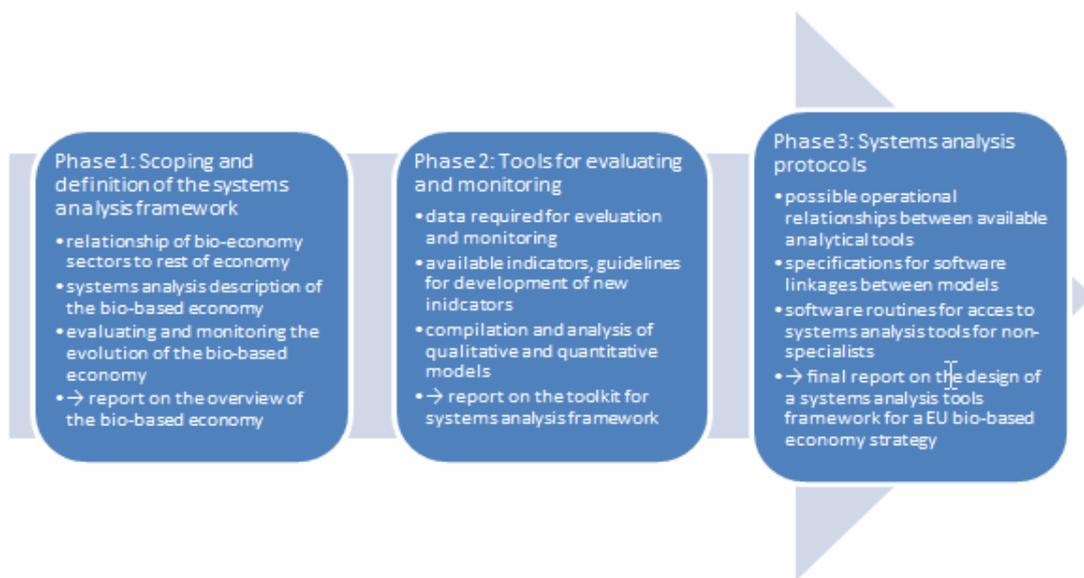
¹ [Innovating for Sustainable Growth: a Bioeconomy for Europe](#) (COM(2012)60).

In the SAT-BBE project the development of the analysis tool for the EU bioeconomy strategy is structured in three phases (Figure 1):

1. scoping and definition of the systems analysis framework (WP 1);
2. tools for evaluating and monitoring (WP 2);
3. systems analysis protocols (WP 3).

Note that in reality this procedure is iterative, in fact, as the requirements for evaluating and monitoring a bioeconomy strategy themselves generate data needs, and in turn the appropriate indicators; the models available, however, also have precise possibilities for using data and can work with only certain types of indicators, so a match has to be found. This working paper D1.4 describes the key findings of WP1 on 'Scoping and definition of the bioeconomy', as further explained in the next section.

Figure 1. Work programme of SAT-BBE project



1.2 Challenges of Work Package 1

The objective of WP 1 in the SAT-BBE project is to define the scope and definition of the analysis tool for monitoring the evolution of the bioeconomy, or more specifically:

1. to structure the concepts to be used in a bioeconomy strategy, including both the place of sustainability within the bioeconomy, as well as the biobased sectors and its drivers in relation to the rest of the economy;
2. to elaborate the foundations and analytical setting for a systems analysis framework and monitoring the implementation of a biobased economy strategy using appropriate data and indicators. The work will be done in particular in relation to other EU policies where there are interdependencies;
3. to communicate the conceptual structure of a systems analysis framework as can be applied to an EU bioeconomy strategy.

The scope and definition of the bioeconomy is discussed in Chapter 2. The drivers, impacts and responses of the bioeconomy system are structured into a first prototype of the conceptual analysis framework in Chapter 3, including data and indicators, based on the scope and definition of the bioeconomy as defined in Chapter 2. These issues follow each other in a logical order, and culminate with elaborating the concept and design of the systems analysis framework for the bio-based economy in Work Packages 2 and 3 of the SAT-BBE project. Chapter 4 discusses ideas and concepts that will be helpful when developing the systems analysis framework and evaluating its impacts. Finally, the key findings of this document (WP1) are described in Chapter 5.

2. Description of the bioeconomy

2.1 Definition

Until 2005 the term *bioeconomy* has mainly been used in relation to economic activities derived from scientific and research activities focused on biotechnology, i.e. on understanding mechanisms and processes at the genetic and molecular levels and its application to industrial process. Since 2005 several broader and overlapping definitions of the bioeconomy, have been used that vary with respect to scope and issues covered. In total seven definitions were found in the literature, each with specific advantages and disadvantages (see further SAT-BBE working paper D 1.1). One of them came about from an on-line consultation of the European Commission on the bioeconomy, held from February 2011 to May 2011 (EC 2011). Stakeholders on this consultation mentioned that the definition of the bioeconomy should be broad enough to capture the concept of *sustainable development*, taking into account environmental, social and economic issues, including the *ecosystem* dimension of the bioeconomy. Also the drivers of the bioeconomy were specifically addressed. In response to this consultation, the EC formulated the following definition that was published in the 'Communication on Innovating for Sustainable Growth: A Bioeconomy for Europe' (EC, 29 February, 2012):

'The bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. 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), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge.'

The SAT-BBE project has adopted this relatively broad and generic definition also, considering the broad scope and goal of the project, the wide scope of quantitative and qualitative research studies, the emphasis on a sustainable development, and the diverse driving forces of the bioeconomy. Despite it is not mentioned explicitly in this definition we want to stress the concept of a circular economy and the role of eco-system services. For example, although not explicitly mentioned, it takes into account the important process of moving from a linear towards a *circular economy* by using agricultural waste streams at farm (e.g. manure), post-harvest (e.g. straw, plant residuals) and retail levels (e.g. food wastage). Instead of looking at waste as a cost factor linked to currently existing bans on dumping waste, organic or biodegradable waste could be treated as a by-product or return factor of agrofood and fishery. Moreover, the definition allows for an *ecosystem-driven* green economic and industrial vision on the bioeconomy, i.e. in which fossil fuels are replaced by biobased substitutes, not only for energy, but also for material, clothing, plastic, and chemical applications and *non-market services* (United Nations, 2005). The transition towards a bioeconomy thus implicitly embeds a transition towards a circular economy, ensuring the sustainable use of agricultural waste and by-products, contributing to new competitive opportunities of the concerned sectors, reducing the potential harm to the environment and taking into account the value of non-market services.

2.2 Sectoral scope and structure

The definition of the bioeconomy in the SAT-BBE project has a clear sectoral orientation: it includes the agricultural, forestry, fishery and food industries, as well as biobased parts of the chemical, biotechnological and energy industries. This means that a sufficient **sectoral** and **product** breakdown is needed to represent the frontiers of the bioeconomy. These breakdowns most likely follows the sector and product classifications that are covered in the authorized statistical classification systems as these use common rules regarding the compiling and presenting of statistics and tools used across countries. Table 1 distinguishes the bioeconomy into four types of sectoral biobased activities, linked to their nomenclature in the Statistical Classification of Economic Activities in the European Community (NACE; Eurostat, 2008). NACE contains comparable statistical data on economic activities in both EU and world regions. Annex 1 lists the currently available statistical classification systems applicable to analyse and monitor the development of the bioeconomy.

Table 1. Specification of biobased sectors, according to NACE

Biomass related sectors	NACE sectors
<i>Primary sector activities:</i> natural resource-based activities that directly exploit the bio-resources to be used as input for the bioeconomy	Agriculture, forestry, fishing
<i>Secondary sector activities:</i> conventional users (direct users) of raw agricultural products	Food, beverages, tobacco, textile, wearing apparel, leather products, (products of) wood and cork (excl. furniture); articles of straw and plaiting material, paper and paper, furniture, construction of buildings, civil engineering (e.g. wood use for bridges)
<i>Tertiary sector activities:</i> new users of renewable raw materials	Manufacture of coke and refined petroleum (e.g. biofuel blends); manufacture of chemicals and chemical (e.g. biobased ethylene); manufacture of basic pharmaceutical products and preparations from biobased resources; manufacture of biobased rubber and plastics; electricity, gas, steam and air conditioning supply from biomass (e.g. wood chips) and its derivatives (e.g. biogas)
<i>Ecosystem or non-market services:</i> conventional users of green resources, such as sea, parks and forest	Forestry, water supplying services, non-market services of recreational and cultural activities

The sector-based approach of the biobased economy can support policy makers with their task to monitor the changes occurring in the economy as they are today and tomorrow, with the technologies as they are today and tomorrow. The conventional biobased sectors (*primary* and *secondary sector activities* in Table 1) will interact with sectors that are not immediately biobased from their origin (*tertiary sectors activities* in Table 1). A key challenge for monitoring the bioeconomy is to determine the biobased share in these tertiary sectors. The new sectoral interactions will generate new trade-off effects across sectors which are regarded as spin-offs of the bioeconomy. Further, new competing claims for biomass resources will occur, no matter what its origin (land, water, waste, by-products) is. Biomass is increasingly used as a production factor in more sectors and industries when the world transmits towards a bioeconomy.

A further sector disaggregation is potentially needed for monitoring the economic, societal and environment performances of the bioeconomy. For example, it helps to distinguish the agricultural sector into *subsectors* for horticulture, arable and livestock farming, because each production direction has its specific links with the biomass market. The NACE3 and NACE 4 classifications, for industrial groups and classes respectively, provide disaggregated sector data at EU member state levels. However, it might be necessary to go another level deeper, depending on the objectives of the monitoring and impact analyses. The Community Production (PRODCOM) statistics, which is consistent with the International Standard Industrial Classification of all Economic Activities (ISIC) and NACE, provides production data for 4500 manufactured *products* at EU member state level (Eurostat 2012). Of course not all 4500 commodities are relevant for studying the bioeconomy, and reversely not all products that are relevant to the bioeconomy are covered by PRODCOM. Nowicki et al (2007) identified around 780 manufactured products that already have or *potentially* have biobased ingredients. Moreover, his study estimated the current and potential shares of the biobased composition in these products, herewith indicating the extent that fossil resources are substitutable with biobased resources.

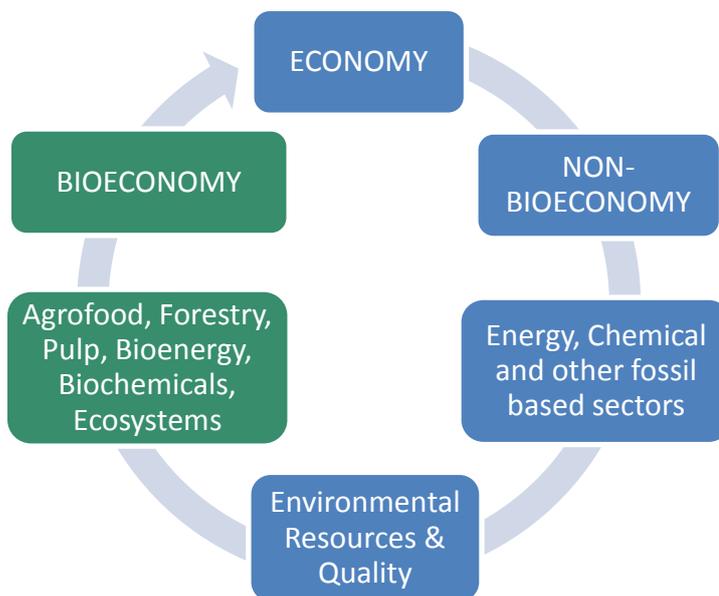
A special note regards the activities of the *ecosystem* or *non-market service activities* that are also covered by the definition of the bioeconomy used in the SAT-BBE project. Four ecosystem services can be distinguished, based on the definition of ecosystem services in the Millennium Ecosystem Assessment (United Nations 2005), namely *provisioning ecosystems*, such as the production of food and water; *regulating ecosystems*, such as the control of climate and disease; *supporting ecosystems*, such as nutrient cycles and crop pollination; and *cultural ecosystems*, such as spiritual and recreational benefits.

With a growing world population the environmental impacts are becoming more apparent, leading to a deterioration of air and water quality, overfishing of oceans, deforestation, etc. It is clear that ecosystem

services play a role and compete with other sectors in getting access to sustainable processes and biomass products. The society is aware that ecosystem services are limited as well as threatened by human activities. There is thus a need to take the long-term ecosystem health and its role in enabling human habitation and economic activity into consideration when designing the systems analysis tool for the bioeconomy. Although analytical data and tools to measure ecosystem services do not clearly exist yet, it is important that those services would be captured in one or another way in the systems analysis tool to be developed.

In an economy, the bundle of biobased sectors (left side of Figure 2) competes with the fossil based (and other) sectors (right side of Figure 2) for resources and production factors (labour, capital and land) for the production of goods and services. The systems analysis framework for the bioeconomy to be designed must contain components – to be filled with empirical information - that are able to investigate links between the bioeconomy and other parts of the economy.

Figure 2. Sectoral structure in a bioeconomy



2.3 Geographical and temporal scope

Depending on the research questions to be analysed, the evolution of the EU bioeconomy needs to be monitored and analysed taking into account the appropriate **geographical scope**. For example, benchmark studies across e.g. EU member states or world regions could show why countries or regions perform better than others. Also, trade related research questions can only be addressed taking into account by considering interactions between countries and regions.

The *EU27* is the most important geographic angle that needs to be addressed in the SAT-BBE project, though it is useful to conduct analyses at the *member state* level as well. Further, for measuring the development of biobased employment and value added within country regions, the member state level must be further disaggregated into NUTS2 and NUTS3 *regional levels* (EUROSTAT, 2011). A more precise geographic resolution is required when evaluating environment impacts. A relatively low spatial resolution (0.5 x 0.5 degrees, i.e. about 50 km x 50 km at the equator) is helpful to analyse and monitor the local impacts of climate change. Analysing the impacts on biodiversity could best be based on a 1 km x 1 km (or even lower) spatial resolution.

The **temporal scope** of the bioeconomy becomes important when the progress of the bioeconomy over time in a specific sector or region needs to be examined. Added to the sectoral and geographic scopes, a time factor is determining the frontiers of the bioeconomy, which pave the way to conduct ex-post, real time and ex-ante studies. The time dimension emphasizes the fact that e.g. bioeconomic related policies or technological innovations need shorter or longer timeframes in achieving their desired impacts.

Typically three timeframes are used, namely *Short term (1 to 3 years)*, *Medium term (3 to 10 years)* and *Long term (several decades)*. An example of a short term issue is the immediate effect on prices and production of biofuel policies on agricultural commodities. On the longer term, other factors become more important, such as the increasing global population or the climate change in particular influence the long term performance of the bioeconomy.

2.4 Scenario scope

The potential economic, social and environmental performance of the bioeconomy on the longer term (for example 2030) is surrounded with many uncertainties. **Scenarios** are helpful to identify the impact of these uncertainties and to reveal the dynamics of change. Most importantly, scenarios help to understand the mechanisms underlying changes, and thus could strengthen a strategic planning with regard to the development of the bioeconomy.

Key uncertainties are, for example, international fossil energy prices (oil, coal, and gas), the degree in openness of international trade markets, the global macroeconomic situation, and the speed of technological learning and developments (e.g. conversion technologies, 2nd, 3rd and 4th generation biofuel technologies). The increased use of biomass will not only depend on developments in biobased sectors, but changes and progress in fossil-based sectors and non-biomass renewable energy sectors play roles as well. Scenarios could provide possible bandwidths in biomass availability and prices, in the competitiveness of biobased sectors with non-biobased renewable energy sectors and fossil-based sectors, and in the potential strength of the bioeconomy. Scenarios could also add the importance of sustainability dimension (including circular economy and eco-system services) in the view of the future.

There are various scenario approaches. Starting from a business-as-usual scenario, divergent developments are captured as narratives of a scenario, mostly leading to different development of the biobased economy. For example, the systems analysis framework should allow the analyst to make choices regarding technological progress, technical learning, and the sustainability requirements of new technologies. These are uncertain though critical parameters, which set the pace of developments of a sustainable bioeconomy. For long run scenarios (2050, 2100), such as the IPCC scenarios, often four contrasting story lines, that are all plausible and internally consistent, are determined, based on two key uncertainties. Besides these positive scenarios also normative scenarios or desired visions can be developed to obtain a desired picture of the future. The combination of the various approaches is interesting as it can depict various developments given certain uncertainties whereby the normative scenarios or visions could be used as a target. Policies can be used to see whether it is possible to set a pathway from a certain scenario outcome towards the desired outcome. Besides the sectoral, geographic and temporal dimensions, the scenarios perspective is thus regarded as a fourth dimension relevant when examining the development and impacts of the bioeconomy.

3. Contours of Conceptual Framework

3.1 Aspects of the Bioeconomy Systems Analyses Process

Section 1.1 mentioned the **objectives** or **policy targets** for establishing a sustainable bioeconomy:

- reducing dependence on non-renewable resources;
- adapting to climate change;
- ensuring food security;
- managing natural resources sustainably; and
- enhancing economic growth, creating jobs and maintaining European competitiveness.

To make these objectives or policy targets measurable, they must be transformed into **criteria**. For example, the objective 'enhancing economic growth' can be represented by the criteria 'create 20% extra green jobs between 2013 and 2020'. Alternatively, the objective 'adapting to climate change' could be reflected in the criteria 'reduce greenhouse gas (GHG) with 25% from 2013 to 2025'. Therefore, meaningful **indicators** must be assigned useful to measure the development and impacts of the bioeconomy in relation to the criteria and policy targets. For example, the indicator '% jobs in biomass sectors' could be applied to measure the **impact** on the criteria 'create 20% more green jobs'.

Insights into the impacts on the criteria/objectives will likely trigger **responses** from policy makers (i.e., by reforming the policy or introducing new measures) or from stakeholders in the private sector (i.e., by investing in techniques or changing their management). On their turn, the responses might influence the **drivers** behind the development of the bioeconomy, such as consumer preferences, economic development, innovation and technical change.

SAT-BBE represents the aforementioned iterative process of impacts and responses related to the objectives of the bioeconomy as a Driver-Impact-Response (DIR) framework². To elaborate on this framework for describing and assessing the bioeconomy in the EU, a structure is chosen that is organized along the economic, social and environmental sustainability angles. The DIR framework represents a systems analysis view: the social, environmental and economic drivers of the bioeconomy lead to impacts on the state of human health, ecosystems, and supply and demand of materials. That may elicit a societal or policy response that feeds back on the driving forces. In this way, the importance of various drivers and pressures when evaluating the sustainability of the bioeconomy is emphasized (Hockings, Stolton et al., 2006).

The DIR framework is adopted as a first, very generic conceptual prototype along which the systems analysis tool in the SAT-BBE project is designed. In the course of the project, this prototype is further shaped, improved and specified towards a framework that is able to express the current and the potential status of the long-term bioeconomy. The DIR structure is used to ensure that various types of drivers, impacts and responses are discussed in a comprehensive manner, i.e. within each of the three sustainability dimensions (see Section 3.2). In Section 3.3 these elements are integrated in the SAT-BBE conceptual framework for the bioeconomy. Section 3.4 discusses synergies with the analytical framework of the Bioeconomy Observatory (BISO).

3.2 Drivers, Impacts and Responses

3.2.1 Drivers and Impacts

Impacts

Table 3 presents the five main objectives of the bioeconomy (column 1) that are scheduled under their corresponding sustainability principle (column 2). Dependent on the type of research to be conducted, measurable criteria are formulated for each specific objective (column 3). On their turn, indicators are selected to measure the impacts on a specific objective/criteria and impact category (column 4), driven from factors such as availability of land, water and labour resources, technical innovation, policy

² The DIR concept is based on the Driver-Pressure-State-Impact-Response (DPSIR) model (EEA, 2007²), which is a causal framework for describing the interactions between society and the environment. On its turn the DPSIR framework is based on the Pressure-State-Response model, developed by the OECD.

measures, organisational structures, management skills. Indicators could be quantitative or qualitative parameters.

Table 3. Objectives and its sustainable principles, criteria and indicators

Objective	Sustainable principle	Criteria	Indicators
Ensuring food security	Social	Food availability, food access, food utilisation, affordable food prices, land tenure access	Food-security rates, food price change (consumer, producer), income changes, land rights (particular in developing countries)
Managing natural resources sustainably	Environmental	Protecting biodiversity, protecting high carbon-stocked land	Biodiversity, water quality, soil quality; air quality, land use change
Reducing dependence on non-renewable resources	Economic (political)	Use of renewable and non-renewable resources from domestic and imported origin.	% biomass use in chemical/energy sectors, fossil and non-fossil energy self-sufficiency, trade balance, biomass self-sufficiency rates,
Adapting to climate change	Environmental	Minimum GHG saving, reducing environmental footprint	GHG emission, % use of green energy
Enhancing economic growth	Economic/Social	Economic feasibility, creating jobs, improving employment conditions	GDP, sectoral value added, trade balance, commodity price changes, employment; human resource capital

Drivers

These policy objectives are not the same as drivers, although it is not always obvious what a driver is and what not. Based on consultation with scientific experts and policy advisors in the SAT-BBE project (Brussels meeting, 26 April 2013), three types of drivers are distinguished: *Systems* drivers relate to human processes (population growth, consumer preferences) and biophysical processes (climate change); *Policy* drivers relate to instruments and targets; and *Constraints* relate to the availability of production factors (land, water, human capital/labour). Further, drivers can be separated into *supply* side systems drivers that affect the supply of biomass (e.g. technological progress) and *demand* side systems drivers that affect the demand for biomass (e.g. demographic factors). Herewith, the SAT-BBE project takes into account the following driver types that influence the development of the bioeconomy: system supply drivers, system demand drivers and constraints. The policy drivers are discussed in the response component of the system (Section 3.3) as policy makers are able to influence these drivers directly.

Systems supply drivers

Examples of systems supply drivers that affect the supply of biomass are climate change, resource efficiency, technical development and innovation. Climate change influences for example, the productivity of forestry, fishery and agricultural sectors due to the gradual climate change and the currently extreme weather circumstances.

To anticipate on the climate change issue, *resource efficiency* of the EU bioeconomy systems is seen as one of EU's flagship initiatives in the 'Europe 2020' strategy. On top of inorganic resources, it encompasses organic resources (e.g. biomass, food, soil and fossil energy) and conversion efficiencies that must endorse lower pressure on the environment.

Innovation and technical change is another key factor for achieving green biobased economic growth. New technologies can generate efficiencies gains, increased competitiveness of bio-products and knowledge driven jobs, but can also lead to changing demand patterns for land and resources across world regions. Further, innovations and technological developments depend, to a certain extent, on the societal acceptance. For example, genetic engineering is expected to play a role in food and non-food applications, although their use is subject of intense debate. Also innovative biomass processing chains, such as biorefineries are considered as an efficient manner of valorising biomass into a spectrum of biobased products. Its production process is aimed to close material cycles (e.g. by providing valuable fertilisers) or to reduce the non-valorised waste production.

Systems demand drivers

Systems factors that drive the demand for biomass include, among others, e.g. demographics (population growth, human capital, and education), consumer preferences (taste, behaviour) and economic development (income growth). The *growing world population* is increasing the demand for cultivated area of major crops and will strengthen yield increases either by technological progress or the intensification of farming systems. At the same time, *consumer preferences* are changing towards protein rich diets due to increasing incomes. However, consumer preferences have to do with awareness about depletion of resources and environmental and societal problems as well, which might move preferences towards 'green' products. *Economic development* or income growth directly influences the budgets available for buying food and non-food products. If income levels per capita are low a large part of income is spend on food consumption whereas richer people spend relatively less on food.

The strong world population growth in conjunction with the associated changing consumer preferences are resulting into additional competing claims for biomass, herewith increasing the pressure on feed and cropland usages. Also, pressure on cropland use is further expanding due to a higher demand for non-food biomass that is induced by the evolution towards a bioeconomy. The increasing competing claim for cropland is at the expense of shrinking grasslands, savannahs and forests, primarily in tropical countries (Bringezu et al. 2009), and potentially leads to biodiversity losses and greenhouse gas emissions.

Constraints

The increasing demand for biomass may lead to competing claims on biomass and on supplying resources such as land, water, waste and human capital. These resource constraints differ from the systems supply drivers in the sense that they constrain the production factors, but both affect the availability and supply of biomass.

Especially critical in the bioeconomy debate is the competition for *land* between conventional biomass using sectors (food, feed, paper) and new biomass users (energy, chemistry) and also non-market service activities. In conjunction with the increased demand for biomass, the so called *indirect land change* impacts are intensively researched and discussed in the EU and elsewhere. Therefore, the regional biomass availability will be constrained by sustainability criteria that go beyond CO₂ emissions savings and by the *land* that is permitted to be used for non-food biomass purposes. Biofuels and bioliquids, for example, shall not be made from raw material obtained from land with high carbon stock (wetland, peatland, forested areas (RES Directive 2009/28/EC, 2009).

With an increasing biomass production, the additional *water usage* in agricultural (mainly for irrigation) and processing stages potentially increases the pressure on scarce fresh water resources. This may negatively influence the environment (e.g. biodiversity in aquatic and terrestrial ecosystems) and human health (e.g. due to malnutrition), depending on the water available in the region (Pfister et al. 2011). Further, Pfister addressed potential trade-off mechanisms between water consumption and land use. Yield maximization would reduce the pressure on land, but could be rather inefficient with regard to water use. The latter mechanism indicates trade-offs in resource use and in environmental impacts.

The availability of human capital is another key resource that influences the development of the bioeconomy. The transition towards a bioeconomy requires a diverse skilled workforce. As is identified in the definition of the bioeconomy there is a need of skills in the field of sciences (life sciences, agronomy, ecology, food science and social sciences), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge.

3.2.2 Responses

Response indicators demonstrate the efforts of the society, i.e. from politicians, decision-makers, private stakeholders, to solve problems when realising the objectives of the bioeconomy. Not all impacts will necessarily be favourable to all types of objectives due to correlation and feedback effects and trade-off mechanisms. Policy reforms, newly adopted policies, changing management and organisation forms etc. are required to turn the negative effects into positive benefits for the bioeconomy. Integrated, holistic views are needed to avoid that differing policies or instruments do conflict.

As explained in the previous section, policy targets are quite closely connected to drivers. They are answers that anticipate to the affected sustainable objectives caused by systems drivers and resource availabilities. On their turn, the adapted policy targets in conjunction with the systems drivers will again influence the sustainable objectives behind the bioeconomy. This iterative process will continue until the environmental, economic and social sustainable objectives will be sufficiently satisfied. In principle, each systems driver can be connected to a policy target or instrument (Table 4). Table 4 summarizes the key drivers\constraints (Section 3.2) and policy responses of the bioeconomy. They are structured along the abovementioned driver types and connected to related policies. As indicated in Section 2.3 we elaborate the policy responses in this section.

Table 4. Drivers, its types and related policies.

Driver/ constraint	Type	Policies
Climate change	Systems, supply	Mitigation and adaptation policies, reducing emissions from deforestation and land degradation (REDD), renewable energy directive (RED),
Innovation and technical change	Systems, supply	Science and innovation policies, knowledge diffusion policies
Demographics	Systems, demand	Number of child policies (e.g. China), fiscal measures
Consumer preferences	Systems, demand	Tax system (e.g. meat tax), public advertising
Economic development	Systems, demand	Various policies, investment policies
Land resources	Constraint, supply	Environmental policies especially land regulation policies
Water resources	Constraint, supply	Environmental policies, especially water policies and directives
Waste	Constraint, supply	Environmental policies
Human capital resources	Constraint, supply	Education policies

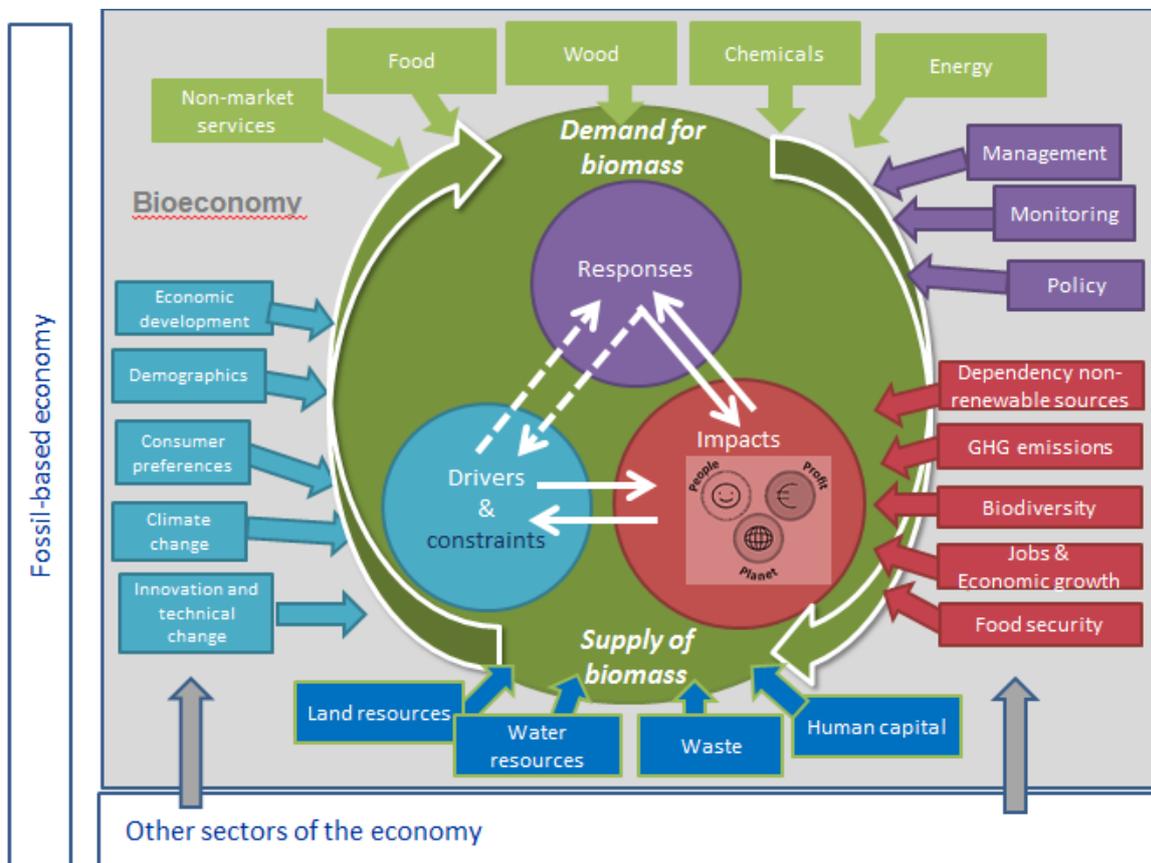
Policy responses (drivers) are identified policies (e.g. biofuel policies, renewable energy directive, agricultural policies, trade policies, climate change policies, environmental policies, and science and innovation policies) and pathways that stimulate the sustainable development of the bioeconomy. Policy drivers address responses from policy makers to realise the objectives of the bioeconomy. In fact, most system drivers are linked to a specific policy incentive or policy target. To get to a more desirable outcome policy makers adjust policies to influence the supply and demand drivers and thereby the outcomes or impacts (people, planet, profit). In the next stage of developing the DIR-framework within the systems analysis tool, policy makers are triggered to respond on impacts, for example, by adjusting an existing policy instrument or by adopting a new policy target. The degree of response or reaction will depend on the speed and magnitude of the impacts and the progress compared to the set criteria and targets.

3.3 Structure of Systems Analyses Framework

The systems analysis tools framework that will be developed in the SAT-BBE project needs to incorporate the functional requirements and needs to be able to monitor the development and impact of the biobased economy. The term *systems analysis* implies that the framework needs the capacity to understand relations between parts, and the nature of both the parts and their relationships. Based on the simple DIR framework, described in section 3.2, a more extensive, though still generic structure of the systems analyses framework for the bioeconomy is designed (Figure 3).

The increasing production of biomass feedstock and conversion to conventional and new uses have important direct and indirect consequences, which, directly and indirectly, influence the environmental and socio-economic performance of bioeconomy systems and policies. In order to perceive a comprehensive overview for the complex analyses of the bioeconomy we use a supply-demand framework that connects the building blocks (drivers, impacts, responses) for our analyses (see, Figure 3). The current fossil-based economy (white boxes) is the starting point, whereby the pathway of transition to a sustainable bioeconomy (grey box) is influenced by system drivers\constrains (blue boxes) and policy\management responses (purple boxes). The bioeconomy has interrelations with the fossil-based economy in the sense that both worlds compete for production factors and market demand. The core of the bioeconomy is represented in the green centre of the figure. That circle illustrates the interaction of drivers, impacts and responses through the supply and demand of biomass. The demand for the bioeconomy is coming from a linked system of food, wood, energy, chemicals and non-market services. The supply of biomass uses land, water, waste and human capital resources and these are linked to the demand system. The system drivers of the bioeconomy (blue boxes) are related to the supply and demand side of the bioeconomy. Demographic growth, consumer preferences and economic growth are identified as key drivers for the demand side and technological and climate change for the supply side of biomass. For the supply side also the natural and human capital resources are important.

Figure 3 Conceptual systems analyses framework for the bioeconomy



Given the complexity of the system the bioeconomy developments generate many direct and indirect effects and (potential) developments should be assessed on sustainability, and therefore the people, planet and profit indicators can be taken into account (red boxes in Figure). The impacts of a sustainable development of the bioeconomy are measured and confronted with the broader policy objectives or policy targets for establishing a sustainable bioeconomy. The red boxes provide broad indicators linked to policy objectives: reducing dependence on non-renewable resources, adapting to climate change (GHG emissions), managing natural resources sustainably (biodiversity), enhancing economic growth and creating jobs, and ensuring food security.

The third block (purple boxes) are policy and management *responses* to achieve the policy targets by influencing the system drivers. For many applications, the cost of renewable energy is currently higher

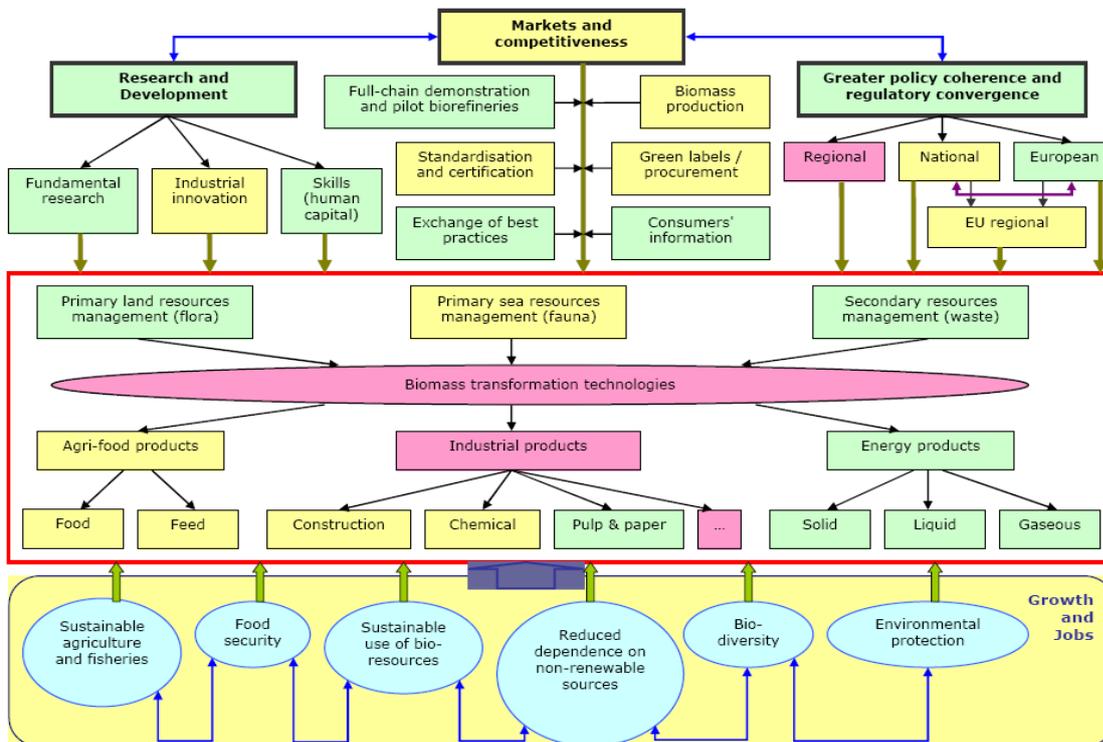
than for technologies that produce electricity, heat or fuel from fossil fuels. One assumption behind the current incentives is that they will eventually drive down the cost of these technologies, through economies of scale and learning by doing. In that sense, these incentive policies play a critical role in the innovation process of renewable-energy technologies. According to Bahar et al. (2013) some policies focus on creating demand for these technologies in order to pull them into the market place (market-pull policies, e.g. mandates and feed-in tariffs), while others focus on production of the technology or fuel itself in order to increase supply or foster innovation (technology-push policies). Regulation are often needed to prevent negative side effects on, for example, food prices and biodiversity. In general, demographic, consumer, agricultural, energy, economic growth, technology and environmental policies can be used to facility the transition from a fossil based to a sustainable bioeconomy.

3.4 Synergies with the Bioeconomy Observatory (BISO)

The EU Bioeconomy Strategy addresses the need to establish a Bioeconomy Observatory (BISO). This is an information system (Figure 4) allowing the Commission and other stakeholders to assess the progress and impact of the bioeconomy. It must bring together relevant data sets and information sources, and would use assessment, modelling and forward-looking tools meant to provide a coherent basis for establishing baselines, monitoring, and scenario modelling for the bioeconomy as a whole.

Figure 4 reflects the analytical framework of the EU economy, as proposed in a JRC report (2013). The colouring is connected to the level of difficulties in collecting data and information, and in making analysis: green means that no major difficulties are expected; yellow means that difficulties are expected; and red means that significant difficulties are expected. The Observatory framework is built up in three parts. The top part covers 'Research and Development', 'Markets and Competition' and 'Greater Policy coherence' as priority topics determined by the Commission. The middle part shows the most important bioeconomy flows. The bottom part presents the constraints and governing interrelated factors that underpin the bioeconomy, encompassed by the EU key objective to generate growth and jobs.

Figure 4. The analytical framework of the EU Bioeconomy



Source: Bio-economy and sustainability: a potential contribution to the Bio-economy Observatory (JRC, 2013)

The main objective of the BISO project is to monitor the bioeconomy in the past, by collecting, structuring and storing observed data in an information system. Reversely, the SAT-BBE is looking forward in the sense that it is investigating what type of data and models will be required to monitor the evolution of the bioeconomy. More precisely, the aim of SAT-BBE is to design a systems analyses framework that enables stakeholders to conduct policy analysis, scenario studies, and impact assessments in respect with the long term EU bioeconomy.

Aforementioned purposes show that both projects have complementary objectives to fulfil, and could benefit from each other (Table 6):

- SAT-BBE provides knowledge on the type of indicators, criteria that are useful to conduct ex-ante impact assessment studies; herewith it could advice on what information must be implemented in the BISO information system;
- BISO provides information on existing bioeconomy related indicators and tools, and centralizes them in an information system in order to make them accessible.

Table 6. Comparison between BISO project and SAT-BBE project.

Category	Bioeconomy Observatory (BISO)	System Analysis Tool for bioeconomy (SAT-BBE)
Objective	Bring together and organize relevant data sets, indicators and quantitative and qualitative methods, to perform EU capacity mapping, technology watch, bioeconomy policy outlook and market monitoring in areas related to the bioeconomy	Identify how to describe (in terms of data and indicators), monitor and model the bioeconomy part of the economic system, by the development of an appropriate toolkit. The concepts of bioeconomy and non-bioeconomy sectors will be defined, major interactions and feedback effects between the bioeconomy and other parts of the system will be identified and analysed, and the likely impacts and trade-offs of the bioeconomy "drivers" will be studied.
Main Activity	System shaping, centralization, and sharing of existing data, indicators, and tools relevant to the Bioeconomy	Demonstrating how the existing data and quantitative models and their future extensions and improvements, as well as qualitative analyses (e.g. foresight analyses), can be used to describe the bioeconomy development, its interactions with the rest of the economy, and its impacts to environmental resources and their quality. Identify research gaps based on existing data and tools.
Duration	March 2013 - February 2016	October 2012 - March 2015
Consortium	JRC Headquarter Brussels (Belgium), IPTS Seville (Spain), ISPRA (Italy)	LEI-WUR (NL), Utrecht University (NL), European Forest Institute (Finland), Wuppertal Institute (Germany), IIASA (Austria), IFPRI (USA), Institute for Environmental Studies-VU University Amsterdam (NL), Thünen Institute (Germany)
External Cooperation	EU Commission services EU Member States International organizations (Key) Third countries (non-EU) Industry associations and expert groups	European Commission services External expert groups

4. Expected evolution of the bioeconomy

This chapter discusses some important ideas and concepts that help to organise the thinking around possible pathways of the bioeconomic future. These are traced from the literature of model-based, economic and environmental assessments and from expertise available in the SAT-BBE consortium. The information presented here is based on the "Story-and-Scenario" approach, which is one of the most enduring and appealing approaches to combining the qualitative nature of certain scenario specific trends and tendencies with quantitative measures of methods of modelling economic and environmental approaches (Alcamo, 2009). It has been applied in important global studies, such as the Millennium Ecosystem Assessment (MEA, 2005), the UNEP Global Environmental Outlook (UNEP, 2007) and the various assessments report of the Intergovernmental Panel on Climate Change. In these publications 'storylines' are developed based on generic plausible trends of key driving forces of economic, environmental and social systems. Some drivers can only be qualitatively described (e.g. social cohesion, governance aspects), while others can be more directly quantified and corroborated with data and model-based outputs. Drawing from the examples of 'storylines' derived in the MEA and GEO-4 assessments (Alcamo, 2009), the scenarios for the bioeconomy could be developed around two key tendencies.

'Fossilised' scenario

This scenario assumes inward-looking, fragmented and non-cooperative tendencies of national governments and institutions that lead to low levels of technical innovation, openness to trade and exchange of ideas, migration, economic growth; reluctance to form cooperative, beneficial political or monetary unions. It reflects higher levels of population growth, localised concentrations of poverty, malnutrition and socially-depressed populations within countries and regions. It fits to the "Order-From-Strength" or "Security-First" scenarios of the MEA and GEO-4 assessments, with little progress towards a knowledge-based worldwide bioeconomy.

'BioProgressive' scenario

This scenario is based on tendencies towards a more open exchange of commerce, ideas and innovations that allows innovations to spread faster and for populations within a more globalised environment to benefit from the spill-overs related to faster technological progress and productivity and efficiency advances. The rates of technical innovation and productivity improvements are high, there is higher freedom of movement for human populations, more liberalised labour markets and competitive wages, higher economic growth, generally lower population growth accompanied by higher levels of education, overall higher levels of human well-being. Fits to the "Techno-Garden" or "Sustainability First" storylines of the MEA and GEO-4 assessments, with fast progress towards a knowledge-based global bioeconomy.

Taking the sectoral perspective of the bioeconomy as starting point, Table 7 presents a plausible evolution of trends and conditions across the contrasting scenarios in the biobased sectors. For each scenario the impacts on the performance indicators are measured by comparing the scenarios outcomes with these under a Business-as-Usual baseline scenario. A baseline normally takes the historical trends of economic and technical productivity and population growth – relying on the current UN medium variant population projections, and the projections of economic growth from OECD and the World Bank Global Economic Prospects - as starting points. Furthermore, the baseline assumes that current bioenergy related policies remain in place, and that the key technologies currently in use within the agrofood, forestry, biochemical and biotechnology sectors persist for the coming decades.

Table 7. Plausible evolution of the bioeconomy sectors under the "Fossilised" and "BioProgressive" cases

Category	'Fossilised' case	'BioProgressive' case	Performance indicators
Agriculture			
Crops	Lower productivity growth with more reliance on area expansion than yield gains	Faster productivity growth with less crop area expansion and higher harvest intensity	Share of production growth in yield gains
Livestock	Slower productivity growth with stagnant feeding conversion ratios	Faster productivity growth with rapidly improving feeding efficiencies	Livestock production per unit feed
Fisheries	Slower expansion of aquaculture growth with persistence of disease and little innovation in feed substitutes for fishmeal	Faster expansion of aquaculture growth with rapid decline in antibiotic use and steady innovations in feed alternatives	Fish production per unit feed
Forestry			
Pulp & paper industry	Stagnant levels of productivity and slow innovation in use of forestry by-products	Steady productivity growth with steady innovation in use of forest by-products for fuel and other uses	Value added generated per unit area of forest
Bioenergy	Slow innovations in bioenergy and continued reliance on first-generation biofuels with limited growth in advanced biofuels and limited use of co-products	Faster innovation in bioenergy with steady replacement of first-generation technologies with more advanced cellulosic technologies and broadening range of co-products	Share of energy in renewables KJ per kg feedstock
Biochemicals	Stagnant development of biochemical products with limited innovations in conversion processes and development of useful co-products	Rapid development and innovation in range and utility of bio-products with improving efficiencies and proliferation in commercial co-products	Share of chemical sector output in advanced biochemicals

In order to fully exploit the benefits of the BioProgressive scenario, possible trade-offs must be managed and negative impacts need to be minimised. The most important drawbacks expected in the areas of economy, society and environment are related to the increasing demand for land and competition with food crops. These may result in socio-economic impacts, affecting employment, economic growth, food security, prices of agricultural commodities and food, environmental impacts such as climate change (through the ILUC mechanism and market leakage), impacts on biodiversity of terrestrial and aquatic ecosystems. Possible strategies or responses for addressing environmental drawbacks are, for example, increased use of organic wastes, forests and/or agricultural residues, but also the development of biorefineries that allow for a more complete use of the biomass for producing biobased materials, energy, fuels and heat. Incorporating strategies that control the trade-offs that may occur under a 'BioProgressive' or 'Fossilised' case should be key in providing a complete assessment and accounting of the potential pathways of the EU's bioeconomy.

5. Key findings

The SAT-BBE project responds to the challenge of optimizing the emerging bioeconomy by providing a design of an analytical framework to assess and address the short and long term challenges for an effective and sustainable EU strategy. The project provides an interdisciplinary scientific basis to inform the bioeconomy policy development and decision-making by all stakeholders working within the EU to help improve the conditions for satisfying the bioeconomy potential today and in the coming decades. The outcome of SAT-BBE is a Systems Analysis Framework for the Bioeconomy.

The objective of the SAT-BBE project is to describe, monitor and model the bioeconomy part of the economic system, by the development of an appropriate conceptual toolkit. The concepts of bioeconomy and non-bioeconomy sectors will be defined, the major interactions and feedback effects between the bioeconomy and other parts of the system will be identified and analysed. Also, the likely impacts and trade-offs of the bioeconomy drivers (e.g. economic growth, climate change) will be studied.

Definition of Bioeconomy

Since 2005 several definitions of the bioeconomy have been used in policy documents and presentations (Aguilar, Bochereau et al. 2010). In 2012 the EU Communication on the Bioeconomy launched the following definition (EC, 29 Feb 2012):

'The bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. 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), enabling and industrial technologies (biotechnology, nanotechnology, information and communication technologies (ICT), and engineering), and local and tacit knowledge.'

The SAT-BBE project has adopted this description for setting its scopes of the conceptual analysis tool to be developed. The definition's focus is broad and interdisciplinary enough to analyse and monitor bioeconomy pathways and activities, now and in the future. Besides the aspects that are originally linked to bioeconomy sectors like agro-food, forestry, pulp and paper, the definition captures non-traditional bioeconomy activities such as bioenergy and biochemistry, as well as agricultural wastes, post-harvest losses and wastes at the retail levels. Current losses (waste) in the agrofood chain account to 30% to 40% of the total chain production. Transferring waste into by-products will generate new business opportunities for stakeholders in the value chain, and will reduce the pressure on land use and stimulate the transfer towards a circular economy. Moreover, this definition also considers non-market ecosystems, i.e. ecosystem services. Non-market ecosystem services provide people access to resources such as clean drinking water and fresh air. Herewith, ecosystem services compete with other sectors in getting access to sustainable processes and biomass products.

Further, with regard to analysing and monitoring the evolution of the bioeconomy, the bioeconomy definition must be able to address the following inter-disciplinary topics:

- economic, environmental and social sustainability of the bioeconomy;
- non-linear (circular) processes, carbon recycling, cascading principle;
- worldwide, national and regional analyses;
- forward looking analysis of a knowledge-based and innovative bioeconomy.

Systems analysis tool to be designed

The EC's Bioeconomy Strategy (2012) identifies five societal objectives related to the development of a bioeconomy: ensuring food security, managing natural resources sustainably, reducing dependence on non-renewable resources, adapting to climate change, and enhancing economic growth, creating jobs and maintaining European competitiveness.

The systems analysis tools framework to be developed in SAT-BBE has the purpose to understand the functional requirements of a bioeconomy and to measure the necessary extent for transformation of the economy as a whole to a biobased foundation. A systems analysis implies the capacity to understand

relations between parts, and the nature of both the parts and their relationships; it will be based on a Driver-Impact-Response (DIR) framework. *Drivers* (D) are factors that drive the development of the bioeconomy. Indicators measure the *Impacts* (I) of the drivers on the objectives. Insight into the impacts will trigger *Responses* (R) from e.g. policy makers and stakeholders in the private sector.

In this stage of the project, serious efforts were put in achieving consensus on the definition of drivers, impacts and responses and how these elements fit in the conceptual systems tool that is developed. The proceedings of the meetings with consortium partners, EC representatives and the advisory board show that discussions were and will remain useful to clarify definitions and to determine key drivers, indicators and criteria in order to achieve consistency across them.

Purposes of the systems analysis tool

An important purpose of the systems analysis tool will be to provide policy makers with an instrument that can monitor the changes occurring in the current and future economy, with the technologies as they are today and tomorrow. Second, it must be possible to regard non-traditional bioeconomy activities, which implies that SAT-BBE must clearly point out that the regional and worldwide nature of bioeconomy sectors are changing in the future. Third, it must indicate that specific biobased aspects, for example the activities beyond the ecosystem (non-market) services, will require analytical tools that don't exist yet. Fourth, the knowledge and availability gaps of potential data and tools that are suitable and applicable to analyse and monitor the bioeconomy evolution must be closed. The SAT-BBE project is expected to recommend on how these gaps could be satisfied the best: by developing new conceptual and analytical tools or by linking differing types of biobased related models. In principle, SAT-BBE indicates what is possible with existing data and tools and what are the research gaps.

Relation between SAT-BBE and BISO

The main objective of the BISO project is to monitor the bioeconomy in the past, by collecting, structuring and storing observed data in an information system. Reversely, the SAT-BBE is looking forward in the sense that it is investigating what type of data and models will be required to monitor and steer the evolution of the bioeconomy. More precisely, the aim of SAT-BBE is to design a systems analysis framework that enables stakeholders to conduct policy analysis, scenario studies and impact assessments in respect with the long term EU bioeconomy. Both projects have complementary objectives to fulfil, and could benefit from each other

At last

The outcome of SAT-BBE is expected to be a conceptual systems analysis tool that will clearly explain which bioeconomy connected issues could be addressed, and which questions could be answered with the currently existing set of data and models. On top of this, the project will point out which type of research questions couldn't be answered with the current tools. Work Package 2 is going to provide an overview of different data and tools that could be applied in the bioeconomy research, which type of questions they could answer and which not, what their pros and cons are, etc. One of the outcomes will thus be an inventory of knowledge, data and tools gaps. In this way, the SAT-BBE project can support the Commission with targeting its research and development agenda, and whether or not specific data and tools need new or further development. Such targeting actions are essential to ensure that the current and future bioeconomic analyses and monitors will be captured in sufficient and efficient ways.

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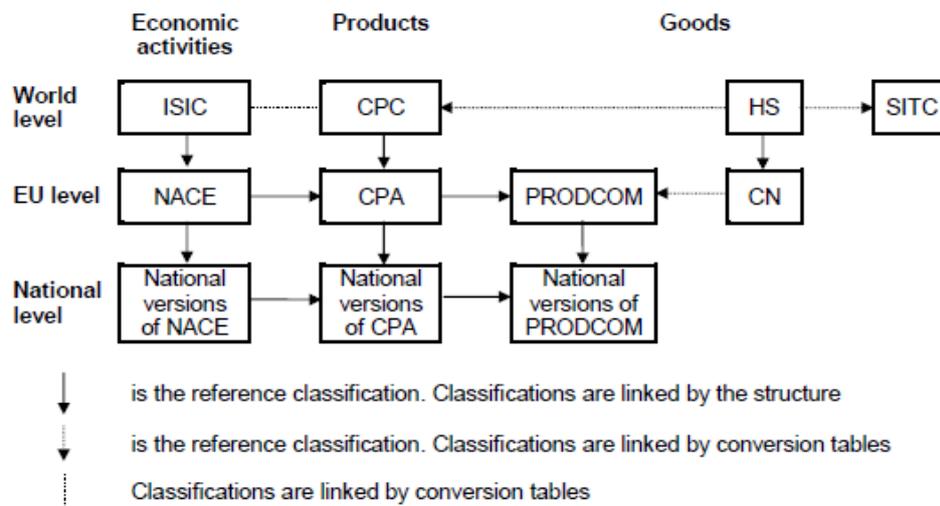
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Annex 1. Classification of biobased sectors and products

Box 1 Classification of biobased and other products: links across databases

Recognised classification systems that accommodate the range of available statistical data lie on the basis of the conceptual analysis framework for the bioeconomy to be designed. Classification systems provide a common language for both the compilation and the presentation of statistics used across EU member states and Community institutions.

Economic statistics require different classifications for different purposes. Hence, international classifications have been developed, ranging from the branch classification that is embodied in the System of National Accounts (SNA), to the International Standard Industrial Classification of All Economic Activities (ISIC) and to the very detailed commodity classification of the Harmonised System (HS). Next figure shows the linkages across the different classification systems, including PRODCOM.



Where:

- ISIC is the United Nations' International Standard Industrial Classification of all Economic Activities.
- NACE is the statistical classification of economic activities in the European Communities (the acronym is derived from the French title "Nomenclature générale des Activités économiques dans les Communautés Européennes").
- CPC is the United Nations' Central Product Classification.
- CPA is the European Classification of Products by Activity.
- HS is the Harmonized Commodity Description and Coding System, managed by the World Customs Organisation.
- CN is the Combined Nomenclature, a European classification of goods used for foreign trade statistics.
- SITC is the United Nations' Standard International Trade Classification, an international classification of goods used for foreign trade statistics.
- PRODCOM is the classification of goods used for statistics on industrial production in the EU.