Working paper D1.1

The relationship between bioeconomy sectors and the rest of the economy

This document is the result of
WP 1 ‘Conceptual model of a systems analysis of the biobased economy’
of the EU FP 7 SAT-BBE project:
Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy

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SAT-BBE

Project consortium and contribution

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1 Introduction

One of the biggest challenges facing global society today is the increasing provision of food, water, energy, healthcare and other resources and ecological services. The SAT-BBE project (fill title 'Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy') studies the contribution of a bioeconomy in many of these areas to ensure long term economic and environmental sustainability. Given that the lead time for some social and technological solutions is long, there is a need for a framework to structure long-term analytical capacity for providing guidance for the execution of consistent, coherent, long-term strategies with desirable consequences.

The goal of the SAT-BBE consortium is to design a systems analysis tools framework that is able to evaluate the socio-economic and environmental performance of the biobased economy and relevant policies. The systems analysis tools framework will cover the functional requirements of a biobased economy and will measure the necessary extent for transformation of the economy as a whole to a biobased foundation. Further, 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. The project will match the tools with the requirements of the systems analysis and ensure that links between the tools and their access by non-specialists are explicitly addressed. Data requirements and indicators are designed according to the inputs required, and the outputs desired, for the type of analyses intended.

These objectives of the SAT-BBE project will be realized through the sequential development of a conceptual model, the associated analytical tools, and an accompanying analytical framework in three steps:

1. WP 1: Conceptual model of a systems analysis of the biobased economy;
2. WP 2: Analytical tools: databases, indicators and models (quantitative & qualitative);
3. WP 3: Analytical framework: how the tools are to be used.

This working paper is part of WP 1, which has three main objectives:

- To structure the concepts to be used in a biobased economy strategy, including both the place of sustainability within the biobased economy, and the biobased sectors and its drivers (principally bio-technology) in relation to the rest of the economy.
- 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.
- To communicate the conceptual structure of a systems analysis framework as can be applied to an EU biobased economy strategy.

This Working paper '*describes the drivers of the bioeconomy and relationship between the bioeconomy sectors and the rest of the economy; this focuses on understanding what activities are part of the 'bioeconomy'*, as is defined in the project proposal. In Section 2 the biobased economy is defined, including a description of both the place of sustainability within the bioeconomy and the sectors of the economy that are relevant. Next, the size of the biobased economy in the EU-27 and relationships between the biobased economy and the rest of the economy are investigated (Section 3). In Section 4 the key drivers of the biobased economy and the key impact categories are discussed. In the last section the results from Sections 1 to 3 are summarized and links with further work within WP 1 are discussed, i.e. the concept of the systems analysis framework for the bioeconomy in the EU that will be the final output of WP 1. An advanced draft of this document will be discussed with the Steering Group. Completion of this paper will mark the end of the first step in WP1 in line with the first objective mentioned earlier.

2 Defining the biobased economy

In this section the biobased economy is defined. First, various definitions of the biobased economy are discussed, based on which a definition is chosen that will be used in the SAT-BBE project. Second, a more detailed description of sectors relevant for the biobased economy is given in Section 2.2.

2.1 Definition of the biobased economy

The term biobased economy originates from the field of biotechnology. The term was first defined by Juan Enriquez-Cabot and Rodrigo Martinez at a seminar on genomics in 1997 and an excerpt of their paper was published in Science Magazine (Enriquez 1998). Until 2005 the term biobased economy 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 term biobased economy, or bioeconomy, have been and are being used in various policy documents and presentations (Aguilar, Bochereau et al. 2010). The most frequently used definitions are:

> Definition 1: '*The bio-economy includes all industries and economic sectors that produce, manage, and otherwise exploit biological resources (and related services, supply or consumer industries) such as agriculture, food, fisheries, forestry etc*.'. This definition was used at a bioeconomy conference of the EC in 2005 (EC 2005).

> Definition 2: '*Worth nearly €2 trillion, the European bio-economy provides around 22 million jobs in Europe across sectors as diverse as agriculture, forestry, fisheries, food, chemicals and bio-fuels. This is the impressive reality of the European bio-economy. It is an indispensable part of all of our lives and plays a major role in making our lives better*.' (Maire Geoghegan-Quinn, 2010 quoted, in the conference report of The Knowledge Based Bio-Economy towards 2020 conference held in 2010 in Brussels (Ascham Associates 2010)).

> Definition 3: '*A bio-based economy is based on production paradigms that rely on biological processes and, as with natural ecosystems, use natural inputs, expend minimum amounts of energy and do not produce waste as all materials discarded by one process are inputs for another process and are reused in the ecosystem*.' (Franz Fischler (WWF), 2010, quoted in the conference report of The Knowledge Based Bio-Economy towards 2020 conference held in 2010 in Brussels (Ascham Associates 2010).

> Definition 4: '*The Bioeconomy refers to the sustainable production and conversion of biomass into a range of food, health, fibre and industrial products and energy. Renewable biomass encompasses any biological material (agriculture, forestry and animal-based including fish) as a product in itself or to be used as raw material*.' (BECOTEPS 2011). Note that this definition is also used in the SAT-BBE project proposal.

Definition 5: *'The bio-economy is the sustainable production and conversion of biomass, for a range of food, health, fibre and industrial products and energy. Renewable biomass encompasses any biological material to be used as raw material*' (Clever Consult 2010).

The scope and emphasis of these definitions varies and as a result each of these definitions has specific (dis)advantages as also was identified during the on-line consultation of the European Commission on the biobased economy, which was held from February to May 2011 (EC 2011). For example, the technology platform TP Organics preferred the relatively broad definition (definition 3 in the list above), in order to keep enough flexibility in view of potential future developments (EC 2011). The Food and Agriculture Organisation of the United Nations (FAO) highlighted the need to think in terms of a 'sustainable biobased economy' through an ecosystem approach and enabling environment (EC 2011). Along these lines of thought, the Alliance for Beverage Cartons and the Environment (ACE) called for including the 'sustainable sourcing of raw materials' (EC 2011). Therefore, the EC formulated a sixth definition during the consultation, more elaborate definition of the biobased economy, which was supported by all actors that participated in the on-line consultation on biobased economy (EC 2011):

Definition 6: *'[…] a low waste production chain starting from the use of land and sea, through the transformation and production of bio-based products adapted to the requirements of end-users. More precisely, a bio-based economy integrates the full range of natural and renewable biological resources — land and sea resources, biodiversity and biological materials (plant, animal and microbial), through to the processing and the consumption of these bio-resources. The bio-economy encompasses the agriculture, forestry, fisheries, food and biotechnology sectors, as well as a wide range of industrial sectors, ranging from the production of energy and chemicals to building and transport. It comprises a broad range of generic and specific technological solutions (already available or still to be developed) which could be applied across these sectors to enable growth and sustainable development, for example in terms of food security and requirements for industrial material for future generations.'*

Also relevant is the 'Communication on Innovating for Sustainable Growth: A Bioeconomy for Europe', published on 29 February 2012 (EC 2012).. In this communication (and the underlying commission staff working document) the biobased economy is referred to as the bioeconomy and defined as follows:

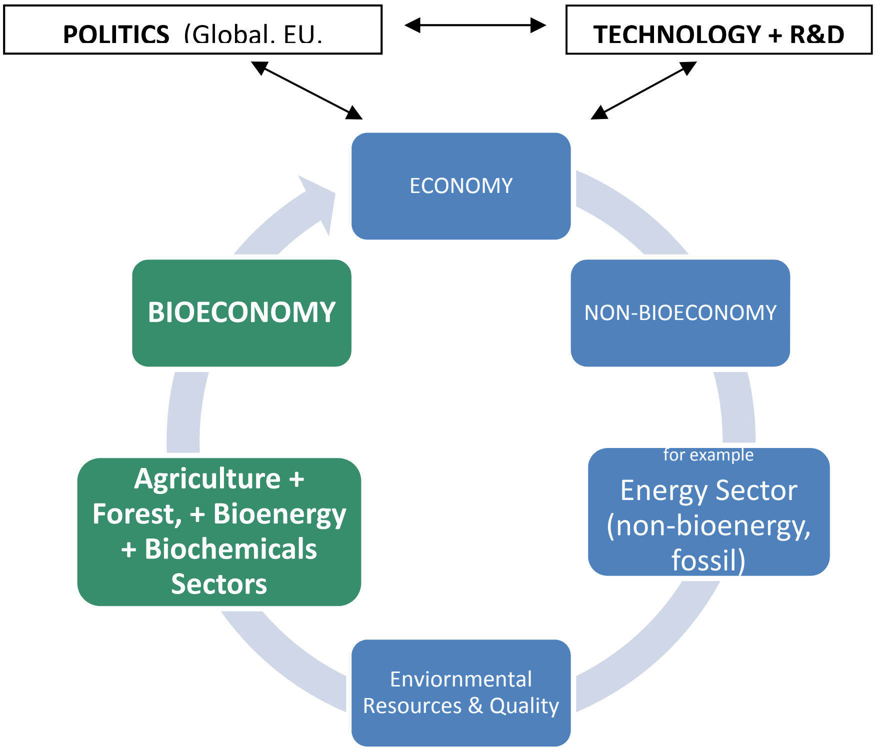
Definition 7: '*The bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products*[1] *and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and 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*.'

For the SAT-BBE project a broadly defined and generally accepted definition of the term biobased economy is essential, considering the broad scope and goal of the project (as defined in Section 1),

[1]Bio-based products are products that are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised,

the wide scope of work and emphasis on sustainable development (as formulated in the project proposal) and the many diverse drivers of the biobased economy (as discussed in Section 3.1). Therefore, in the SAT-BBE project we adopt the relatively broad and general definition 7, which is also the most recent definition that is also accepted by the EC. By doing so the scope of the biobased economy of the SAT-BBE project includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries. (Figure 1). Note that from now on we use the term bioeconomy instead of biobased economy, following the preference and definition of the EC.

Figure 1: Overview of the bioeconomy and the System Analysis Framework that will be further developed within the SAT BBE project.



2.2 Definition of sectors of the bioeconomy

The bioeconomy as defined above *'includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries'*. A more detailed definition of sectors in the bioeconomy is required when investigating the link between the sectors of the bioeconomy and other sectors of the economy (as further investigated in Section 3) and also when developing the systems analysis tools framework for the bioeconomy.

In this section two classification systems of sectors of the bioeconomy are discussed, which vary with respect to the level of detail. The two systems represent the most and least detailed classification systems that are available. In a similar manner, the level of detail varies between the different types of models and tools included in the systems analysis tools framework. The objective of the analysis in terms of scope and level of detail also has implications for the nature and level of aggregation of data, as well as practical considerations such as computing time and data availability.

Fine-scale analysis (example: the Prodcom database)

The ultimate limitation to the level of detail of a systems analysis of the bioeconomy is the level of detail for which empirical data are available on production, consumption, trade, prices, etc. The most detailed dataset that contains comprehensive data at EU level per member state on manufactured goods is the Prodcom database (Eurostat 2012). The term comes from the French "PRODuction COMmunautaire". Prodcom provides statistics on the production of manufactured goods. Prodcom uses the product codes specified on the Prodcom List, which contains about 4500 different types of manufactured products. Products are identified by an 8-digit code:

- the first four digits are the classification of the producing enterprise given by the Statistical Classification of Economic Activities in the European Community (NACE) and the first six correspond to the Statistical classification of products by activity, abbreviated as CPA.
- the remaining digits specify the product in more detail.

Note that not all of the 4500 commodities are relevant for the bioeconomy and that not all products relevant for the bioeconomy are included at this moment. Nowicki et al (2007) identified some 780 manufactured products (among those that are non-food and non-beverage) as already having or *potentially* having biobased ingredients (see further Section 3). Next, the current and potential degree of biobased composition was estimated, and this gave a rough idea of potential volume and value of possible substitution. This is of course a very rough sort of analysis, but it served to identify which classes of products would be most likely to become biobased in the near future, and what would be the relative financial incentive to accomplish such a transformation when comparing one class of products to another. Considering all the products together, it was also a way to have an idea of what would be the interest of promoting a bioeconomy at a policy level.

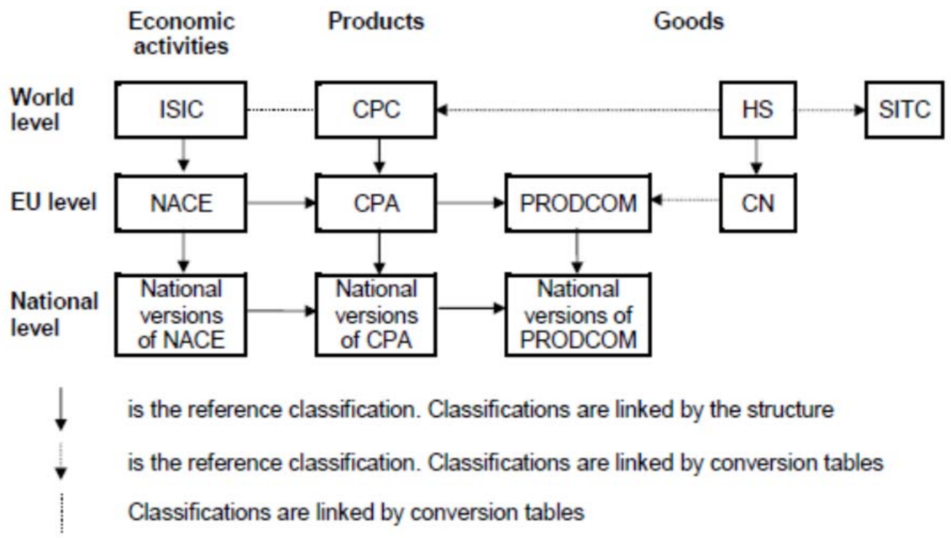
Use of Prodcom data makes it possible to ground the SAT-BBE project on information which is traceable to the recorded reality of EU commodity production and its trade. Another benefit is that the Prodcom database is consistent with the International Standard Industrial Classification of all Economic Activities (ISIC) of the UN by means or the European Classification of Economic Activities (NACE) and other classification systems (see Box 1). NACE is an important tool for comparing statistical data on economic activities at the world level, and use of NACE is mandatory within the European Statistical System. The classification used in the Prodcom database is thus consistent with other databases at international level, EU level and national level. Note that data on some products or commodities under PRODCOM per individual country remain confidential (e.g. ethylene glycol, where only Germany reports on a national publically available level). Especially relevant is the UN Comtrade database (UN Commodity Trade Statistics Database), which has over 140 reporter countries providing annual international trade statistics data detailed by commodities and partner countries. UN Comtrade is also the largest depository of international trade data and it contains over 1.1 billion data records.

Box 1 Classification of biobased and other products - the link between Prodcom and other statistical databases

One of the basic requirements when developing a analysis framework for the biobased economy is the existence of a recognised framework which can accommodate the vast range of statistical data available so that they can be presented and analysed in a meaningful way. Classifications provide that common language for both the compilation and the presentation of statistics.

To achieve an effective single market and biobased economy in the EU, it is essential, for both macro- and microeconomic analysis and for commercial marketing, to have a single, up-to-date classification system that can be used in all Member States and by the Community institutions

Economic statistics require different classifications for different purposes. Hence, international classifications have been developed. These range 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 the very detailed commodity classification of the Harmonised System (HS). The link between different classification systems, including Prodcom, is shown in the Figure below.



here:

- 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.

Source:

Corse-scale analysis (example: the GTAP database)

An important component of the systems analysis tools framework proposed in the SAT-BBE project program will consist of computable and partial equilibrium models that model dynamics of agriculture, forest sector and energy production, consumption and trade, but also other tools are potentially useful, such as input-output / social-accounting matrix analyses. These tools typically use datasets that are directly or indirectly derived from datasets such as the Prodcom database, but only at a highly aggregated level. Especially relevant is the classification used in the Global Trade Analysis Project (GTAP) database (GTAP 2012), which is used both in the MIRAGE model, which is operated by IFPRI, and in the MAGNET model, which is operated by LEI. The GTAP database is the most widely used collection of global data, describing bilateral trade patterns, production, consumption and intermediate use of commodities and services, but it is also probably the least detailed dataset. Underlying the data base there are national input-output tables, trade, macroeconomic, and protection data from several sources, such as Prodcom. The underlying input-output tables are heterogeneous in sources, base years, and sectoral detail, and thus for achieving consistency substantial efforts were made to make the disparate sources comparable.

The current release of the GTAP database is version 8, which includes dual reference years of 2004 and 2007 as well as 129 regions for all 57 GTAP commodities. The input-output tables of several countries, especially OECD members, were adjusted in the GTAP 8 version, to match 2004 and 2007 agricultural production statistics by sector. These are particularly important adjustments for the bioeconomy, given the large percentage that agricultural products contribute to the final costs of bio-energy products. The 57 commodities / sectors are shown in the list below; including which sectors can be considered as 'biobased'. About. 30 of the 57 sectors are classified as biobased or potentially bioeconomy sectors, although some sectors include activities that are partially biobased, such as food processing, wood and paper industries.

No.	Code	Sector description	Direct relevance of the sector for the bioeconomy
1	pdr	Paddy rice	Y
2	wht	Wheat	Y
3	gro	Cereal grains nec	Y
4	v_f	Vegetables, fruit, nuts	Y
5	osd	Oil seeds	Y
6	c_b	Sugar cane, sugar beet	Y
7	pfb	Plant-based fibers	Y
8	ocr	Crops nec	Y
9	ctl	Cattle,sheep,goats,horses	Y
10	oap	Animal products nec	Y
11	rmk	Raw milk	Y
12	wol	Wool, silk-worm cocoons	Y
13	frs	Forestry	Y
14	fsh	Fishing	Y
15	coa	Coal	N
16	oil	Oil	N
17	gas	Gas	N

18	omn	Minerals nec	N
19	cmt	Meat: cattle,sheep,goats,horse	Y
20	omt	Meat products nec	Y
21	vol	Vegetable oils and fats	Y
22	mil	Dairy products	Y
23	pcr	Processed rice	Y
24	sgr	Sugar	Y
25	ofd	Food products nec	Y
26	b_t	Beverages and tobacco products	Y
27	tex	Textiles	Y
28	wap	Wearing apparel	
29	lea	Leather products	Y
30	lum	Wood products	Y
31	ppp	Paper products, publishing	Y
32	p_c	Petroleum, coal products	N
33	crp	Chemical, rubber, plastic prods	Y
34	nmm	Mineral products nec	N
35	i_s	Ferrous metals	N
36	nfm	Metals nec	N
37	fmp	Metal products	N
38	mvh	Motor vehicles and parts	N
39	otn	Transport equipment nec	N
40	ele	Electronic equipment	N
41	ome	Machinery and equipment nec	N
42	omf	Manufactures nec	N
43	ely	Electricity	Y
44	gdt	Gas manufacture, distribution	Y
45	wtr	Water	N[2]
46	cns	Construction	Y
47	trd	Trade	?
48	otp	Transport nec	N
49	wtp	Sea transport	N
50	atp	Air transport	N
51	cmn	Communication	N
52	ofi	Financial services nec	N
53	isr	Insurance	N
54	obs	Business services nec	N
55	ros	Recreation and other services	N
56	osg	PubAdmin/Defence/Health/Education	N
57	dwe	Dwellings	N

[2] Note that biomass production and processing can be water intensive activities. The water sector in GTAP involves collection, purification and distribution of water and excludes the use of water for irrigation. Note that the use of water for irrigation is considered explicitly in GTAP-W (water) model and database, whereby a distinction is made between rainfed land and irrigated land. Substitution is allowed between irrigation and other primary factors. These aspects will be further elaborated later in the SAT BBE project.

The GTAP database and sectoral breakdown has been, and will be further refined by IFPRI and LEI to account for new sectors relevant for the bioeconomy. Both MIRAGE and MAGNET already have included first-generation biofuels as separate sectors. Also more advanced bioeconomy sectors, such as second generation biofuels and biochemicals, have been successfully implemented in the GTAP-MAGNET modelling framework, as well as in input-output analyses and social accounting matrix analyses, and need to be further implemented in the future. The supply of biomass from woody or grassy crop and from residues and waste are not considered yet, but might be in the future. Furthermore, several other modifications are made to better account for certain aspects relevant for the bioeconomy. For example, both MIRAGE and MAGNET consider fertilizer as a separate section, considering the impact of this sector on crop yields and thereby on land use change, as well as on emissions from fertilizer use. Also, water availability is a key issue, which is not covered in the standard GTAP database and family of models like MIRAGE and MAGNET, although there are versions that attempt to include the economics of irrigation (GTAP-W (water)). These issues will be further discussed later when designing the model framework in the SAT BBE project.

3 Relevance of the bioeconomy in the EU

In this section the relevance of the current bioeconomy in the EU is discussed, based on the definition and scope of the bioeconomy discussed above. First, the current size of the bioeconomy is investigated (Section 3.1). This permits an understanding of the complexity of the bioeconomy. Second, the links between biobased sectors and other sectors in the economy are investigated based on various assessment tools (Section 3.2 to 0). This permits an understanding of the different ways to estimate and measure the bioeconomy.

3.1 Overview of the bioeconomy in the EU

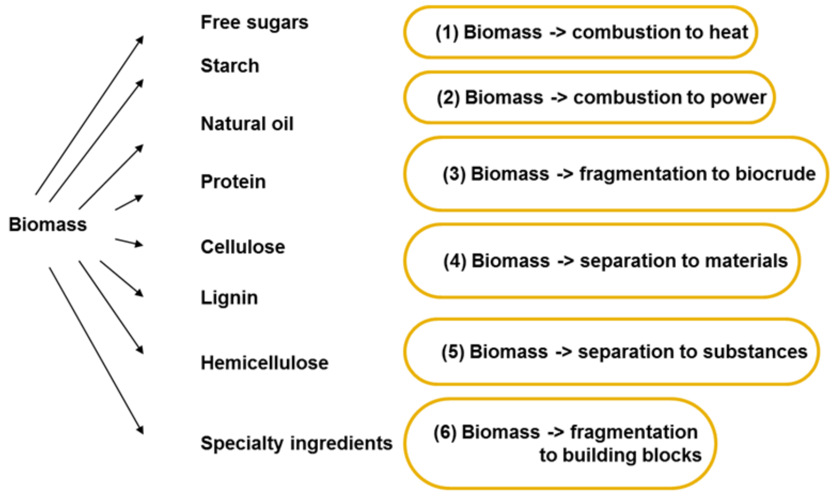
At this moment the turnover of the agri-food and other biobased sectors in the EU exceeds 2 000 billion euros a year and total employment is roughly 22 million workers (Table 1). Note that these results are based on a broad and inclusive definition of the bioeconomy similar to the definition adopted in the SAT-BBE project (see Section 2).

Table 1: Agri-food and other biobased sectors in the EU in 2009. Source: (Cardenete, Boulanger et al. 2012).

	Turnover (Meuro)	Employment (fte)
Food	965000	4400
Agriculture	381000	12000
Paper/pulp	375000	1800
Forestry/wood incl.	269000	3000
Fisheries and aquaculture	32000	500
Biobased industries		
- Bio-chemicals and plastics	50000	150
- Enzymes	800	5
- Biofuels	6000	150
Total	2078000	22005

In 2009, compared to the agri-food sector, the biobased industries as defined above had a relatively low turnover — i.e. about 57 billion euros by contrast to more than 2 000 billion euros for the whole agri-food sector. Note that bioenergy production is not explicitly shown in the table, although the use of biomass for energy is quickly becoming more important. The true potential of the bioeconomy in the EU is, however, much larger than the values shown in the table above. Nowicki et al (2007) carried out an assessment of the potential impact of biobased industries (referred to in the table above) and related industries. This was done based on an analysis of EU production, using Prodcom statistics on production in combination with expert judgement to determine which products could be biobased, assuming possible substitution for petroleum (or other primary material). In order to organise relevant products into internally consistent groupings, two layers of sieving were carried out. The first is by production process. Here, 6 types of production process have been identified. Of these 6, the last three are directly relevant for the manufactured products contained in the Prodcom database.

Figure 2: Resources and processes underlying a bioeconomy. Source: (Nowicki, Banse et al. 2007).



The products are also identified by 'families', which are logical clusters such as 'fabrics' and 'polymers', etcetera, that have a similarity in their use. The composite framework for the families of products are given in the table below, arranged according to the production process involved. It is readily apparent that some families are divided over all three types of production process related to manufactured goods, which is a reflection of the difficulty to establish a typology with mutually exclusive parameters. On the other hand, this situation is an indication of the complexity behind any analysis in the domain of the bioeconomy beginning with the basic question of what exactly falls within the boundaries of the subject and how to delineate the subject matter. The literature search has not found a commonly recognised systematic treatment of the subject, which in itself is a conclusion that supports the type of systematisation undertaken within this study. Note that cascading is not explicitly considered in the overview of resources and processes underlying the bioeconomy and in the overview of current and potential value of the bioeconomy in the EU. Cascading is the subsequent use of biomass for materials, recycling and energy recovery and can greatly improve land use efficiency, CO2 emission reduction and economic performance.

The potential % substitution/replacement of a current product with a bio-based alternative was estimated using the following considerations:

- What is the current (petro)chemical process (if known) for the production of the chemical in question?
- What is the initial starting material for this process (such as benzene, ethylene etcetera) and is it possible to prepare this in a bio-based way (for example for example ethylene may be produced from bio-mass)?
- Considering the subsequent steps (thus the same as the current process), do these involve the use of co-reagents (e.g. chlorine, hydrogen etcetera) and can these be obtained from a bio-based origin?

Table 2: Current value and potential value of the bioeconomy in the EU-25. Source: (Nowicki, Banse et al. 2007).

	Number of items	Share of item values recorded	Total value EU-25	Actual biobased value	Potential biobased value
	#	%	keuro	keuro	keuro
(4) Separation into materials					
Biomass	1	0			
Chemicals	1	100	94,320	94,320	94,320
Fabrics	21	100	9,469,465	9,340,708	9,469,465
Fibres	29	100	5,908,151	5,908,151	5,908,151
Free sugars	10	80	15,606,826	1,560,683	1,560,683
Lignocellulose	1	100	544,890	27,244	27,244
Oils and fats	18	80	10,268,743		
Pharma and netraceuticals	13	69	2,209,266	1,934,784	2,209,266
Proteins	2	50	348,283	104,485	104,485
Pulp and paper	124	78	136,642,951	95,650,066	122,978,656
Skins and leather	19	26	1,346,874	1,259,538	1,303,206
Starch	7	86	2,666,614	1,026,981	1,026,981
Wood and ligneous materials	77	79	68,104,970	55,510,555	65,586,087
Totals	323	78	253,211,353	172,417,515	210,268,544
(5) Separation into substances					
Biodiesel	1	100	6,647,825	4,653,477	6,315,433
Chemicals	5	40	2,136,190	281,436	366,801
Cosmetics	11	24	2,428,273	1,214,136	1,699,791
Glue	7	86	1,286,205	900,344	1,157,585
Lubricants	17	76	5,344,504	2,857,958	3,982,408
Oil and fats	3	67	407,932	406,251	406,251
Paints	21	86	17,721,451	3,738,348	15,473,848
Pharma and netraceuticals	1	100	195,915	97,958	137,141
Polymers	9	56	4,236,910	2,118,455	2,118,455[3]
Pulp and paper	10	10	3,023,858	2,872,665	2,872,665
Solvent and detergents	16	50	6,241,165	4,012,976	4,012,976
Totals	101	60	49,670,228	23,154,004	38,543,354
(6) Fragmentation into building blocks					
Additives	41	39	6,702,867	99,997	6,026,698
Agrochemicals	4	0			
Base chemicals	2	0			
Bioethanol	1	100	354,746	283,797	354,746
Chemicals	131	7	2,039,661	229,196	710,110
Cosmetics	9	89	10,290,596	2,627,543	5,145,298
Enzymes	1	100	933,696	746,957	933,696
Fabrics	17	88	8,307,865	1,921,229	5,114,547
Fibres	37	81	9,704,653	0	4,269,021
Paints and inks	2	50	558,556	167,567	390,989
Pharma and netraceuticals	68	56	116,342,729	28,375,266	58,695,086
Polymers	43	0			
Totals	356	33	155,235,368	34,451,552	81,640,191
TOTAL	**780**	**55**	**458,116,949**	**230,023,071**	**330,452,089**

In total 780 of the 4500 products (non-food and non-beverage) in the Prodcom database were identified as already having or potentially having biobased ingredients. There is a theoretical potential for a substantial number of industrial products, which are not directly part of the food and feed market sectors, to underpin a bioeconomy. The estimated value at present of the part of biobased components in these three industrial product groups is on the order of 230 billion euro,

[3] Note that the figures about the contribution of biobased may be overestimated, according to expert judgement from SAT BBE partners.

compared to 460 billion for food (not including beverages) and feed, as recorded for the annual output of EU-25 manufacturing goods in 2005. The largest group of product families (production type 6) is by nature closely related to the knowledge intensive chemical industry. The total potential of the three sectors of the bioeconomy is much larger than the current potential, namely 330 billion, which is 1 billion more than the current situation.

3.2 Links between bioeconomy and rest of the economy

In this section the links between the bioeconomy and the rest of the economy are investigated, using results from three types of economic analyses: Input/Output analysis, Section 3.2.1; Social Accounting Matrix analysis, Section 3.2.2; Computable General Equilibrium and Partial Equilibrium analysis, Section 0. The focus is on economic linkages; other links will be discussed later in this project. The results show that various tools are available that are able to investigate (economic) links between the bioeconomy and other parts of the economy. Input/Output analysis and Social Accounting Matrix analysis can be used to evaluate linkages in terms of value added, employment, turn cover, income, etc. A key bottleneck of both methods is that not all economic linkages are considered, such as price and trade effects.

3.2.1 Results from I-O (Input/Output) analysis

Input-output analysis, attributed to Leontief, is used for assessing the impact of a change in the demand conditions for a given sector of the economy. Input-output analysis hinges on the crucial assumption that sectoral production is completely demand-driven, implying that there is always excess capacity in all sectors that is capable of meeting increased demand with no price increase. Because this assumption is likely to be unrealistic on the longer term, input-output models are more useful for short term descriptive analysis, as guidelines to potential induced linkage effects of the bioeconomy, and as indicators of likely bottlenecks that may occur in a growing economy, than as predictive models. Descriptive input-output analysis are useful to get insights into the inter-linkages of sectors in a regional economy and to investigate the key sectors in a region in terms of value added, employment, emissions, land and water use, energy use. This type of analysis can be done in a relatively easy way.

Further, I-O models assume a constant returns to scale production function with no substitution among the different inputs. Prices are also assumed constant, which is not a major problem as substitution among factors is expected to be induced only by non-existent relative price movements. Extension of the I-O model to a social accounting matrix (SAM) framework is performed by partitioning the accounts into endogenous and exogenous accounts and assuming that the column coefficients of the exogenous accounts are all constant. Endogenous accounts are those for which changes in the level of expenditure directly follow any change in income, while exogenous accounts are those for which we assume that the expenditures are set independently of income. In determining exogenous accounts, it is common practice to pick one or more among the government, capital, and the rest of the world accounts based on macroeconomic theory and the objectives of the study.

An example of an I-O analysis is the study of Nowicki et al (unpublished results related to (Nowicki, Banse et al. 2009). In their study the macro-economic effects on the Dutch economy are investigated if 10% of the current plastic production of the rubber industry will be substituted by biobased raw materials from wheat and sugar beet in the production of polyethylene. The following links are investigated:

- The use of biomass for production of plastics expressed in terms of value added and employment by comparing the biobased case with the reference situation.
- The contribution of different sectors of the agricultural complex to the total economy
- The change in value added and employment of the production of biobased plastics

Compared to the 2006-reference situation, the value added of the primary arable production will increase due to the additional production of wheat and sugar beets in order to achieve the 10% biobased goal of plastics production (a direct effect of 21 million and an indirect effect of 8 million euro). In the biobased case, the total value added of the arable farming complex will rise 197 million euro above the reference level. As the value added of all other complexes remains the same, the importance of the arable complex in the total agricultural complex increases from 19.7% to 20.4%.

Also, there are two effects on the employment of the arable farming complex:

- A direct effect of 1213 labour units (1516 of the biobased case minus 303 of the reference): 10% of the employment generated by the rubber industry will be 'green' based and has been allocated to the complex;
- An indirect effect of 1392 labour units, which relates to all other sectors that allocate labour in order to produce the required deliveries to the 'green' part of the rubber industry.

Results also show that traditionally the grassland-based livestock complex contributes most to the value added and employment of the total agricultural complex. However, the share of the arable farming complex would relatively increase in the biobased case compared to the shares of the other sub-complexes. The arable farming complex (inclusive the biobased rubber industry) gains 197 million euro (+4.1% compared with reference) and 3341 jobs (+4.7%), which are combinations of direct and indirect effects. So in the biobased case, the arable farming complex could be considered as a winner in terms of value added and employment.

On the other hand, the chemical-base industry will lose value added and jobs as the polyethylene deliveries to the rubber industry will be reduced. The chemical-base industry loses 68 million euro (-0.4% compared with the reference) and 1,233 jobs (-0.8%) due to the smaller amount of polyethylene deliveries to the rubber industry. Moreover, the importance of the non-biobased rubber industry is decreasing as part of its original size has been allocated to the arable farming complex. The non-biobased rubber industry will lose 139 million euro (-2.3% compared with the reference) and 2,159 jobs (-2.4%) as the size of the industry decreased. Finally, compared to the reference situation, the national value added fall by 10 million euro and the national employment by 51 jobs in the biobased case. In percentages, these reductions amount to 0.002% and 0.001% of the current national value added and national employment respectively.

The results demonstrate the ability of I-O analyses to depict and analyse the dependence of one biobased industry or sector on a non biobased industry or sector. However, I-O analyses cannot cover the full spectrum of dependency relations in a market economy. The most important omissions is that price effects are ignored. Computable General Equilibrium and Partial Equilibrium analysis are more suitable. Also the scope and level of detail of I-O analysis is often limited, e.g. household level data are typically not considered and I-O analysis do not consider all monetary flows in an economy. The latter aspects can be investigated using social accounting matrixes (SAMs) as further discussed in the next section.

3.2.2 Results from SAM (Social Accounting Matrix) analysis

The SAM is a square matrix representing a series of accounts which describe flows between agents of commodity and factor markets and institutions. It is a double-entry book-keeping system capable of tracing monetary flows through debits and credits and constructed in such a way that expenditures (columns) and receipts (rows) balance.

Like I-O accounts, social accounting matrices provide a comprehensive accounting structure of market-based productive activities and utilize similar double-counting book-keeping entries. Unlike I-O, however, social accounts focus on the household as the relevant unit of analysis and provide a comprehensive, and additional, set of accounts that track how household income is generated and distributed among sectors/regions. Where I-O tables are focused on industries and their respective relationships with regional output, SAMs extend this into a more complete range of market mechanisms associated with generating household income.

From an I-O perspective, the rows and columns that correspond to industry and commodity are the focus. Whereas I-O is limited to this industrial perspective, social accounting matrices extend the dataset to more fully capture income distribution resulting from returns to primary factors of production (land, labour, and capital). In this way, the circular flow of goods and services to households from firms and the corresponding factor market flows to firms from households are captured.

A relevant example of a SAM analysis is the study ‘An approach to describe the agri-food and other bio-based sectors in the European Union’ of the Institute for Prospective Technological Studies of the Joint Research Centre of the EC. The study is based on a set of SAMs for the EU-27 with a detailed disaggregated agricultural sector (AgroSAMs) for the year 2000 (Cardenete, Boulanger et al. 2012). The SAMs are used to identify key sectors of the bioeconomy and to extract the main tendencies in the behaviour of an economy. For this purpose, all sectors of an economy can be ranked according to a hierarchy derived from two types of indexes: a backward linkage (BL) and a forward linkage (FL), traditionally obtained from a symmetrical input-output table (SIOT). The backward linkage indicator (BL) analyses the effect on the rest of the economy of a change in the final demand of a sector. The forward linkage indicator (FL) evaluates the effect of a joint change in the final demand of all sectors on the production of a specific sector. Potential key sectors are sectors with a BL greater than 0.9, independently of the FL level. Thus, developing the FL of these agri-food and other biobased sectors would convert them to true key sectors.

In addition to BL and FL analysis, an additional multiplier is used to identify the accounts that generate more employment when they receive a unitary exogenous injection of income. The employment multipliers are the result of a new diagonal matrix. This matrix includes the quotients between the volume of employment and the total resources for each productive sector. As a second step, this matrix is multiplied by the part of the SAM that incorporates the rows and columns corresponding to the productive sectors. When increasing the income of an endogenous account, we obtain the impacts of this change on the corresponding column of the partition of SAM and, by means of the diagonal matrix E, we convert this impact into the number of jobs created.

Results are given for all EU-27 countries. Potential key agri-food and other biobased sectors - twenty-one out of a total of sixty-nine sectors - for at least twenty of the twenty-seven countries are: 'Other cereals', 'Potatoes', Agri-food and other biobased sectors in the European Union. 'Sugar beet', 'Other crop products', 'Live plants', 'Fodder crops', 'Raw milk from cattle', 'Cattle, slaughtered', 'Swine, slaughtered', 'Raw milk from sheep and goats', 'Sheep, goats, horses, asses, mules and hinnies, slaughtered', 'Eggs', 'Poultry, slaughtered', 'Other animals, live, and their products', 'Products of forestry, logging and related services', 'Dairy products', 'Meat of cattle, fresh, chilled, or frozen', 'Meat of swine, fresh, chilled, or frozen', 'Prepared animal feeds', 'Electrical energy, gas, steam and hot water' and 'Collected and purified water, distribution services of water'. On the other hand, potential extended agri-food key sectors for three or fewer countries are: 'Durum wheat', 'Rice, milled or husked', 'Other food products' 'Soya Seed', 'Chemical, chemical products and man-mad fibres'. Only one sector, 'Tobacco products', is never a potential key sector.

This first insight from the pan-EU analysis sheds some light on the key features of disaggregated agri-food and other bio-based sectors. Livestock and related products (including fodder, milk and dairy products) present the highest backward linkages within these sectors at the European level. Energy and water sectors are also important potential key sectors. On the other hand, some primary sectors - durum wheat, soya and sunflower seeds, grapes, fresh and vegetables, fruits and nuts - cannot be considered as key agri-food and other biobased sectors at the EU level, although they may be key for some countries. The same observation applies to chemicals, rubber and plastic products. Further research may use the methodology presented here on an updated database for a detailed pan-EU diagnosis.

This JRC-IPTS study uses for the first time fully disaggregated AgroSAMs in order to provide a descriptive analysis of the agri-food and other bio-based sectors and linkages. The limits of this approach are evident, as many changes in the EU economies have taken place within a decade. However, the AgroSAMs are the EU database providing details of all the relevant sectors mentioned. An update of the AgroSAMs for the year 2007 is on-going and will provide more recent data and results. The methodology adopted in this study allows automated reviews, in space and time, of the European agri-food and other bio-based sectors. A key limitation of SAM analysis is that no price effects are taken into account and economy wide correlations are only partially considered. These links and correlation can be investigated using Computable General Equilibrium and Partial Equilibrium analyses.

3.2.3 Results from CGE (Computable General Equilibrium) and PE (Partial Equilibrium) analysis

The CGE framework encompasses both the I-O and SAM frameworks by making demand and supply of commodities and factors dependent on prices. A CGE model simulates the working of a market economy in which prices and quantities adjust to clear all markets. The general equilibrium model is a framework for analysing linkages between markets and thus interactions between industries, factor resources and institutions. Inter-industry linkages are best captured in a general equilibrium framework. In the past, implementation of general equilibrium analysis was constrained by inadequate data and computational resources. Currently, however, the existence of large-capacity computer technology has made possible applications of such models to actual market situations.

In a market economy there is generally a large number of homogeneous goods and services, which include not only consumption items but also factors used in production. Each of these goods and services has a market price, determined by the forces of supply and demand. Every market is assumed to clear at this set of prices.

Under these conditions, computable general equilibrium (CGE) models are similar to multimarket models, in which agents' decisions are price responsive and markets reconcile supply and demand. In a CGE model, production creates demand for value-added factors and goods and services used as intermediate inputs. Intermediate inputs consist of both imports and locally produced goods and services. Demand for value-added factors interacts with available factor supplies to determine factor prices. Equilibrium occurs at prices which equate the demands for goods and services with supplies, and the demands for factors with factor supplies (land, labour, and capital).

Unlike I-O and SAM models, which are based on Leontief technology, neoclassical theory guides specification of production in regional CGE models. In consequence, the CGE model does not represent factor demands as linear functions of output. Instead, factor demands depend on both output and relative prices. The only exception, however, is in relation to treatment of those goods and services that are used as intermediate inputs. The Leontief input-output production function is used to represent production of regional output with fixed proportions of composite primary factors and composite intermediate inputs.

The composite primary factors generally enter the production process in a manner allowing factor substitution. Thus, production is best described as a multi-level or nested production process. All factors in a constant elasticity of substitution (CES) function have the same elasticity of substitution between any pair of factors. To allow for differing elasticities between sets of factors, multi-level or "nested" production function forms are used in CGE, with each level containing a different set of factors and their own corresponding elasticities of substitution. That is, the use of a multi-level structure allows for use of both fixed-coefficients and price responsiveness in the CES form.

A large number of PE and CGE model analyses have been carried out that focus on the link between biofuel production and consumption and agricultural markets, food security, land use, economic growth, oil markets, etc. (Ewing and Msangi 2009; Gehlar, Winston et al. 2010; Hochman, Rajagopal et al. 2010; Banse, van Meijl et al. 2011; IEA 2011; Laborde 2011; Rajagopal, Hochman et al. 2011;

Thompson, Whistance et al. 2011; Villoria and Hertel 2011). Also the impact of the bioeconomy on other economic sectors, especially various service providing sectors (e.g. financial, legal, technical, organisational services) is potentially important. This is especially relevant considering the increasing relevance of services in the EU, both in terms of turnover, value-added and employment (EC 2012).

Here we focus on a study (Nowicki, van Leeuwen et al. 2010) that deals with an innovative and rapidly growing biobased sectors, namely the production of bioplastics. The analyses are carried out for the Netherlands based on the ORANGE CGE model, which allows industries to substitute between the intermediate use of oil-based and biobased plastics. In order to create a shock in the CGE model a 20% subsidy on the intermediate use of biobased plastics (PlasticBio) through a hypothetical reduction in the sales tax is included; this makes it theoretically more attractive for all sectors that use this product to choose it over oil-based plastics (PlasticOth). The subsidy is introduced in 2007, and remains through to the end of the trial period, i.e. 2010. The CGE model experiment deals with a large number of linkages between the bioeconomy and other parts of the economy. More specifically:

- The total macro-economic impact and sectoral impacts.
- The impact on demand for biobased plastics (boost to this sector).
- The substitution away from oil-based plastics (reduction in this sector).
- The increase in the demand for the inputs of the biobased plastics sector, including the agricultural products potentially used for these inputs.
- The increase in the demand for agricultural products would include both domestic and imported agricultural commodities, with concomitant increases in the demand for land when domestic crops are involved.

The results demonstrate, firstly, that it is possible to combine information on technical biobased production processes (in chemical terms) with economic based production processes of sectors (in euros). Secondly, the testing of the CGE model specifically adapted for handling the bioeconomy shows that it is possible to provide outcomes with regard to precise issues; the particular experiment chosen was the substitution of biobased PLA in the place of an oil-based substance. In terms of the underlying theme of this research – the influence of the bioeconomy on agricultural markets – it is certain that the bioeconomy will create a new demand for agricultural commodities for the production of goods that are now using primary or intermediary materials coming from the oil-based economy. This shift between two economic systems will (a) create greater demand for agricultural output and, as a consequence, (b) require more land for the agricultural sector. Some of the satisfaction of this new demand will be sourced domestically (within a nation state), but the amount of land required will be far beyond the capacity of a densely populated country such as The Netherlands to provide. This will have the outcome of increasing crop and land prices domestically, reducing the export of some crops, and increasing imports for the balance of the agriculturally produced commodities required. The resulting indirect land use change (ILUC) effects also affect greenhouse gas emissions and biodiversity effects. It was not possible, within the scope of this research project, to determine whether the overall result would be positive, negative or neutral for the Dutch economy as a whole. But certainly the agricultural sector would benefit, on the one hand, from the increased commodity prices; but it might also suffer, on the other hand, from the increased rental value of land and the increased cost of living generated by higher agricultural prices. The overall cost of living – for farming and non-farming households alike – would be determined by the extent of a decrease in costs that biobased production might bring about in general.

4 Key drivers and aspects of the bioeconomy

The increasing demand for a sustainable supply of food, raw materials and fuels, together with recent scientific progress, are the major economic driving forces behind the bioeconomy in the EU over the last decades. In addition to being economically favourable, the bioeconomy may also help to meet the most urgent global challenges improving public well-being in general. Areas that it can benefit include social and demographic development and its impact on agriculture, the growing pressure on water, the threat of climate change, the limited resources of fossil fuel, the need for sustainable development, the impact of changes in lifestyles and eating habits, the demand for safer and healthier foods and the prevention of epizootic and zoonotic diseases.

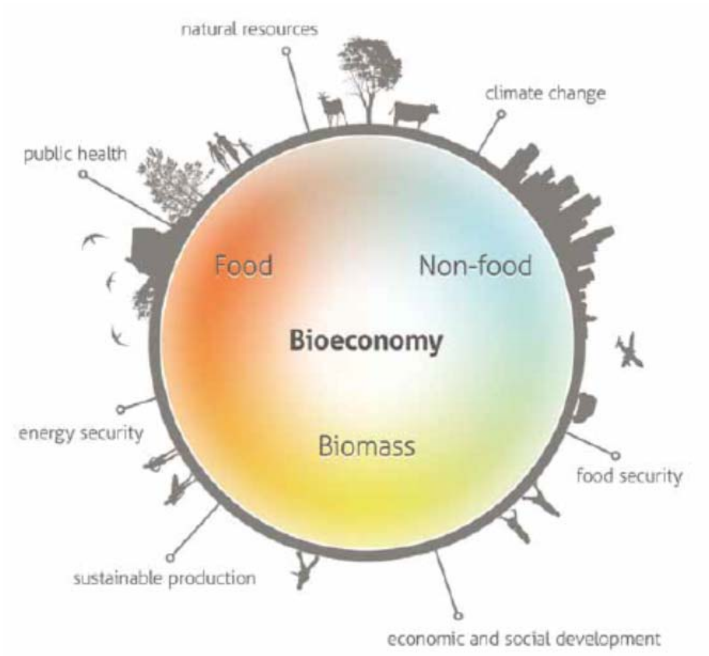


Figure 3: The key drivers and aspects of the bioeconomy in Europe. Source: (BECOTEPS 2011)

For the assessment of bioeconomy options and possible future developments, a comprehensive systems perspective needs to be developed that takes into account the key drivers[4] and aspects of the bioeconomy (Figure 3). Key features of the SAT-BBE framework that need to be considered are:

1. The drivers of biomass production and consumption (including policy incentives and mandates) and the economic competition with non-biomass substitutes.
2. The impacts of increased biomass use: socio-economic effects (income, employment) and environmental effects (net GHG balance, eutrophication, land use change, biodiversity loss, environmental toxicity, etc.).
3. Also, impacts on human health if grouped under socio-economic effects are not evident in the parenthesis); both within the EU and in other regions (e.g. to consider problem shifting and indirect effects via trade)

[4] Note that the term driver is used differently in different models and analysis tools. Here the term driver refers to driving forces relevant for the biobased economy. Later during the SAT BBE project the term drivers will be discussed in more detail where needed.

4. The (comparative) analysis of selected production-consumption chains (considering different allocation assumptions) versus the analysis at the economy-wide level, including all industrial sectors (in order to capture shifts between sectors and regions and overall effects)
5. The assessment of a business as usual (BAU) scenario and alternative scenario developments against reference values, in particular of sustainable potentials for biomass use (e.g. 'safe operating space') and its contribution to reach target values (such as lower GHG emissions).

The various key drivers and aspects of the bioeconomy are clustered in four issues, which will be further discussed and investigated when designing and developing the systems analysis tools framework for the bioeconomy in the EU.

- **Climate change and resource efficiency:** A lower carbon economy and sustainable primary production - reduction of CO_2 emissions, resource and land-use efficiency is a key policy target within the EU and its member states. The 15 countries that were EU members before 2004 ('EU-15') are committed to reducing their collective emissions to 8% below 1990 levels by the years 2008-2012 as part of the Kyoto Protocol. For 2020, the EU has committed to cutting its emissions to 20% below 1990 levels. This commitment is one of the headline targets of the Europe 2020 growth strategy and is being implemented through a package of binding legislation. And for 2050, EU leaders have endorsed the objective of reducing Europe's greenhouse gas emissions by 80-95% compared to 1990 levels as part of efforts by developed countries as a group to reduce their emissions by a similar degree. The European Commission has published a roadmap for building the low-carbon European economy that this will require. Bio-energy is currently a key element in all climate change policies of the EU and also in many EU member states and also the EU level. Especially relevant for the SAT-BBE project is the issue of competition between the use of land for bioenergy crop production, food crop production and other sectors of the bioeconomy. For example, indirect land use change impacts of biofuels, also known as ILUC, relates to the unintended consequence of releasing more carbon emissions due to land-use changes around the world induced by the expansion of croplands for ethanol or biodiesel production in response to the increased global demand for biofuels. Various studies indicate that the resulting land use induced emissions of greenhouse gasses and biodiversity effects can be substantial; also the impact on food security in developing regions is a key concern. This is also an important rationale behind an integrated bioeconomy and crucial for the overall resource efficiency, climate change and food security (Hellmann and Verburg 2010; Villoria and Hertel 2011; Popp, Krause et al. 2012).
- **Economic growth:** The bioeconomy can contribute to economic growth, building competitive bio-industries—new business opportunities, higher potential for value creation through cascading use of biomass and reuse of waste materials, and EU global market leadership. There is now general agreement that the era of cheap oil has ended and also the price of other energy carriers has increased rapidly during the previous decades. Moreover, the energy supply security of the EU is decreasing as the supply of oil and natural gas will increasingly come from (partially unstable suppliers) outside the EU. The economic impacts of these developments can be substantial, especially when also the economic and social costs of climate change and other types of environmental degradation are considered. The bioeconomy may contribute to mitigate these negative effects and contribute to economic by replacing conventional fossil energy based sectors by more cost-effective and less polluting biobased sectors and by developing novel biobased production systems.

- **Food security:** The widespread prevalence of hunger and food insecurity is a key concern in many developing countries and also an important policy area for the EU. Expanding consumption as well as volatility in global food prices over the past years have fuelled concerns about global food and nutrition security (FNS). Given that the development of societal and technological solutions requires time, long-term visions on global food and nutrition security and knowledge-based policies are required, taking into account competition for biomass, land, labour, capital, etc. between different sectors of the bioeconomy. In spite of the many worries of increased competition for land and competition with food production, the bioeconomy may contribute to improving food security by developing and implementing more efficient agricultural and industrial production systems, and integration of policies are required to ensure positive food security effects in other parts of the world as a result of the bioeconomy in Europe (Smith, Gregory et al. 2010; Lambin and Meyfroidt 2011).
- **Employment and regional development:** The EU bioeconomy already has an estimated turnover of nearly €2 trillion and employs more than 22 million people, accounting for 9% of total employment in the EU. The potential of the bioeconomy in the EU is much larger (as discussed in the previous section). The bioeconomy can therefore contribute to developing the European science base and stimulating high-skilled jobs as well as new integrated structures between researchers and research funders and further research and innovation excellence in the EU.
- **Innovation and technical change:** Technological change and innovation involve the overall process of invention, innovation and diffusion of technology or processes innovation and technological change. Innovation and technological change through research and learning by doing result in more efficient use of biomass for the production of energy, materials, pharmaceuticals, etc., and are therefore key drivers behind the bioeconomy. For example, the emergence of new technologies, such as technologies to produce second generation biofuels, is expected to lead to significant reductions in costs, while at the same time the price of conventional fossil oil based technologies is expected to increase (e.g. through resource depletion or environmental policies). But also existing agricultural chains and biobased chains may have significant potential for cost reductions through learning-by-doing. For example, in recent literature, a number of analyses has been performed to quantify learning in bioenergy systems, which has been proven both for energy crop production (sugar cane, corn, rapeseed), logistics of energy crop production (wood chips in Sweden), investment and operation & maintenance costs and final energy carriers. Several other studies indicate that there is a large potential for technical change and innovation of advanced applications with high value-added (pharmaceuticals, biochemicals), partially using industrial biotechnology and complex biorefinery biomass processing pathways in which biomass is separated into compounds to produce food, feed, chemicals, materials and energy. Potential risks could arise at the level of food, agriculture and the environment, particularly if policies are developed and implemented in a disintegrated way. Risks include competition between food supply and biomass production, reindustrialization and centralisation of the agri-food production, relocation of innovative industry actors, over-exploitation of natural resources and loss of biodiversity, and loss in consumer trust. Mitigating these risks requires integrated assessments and monitoring, as well as coherent and integrated policies to ensure long term economic and environmental sustainability of the bioeconomy in Europe.

5 Synthesis

This Working paper 'describes the drivers of the bioeconomy and relationship between the bioeconomy sectors and the rest of the economy; this focuses on understanding what activities are part of the 'bioeconomy', as is defined in the project proposal.

For the SAT-BBE project a broad definition of the term bioeconomy is used, considering the broad scope and goal of the project, the wide scope of work and emphasis on sustainable development (as formulated in the project proposal) and the many diverse drivers of the bioeconomy. Therefore, in the SAT-BBE project we adopt the following relatively broad and general definition, which is also accepted by the EC:

> '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'

By doing so, the scope of the bioeconomy of the SAT-BBE project includes both includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries.. Next, two classification systems of sectors of the bioeconomy are discussed, which vary with respect to the level of detail. The most detailed level is based on the Prodcom database (and related databases). Nowicki et al (2007) identified some 780 products (non-food and non-beverage) of the 4500 products in the Prodcom database as already having or potentially having biobased ingredients. The least detailed level is the Global Trade Analysis Project (GTAP) database, which is used collection of global data, describing bilateral trade patterns, production, consumption and intermediate use of commodities and services. The GTAP database includes data for 129 regions for all 57 GTAP commodities and is used in most global CGE models.

Next, the size of the bioeconomy in the EU-27 and relationships between the bioeconomy and the rest of the economy are investigated (Section 3). In 2009, compared to the agri-food sector, the biobased industries had a relatively low turnover — i.e. about 57 billion euros by contrast to more than 2000 billion euros for the whole agri-food sector. The true potential of the bioeconomy in the EU is however much larger than the values shown in the table above. Next various analyses are reviewed in which the (economic) links between bioeconomy sectors and other sectors of the economy are investigated, focussing on competition, changes in value added and turnover, trade balance effects, etc.

In Section 4 the key drivers of the bioeconomy and the key impact categories are briefly discussed. These are clustered in four issues: 1) Climate change and resource efficiency, 2) Economic growth, 3) Food security, 4) Employment and regional development and 5) Innovation and technical change. Results show that potential risks could arise at the level of food, agriculture and the environment, particularly if policies are developed and implemented in a disintegrated way. Mitigating these risks requires integrated assessments and monitoring, as well as coherent and integrated policies to ensure long term economic and environmental sustainability of the bioeconomy in Europe. These issues and more detailed aspects will be further discussed and investigated when designing and developing the systems analysis tools framework for the bioeconomy in the EU.

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