



Promoting stakeholder engagement and public awareness
for a participative governance of the European bioeconomy



Summary report on the social, economic and environmental impacts of the bioeconomy

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EXECUTIVE SUMMARY

The BioSTEP database reported in Deliverable 2.1 aims to make existing information on bioeconomy products and processes available to stakeholders and the public at large as a resource in opening up broader public dialogues about the future of the bioeconomy. Rather than attempting to exhaustively list the whole plethora of products and processes in the bioeconomy, the database presents a taxonomy of the main product categories, production processes and types of feedstock in the bioeconomy as well as some salient sustainability impacts and governance issues.

The present report, Deliverable 2.2, explains that the bioeconomy encompasses a broad range of activities, situated along a multitude of different value chains, each including suppliers, producers, distributors, and purchasers. It shows that the social, economic and environmental impacts of bioeconomy activities are thus not always limited to the place of production of a bio-based product (e.g. within a regional bioeconomy cluster), but can reach back to the location of biomass provision/production and may affect people, regions and countries in different ways.

Bio-based products and processes may entail (intended or unintended) impacts on human society and the environment. These impacts may occur along the entire value chain of bio-based products and might be linked to the production of biomass, to biorefinery (and related) processes, and to the actual characteristics and effects of the new, bio-based products. One single product or process can have several impacts, which are also influenced by factors, which are not related to the product or process.

The broad spectrum of identified bioeconomy impacts highlights that the involvement of different stakeholder groups and citizens in the development of strategies promoting a bio-based economy is crucial. Specifically, the following aspects reflect the urgency to develop a broad inclusion of both interested and affected stakeholders and citizens:

- Opportunities for stakeholder engagement and public engagement in the governance of the bioeconomy occur particularly at the regional level, where biorefinery activities materialise in concrete processing plants.
- Effects on rural development depend highly on whether the bioeconomy is 'mainstreamed' and a broad part of the population benefits from it.
- Interacting with a broad group of stakeholders and different 'publics' is critical to increase mutual understanding and address value conflicts that may be difficult to solve.
- Making better use of good practices: There is already evidence on the engagement of citizens and SMEs in waste management, which is significant for the use of waste-based resources.
- A broad cooperation between decision-makers, scientists, civil society and NGOs is necessary to ensure a holistic approach for an inclusive, sustainable and ambitious bioeconomy.

Key recommendations on how to manage the negative impacts of specific bio-based products include the promotion of standards that ensure the sustainable production of imported biomass and changes to the current policy framework.

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Abbreviations

CO₂	Carbon dioxide
FP7	The Seventh Framework Programme
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GMOs	Genetically modified organisms
GM (crops)	Genetically modified (crops)
GNI	Gross national income
IEA	International Energy Agency
IFEAT	International Federation of Essential Oils and Aroma Trades
ILUC	Indirect land use change
LULUCF	Land use, land-use change and forestry
NIMBY	Not in my backyard
KBBE	Knowledge-based bioeconomy
R&D	Research and Development
SAT-BBE	Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy
US	United States of America

1 Introduction

McDonagh (2014: 2) holds that, generally, “there is little consensus on what the bioeconomy is or what it does or does not include”. However, the European Commission has been promoting the concept of the bioeconomy for a while already and in 2012 published a strategy for “Innovating for Sustainable Growth: A Bioeconomy for Europe”, which contains a general definition of the bioeconomy and an overview of its features. The strategy document states that the bioeconomy “encompasses the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy [and] includes the sectors of agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries” (European Commission, 2012: 3).

Economically, the bioeconomy encompasses a broad range of activities, situated along a multitude of different value chains, each including suppliers, producers, distributors, and purchasers (Gołbiewski, 2013). At the same time, biomass is the basis for all bio-based products and processes and thus the starting point of all bioeconomy-related value chains. In this context, it is important to acknowledge that the social, economic and environmental impacts of bioeconomy activities are not always limited to the place of production of a bio-based product (e.g. within a regional bioeconomy cluster), but can reach back to the location of biomass provision/production.

For an initial understanding of the taxonomy of the bioeconomy, one can distinguish between the ‘old’ and the ‘new’ bioeconomy. The two ‘generations’ of bioeconomy differ mainly in terms of resource efficiency and sustainability (European Commission, 2010). The ‘new’ bioeconomy is often defined as a ‘knowledge-based bioeconomy’ (KBBE) (McCormick and Kes, 2010; European Commission, 2010). This term describes the new uses and processes of biomaterial, which are feasible because of new technologies and knowledge, where the objective is to achieve greater resource efficiency and sustainability. The terms ‘bioeconomy’, ‘bio-based economy’ and ‘biotechnology’¹ are used interchangeably. In order to facilitate the identification of relevant bioeconomy activities and their respective impacts, BioSTEP uses a framework that distinguishes between input (feedstock, biomass), throughput (processing, biorefinery) and output (biofuels, biomaterials).

The number of different sectors and policy domains, which govern the bioeconomy, are as heterogeneous as the different bioeconomy activities. Strategies that aim at the strengthening of the bioeconomy at regional, national or European levels affect people, the economy and the environment – within the boundaries of the respective area and beyond. New markets, novel cash crops and changes in land tenure may lead to environmental benefits and socio-economic opportunities, for instance by revitalising rural and coastal areas by providing new income sources, thereby preventing rural exodus. At the same time, challenges might occur. Economic benefits might be distributed unequally over the supply chain of bio-based products, as well as geographically. Regarding the environmental impacts of bio-based products and processes, the replacement of oil-based products by bio-based products is potentially favourable in terms of mitigated CO₂ emissions. However, the impacts on the environment via monocultures, genetically modified organisms (GMOs) or the massive use of fertilisers and agricultural chemicals might be significant, too.

This report provides an overview of the spectrum of potential impacts of the bioeconomy. It builds on a comprehensive literature review (Deliverable 2.1) that has identified relevant social, economic and environmental impacts of selected bio-based products and processes. All economic, social and environmental impacts are shown with the help of flow charts and case studies. The document ends with a discussion of the relevance of the findings for stakeholder engagement, public participation and strategy development.

¹ With regard to biotechnology, one can distinguish between “white” biotechnology (BMBF, 2007), meaning industrial applications of it and “green” biotechnology, meaning biotechnology applied to agricultural processes (Kniūkšta, 2009).

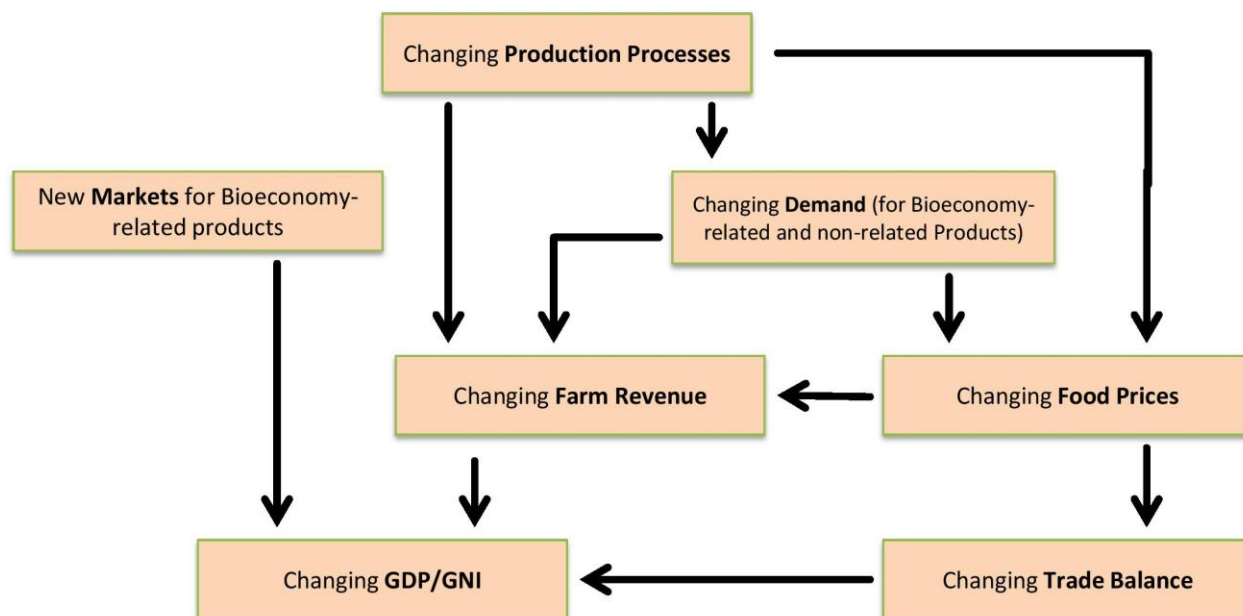
2 Impacts of the bioeconomy on economy, society and environment

Bio-based products and processes may produce (intended or unintended) impacts on human society and the environment. These impacts may occur along the entire value chain of bio-based products and can be linked to the production of biomass, to biorefinery (and related) processes, or to the actual characteristics and effects of the new, bio-based products. One single product or process can have several impacts, which are also influenced by factors that are not related to the product or process. Since these impacts are context-specific and can be partly positive and partly negative, it is challenging to state whether the overall impact of a product or process is negative or positive.

This chapter presents a typology of the social, economic and environmental impacts of the bioeconomy. It draws on the work that has been carried out within the FP7 project “Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy” (SAT-BBE)², which aimed at providing a design of a system analyses tool framework to assess and address the short-term and long-term challenges related to the European bioeconomy. The objective of chapter 2 is to provide a general framework and understanding for the analysis of impacts of selected bio-based products and processes in chapter 3.

2.1 Economic impacts

Figure 1 Overview of economic impacts



As figure 1 shows, bioeconomy-related innovations provide the opportunity for new production processes. Besides these innovations as a key driver for impacts, the changing demand for products leads to several impacts. A growing bioeconomy leads to a rising demand for bioeconomy-related feedstock (= input) and products, while the demand for fossil fuel based products might potentially decrease. However, this effect also depends on the fossil-fuel dependency of feedstock production.

An increasing demand for bioeconomy-related feedstock and products can lead to changes of the respective commodity prices (such as food, fibre etc.). At the same time, new bioeconomy processes also potentially alter production methods, biomass productivity and processing.

² SAT-BBE project website: <http://www3.lei.wur.nl/satbbe/default.aspx> (last accessed 28 February 2016)

An increased demand for feedstock and input for the bioeconomy potentially provides significant economic perspectives for producers of these commodities in terms of new sources of income. At the same time, increasing commodity prices could enhance pressure on other consumers of these commodities. Changing demand and prices for bioeconomy-related products and processes could also have a significant influence on regional and national trade balances. New markets and changing trade balances then have an effect on the overall gross domestic product (GDP) and gross national income (GNI). Table 1 summarises the possible economic effects of the bioeconomy in more detail:

Table 1: Economic impacts of the bioeconomy

Impact	Possible indicator
Change in GDP/GNI	<ul style="list-style-type: none"> • Change in GDP/GNI • Rural development perspectives
New market for innovative bio-based products	<ul style="list-style-type: none"> • Change in turnover of bio-based sectors • Business opportunities/challenges
Change in trade balance	<ul style="list-style-type: none"> • Change in trade (biomass (incl. wood) & animal-based products (incl. Fish)) • Energy diversification
Change in commodity prices	<ul style="list-style-type: none"> • Change in food process • Real wood & forest product prices
Change in demand for biomass products	<ul style="list-style-type: none"> • Change in cropland-based demand for products/energy • Change in wood/wood fibre demand for forest products • Change of biomass demand for energy use
Change in public cost	<ul style="list-style-type: none"> • Dependence on subsidies
Change in farmers revenue	<ul style="list-style-type: none"> • Yield/hectare • Costs for agrochemicals/year

Based on SAT-BBE Consortium (2013)

Infobox 1: Case study: Business opportunities & challenges; rural development

The bioeconomy is a potential driver for the revitalisation of rural areas, since it provides incentives for enhanced agricultural activities in these regions. This can be a driver for regional revitalisation. On a global level, countries from the Global South could benefit from new markets for feedstock. For example, biofuel production could potentially have a positive impact on agricultural employment and livelihoods, especially when the cultivation involves small-scale farmers and the conversion facilities are located near the crop sources in rural areas (IEA, 2004).

In Europe, the knowledge-based bioeconomy (KBBE) generated an annual turnover in Europe of around €57bn in 2009 with bio-based applications, employing around 305,000 people (Clever Consult BVBA, 2010). The food, agriculture, paper and forest industries even accounted for an estimated annual turnover of €1,990bn and employed 21.2m (Clever Consult BVBA, 2010). The European Commission's strategy and action plan estimates that each Euro invested in EU-funded bioeconomy research and innovation today can trigger ten Euros of value added in bioeconomy sectors by 2025. Economically, the bioeconomy potentially creates new income sources for rural and coastal communities (Johnson, 2014).

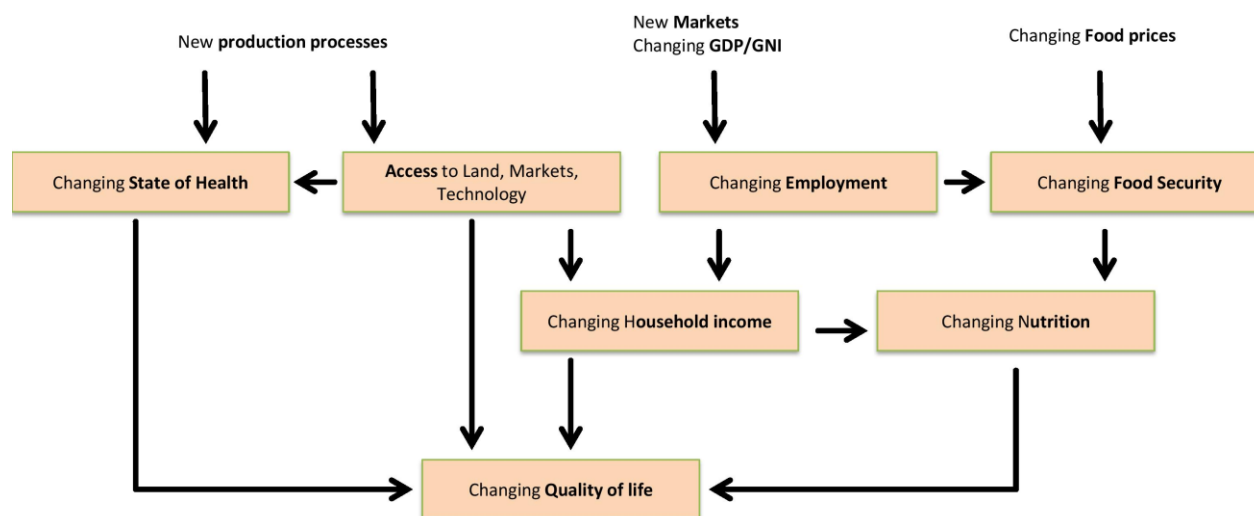
However, bioeconomy strategies also can lead to violations of the traditional land rights of local communities – as seen in Indonesia, for example (Dufey, 2006). Additionally, disruptive technologies of processing could have adverse effects. For example, Haiti, which is the world's leading producer of vetiver (used for perfume production), struggles with the invention of cheap, synthetic biology alternatives (Brown, 2014). Examples of biorefinery affecting small to medium-scale crop production and processing could also be Patchouli oil (IFEAT, 2014), essential oils like lemon or lime (IFEAT, 2014) and many more. These new products, especially flavours produced by genetically modified yeast or chemical decomposition of biomaterial are additionally challenged by low consumer acceptance (Hayden, 2014).

Infobox 2: Case study: Improved trade balance (less imports, energy diversification)

Reduced reliance on imported oil is often considered the main driver behind the earliest experiences with biofuels in Brazil and the US (Dufey, 2006). The volatility of world oil prices, the uneven global distribution of oil supplies and the uncompetitive structures governing it are still strong arguments for energy diversification. At the same time, foreign exchange can be saved, if not used to import oil. This is especially relevant for countries in the Global South with limited resources (Dufey, 2006). At the same time, a strong focus on improvement of the national trade balance could encourage an introduction of protectionist measures against biofuel imports (Dufey, 2006).

2.2 Social impacts

Figure 2: Overview of social impacts



As figure 2 shows, many drivers of social impacts have an economic background. A big part of these impacts is based on questions of distribution, i.e. “who is benefitting?” and “who is losing?”. Changing income levels, new markets and production processes, for example, have potentially positive effects on employment, health and food security. At the same time, questions about the distribution of income and economic possibilities are relevant to assess social impacts. These concerns are very much linked to access to land, markets, seed capital and technology. Limitations in access can potentially indicate which communities or individuals are not benefitting from the bioeconomy.

At the same time, changing prices on bioeconomy-related commodities can directly or indirectly affect food security. All these changes, like changing household income, consumer prices, health, but also access issues have an impact on people’s quality of life. Table 2 summarises the possible social effects of the bioeconomy:

Table 2: Social impacts of the bioeconomy

Impact	Possible indicator
Food security (including GMO crops)	<ul style="list-style-type: none"> • Use of agrochemicals (incl. fertilisers) and GMO crops • Change in food prices (and its volatility) • Malnutrition • Risk of hunger • Macronutrient intake/availability
Land access (incl. gender issues & tenure)	<ul style="list-style-type: none"> • Land prices • Land tenure • Property rights (incl. gender equality) • Access to land (incl. gender equality)
Employment	<ul style="list-style-type: none"> • Change in employment rate • Full time equivalent jobs • Job quality • Need for/lack of highly specialised workforce

Impact	Possible indicator
Household income	<ul style="list-style-type: none"> Income of employees in bioeconomy sector (total) Distribution of income
Workdays lost due to injury	<ul style="list-style-type: none"> Number of work days lost per worker and year
Quality of life	<ul style="list-style-type: none"> Change in quality of life Equality (of gender etc.)
Health	<ul style="list-style-type: none"> Exposure to agrochemicals Numbers of multi-resistant organisms Toxicity of 'green' vs. 'grey' industrial products

Based on SAT-BBE Consortium (2013)

To provide a more detailed picture of the social effects of the bioeconomy, the following case studies about food security and the gender gap are provided. The gender gap is an impact that has received relatively little attention, and its effects might be underestimated (Global Forest Coalition, 2013).

Infobox 3: Food security (including GMO crops & socio-economic structure)

The cultivation of bioeconomy feedstock potentially increases the demand for agricultural areas, which may result in a displacement of food crops and higher prices for agricultural goods and areas (Harvey and Pilgrim, 2010). On the other hand, some authors argue that the prospects of recombinant genetics and biotechnology could enhance food security by cultivating genetically modified (GM) crops (OECD, 1992). Positive impacts of the bioeconomy on food security relate mainly to yield increases due to the application of recombinant genetics and biotechnology in agriculture ranging from diagnostic aids through to gene mapping, which enables a speedier identification of interesting genetic material for every kind of plant usable in agriculture or forestry (OECD, 1992; De Groot, 1990). At present, there are primarily two GM crop types: Some are modified to express the *Bacillus thuringiensis* (Bt) toxin, a natural insecticide. Other major GM crops are modified to express herbicide tolerance, which then can be used easily by the farmers (Qaim, 2009). While Bt variants for maize and cotton are available on a commercial scale, herbicide tolerance is the prevailing trait for all dominant crops (Sanvido et al., 2007). Studies have proven that cultivating herbicide tolerant crops do not generally improve yields, but often enhance farm incomes by reducing expenditures on agro-chemicals (Qaim, 2009). The exact yield increase depends very much on the prior pest pressure before adopting GM crops (Popp et al., 2012). At the same time, negative health impacts by pesticides can be potentially avoided (Antle, 1994).

However, other studies suggest that herbicide use potentially rises after the adoption of herbicide tolerant crops, which can pose risks for biodiversity (Hawes et al., 2003). Herbicides for example are often used in place of tillage to reduce labour (Qaim, 2005). Besides increased costs due to increased herbicide use, there may be higher costs because of the seeds, which have to be bought annually since they are often patented and infertile (Louwaars et al., 2005).

The use of these new seeds can also change the socio-economic structure at the local level and could undermine the economic and social structure of rural smallholder farmers (Fransen et al., 2005). Farmers who used to exchange seeds, for example, cannot do this anymore. An increase in the use of agrochemicals may be due not only to land management measures, such as the replacement of tillage with chemical treatments, but also due to the potential rise of resistant pests (Benbrooke, 2012). Beside these social and socio-economic impacts, several environmental impacts could be listed, such as a potential gene flow of crops to wild relatives (Dale et al., 2002) or impacts on soil and soil organisms (Dale et al., 2002).

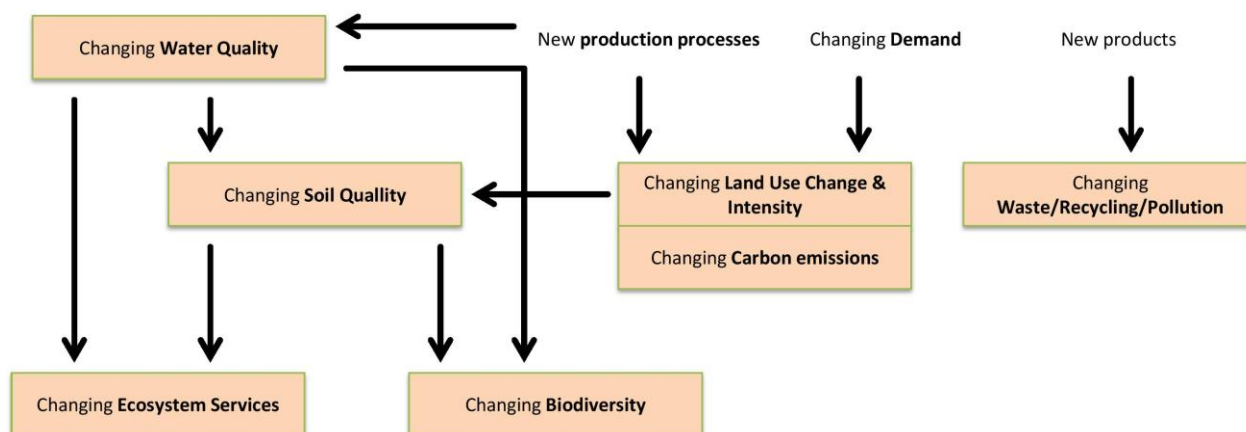
Besides the ongoing discussions about the effects of GM crops on food security, the cultivation of non-GM crops as feedstock for the bioeconomy may also impact food security. Negative impacts in this regard mainly refer to the large-scale use of first-generation biofuel feedstock, which may result in 'food displacement' due to a competition for land (Matondi et al., 2011).

Infobox 4: Case study: Gender gap

A report by the Global Forest Coalition (2013) argues that bioeconomy policies potentially increase the gender gap. Especially women in the Global South could be in a worse position due to bioeconomy crops, because in many places they are likely to manage and use natural resources and might be excluded from bioeconomy-related supply chains. This is mainly because of their role in small-scale agriculture and food production, but also because they lack formal land tenure and involvement in decision-making processes, which make them more vulnerable to exclusion than men (Global Forest Coalition, 2013). Hence, if bioeconomy policies are not designed in an integrated way, they can exclude people (especially women) from natural resources and potentially cause a 'feminisation of poverty'.

2.3 Environmental impacts

Figure 3: Overview of environmental impacts



An essential reason for promoting bio-based products are beneficial environmental impacts of the bioeconomy by replacing oil or oil-based products. The motivation of this replacement goes beyond moving away from finite resources (and import dependency) to lowering the carbon intensity of the production. Besides carbon emissions, however, there are numerous other environmental impacts (figure 3), such as land use change/intensity and soil and water quality. These effects also have an impact on biodiversity and ecosystem services. Table 3 summarises the possible environmental effects of the bioeconomy:

Table 3: Environmental impacts of the bioeconomy

Impact	Possible indicator
Land use change	<ul style="list-style-type: none"> Change in cropland / grassland / forest area, non-arable land use Short rotation plantations
Land use intensity	<ul style="list-style-type: none"> Change in land use intensity Forest carbon content
Soil quality depletion	<ul style="list-style-type: none"> Acidification Salinisation Bulk density Soil carbon content

Impact	Possible indicator
Biodiversity loss & threats (including invasive species)	<ul style="list-style-type: none"> • Rate of biodiversity loss • Habitat loss • Forest fragmentation
Decline in ecosystem services provision	<ul style="list-style-type: none"> • Change in ecosystem service provisioning
Water depletion	<ul style="list-style-type: none"> • Water scarcity • Consumptive water use • Water exploitation index • Water use for agriculture • Forestry • Manufacturing • Recycling
Water pollution	<ul style="list-style-type: none"> • Eutrophication • Toxicity level of water pollution
Reduced consumption of fossil resources	<ul style="list-style-type: none"> • Change in consumption level of fossil resources
Increased consumption of biomass	<ul style="list-style-type: none"> • Change in wood resource balance • Consumption level of biomass
Increased re-use of biomass	<ul style="list-style-type: none"> • Organic waste diverted from landfills
Increased consumption of fish	<ul style="list-style-type: none"> • Change in fish stocks
GHG emissions	<ul style="list-style-type: none"> • Change in GHG emissions • LULUCF carbon baseline
Atmospheric pollution	<ul style="list-style-type: none"> • Level of emission • Concentration of air pollutants
Material carbon pools	<ul style="list-style-type: none"> • Change in carbon stocks
Products characteristics	<ul style="list-style-type: none"> • Degree of the products biodegradable parts • Level of the products toxicity

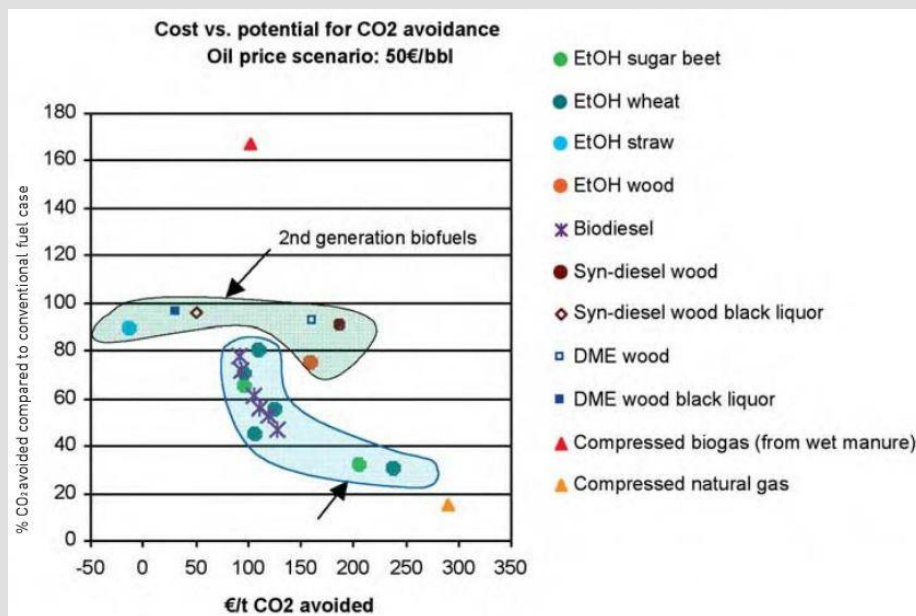
Based on SAT-BBE Consortium (2013)

To provide a more detailed picture of the environmental effects of the bioeconomy, the following case studies about biofuels and carbon emissions, as well as invasive species, are provided.

Infobox 5: Case study: Biofuels and carbon emissions

The carbon dioxide emissions of biofuels are highly dependent on the type of feedstock, cultivation methods, conversion technologies, energy efficiency assumptions and disparities regarding reductions associated with co-products (Dufey, 2006). Hence, the carbon intensity from biofuels varies from carbon positive biofuels to carbon negative biofuels. Carbon positive biofuels are products of biomass, which are cultivated carbon intensely. Carbon negative biofuels are fuels that remove more carbon from the atmosphere than they put back in through burning. This can be undertaken by converting a part of the biomass into biochar and fertilise the soil with it (Mathews, 2008). As figure 4 shows, second generation biofuels should be especially environmentally favourable.

Figure 4: CO₂ emissions efficiency.



Source: (Biofuels Research Advisory Council, 2006)

Infobox 6: Case study: Invasive species

Newly introduced crop species for bioeconomy feedstock pose significant invasion threats – potentially affecting human well-being directly through impacts on human health or indirectly through disruptions to production or semi-natural and natural systems (Sheppard et al., 2011; Raghu et al., 2006). Furthermore, novel crops often have their own suites of pests, weeds and diseases that will affect not only their economic viability, but also the pest management systems of other crops in the landscape (Sheppard et al., 2011). Additionally, it is likely that future key crops for the bioeconomy will be genetically modified. The reasoning for genetic modifications lists higher yields and enhanced resilience (facing pests and challenging weather) (Koonin, 2006).

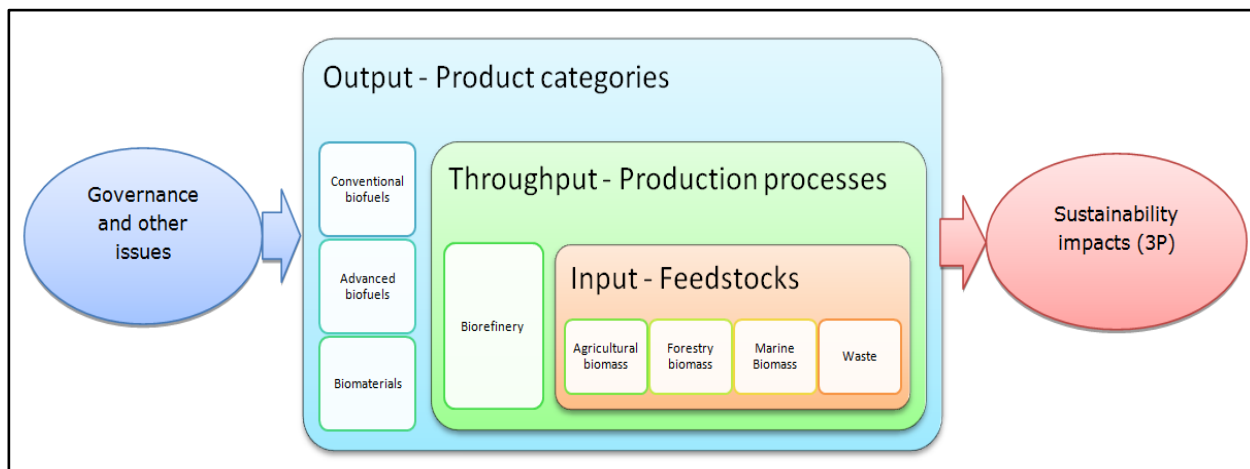
3 The BioSTEP database on bioeconomy products and processes

3.1 Objective and concept of the database

The BioSTEP database reported in Deliverable 2.1 aims to make existing information on bioeconomy products and processes available to stakeholders and the public at large, as a resource in opening up broader public dialogues about the future of the bioeconomy. Rather than attempting to exhaustively list the whole plethora of products and processes in the bioeconomy, the database presents an overview – a taxonomy – of the main product categories, production processes and

types of feedstock in the bioeconomy as well as some salient sustainability impacts and governance issues. This is depicted in Figure 5 below.

Figure 5: Taxonomy of the main bioeconomy product categories



3.2 Methodology used

Starting from a detailed and structured analysis of the state of the art with regard to products and processes in the bioeconomy, a data collection template has been designed according to different criteria. This template has been used to create an overview of processes and products of the bioeconomy, their potential and their strengths, making a selection to allow maximising the strengths and minimising the weaknesses of any database structure. Data collection through a quick scan of the Internet and the available literature supported the following template of product and process categories:

Figure 6: Data collection sheet

	Social impacts (describe)	Environmental impacts (describe)	Economic impacts (describe)	Governance issues (describe)	Other issues (describe)
Product category (tick box)					
<input type="checkbox"/> Biofuels					
<input type="checkbox"/> Bioplastics including wood-plastic-composites					
<input type="checkbox"/> Industrial, aircraft and automotive parts					
<input type="checkbox"/> "Green" chemicals including industrial solvents					
<input type="checkbox"/> Lubricants					
<input type="checkbox"/> Personal care and home care					
<input type="checkbox"/> Fibre products including textiles, pulp and paper, insulating m					
<input type="checkbox"/> Food and feed additives					
<input type="checkbox"/> Other (describe)					
Product examples (describe)					
Process category (tick box)					
<input type="checkbox"/> Synthetic fuel / hydrocarbon via gasification					
<input type="checkbox"/> Biomethane / other gaseous fuel via gasification					
<input type="checkbox"/> Ethanol and higher alcohols via fermentation					
<input type="checkbox"/> Renewable hydrocarbon via biological / chemical processes					
<input type="checkbox"/> Conventional biofuel					
<input type="checkbox"/> 3D printing					
<input type="checkbox"/> Other (describe)					
Process scale (tick box) (1 = very small; 5 = very large)					
<input type="checkbox"/> 1					
<input type="checkbox"/> 2					
<input type="checkbox"/> 3					
<input type="checkbox"/> 4					
<input type="checkbox"/> 5					
Feedstock category (tick box)					
<input type="checkbox"/> Agricultural biomass					
<input type="checkbox"/> Aquatic biomass					
<input type="checkbox"/> Forestry					
<input type="checkbox"/> Waste					
<input type="checkbox"/> Other (describe)					

The collected data were then aggregated and condensed into the format of the database.

3.3 Identified impacts

3.3.1 Biomass as feedstock

The economy of the pre-industrial era (roughly before 1800) could be described as a bioeconomy in which biomass was the main input or feedstock for the production of energy and matter. The industrial era (roughly from 1800 to 2000) has been the era of physics and chemistry and largely replaced this bioeconomy with an economy based on fossil resources. The post-industrial era (roughly after 2000) promises to become the era of biology or the life sciences and entails a transition to a bioeconomy 2.0, which once again replaces fossil resources for biomass as feedstock for the production of energy and matter but not as a regression to the pre-industrial bioeconomy.

It is important to remember that even in the industrial era large parts of the economy always remained based on biomass, i.e. food and feed but also fibre (e.g. textile and paper) production. Conceptually, these are not the main economic domains of concern in discussions about feedstock in the bioeconomy. Those discussions rather focus on replacing fossil resources for agricultural, aquatic and forestry biomass and thus on replacing the very long cycle of storing and using carbon compounds in and from fossil sources for the much shorter cycle of storing and using carbon compounds in and from plants. This feedstock transition claims space and it really does not matter that much whether we talk about processing plants into fuels and materials that could also be consumed as food by humans or about processing non-food crops harvested from space that could also have been used for growing food crops or about processing, for instance micro-algae into jet fuels that also count as excellent feedstock for the production of novel protein foods. This issue of the so-called food versus fuel discussion is key to more generic public dialogues on national and supranational levels and emphasises indirect land use change. It also includes food versus material and indirect water use change dimensions.

One particular category of biomass feedstock is conceptually different – waste. Here, the discussion is not so much about competing space claims for biomass production, but on waste valorisation, recycling and the use of end and by products from other production processes. This latter discussion is strongly related to the notion of a circular economy.

The database in Deliverable 2.1 shows how much the discussion on conventional biofuels is constitutive for broader discussions about biomass as feedstock in the bioeconomy as a whole. Since conventional biofuels use food crops as feedstock, the so-called food versus fuel discussion with its emphasis on indirect land use changes is the most heated debate on the bioeconomy, whereas the higher yields and lower price variations of non-food parts or non-food crops as feedstock for advanced biofuels and various biomaterials receive much less attention. Moreover, these types of feedstock suffer from a competitive disadvantage as a result of regulatory support for conventional biofuels.

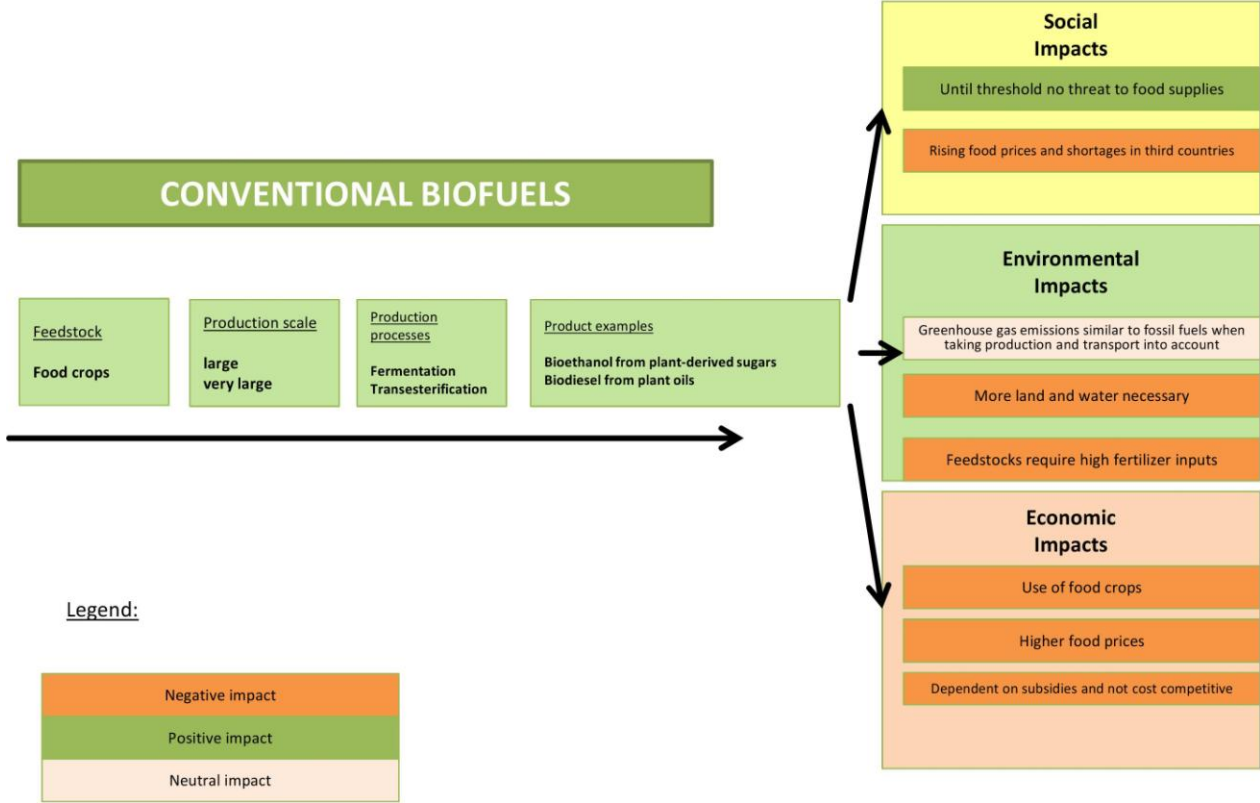
3.3.2 Biofuels and Biomaterials

It is important to consider that the societal appraisal of bioenergy and biofuels is not only relative to fossil energy and fuels, but that there is also the relation to an even shorter cycle of storing and using energy, i.e. solar energy (either directly or indirectly via storage of entropy in, for instance, wind and water). Key to more generic public dialogues at the national and supranational levels is the competition with and competitiveness of biofuels and biomaterials in relation to fossil equivalents.

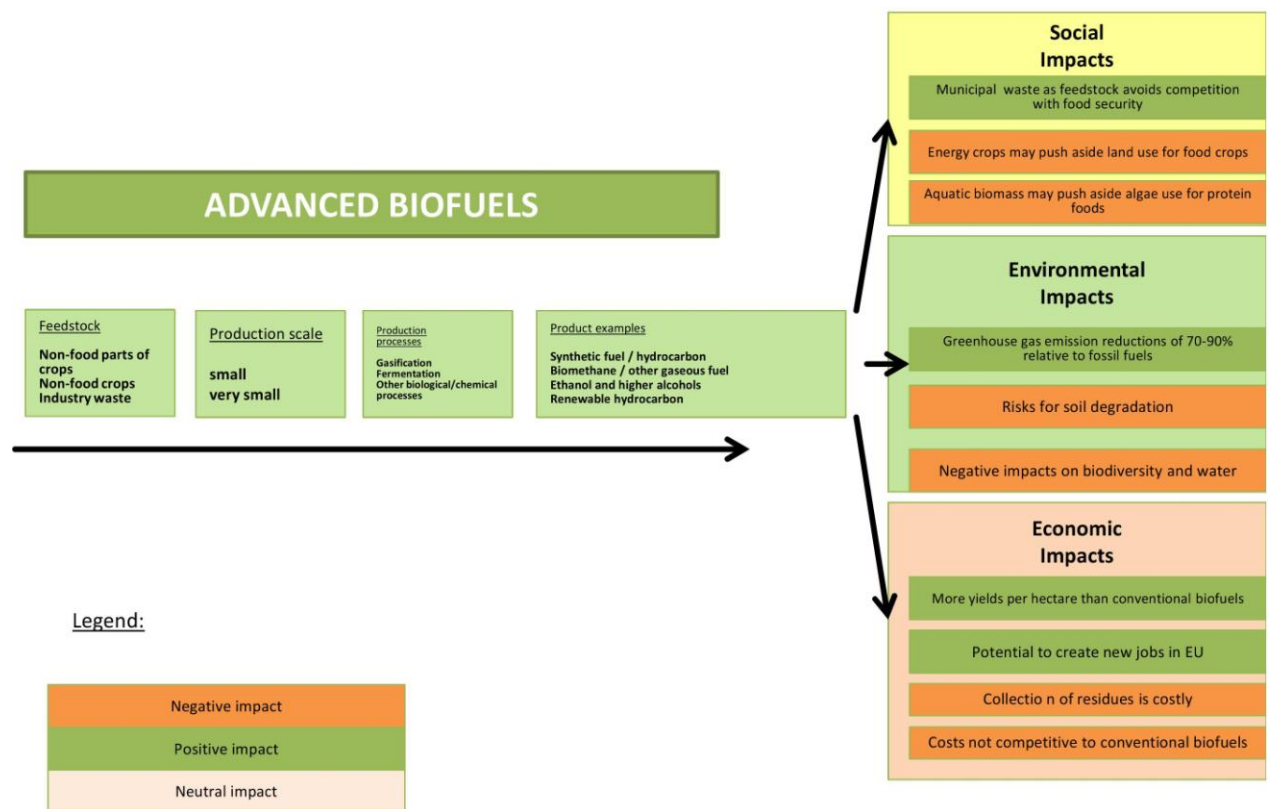
Biofuels

Biofuels are a family of different products, such as ethanol and biodiesel, used as fuel for transportation. Biofuels for transportation can be divided into conventional and advanced biofuels. The former refers to biofuels that are currently produced and commercialised in large-scale, for example produced from sugar cane. The impacts of conventional biofuels are depicted in figure 3.

Figure 7: The impacts of conventional biofuels



‘Advanced biofuels’ comprise novel processes of biofuel production, which are under development or that are feasible at a demonstration scale, for example produced from wheat straw (through lignocellulosic conversion). There impacts are shown in figure 6.

Figure 8: The impacts of advanced biofuels

The sustainability of biofuels depends on the configuration and characteristics of different socio-technical systems of which they are part. These involve the types of feedstock used, the processes that convert feedstock into biofuels and the environmental and socio-economic context within which the production and distribution chains develop. The impacts of biofuel production, distribution and use depend on the features of socio-technical systems, which are flexible, context-dependent and that may change with time. Therefore, the appraisal of their positive and negative impacts depends on the availability of data on (i) the characteristics of the production and supply chains under analysis, i.e. actors and technical processes involved, and (ii) the specific baseline conditions related to the context of implementation of biofuel developments.

The database in Deliverable 2.1 shows that, taking the whole life cycle into account, CO₂ emissions of conventional biofuels are not much lower than those of fossil fuels, whereas advanced biofuels promise reductions of CO₂ emissions in the order of 70-90% in comparison with fossil fuels. Otherwise, high levels of uncertainty prevail about the sustainability impacts of advanced biofuels.

Biomaterials

Whereas the discussion on biofuels focuses on storing, harvesting, processing and using the energy of carbon compounds, the discussion on biomaterials focuses on the matter in these carbon compounds. This also means that no solar equivalent of biomaterials exists. The database in Deliverable 2.1 shows that although most biomaterials are still in the early stage of product development for hitherto relatively small niche markets, these biomaterials might not only perform better than their fossil counterparts in terms of CO₂ emission reductions, but also in terms of other relevant product qualities like weight, toxicity and being recyclable. It is these and other product properties that might benefit from the further development of private grades and standards in the relative absence of public regulatory support. The following seven flowcharts summarise the information in Deliverable 2.1 for the various categories of biomaterials:

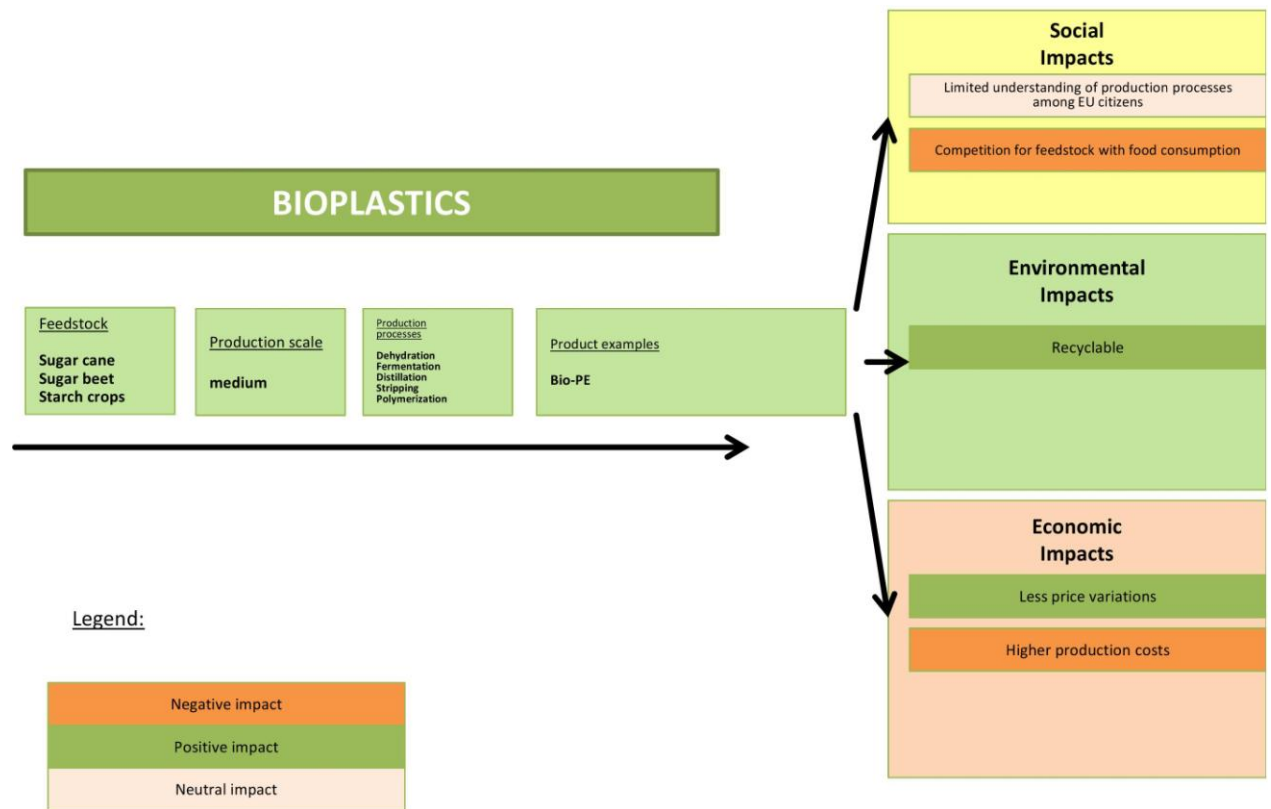
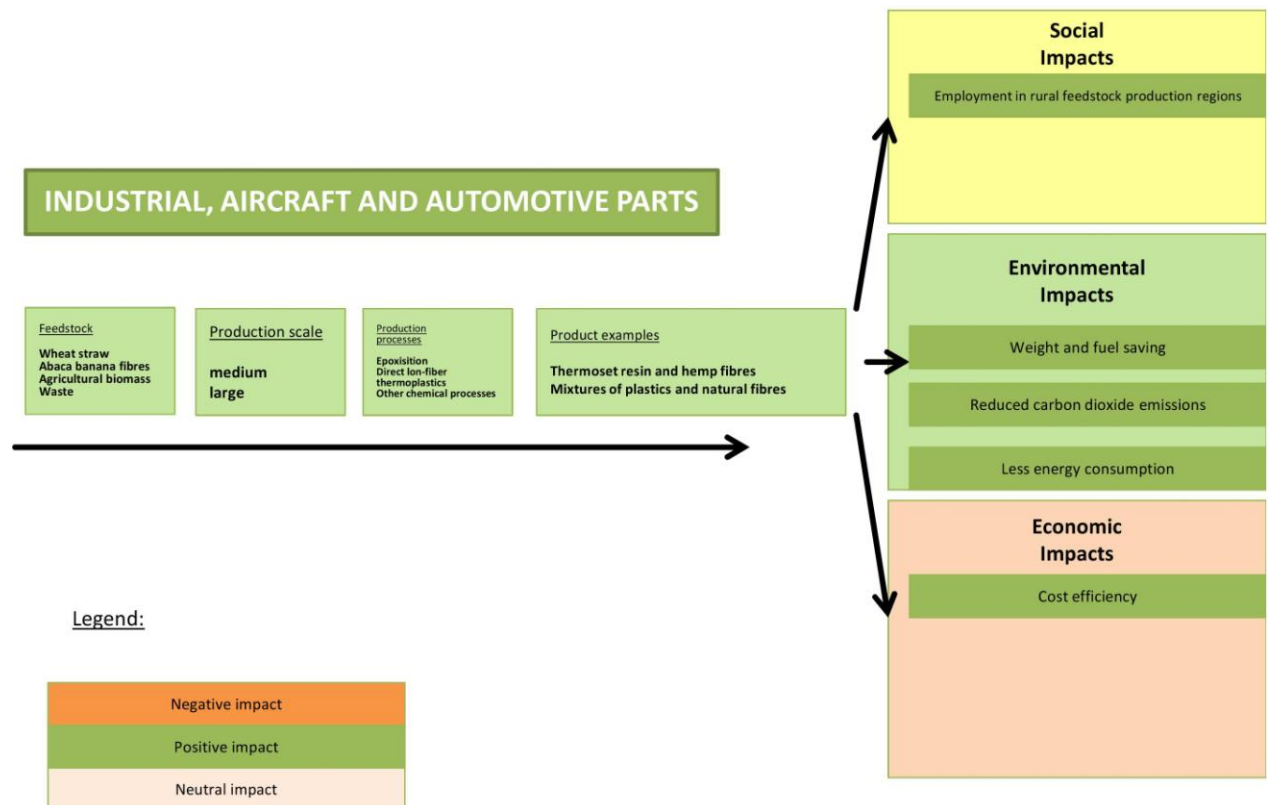
Figure 9: The impacts of bioplastics**Figure 10: The impacts of industrial, aircraft and automotive parts**

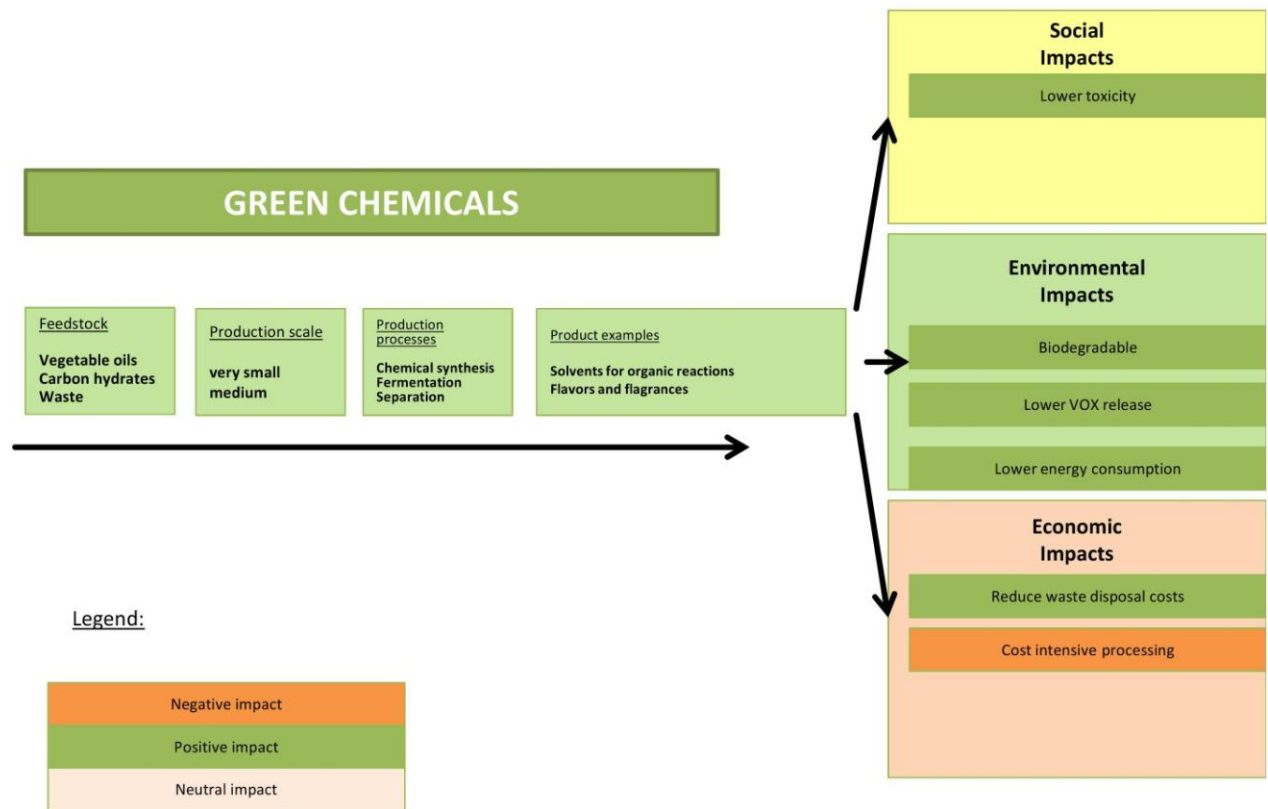
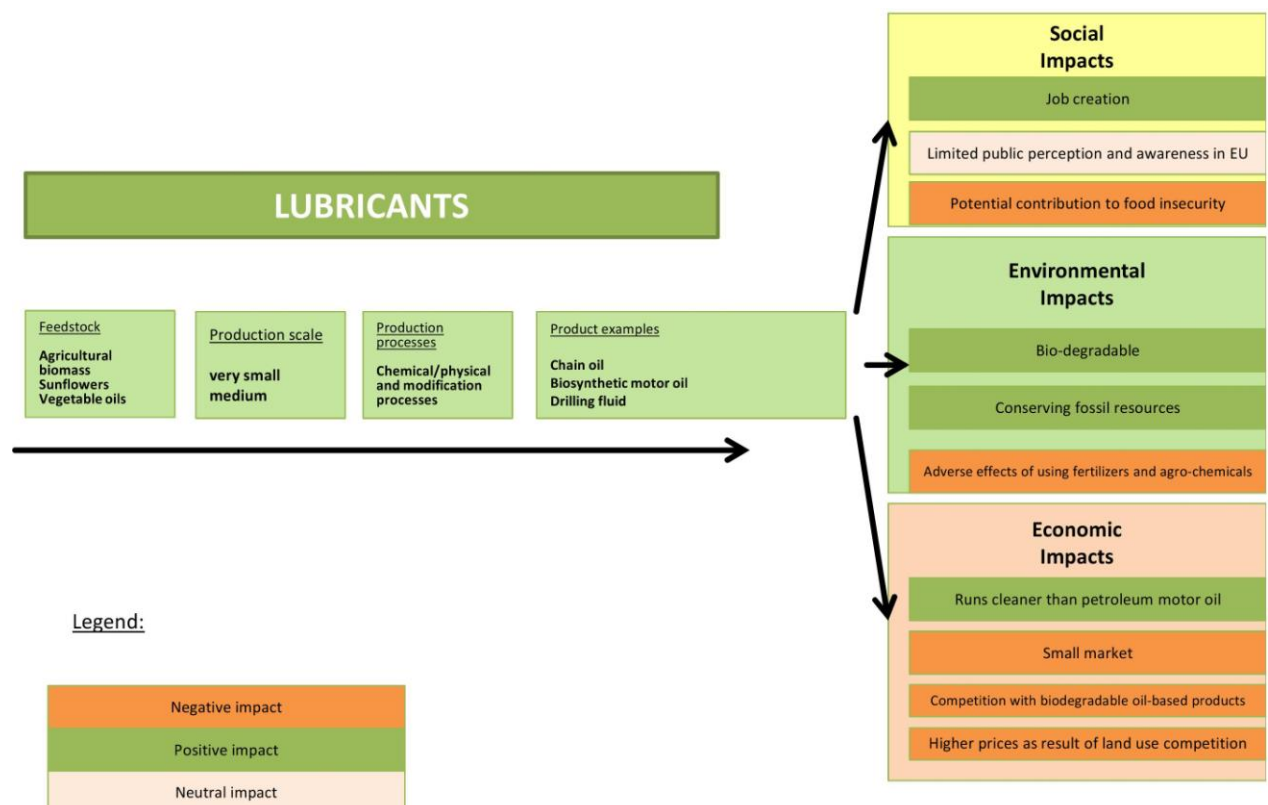
Figure 11: Green chemicals**Figure 12: Lubricants**

Figure 13: Personal and home care

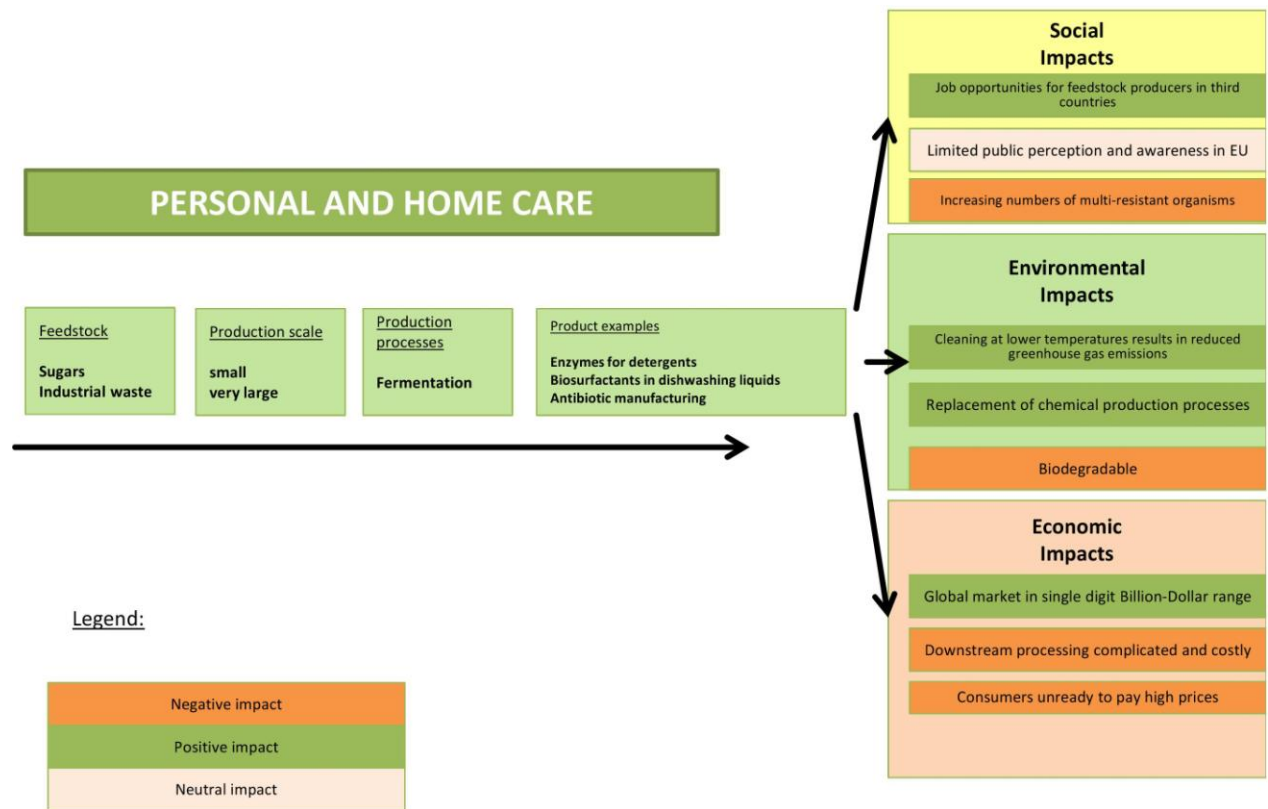


Figure 14: Fibre products

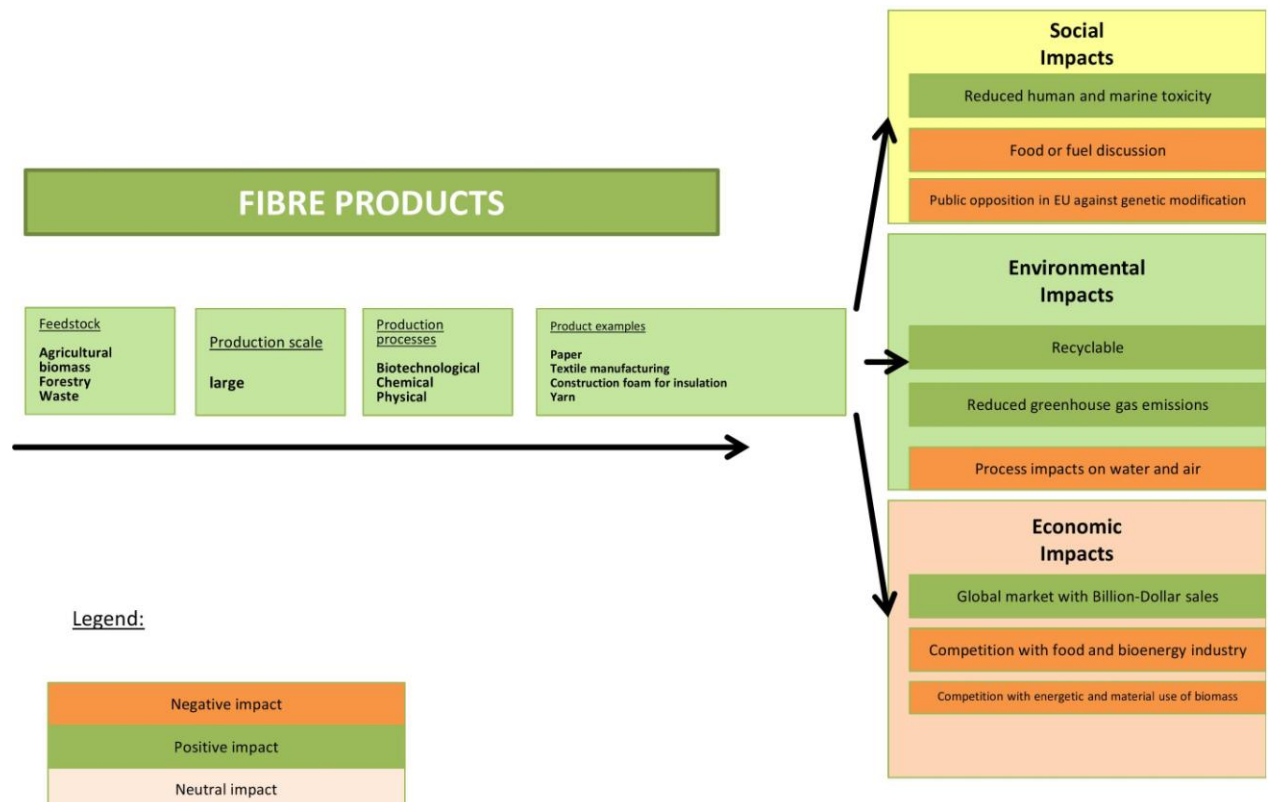
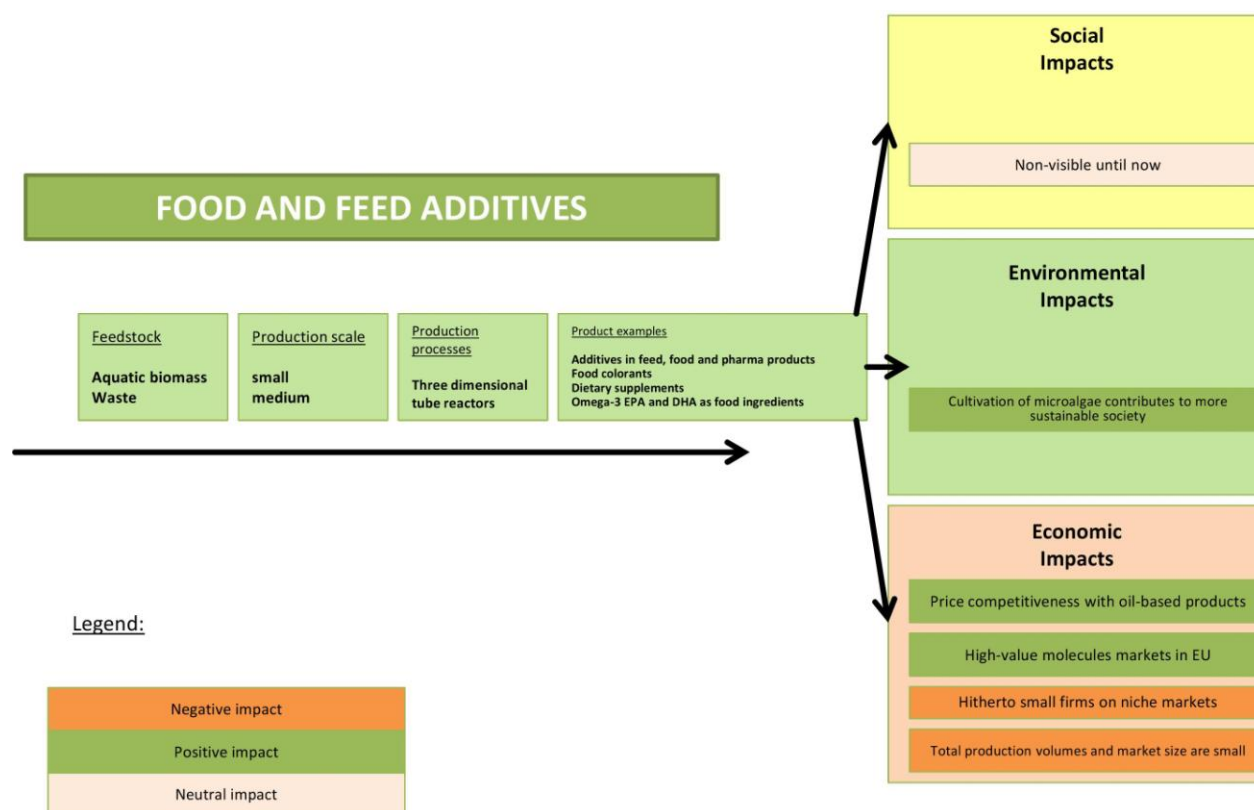


Figure 15: Food and feed additives

3.3.3 Biorefinery as processes

Discussions about feedstock for and products from the bioeconomy can be very heated. However, at the end of the day preferential hierarchies (both demand- and supply-driven) are obvious in generic terms. The demand-driven preferential hierarchy with respect to inputs for producing fuels and materials is 1) solar (only possible for fuels); 2) waste; 3) harvested biomass; and 4) fossil. This is a both-and and not an either-or hierarchy, since it is highly unlikely that we can do without any of these inputs before the end of this century. The supply-driven preferential hierarchy with respect to outputs from biomass is 1) materials and 2) fuels, since for fuels the shorter cycle in using solar energy is the superior alternative.

Discussions about the bioeconomy become interesting when considering biorefinery as the processing of feedstock into products. This is where most R&D investments (both public and private) in the bioeconomy go and this is also where the primary focus of integrated sustainability impact assessments should go. These discussions on R&D investments and sustainability impacts tend to be restricted to an inner circle of experts and stakeholders but since processing is done in plants, this is also where the bioeconomy comes home, in the backyard, to lay people. Key to more generic public dialogues at national and supranational levels is the comparative whole life cycle analysis of fossil versus biofuels and biomaterials. At the same time, key to more specific public dialogues at subnational, i.e. regional, levels is the place and space of biorefinery plants and clusters. Size matters to the public at large, and dialogues had better not be closed down by coining these concerns as 'Not In My Backyard' (NIMBY) issues.

Apart from the scale of processing in biorefinery plants, the database in Deliverable 2.1 flags a number of salient other issues for discussions with stakeholders and the public at large, i.e. the creation of jobs for a well-qualified workforce or the competition between biorefinery start-ups and established multinationals in fossil resources processing. One of the main reasons for much of the current ignorance among broader groups of stakeholders and the public at large about biorefineries is probably related to the relatively early stage of technology development, which makes it rather difficult to engage people in meaningful dialogues about biorefineries. Yet, for instance, the use of

industrial biotechnologies presents every reason to initiate such discussions right now when there are still possibilities for more targeted investments in costly processing technologies.

4 Relevance of the findings for stakeholder engagement, public participation and strategy development

There is a wide range of positive and negative impacts of bio-based products and processes which make drawing general conclusions difficult. The impacts and their implications may affect people, regions and countries in different ways. For example, biofuel feedstock is often cultivated in developing countries where large suitable lands may be accessed at lower economic and opportunity cost (German et al., 2011). Consequently, low and middle-income countries of the Global South are more vulnerable to negative social and environmental impacts like indirect land-use change (ILUC), food security or biodiversity loss. The Global North might amplify these effects due to an increased demand for feedstock for bio-based products.

However, impacts may occur in industrial countries as well, e.g. ILUC and possible adverse effects related to the use of fertilisers and agro-chemicals. In this particular context, stakeholder engagement in determining and analysing environmental, social and economic risks and benefits at the local level are crucial to identifying and avoiding negative impacts and to finding trade-offs, where positive and negative impacts are occurring at the same time.

The data collected in Deliverable 2.1 suggest that at least the following three issues are key to more generic public dialogues and national and supranational levels: 1) the so-called food versus fuel discussion that emphasises indirect land use change and also includes food versus material and indirect water use change dimensions; 2) the comparative whole life cycle analysis of fossil versus biofuels and biomaterials; 3) the competition with and competitiveness of biofuels and –materials in relation to fossil equivalents. It also suggests that key to more specific public dialogues at subnational, i.e. regional dialogues, is the place and space of biorefinery plants and clusters. Size matters to the public at large, and dialogues had better not be closed down by coining these concerns as NIMBY issues. The latter aspect is also where the bioeconomy comes home, in the backyard, to lay people.

In addition, the database in Deliverable 2.1 provides information on specific governance issues related to individual products and processes. The table below summarises selected product categories with specific implications on governance.

Table 4: Implications for governance

Category	Issues
Advanced biofuels	<ul style="list-style-type: none"> Advanced biofuels suffer from a competitive disadvantage as a result of regulatory support for conventional biofuels.
Green chemicals	<ul style="list-style-type: none"> Research funding is needed to tackle technological issues. Upscaling is a challenge.
Lubricants	<ul style="list-style-type: none"> Development is positively influenced by standards, certificates and labels.
Fibre products	<ul style="list-style-type: none"> Regulatory burdens exist to bringing products to market.
Bioplastics	<ul style="list-style-type: none"> No supportive EU legislation. Cessation of EU-starch potato subsidies leaves potato cultivation unattractive. Pilot demonstration facility is needed for high value lignin end-uses. Development is positively influenced by

Category	Issues
	standards, certificates and labels.

The broad spectrum of identified bioeconomy impacts highlights that the involvement of different stakeholder groups and citizens in the development of strategies promoting a bio-based economy is crucial. Specifically, the following aspects reflect the urgency to develop a broad inclusion of both interested and affected stakeholders and citizens:

- Opportunities for stakeholder engagement and public engagement in the governance of the bioeconomy occur particularly at the regional level where biorefinery activities materialise in concrete processing plants. The most salient issues to discuss are scale of plants, regional benefits and community interaction.
- Effects on rural development (income levels and distribution and employment) depend highly on whether the bioeconomy is 'mainstreamed' and a broad part of the population benefits from it.
- Interacting with a broad group of stakeholders and different 'publics' is critical to increase mutual understanding and address value conflicts that may be difficult to solve.
- Making better use of good practices: There is already evidence on the engagement of citizens and SMEs in waste management, which is significant for the use of waste-based resources.
- A broad cooperation between decision-makers, scientists, civil society and NGOs (going beyond the triple helix) is necessary to ensure a holistic approach for an inclusive, sustainable and ambitious bioeconomy.

Key recommendations on how to manage negative impacts include the promotion of standards that ensure the sustainable production of imported biomass and changes to the current policy framework (e.g. biofuel subsidies, regulation burdens for bridging bio-based products to the market). Building on a series of stakeholder workshops, these recommendations will be further elaborated within WP4 of BioSTEP.

List of references

- Antle J. M., Capalbo S. M. (1994): "Pesticides, productivity and farmer health: Implications for regulators policy and research", *American Journal of Agricultural Economics*, Vol. 76, No. 3, pp 598-602
- Benbrooke, C. (2012): "Impacts of genetically engineered crops on pesticide use in the U.S. – the first sixteen years", *Environmental Sciences Europe*, 24
- Biofuels Research Advisory Council (2006): "Biofuels in the European Union: A Vision for 2030 and Beyond", Final draft report of the Biofuels Research Advisory Council
- BMBF (2007): "White Biotechnology", Federal Ministry of Education and Research, Report by the German Federal Ministry of Education and Research (BMBF), Berlin
- Brown, D. (2014): "Synthetic Biology Could Open a Whole New Can of Worms", Inter Press Service, <http://www.ipsnews.net/2014/10/synthetic-biology-could-open-a-whole-new-can-of-worms/> (accessed 04.11.15)
- Dale, P., J., Clarke, B., Fontes, E., M., G. (2002): "Potential for the environmental impacts of transgenic crops", *Nature Biotechnology*, 20
- De Groot C. (1990): "Forestry Biotechnology", *Biotechnology and Development Monitor*, No. 5, December, p. 20 ff
- De Jong E., van Ree R., Sanders J. and Langeveld J. W. A. (2009): "The bio-based economy: Biofuels, materials, and chemicals in the post-oil era". Earthscan, London pp. 111–130
- Dufey, A. (2006): "Biofuels Production, Trade and Sustainable Development: Emerging Issues", London, International Institute for Environment and Development
- European Commission (2013): "The impact of EU consumption on deforestation: Comprehensive analysis of the impact of EU consumption on deforestation", Final report, Technical Report, ISBN 978-92-79-28926-2
- European Commission (2012): "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Innovating for Sustainable Grow, A Bioeconomy for Europe Brussels, COM(2012) 60 final
- European Commission (2010): "The Knowledge Based Bio-Economy (KBBE) in Europe: Achievements and Challenges"
- Fransen L., La Vina A., Dayrit, F., Gatlabayan, L., Santosa, D., Adiwibowo S. (2005): "Integrating Socio-Economic Considerations into Biosafety Decisions: The role of public participation, Washington, DC: World Resources
- German, L., G. C. Schoneveld, and P. Pacheco 2011. The social and environmental impacts of biofuel feedstock cultivation: evidence from multi-site research in the forest frontier. *Ecology and Society* 16(3): 24.
- Global Forest Coalition (2013): "Increasing the gender Gap: the Impacts of the Bioeconomy and Markets in Environmental Services on woman"
- Gołębiewski, J. (2013): "Value chains within Bioeconomy", Warsaw University of Life Sciences – SGGW, Poland
- Hartwig, J. (2007): „Die Vermarktung der Taiga. Die politische Ökologie der Nutzung von Nicht-Holz-Waldprodukten und Bodenschätzen in der Mongolei“, Stuttgart (Erdkundliches Wissen, Bd. 143)
- Harvey, M., Pilgrim, S. The new competition for land: Food, energy, and climate change. *Food Policy* (2010), doi:10.1016/j.foodpol.2010.11.009
- Hawes C., Haughton A. J., Osborne J. L (2003): "Responses of plants and invertebrate trophic groups to contrasting herbicide regimes in the Farm Scale Evaluations of genetically modified

herbicide-tolerant crops", *Philosophical transactions of the Royal Society Biological Sciences*, 358(1439), pp 1899-1913

Hayden C. E. (2014): Synthetic-biology firms shift focus - Switch to food and fragrances risks consumer rejection, *Nature* 505,598, doi:10.1038/505598a

HM Government (2015): Building a high value bioeconomy - Opportunities from waste, UK, BIS/15/146, Open Government Licence, www.gov.uk/bis

IEA (2004): "Biofuels for Transport An International Perspective", International Energy Agency, Paris, April

IFEAT (2014): Conference paper, 21 - 25 September 2014, Rome, Italy http://www.ifeat.org/wp-content/uploads/2014/05/IFEAT_World_May-2014-.pdf

Johnson, T., G., Altman I. (2014): "Rural development opportunities in the bioeconomy", *Biomass and Bioenergy*, Volume 63, April 2014, Pages 341–344

Kniūkšta, B. (2009): "Preconditions for Developing a Knowledge-based Bioeconomy in Lithuania", *Lithuanian University of Agriculture in Rural Development 2009, Agriculture in Transition towards Sustainable Development: Economics, Management and Policy*

Littlejohn C., Curran T., Rainer W., Wratten S. (2015): "Farmland, Food, and Bioenergy Crops Need not Compete for Land", *Solutions* Vol 6, No. 3. pp. 34-48

Louwaars, N., P., Tripp, R., Eaton, D., Henson-Apollonion, V., Hu, R., Mendoza, M., Muhhuku, F., Pal, S., Wekundah, J. (2005): "Impacts of strengthened intellectual property rights regimes on the plant breeding industry in developing countries: a Synthesis of five case studies", Commissioned by the World Bank, Wageningen UR, Netherlands

Mathews, J., A. (2008): "Carbon-negative biofuels", *Energy Policy* 36, pp 940–945

Matondi, P., B., Havnevik, K., Beyene, A. (2011): "Biofuels, land grabbing and food security in Africa", Zed Books, ISBN: 978-1-84813-878-0

McDonagh, J. (2014): "Do we really have a choice? The bioeconomy and future rural pathways", *Rural geography* III:

Progress in Human Geography 0309132514563449, first published on December 22, 2014

McCormick K. (2010): "The Knowledge-Based Bio-Economy in Europe, Knowledge Cities World Summit"

Kniūkšta B. (2009): "Preconditions for Developing a Knowledge-based Bioeconomy, in Lithuania", *Agriculture in Transition towards Sustainable Development: Economics, Management and Policy*, Lithuanian University of Agriculture in Rural Development

OECD (1992): "Biotechnology, Agriculture and Food", Paris

Popp J., Jahn M., Matlock M., Kempter N. (2012): "The Role of biotechnology in a sustainable food supply", Cambridge: Cambridge University Press

Raghu S., Anderson R. C., Daehler C. C., Davis A. S., Wiedenmann R. N., Simberloff D., Mack R.N. (2006): "Adding biofuels to the invasive species fire?", *Science*, 313, pp 1742

Sheppard et. al, (2011): "Biosecurity as an integral part of the new bioeconomy: a path to a more sustainable future", *Current Opinion in Environmental Sustainability*, 3, pp 1–7

Qaim, M. and Traxler, G. (2005): "Roundup Ready Soybeans in Argentina: Farm level and aggregate welfare effects", *Agricultural Economics*, 32, pp 73-86

Qaim M (2009): "The economics of genetically modified crops", *Annual Review of Resource Economics* Vol 1, pp 665-693

Sanvido O., Romeis J., Bigler F., (2007): "Ecological impacts of genetically modified crops: Ten years of field research and commercial cultivation", *Advances in Biochemical Engineering/Biotechnology* Vol 13., pp 421-434

SAT-BBE Consortium (2013). "Working paper on available indicators and lacunae for monitoring the bioeconomy (D2.2)." Available at <http://www3.lei.wur.nl/satbbe/Papers.aspx>

Zhuang D., Jiang D., Liu Y., Huang Y (2011): "Assessment of bioenergy potential on marginal land in China", *Renewable and Sustainable Energy Reviews* 15 1050–1056