Status quo of data collection methodologies on bioeconomy and recommendations

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D3.1

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Monitoring the Bioeconomy

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1 Introduction

This Deliverable 3.1 of the BioMonitor project provides the basis for the development of methodologies for filling gaps in measuring the EU bioeconomy. In the following tasks of WP3, then, short-, medium- and long-run methodologies for filling data gaps are being developed. This distinction of the methodologies is only related to the time frame needed for implementation and is not meant to indicate *a priori* whether one set of methodologies is preferable over another.

This Deliverable links closely to WP1, where currently the list of indicators for monitoring and measuring the bioeconomy is being prepared, and WP2, where data gaps and needs for these indicators are being assessed.

Short-run methodologies, developed in Task 3.4, pertain to approaches which basically make use of existing statistical sources to estimate the contribution of the bioeconomy in different ways, i.e. a) its detail in bio-based sectors and bio-based products, b) the type of indicators (socio-economic, environmental), and c) the spatial level for which estimates are provided. These methodologies are implementable in the short-term (from the first year in the project), and several examples already exist, because they demand relatively smaller efforts in actual data gathering while great care must be put on the procedure for estimating/calculating the bioeconomy shares.

In Task 3.3, medium-run methodologies are being developed, i.e. methodologies that will become available in the third year of the project. The starting point for this task will be the Material Flow Monitor (MFM) which has been developed by project partner CBS (Statistics Netherlands). This methodology will be further enhanced, improved and populated in Task 3.3 and its general applicability and feasibility will be tested in further case study countries.

While the short- and medium-run methodologies all rely on existing official statistics, the long-term methodologies in Task 3.2 go beyond and propose extensions of existing statistical systems to specifically cover bio-based industries, namely new candidate bio-based products (CPA list) and new bio-based industries (NACE list). The output of this task can only be a recommendation for which new bio-based products and industries could be integrated in the standardized classification and data collecting systems, while an implementation into official statistical frameworks can only take place beyond project duration.

This Deliverable informs about the status quo of all three types of data collection methodologies and provides recommendations for the following work in Tasks 3.2 to 3.4. The focus of this Deliverable is on the availability of the socio-economic/market-related indicators that are currently being considered in WP1. In WP1, however, a broader set of indicators is being elaborated and will include issues such as innovation, environment and policy. Requirements for these indicators (e.g. spatial resolution, frequency of data availability), are currently being defined in WP2.

Once these results as well as further new insights become available in the course of the project, this Deliverable will be updated accordingly.

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2 Short-run methodologies

As mentioned in the introduction, in BioMonitor, a broad set of indicators is being elaborated in WP1 which will not only include socio-economic and market related indicators but also issues such as innovation, environment and policy. However, as Bracco et al. 2018 also confirmed in an international comparison of six countries, the current studies for the measuring and monitoring of the bioeconomy are focused on the contribution of the bioeconomy to economic indicators such as gross domestic product (GDP), turnover and employment while environmental and social indicators are covered only to a limited extent. As one of the few examples, the environmental performance of the bioeconomy is annually monitored for the Netherlands in terms of its energy use (TJ) and emissions (CO_2, CH_4, and N_2O).

The availability of data on these indicators is currently being assessed in WP2, but it is likely that for these indicators, short-run methodologies will need to be evaluated to overcome any gaps in data availability. However, since this set of indicators is not yet finally decided on, the following collection of methodology studies mainly focuses on fundamental issues such as the assessment of raw material flows and economic effects of the bioeconomy. Examples of studies that account for the breakdown of national bioeconomy indicators into regional (NUTS2 and NUTS3) indicators are addressed in sub-section 2.3.

2.1 Determination of bioeconomy shares based on existing statistics

Under this heading, a broad range of publications can be subsumed which all have in common that they take *existing statistics* and *estimate* shares of these statistics that can be attributed to the bioeconomy. This approach is characterised by a relatively lower amount of work for actual data collection but great care that needs to be put in finding good estimates for the bio-based shares. The following subsection provides an overview of studies that have followed this methodological approach.

2.1.1 Output-based methodologies

An early example of such a study is Nowicki et al. 2008. In that study, the Eurostat PRODCOM database was used to identify 780 potentially bio-based products in the EU-25 used for other purposes than food or feed. Estimates for their actual bio-based shares (more precisely, the bio-based shares in input materials) in 2005 as well as their technically feasible bio-based shares were made. These products were further grouped into product families and types of production processes and current and potential bio-based production volumes and values were calculated. The authors concluded that the approach of using product level statistical data encountered problems of data availability for certain product groups, especially fine chemicals, cosmetics and neutral-/pharmaceuticals, as well as difficulties with production volumes provided in different units (kg, l, m^2, m^3, etc.) but that overall the quality of data was quite high and led to well-founded conclusions.

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The Eurostat PRODCOM database contains information on about 4,500 manufactured goods which are coded based on the European CPA (Classification of Products by Activity) system, where the first four digits indicate the Division, Group and Class that the product is belonging to according to the NACE system, the Statistical Classification of Economic Activities in the European Community.

The PRODCOM codes normally relate to one or more 8-digit codes of the Combined Nomenclature (CN) used in the Eurostat trade database, thus enabling to link the products according to PRODCOM with the more detailed product classification according to the trade database. This link can be established with the help of Correspondence Tables (Eurostat 2013b). The fact that the statistics for the external trade of goods provides a higher product disaggregation can be useful for better identifying bio-based products (Ronzon et al. 2017. p. 5).

The PRODCOM database also contains trade data which is in fact obtained by summing up all data for those CN codes that match one PRODCOM heading. While the database is known as PRODCOM, this term more specifically only refers to the production data, while the combination of production and external trade data is termed Europroms (Eurostat 2008).

This combination of production and trade data in Europroms allows to calculate for each product apparent domestic consumption (not itself included as an item), defined as production + imports – exports. However, Europroms does not provide the extra-EU trade flows as a whole. This is only available in the Eurostat-Comext trade database, which reports detailed bilateral trade flows between EU Member States and single partner countries at the CN level. Figure 1 shows in short the linkages between global, European and national classifications of economic activities, products and traded goods.

However, it is important to say that the values on exports and imports are based on customs data, which are reported both by the importers and exporters. Frequently, importers and exporters may report different values for the same trade flows, which means that the international trade data should always be checked and cleaned first and not be trusted directly. This kind of reconciliation of declarations of importers and exporters is for example performed in the BACI trade database, which is constructed from the UN-COMTRADE database (Gaulier and Zignago 2010).

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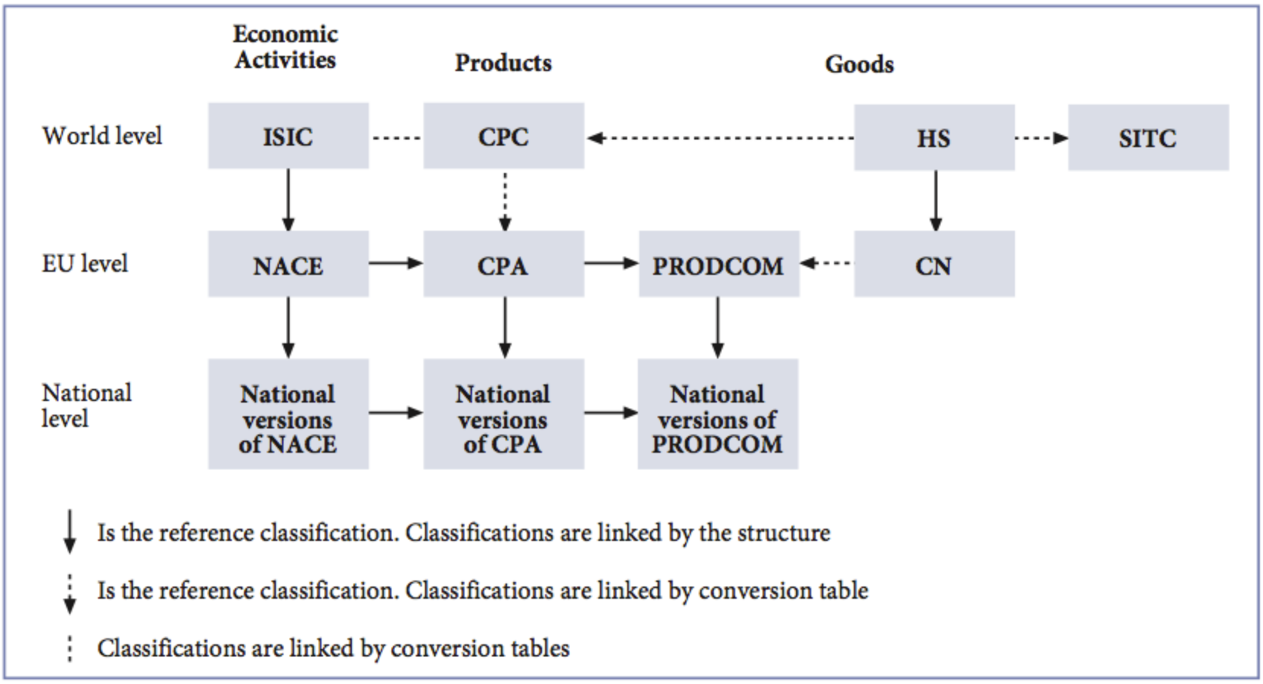

Figure 1 – The international system of economic classification

Source: Eurostat 2008

Also in 2008, Pellerin and Taylor studied the contribution of the bioeconomy to Canada's GDP. For that purpose, subcategories of the American Industry Classification System (NAICS) were selected that could be attributed to the bioeconomy. Since this study had a focus on biotechnology, the selected sectors included Health, Bioprocesses used in copper mining and Pharmaceutical and Medicine Manufacturing (Pellerin and Taylor 2008). In a first step, the direct contribution of the bioeconomy was calculated as a percentage of total economy GDP and this percentage was then applied to the total remaining country economy to account for indirect effects. The fact that this study did neither provide an exact definition of the bioeconomy nor any insights into what criteria were used to assume bioeconomy shares in the economic sectors was criticized subsequently (Avillez 2011).

Vandermeulen et al. 2011 conducted interviews with companies and federations in Flanders in each subcategory of the bio-based economy where they were asked to estimate the part of total production that can be attributed to the bio-based economy. These shares were then used to calculate gross margins and employment shares of the bio-based economy in Flanders.

Building on these previous studies, the Joint Research Centre (JRC) and nova-Institute developed a methodology which is based on estimating product-level bio-based shares for all products in the PRODCOM list. These shares can then be applied to the product-level production volume and value. Applying the shares to the production value circumvents the problem of different units used in PRODCOM for the production volume. The resulting bio-based shares in production value can be aggregated to the sector level (NACE Classes or higher) and applied to various economic indicators (such as turnover, employment and value added). This methodology and results for the EU bioeconomy and single Member States have been published in a number of studies (Piotrowski et

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al. 2016, Ronzon et al. 2017, Piotrowski et al. 2018, Ronzon and M'Barek 2018). Moreover, whole datasets are searchable online at https://datam.jrc.ec.europa.eu (Ronzon et al. 2018), the most recent data for the EU-28 being shown Figure 2.

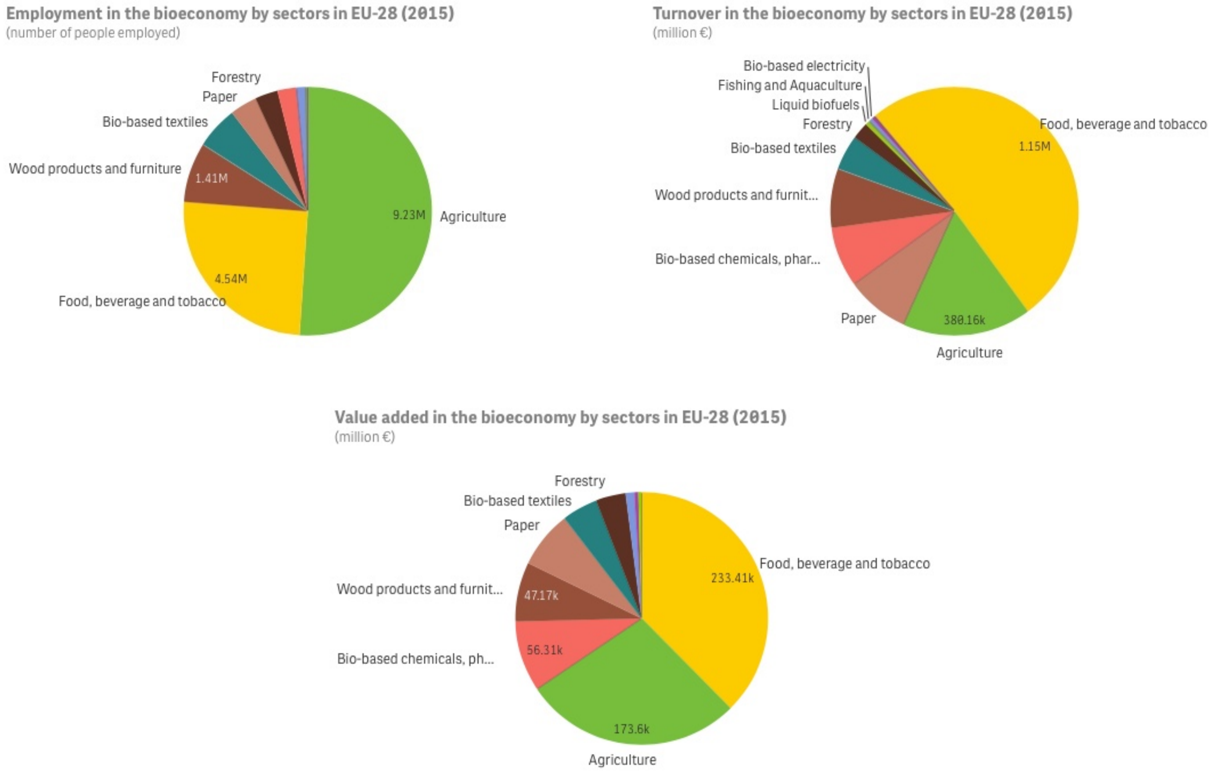

Figure 2 – Employment, turnover and value added in the bioeconomy by sectors in EU-28 (2015)

Source: Ronzon et al. 2018

While this methodology provided the first harmonized socio-economic data for the EU-28, some limitations have been identified which will be approached in BioMonitor (M'Barek et al. 2018). First of all, the methodology only covers the primary and manufacturing industries, while sectors such as bio-construction, waste management and phyto-remediation as well as bioeconomy related services are excluded. Especially the meaning of a "bioeconomy service" is yet ill-defined and hence appropriate data collection methodologies are lacking. Furthermore, there are concerns regarding the consistency and completeness of Eurostat data (e.g. due to missing and confidential values). Finally, there is a large margin of uncertainty associated with the estimated bio-based shares.

Vitunskienė et al. 2017 have conducted a study on the Lithuanian bioeconomy, using a very similar methodology as presented by Piotrowski et al. 2016 and Ronzon et al. 2017. However, this study differs in one important aspect. Based on the CEN definition of a bio-based product as a product that is "wholly or partly derived from materials of biological origin" (CEN - Report on Mandate M / 429), all products that were identified as at least partly bio-based were fully attributed to the bioeconomy (Vitunskienė 2018).

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For example, in Vitunskienė et al. 2017, all at least partly bio-based chemical products were fully attributed to the total amount of bio-based chemical production. As a consequence, the calculated share of bio-based chemicals in the total Lithuanian production value of chemicals in that study was higher than in Piotrowski et al. 2016 (10.3% in 2015 compared to 6.2%).

A closely related methodology was also implemented in Finland by LUKE, the Natural Resources Institute Finland. Selected main indicators for the monitoring of the Finnish bioeconomy were output, value added, investment and people employed (see Figure 3). In compiling these indicators, similar challenges of data availability have been observed as in the study by the JRC. Namely, the determination of bioeconomy shares of the hybrid sectors relied primarily on experts' estimates (M'Barek et al. 2018, p. 12, LUKE 2018).

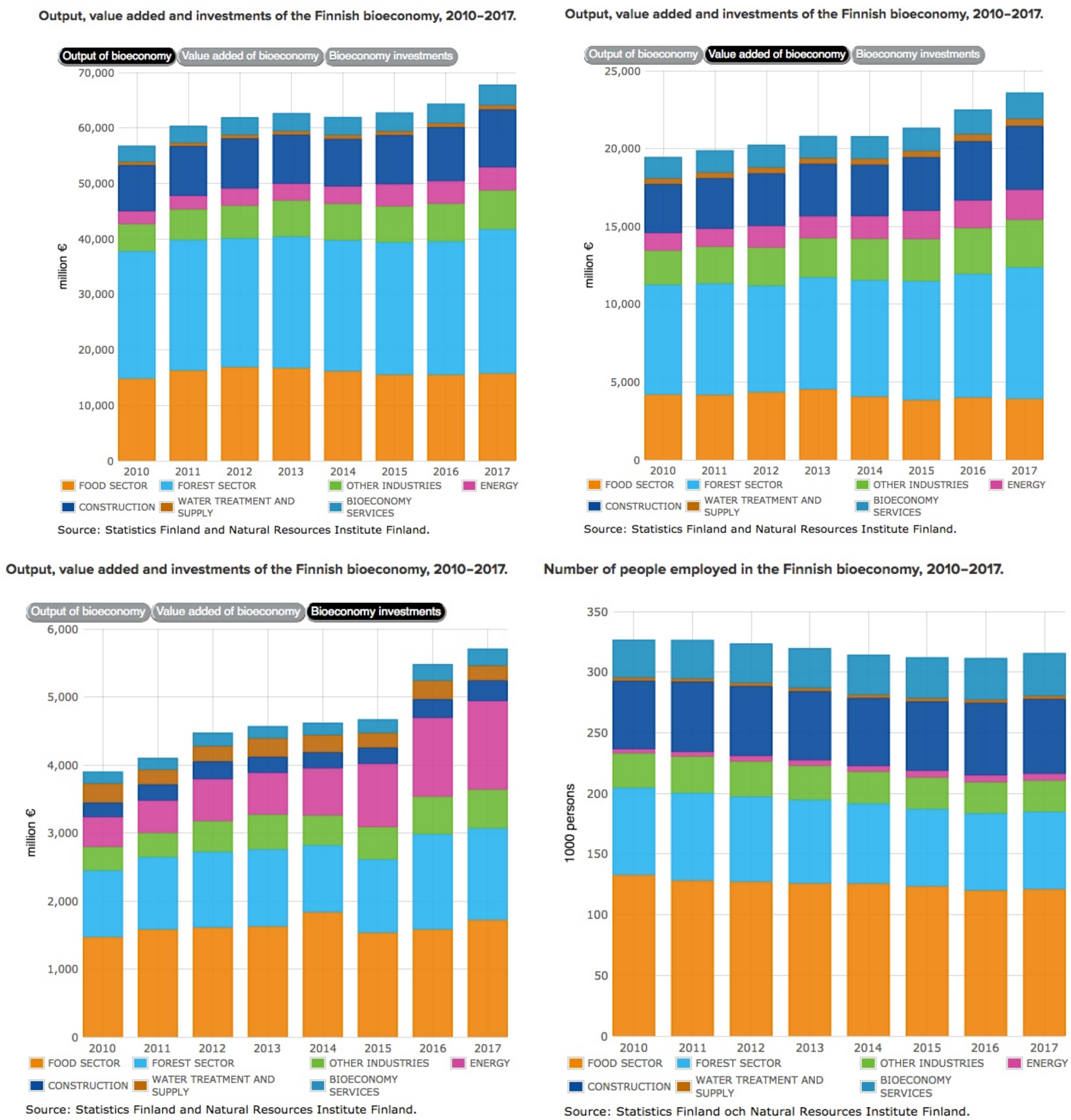

Figure 3 – Output, value added, investments and people employed in the Finnish bioeconomy, 2010-2017

Source: https://www.luke.fi/en/natural-resources/finnish-bioeconomy-in-numbers/

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2.1.2 Input-based methodologies

National Accounts are a system for measuring the economic activities in a country and provide a detailed view into the flows of goods to the different sectors of a national economy. Integral part of the national accounts are the supply, use and input-output tables. The European System of National and Regional Accounts provides a harmonised and reliable framework which permits comparisons between EU Member States (Efken et al. 2016, Eurostat 2013).

The fact that supply and use tables show goods which are inputs into the industrial sectors of an economy allows to identify those bio-based product groups which are apparently inputs for industrial sectors. Then, the shares of bio-based inputs in each sector can be calculated and this share can be transferred to the economic indicators of each sector. This approach has been applied in several studies (Campanini et al. 2018, Delahaye et al. 2015).

In Campanini et al. 2018 and Campanini et al. 2017, the use of input-output tables was restricted to the sector of bio-based chemicals. In this field, the estimation of bio-based shares is particularly difficult. Therefore, first PRODCOM codes were selected relating to bio-based chemicals and then input-output tables were used to quantify the total amount of bio-based inputs apparently taken up by the Italian chemical sector. This led to the result of a production value of bio-based chemicals in Italy of about 3 billion Euro in 2015/2016 (Campanini et al. 2018, p. 7). For comparison, the data set on jobs and wealth in the EU bioeconomy, compiled by the JRC (Ronzon et al. 2018), also reports a turnover of bio-based chemicals in 2015 in Italy of 3 billion Euro. Despite the independent and slightly different methodologies, both studies therefore arrive at the same conclusion in this case.

Efken et al. 2016 used the National Accounts to calculate value added at factor cost and the number of employees of the bioeconomy in Germany. The primary sector was completely considered to belong to the bioeconomy. Nevertheless, the authors acknowledge that this is also a simplification since there are also activities in the primary sector that are not directly related to the use of bio-based resources. As an example that the authors provide, agricultural enterprises with their main activity being farming, and thus belonging to the primary sector, may also generate additional income through tourism services, but these cannot be differentiated in the National Accounts. For deriving shares of the downstream manufacturing sector, the statistic of Materials and Goods received (MGr) by companies, collected by the German Federal Statistical Office, was used. This statistic reports the value of inputs (at or above the NACE Class level) to industries (at the NACE Class level).

In Efken et al. 2016, those inputs which could be identified to contain mainly biological resources (e.g. D 01 Crop and animal production, hunting and related service activities) were added up, their share in total input value was calculated and this share was applied to available economic indicators (from cost structure and turnover tax statistics) of the receiving industries. A shortcoming of this approach is that those inputs which could not be identified to contain bio-based materials based on their description, e.g. D 20 Chemicals and chemical products, were not taken into account.

National input-output analysis

In the Netherlands, the input-output tables provide a much more detailed view of the economy than in most other countries (Verhoog 2015). The agro-food sectors alone is disaggregated into 19

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primary subsectors (e.g. cattle farming, arable farming, forestry) and 20 food and feed processing sectors (e.g. pig slaughtering sugar industry, flower processing).

In van Meijl et al. 2016, this agricultural IO table was used to describe and measure the economic effects (turnover, value added and employment) of the bioeconomy in the Netherlands. In this study, the primary sector (agriculture, forestry and fishery) as well as the food and feed sector were considered to be 100% bio-based. As partly bio-based sectors, textile and clothing, the wood industry, pulp and paper, chemicals, energy, building/construction and R&D services were considered. Apart from the direct economic effects of these sectors, also indirect effects were calculated. Indirect effects, also called spill-over effects, are effects in other sectors of the economy due to the activities in one sector. For example, the building of a new factory needs inputs and services from various sectors such as construction, restaurants, cleaning etc. Moreover, the employees of the factory secure employment in the whole economy due to their consumption. IO tables are able to capture these indirect effects since all sectors are connected with each other. The results regarding bio-based shares, direct effects and multipliers (the factors by which indirect effects increase the direct effects) are shown in Table 1.

Table 1 – Bio-based shares, turnover, value added and employment in bioeconomy sectors in the Netherlands in 2013

Sector	Bio-based shares		Direct effects			Multipliers	
	IO tables (van Meijl et al. 2016)	Kwant et al. 2014	Turnover (mill. Euro)	Value added (mill. Euro)	Employment (labour units)	Value added	Employment
Agriculture, forestry & fisheries	100%	100%	27,573	10,417	161,964	1.69	1.6
Food and Feed	100%	100%	63,697	13,180	131,523	2.18	2.48
Wood (bio-based)	80%	85-95%	4,197	1,606	27,105	1.88	1.65
Paper (bio-based)	77%	85-95%	4,592	1,199	13,240	1.87	1.92
Textile (bio-based)	13%	1-10%	465	153	1,949	2.14	2.14
Chemical (bio-based)	5%	3.7%	2,958	741	5,694	2.04	2.67
Energy (bio-based)	4%	1%	647	249	808	2.52	6.93
Construction (bio-based)	11%	n/a	632	205	2,549	2.28	2.21
Biotechnology	8%	n/a	362	289	2,475	1.39	1.59

Source: Adapted from van Meijl et al. 2016

Similarly, the agricultural input-output table is used to describe and measure the environmental effects (greenhouse gas emissions, energy use) of the bioeconomy in the Netherlands; based on sector information as published in the Environmental accounts of CBS. To be consistent with the outcomes for socio-economic indicators, the direct effects and multipliers presented in Table 2 are for the same year 2013 (Van Leeuwen et al. 2016). Note that these analyses are available at an annual basis so that an annual monitoring of the development of the Dutch bioeconomy is possible.

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Table 2 – Bio-based shares, energy and emissions in bioeconomy sectors in the Netherlands in 2013

Sector	Bio-based shares	Direct effects		Multipliers	
	IO tables (van Meijl et al. 2016)	Energy use (TJ)	Emissions (CO2eq)	Energy use	Emissions
Agriculture, forestry & fisheries	100%	142,022	28,145	1.2	1.1
Food and Feed	100%	81,043	3,526	1.6	1.9
Wood (bio-based)	80%	3,126	313	2.5	1.9
Paper (bio-based)	77%	20,249	438	1.2	1.4
Textile (bio-based)	13%	650	11	1.9	4.1
Chemical (bio-based)	5%	22,496	509	1.1	1.3
Energy (bio-based)	4%	10,830	2,243	1.1	1.0
Construction (bio-based)	11%	2,781	250	1.3	1.2
Biotechnology	8%	65	18	5.7	2.0

Source: Dutch Bioeconomy Barometer in 2013 (Van Leeuwen et al. 2016)

As Table 1 shows, the study by van Meijl et al. 2016 contains a direct comparison to the bio-based shares as presented in the bioeconomy monitoring report for the Netherlands by Kwant et al. 2014. In that study, the bio-based share in the chemical industry was actually determined by the selection of chemical companies in the Netherlands with potentially bio-based production. These companies were then interviewed by phone to assess their bio-based shares in production (Kwant et al. 2014, p. 30). Due to the identification of individual companies, this assessment could even be broken down to the NACE Group level (e.g. 20.1 Basic chemicals and 20.2 Pesticides and other agrochemical products).

Multi-regional analysis

While national IO tables only consider effects on the national economy, Multi-regional input analysis (MRIO) also takes into account induced transnational impacts resulting from imports and exports. The most widely used database for MRIO is EXIOBASE, which is a global, detailed Multi-regional Environmentally Extended Supply and Use / Input Output (MR EE SUT/IOT) database (EXIOBASE Consortium 2015). This database has also been proposed in a number of studies as a possible source of data for modelling of the bioeconomy.

For example, Budzinski et al. 2017 used the EXIOBASE database to analyse the German wood-based bioeconomy. The authors in this study conclude that the detailed analysis of a bioeconomy sector, taking into account the linkages to other economies allowed a differentiated understanding of the environmental and socio-economic impacts of this sector. However, they also discuss a number of limitations in using the EXIOBASE data. For example, the data is rather old, the current base year being 2007. Furthermore, the MRIO-based footprints inadequately address impacts on ecosystems such as biodiversity and soil fertility but also the goal to secure supply of food to the world. As a solution towards a more systemic monitoring of the bioeconomy, Budzinski et al. 2017 propose the linking of different models within an integrated assessment framework that combines different research communities.

Social Accounting Matrices (SAMs) provide an advancement from the traditional input-output models in that they contain a complete and coherent overview of economic and social data for all

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transactions between economic operators in the economy at a given time (Fuentes-Saguar et al. 2017). At the Joint Research Centre (JRC) of the European Commission, Müller et al. 2009 constructed a series of SAMs for each of the European Union Member States with detailed accounts for 30 agricultural activities and 11 food activities, benchmarked to the year 2000. An update of these accounts to 2007 was subsequently employed as a basis for further structural multiplier analysis covering all EU MS, facilitated by statistical clustering and segmentation tests to generate 'typical' EU regional groupings with comparable agricultural sector structures (Philippidis et al. 2014).

Subsequent work by Mainar-Causapé and Philippidis 2018 at the JRC builds on the seminal work of Müller et al. 2009 not only by updating the accounts for all of the Member States (to 2010), but also expanding the definition of bio-based sector activity accounts (henceforth dubbed 'BioSAMS') to encompass additional sources of biomass, as well as contemporary applications of biomass in the fields of liquid fuels, electricity and chemicals, which has also been used to conduct a further structural multiplier analysis of the wealth and employment generating capacities of these sectors (Fuentes-Saguar et al. 2017, Philippidis and Sanjuán 2018).

Instead of *inferring* shares of bio-based inputs into the different industries e.g. from IO tables, one could also try to track biomass from its origin, imports or domestic production, through the value chains to its final use. This, the link between biomass supply and use, is essentially what is missing in the current statistics.

This approach has been applied in the FP7 project BIO-TIC to two groups of raw materials, namely sugar and starch and plant oils (Piotrowski et al. 2015). The idea of tracking biomass from its origin, called the "Total Biomass Flow" approach by the authors, has the advantage that the resulting bio-based shares in industrial products have been checked against the actual raw material basis but the disadvantage that many assumptions on the split of uses must be made along the value chain.

To depict a complete picture of biomass uses by different sectors of the bioeconomy is very challenging, since the official statistics miss a link between biomass supply and use. The Joint Research Centre (JRC) developed a methodology to fill this gap (Gurría et al. 2017). As a result, Sankey diagrams of biomass flows from imports, to domestic supplies, uses in the different bioeconomy sectors and exports are available from the DataM portal of agronomic research (https://datam.jrc.ec.europa.eu/datam). An example is shown in Figure 4.

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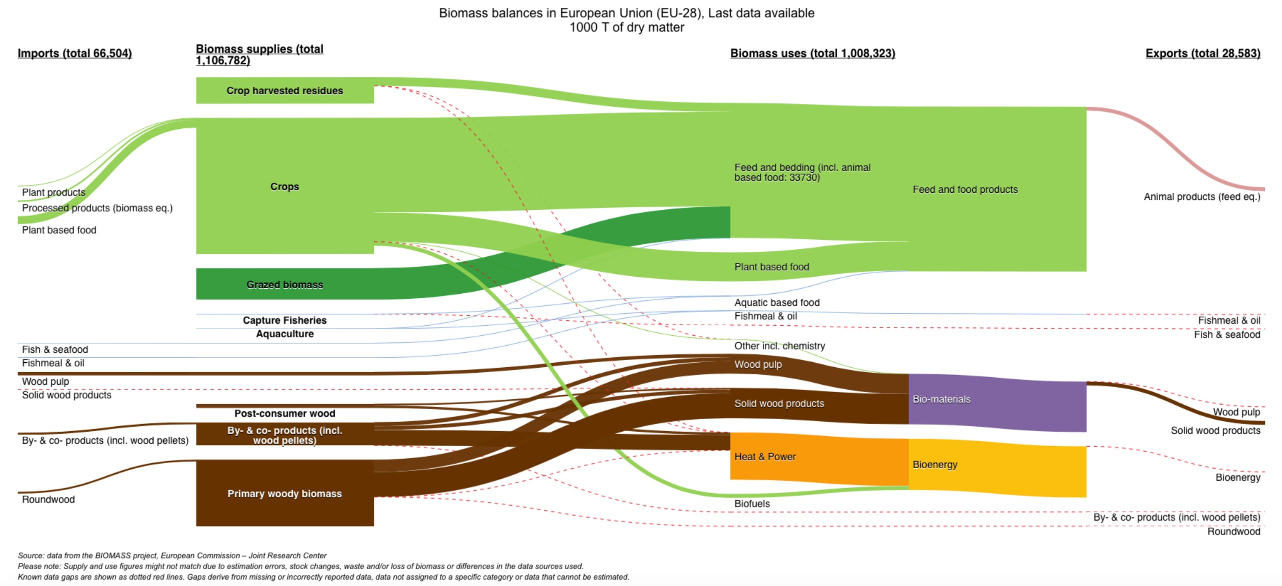

Figure 4 – Screenshot of the Sankey biomass diagram: biomass balances in EU-28

Source: https://datam.jrc.ec.europa.eu/datam

The most complete study of biomass flows from raw material production to products is available for the forestry sector. In the studies of Mantau et al. 2012 and Mantau et al. 2015, all wood flows in the EU-27 in 2010 were analysed and presented in one single flow chart, including material and energy consumption (Figure 5). For this study, first a balance between total wood availability and consumption was established, called the Wood Resource Balance (WRB). Then, the split of the consumption into the different material and energy sectors was estimated based on a variety of sources. For example, the consumption of wood in the pulp industry was taken from the annual statistics of the Confederation of the European Paper Industries (CEPI). For an estimation of the shares of wood in end products, simple assumptions were made. Since the WRB shows wood flows in volume (m^3) of solid wood equivalents (swe), first an internationally agreed conversion factor from tonnes of sawnwood to m^3 of swe was applied (1.77) and then deductions were made for those product categories which are likely to include relevant shares of non-wood materials (15% for packaging, 25% for building materials and 35% for furniture).

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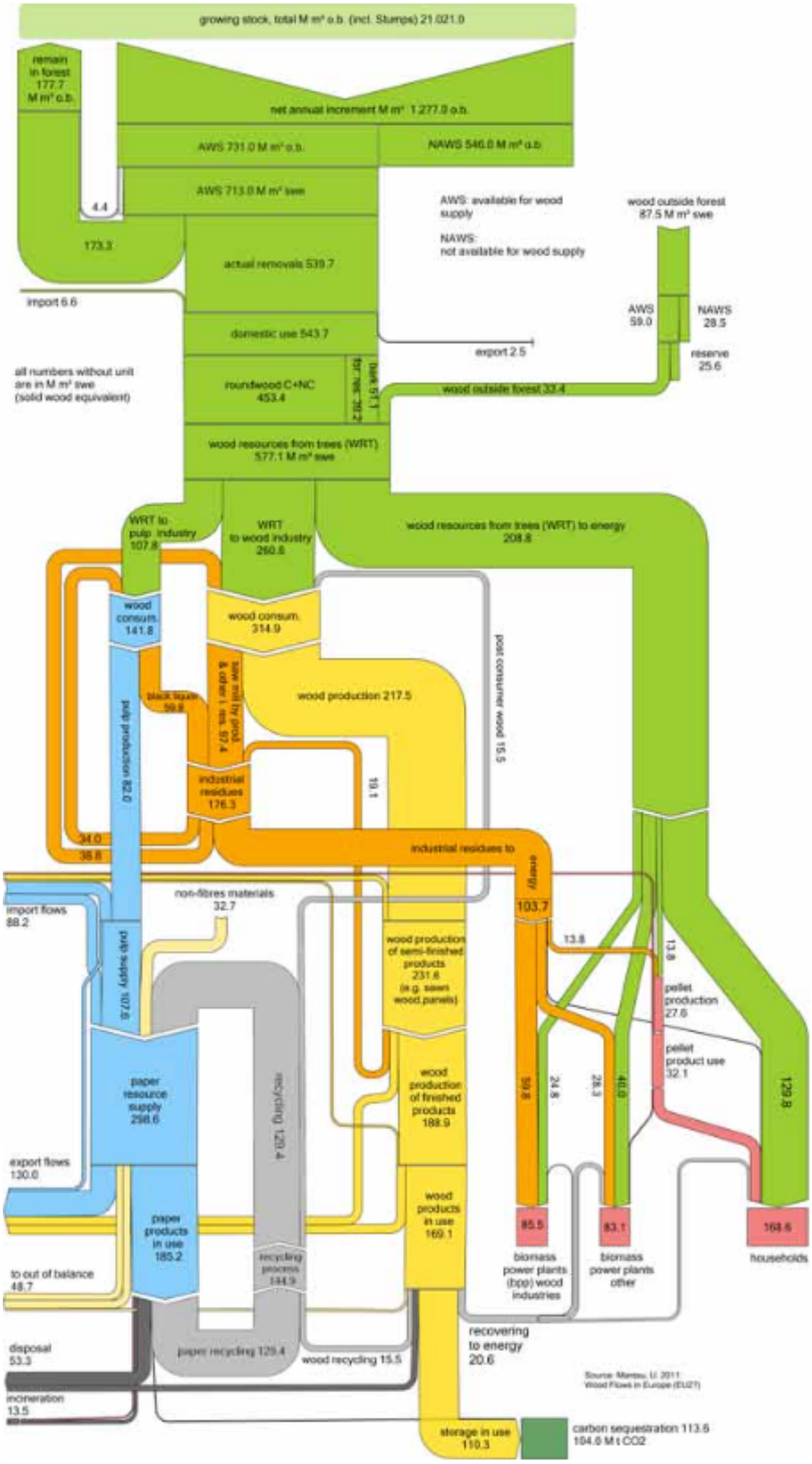

Figure 5 – Wood flow chart from resource to end-use in EU-27

Source: Mantau et al. 2012

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2.2 Industry surveys

The studies evaluated in section 2.1 mainly rely on the existing statistics themselves (in the case IO studies) or on expert judgements regarding the bio-based shares in products (in the case of most of the output-based methodologies). Only in some cases, the studies involved interviews with a representative number of companies (such as in Kwant et al. 2014), but not very extensive surveys of different industries. Compared to these studies, there is a strain of research that aims at gathering company level data first and building up a bioeconomy database from there. A number of these studies is evaluated in the following.

Nattrass et al. 2016 presented results of a survey based on a structured questionnaire which targeted 133 companies in the EU operating in the field of bio-based chemicals. These companies were identified through databases, previous research and information from producer organisations including the European Chemical Industries Council (CEFIC) and the Bio-based Industries Consortium (BIC). 50 of these companies filled in the questionnaire, resulting in a response rate of 38%.

Geographical distribution of companies was concentrated in Germany, the Netherlands and Italy, which are the EU Member States with the strongest bio-based activities. Therefore, the sample was regarded as representative in terms of geographical area covered. Figure 6 shows the bio-based products that these companies stated to currently produce or expected to produce by 2020. The survey also included a more detailed breakdown as to the current and expected production by 2020.

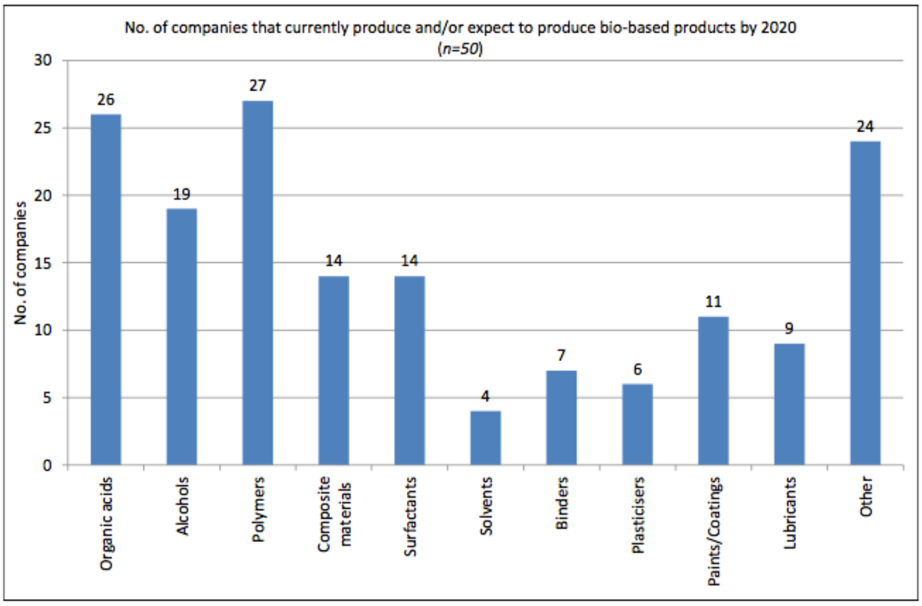

Figure 6 – Number of companies that currently produce and/or expect to produce bio-based product by 2020

Source: Nattrass et al. 2016

The advantage of such an industry survey is clearly, that such forward-looking statement can be made and in general more detailed answers can be obtained from companies than from statistics. The disadvantage is the effort needed to conduct such a survey, which makes it almost impossible to gather such data on a regular basis.

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Overall, this survey contributed to the understanding of the trends that characterise the EU bio-based industry; however, the results of the survey cannot be interpreted as absolute numbers because of the heterogeneity of the responses and the difficulty of obtaining input from a substantial number of the key economic actors.

Ehrenfeld and Kropfhäusser 2017 built up a dataset of companies active in the plant-based bioeconomy in Central Germany. For this purpose, several online and printed databases were screened. The final dataset contained not only the identification of companies by NACE codes but also information about the number of employees and age of the enterprise. This dataset therefore also allowed to draw some conclusions on economic indicators.

The European Commission's Joint Research Centre (Parisi 2018) published a research brief on “Biorefineries distribution in the EU”. About 800 biorefineries have been identified in the EU, of which 507 produce bio-based chemicals, 363 liquid biofuels and 141 bio-based composites and fibres (multi-product facilities are counted more than once). The brief also presents qualitative information on the main feedstock source in the EU in terms of number of biorefineries (not of quantities employed) using either agriculture, forestry, waste, marine and other (i.e. insects-derived) feedstock. Further research aims at determining the level of development of the bio-based industry in the EU and the potential for future growth in terms of number and location of new biorefineries. Future steps in this direction are being carried out by linking the location of current bio-based facilities with the specific kinds of locally available biomass (with main focus on agriculture and forestry at the moment), to establish optimal locations of new biorefineries for the best exploitation of local resources.

A comprehensive report by the European Commission's Joint Research Centre (Spekreijse et al. 2019) provides “Insights into the European market for bio-based chemicals”, with an analysis based on 10 key product categories. This study aims to provide a detailed description of a segment of the EU bio-based products sector (bio-based chemicals), against the background that monitoring the development of the bio-based economy is challenging, since no official European databases are dedicated to bio-based products for industrial use, such as bio-based chemical products.

From a longlist of 350 bio-based products, developed as part of the Bio-Based Industries Joint Undertaking project RoadToBio, 208 products that are available at commercial scale (technology readiness level ≥ 8) were selected. From this list, 50 bio-based products were identified as representative of the 10 product categories (3-9 per product category) and 20 value chain descriptions were created (2 products per category). A detailed market assessment was carried out on the 50 selected products, covering production in the EU, price, turnover, consumption, trade, feedstock use and agricultural land requirement.

It uses two main statistical databases relevant for the collection of information on bio-based products (PRODCOM and Eurostat’s Easy Comext database), complemented with information from the literature, publicly available commercial market studies, expert interviews and, as a last resort, own expert estimates. The reliability of the information collected was scored using an uncertainty indicator.

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Product category	EU bio-based production (kt/a)	Total EU production (kt/a)	EU bio-based production share (%)	EU bio-based consumption (kt/a)
Platform chemicals	181	60,791	0.3	197
Solvents	75	5,000	1.5	107
Polymers for plastics	268	60,000	0.4	247
Paints, coatings, inks and dyes ([a])	1,002	10,340	12.5	1,293
Surfactants	1,500	3,000	50.0	1,800
Cosmetics and personal care products ([a])	558	1,263	44.0	558
Adhesives ([a])	237	2,680	9.0	320
Lubricants ([a])	237	6,764	3.5	220
Plasticisers ([a])	67	1,300	9.0	117
Man-made fibres	600	4,500	13.0	630
Total	4,725	155,639	3.0	5,489

([a]) No total EU production data were found; it has been assumed that total EU production (fossil- and bio-based) equals the total EU market (fossil- and bio-based consumption).

Figure 7 – Estimates of total EU production, the bio-based share of production and the consumption of bio-based products for each category

Source: Spekreijse et al. 2019

Survey activities to characterise the size and evolution of the bio-based industry were also performed outside Europe and could also serve as methodological references. As an example, the USITC (United States International Trade Commission) carried out a survey in 2008 directed to the U.S. chemical and biofuel industries that make use of renewable resources and/or enzymatic/microbiological processes (USITC 2008). The survey was aiming to obtain economic data to analyse the competitive conditions of the industries adopting these new processes and resources.

In Canada, several government institutions conducted survey studies within the framework of the bioeconomy, with a focus on non-conventional industrial bioproducts, which include biofuels, bioenergy, biochemicals and biomaterials. Statistics Canada carried out four surveys on bioproduct activities in Canada, led by Agriculture and Agri-food Canada (AAFC). These surveys were conducted for the reference periods 2003, 2006, 2009 and 2015. Each of the four surveys used different definitions and scopes, as a result of the dynamic evolution of the industry and the required updates (Rothwell et al. 2011, Rancourt et al. 2017). All four surveys used a census approach to identify the in-scope population of establishments. However, due to changes in the survey methodologies, including frame, sampling method, edits, imputation and weighting and changes related to questionnaire content and concept definitions, the target population and the list of establishments differed for each iteration. Therefore, the obtained results are not directly comparable between the four surveys and are not meant to be treated as a time-series (Rancourt et al. 2017).

Another relevant example from North America is the study by Golden et al. 2015 for the U.S. Department of Agriculture (USDA). In this study, direct employment and value added as well as indirect and induced effects of the U.S. bio-based products industry were calculated for the year 2013 (followed by an up-date of this study for the year 2014 by Golden et al. 2016). Additionally, the amount of petroleum displaced by bio-based products is calculated to be approximately 300 million gallons per year.

This study defined the U.S. bio-based industry as encompassing the agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest products and textiles sectors, and reports on innovative products carrying the USDA's BioPreferred® label.

The approach taken to carry out the study was threefold: the collection of statistics, interviews with experts and modelling analysis using IMpact analysis for PLANning data and software (IMPLAN). The study acknowledges that neither the number of different bio-based products nor the number of individual units of bio-based products sold are known. From the number of products registered in the BioPreferred® database (20,000) it is inferred that 40,000 would be a conservative estimate for the actual number of bio-based products since forest products and textile fibre products had only been included in the programme recently (Golden et al. 2016, p. xi). Based on this estimation, the report concludes that the direct value added from sales of bio-based products had amounted to 127 billion USD in 2014, adding up to 369 billion USD if indirect and induced effects are included. Regarding employment, the main result is that the bio-based industry directly supported 1.53 million jobs and, through spill-over effects, supported 4.22 million total jobs throughout the economy in the United States (Figure 8). Unfortunately, the details of how the results have been obtained based on the limited information about bio-based products are not provided in the report. Furthermore, the study does not provide a complete picture of the U.S. bioeconomy as it does not report on the bioenergy sector (Bracco et al. 2018).

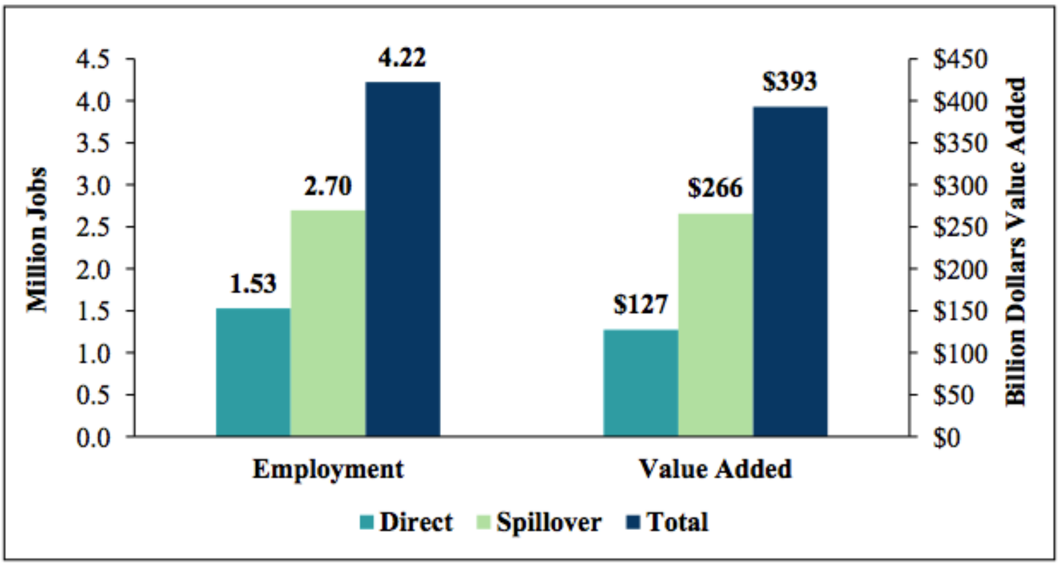

Figure 8 – Total employment and value added to the U.S. economy by the bio-based products industry in 2014

Source: Golden et al. 2016

2.3 Regionalisation

The BioMonitor project aims to establish a data and modelling framework for the EU and its Member States. Within the MS level, the collection of data at regional level is also essential as it is

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there where the bioeconomy needs to be investigated and promoted. This is underpinned by the new EU Bioeconomy Strategy from October 2018 that lists down three main Action Plans that serve as a basis for Europe to progress towards a circular bioeconomy: 1) scaling up and strengthening the bio-based sectors; 2) rapidly deploying the bioeconomies across Europe, and 3) protecting the ecosystem and understanding the ecological limitations of the bioeconomy.

Further, several stakeholders have explicitly demanded for regional bioeconomy data at two recent workshops, i.e. 1) at the first BioMonitor Stakeholder Workshop on October 23, 2018, and 2) at the ERIAFF network and European Forested regions workshop "Successful regional bioeconomy strategies – what should they look like?" in November 2018. In the last one, policymakers identified the gaps and imbalances they face, particularly in terms of lack of regional data on socio-economic, environmental and societal aspects. In addition, they stressed the need for good and reliable indicators (with a clear definition and a clear metrics) for measuring and monitoring the bioeconomy development.

Starting from the regional perspective, BioMonitor will be aligning to the actions mentioned in the recent EU Bioeconomy Strategy. A systems wide-monitor approach will then be created in order to track the progress of EU regions' towards a sustainable and circular bioeconomy based on its various drivers such as job creation, climate mitigation, renewed and strengthened EU industrial base, circular economy, healthy ecosystems and biodiversity.

The aim of the BERST project (2012-2014) was to account for the bioeconomy potential and strategies of a range of different regions in Europe, and therefore to gain understanding of the possibilities and challenges related to the enhancement of regional bio-based economies. The project also provided a support network in order to promote the development of smart specialisation strategies based on the regional bioeconomic potential. As an outcome of this process, regional bioeconomy profiles were created for the participating regions (Van Leeuwen et al. 2015). A set of performance indicators were identified for biomass availability, land use, quality of workforce, demographics, cluster size, employment structure, innovation. Regional (NUTS2 and/or NUTS3) data needed for analysing the indicators were collected from sources like e.g. EUROSTAT, the Regional Innovation Scoreboard, national Chamber of Commerce, LISA for firms and employment in NL, UK's Business register and employment survey, national/regional sources. Gaps in regional data availability were closed by using approximates and regional expert knowledge.

BERST has built a database with quantified bioeconomy related indicators for regions in Belgium (NUTS2), the Netherlands (NUTS3), Finland (NUTS3), Germany (NUTS1), Greece (NUTS2), Slovenia (NUTS3), Spain (NUTS2) and United Kingdom (NUTS3). They are made accessible by an on-line dashboard/visualisation tool which includes a benchmark option to identify a region's relative position that is supportive for developing smart strategies: what are strong assets? What could be strengthened? Figure 9 and Figure 10 are examples of the type of output that can be retrieved from the BERST dashboard with regional indicators (the dashboard can be found here: https://berst.databank.nl/dashboard).

The work in the ongoing RDI2Club Interreg project (2018-2022) on bioeconomy profiles in the Baltic Sea Region relies on the existing work conducted in the BERST project. For the same set of indicators, RDI2Club partners collected bioeconomy related data for regions in Norway (NUTS3),

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Finland (NUTS3), Estonia (NUTS3), Latvia (NUTS3) and Poland (NUTS2). Similarly, gaps in regional data availability were closed by using approximates and regional expert knowledge (Koponen 2019). The BERST dashboard also contains bioeconomy profile factsheets for BERST and RDI2Club regions that not only rely on indicator analyses, but also on network consultations with stakeholders interested in exploring the bioeconomy, see for example the profile for Central Finland (https://berst.databank.nl/dashboard/Dashboard/Central-Finland--Finland-/).

Figure 9 – Bioeconomy Readiness level in Vidzeme (Latvia) compared to Latvia as a whole

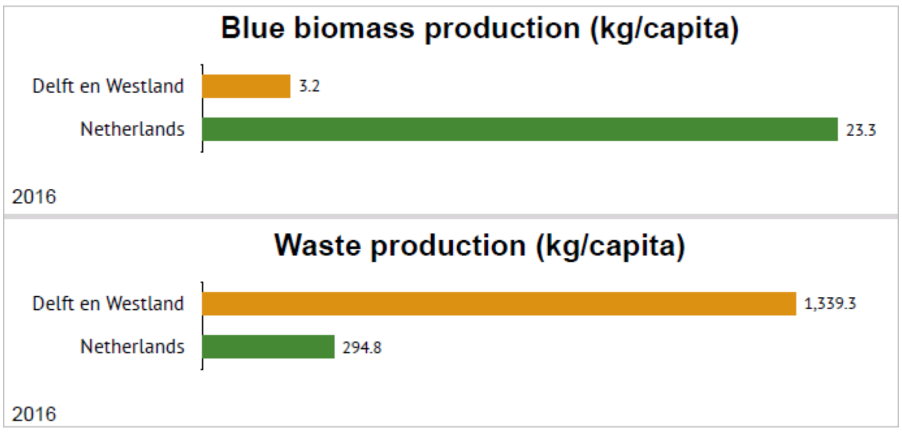

Figure 10 – Availability of blue and waste biomass (kg/capita) in Delft and Westland region, compared to average Dutch region

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3 Medium-run methodologies

This group of methodologies is characterised by the fact that they go beyond making estimates from existing statistics but build an own statistical framework on that basis. One such example is the Material Flow Monitor (MFM) developed by the BioMonitor project partner CBS (Statistics Netherlands).

The main idea of the MFM is to track biomass flows through the economy using supply and use tables (SUT) of the national accounts (Delahaye et al. 2015, Hoekstra et al. 2015). However, SUT are only given in monetary values and first need to be converted in physical units. In the MFM, this was achieved by using price information from different sources like the international trade statistics, production statistics and scanner data from super markets. The development of the MFM benefitted from the very detailed SUT in the Netherlands, so that the general applicability and feasibility of this methodology will be tested in further case studies as part of the BioMonitor project.

The Economy-wide Material Flow Accounts (EW-MFA) is an existing database in Eurostat which shows the domestic extraction, imports, exports and domestic consumption of different kinds of materials (Eurostat 2013). In these accounts, biomass is broken down into several categories, including even grazed biomass and crop residues. What is missing yet in the EW-MFA, however, is a direct link between the biomass supply to its use in industries. This drawback could be overcome by making use of the MFM methodology. The feasibility of combining the EW-MFA and the MFM will therefore be researched in Task 3.3 of BioMonitor.

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4 Long-run methodologies

The most data intensive and comprehensive option for obtaining data on bio-based production would be to actually extend the product classification systems to include dedicated codes for bio-based products and/or for bio-based sectors.

As the following paragraphs show, this approach has been followed in recent years in the EU for a few products, but clearly every additional product adds administrative burden to companies and statistical offices. On the other hand, enterprises benefit a lot from detailed data about products, so that BusinessEurope, one of the leading lobby organisations representing enterprises in the EU, strongly opposed plans a few years ago to reduce the PRODCOM list from the 8-digit to the 6-digit level (BusinessEurope 2016). Also outside of Europe, in Canada and the U.S., an extension of the classification system, in this case the North American Industry Classification System (NAICS), to include specific codes for bio-based products is being evaluated (Golden et al. 2016).

In 2016, three new codes for bio-based products have been introduced to the CN and PRODCOM classification system: bio-based lubricants, succinic acid and 1-4 butanediol (Table 3). The introduction of these products goes back to recommendations of the Renewable Raw Materials (RRM) Group to DG TAXUD, the Directorate General for Taxation and Customs Union (European Commission 2013). The RRM Group had been created in 2001 by the European Commission as a working group of industry experts with the objective to bundle the knowledge on bio-based products, collect data and provide recommendations (Parisi and Ronzon 2016).

Table 3 – Codes for bio-based products in the CN/PRODCOM classification system

Product name	CN code	PRODCOM Code
Lubricants having a bio-based carbon content of at least 25 % by mass and which are biodegradable at a level of at least 60 %	34.03.19.20	20.59.41.59
Butane-1,4-diol or tetramethylene glycol (1,4-butanediol) having a bio-based carbon content of 100 % by mass	29.05.39.26	20.14.23.38
Ethane-1,2-dicarboxylic acid or butanedioic acid (succinic acid) having a bio-based carbon content of 100 % by mass	29.17.19.20	20.14.33.82

Source: Eurostat 2017

The three products shown in Table 3 had been selected for several reasons. First, they were considered, at the time of making the proposals, to have relevant production and trade volumes. According to the Code of Conduct for the Management of the Combined Nomenclature (2000/C 150/03), there shall be statistical thresholds defined to assist in the process of determining whether a CN subheading should be deleted, maintained or created. In guidance documents, an approximate minimum threshold of 50 million Euro of trade value is mentioned (Gammon 2018).

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Second, they were considered to be good "test candidates" to fill gaps in the trade statistics, since there already existed CN codes for a number of bio-based products, such as polylactic acid (39.07.70.00) and glycerol (29.05.45.00), but none for these substance classes.

Third, there had already been activities of the European Committee for Standardization (CEN) going on to establish standards for identifying and testing these bio-based products. In fact, in order to be included in the statistics as a bio-based product, there must already be a CEN standard in place which defines the minimum bio-based carbon content of that product as well as the methodology that needs to be applied for verifying that content. This requirement is important so that customs labs actually can verify and distinguish bio-based and non-bio-based products.

In the case of lubricants, the CEN norm EN 16807 defines that a "bio-lubricant" must contain at least a bio-based carbon content of 25% by mass and must be biodegradable at a level of at least 60%. The term "bio-based product" is further defined in the CEN norm EN 16575: "The bio-based product is normally characterized by the bio-based carbon content or the bio-based content."

For 2016 and 2017, there are now actually production data available in Eurostat for these newly introduced products. However, while the PRODCOM list is updated almost every year, national product classification systems in the Member States in most cases lack behind these rapid changes. For example, the classification system in Germany ("Güterverzeichnis für Produktionsstatistiken") on the basis of which the data collection from enterprises takes place, is updated only every 10 years, the last version dating from 2009 and an updated version being in place from 2019 onwards (DESTATIS 2018). Only this updated version will have the new bio-based products implemented.

While the three new codes for bio-based products have been established with great efforts, there is the risk that due to decreasing trade volumes, these may again be excluded from the CN list. However, continuous availability of production data will be pivotal for a robust monitoring system.

The above-mentioned Code of Conduct (2000/C 150/03) states that "a CN subheading may be created or maintained even though the volume of trade is below the statistical threshold in question, provided that it is supported by the Commission services or by the Member States representing a qualified majority". Whether production data for the newly introduced bio-based products will be available on a continuous basis, irrespectively of the trade volumes, will therefore depend on the political will of the Commission and the Member States.

Furthermore, however, statistical data on some of the bio-based products may be collected but not become publicly available for confidentiality reasons. According to a "confidentiality charter" (Eurostat 2016), eligible reasons for Member States to demand Eurostat to treat product data as confidential are too few enterprises producing a product (1-3 enterprises, as a rule) and the dominance of one or two enterprises (with >85% market share, as a rule). While this issue concerns all kinds of products, it may be of particular relevance for innovative bio-based products, produced only by a small number of enterprises. Nevertheless, this should not become a problem for a bioeconomy monitoring system in which also confidential data can be processed to produce a more aggregated picture of the EU bioeconomy.

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The need for an extension of statistical data does not only relate to processed bio-based products but also to other sectors of the bioeconomy. As an example, the case of Non-Wood Forest Products (NWFPs; e.g. mushrooms and berries) is illustrated below.

Their value on the formal EU market is 1.6 billion Euros (FOREST EUROPE 2015); however, this is a strong under-estimation as “statistical data are incomplete, scattered or not comparable among countries” (Vantomme 2003, p. 160). The value of NWFPs that does not enter formal markets is estimated to be two to three times higher than the value of its formal market (Wahlén 2017), and for now there are no representative estimations of this value based on actual economic activity. To address these challenges, BioMonitor will build-upon findings of the STARTREE project to provide an estimation of the value of NWFPs in the informal market in Europe as based on a representative sample of EU households, the only viable way through which this data can be obtained (Sorrenti 2017).

The main long-term contribution of this exercise will be a shortlist of key NWFPs per each EU Member State that is indicative of a wider set of NWFPs, i.e. a guideline on how to design simple and cost-effective national-level household surveys. This is a long called-for result (e.g. Laird et al. 2010 and FAO 2011, Shackleton and Pandey 2014), and can greatly contribute to national reporting towards EUROSTAT, FAO and FOREST EUROPE.

BioMonitor will also perform a longitudinal analysis of NWFPs within HS6 and CN8 classifications, where many products strongly increase or decrease their economic importance, thus signalling the need for change in the commodity codes (see Pettenella et al. 2014 for earlier work on this topic). Based on these two types of analysis, the final output of the BioMonitor within this context of NWFPs will be an analysis of a need for new CN8 and or HS6 codes.

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5 Methodologies for improving data quality and scope

The previous sections focused merely on the availability of data for monitoring socio-economic indicators of the bioeconomy. In addition to the mere presence of data, it is also important to consider the scope and quality of the data (e.g., frequency at which data becomes available, reliability, completeness across EU Member States, spatial resolution, etc.).

Therefore, appropriate methodologies for improving the data scope and quality may also need to be evaluated and further developed within the project. For instance, most indicator data are typically available at the national level, but not necessarily at sub-national levels (e.g. NUTS 2 or 3 regions). In case indicator data are only available at the national level, disaggregation methods may be applied.

As an example, statistical information on wood production can be combined with auxiliary data (e.g., forest cover maps) to develop spatially explicit wood production maps (Maes et al. 2012). However, the use of forest cover as the only proxy to map wood production is coarse and may result in substantial errors (Eigenbrod et al. 2010), because production patterns may not be equally distributed across forested landscapes (Wendland et al. 2011, Masek et al. 2011).

More advanced methods may estimate a statistical relationship between a target variable (e.g., wood production) and its location factors (e.g., soil quality, topography, accessibility) and then use this relationship to predict the suitability of every location for the target variable at the target grid level for which information on the location factors are available. Such a downscaling approach in which statistical relationships are transferred across scales is called dasymmetric mapping (Eicher and Brewer 2001) and has been used extensively to disaggregate statistical information on farming systems (van de Steeg et al. 2010), livestock (Neumann et al. 2009), nitrogen input (Temme and Verburg 2011) and roundwood production (Verkerk et al. 2015).

Data quality issues are currently being defined in WP2, but it is likely that methodologies are needed to overcome data quality issues. These methodologies will be elaborated in the remainder of Task 3.1, once the indicators, data gaps and their requirements are consolidated.

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6 Conclusions

As stated above, the structure of the proposed data collection methodologies into short-, medium- and long-run methodologies should not create the impression that one set of methodologies is necessarily preferable over the other. For sure, the short-run methodologies are not *per se* easier to be implemented. The distinction of the methodologies in the previous sections was really not more than a temporal delimitation as to the time frame needed for implementation.

As section 2 showed, there are many examples of studies using short-run methodologies which all rely on some kind of approximation procedures. This is not surprising since any kind of approximation or guesstimate can be performed quickly. What is critical, however, is the quality of these guesstimates.

On the other hand, based on the experiences so far, the implementation of the long-run approach of extending the statistical classification systems, as described in section 4, will need several years for just a few products. Once the classification system is extended, reliable and continuous data about the bioeconomy could be available for a monitoring system, provided that the bio-based products are not again removed from the statistics due to trade volumes below the threshold.

The comparison of the different data collection methodologies has therefore shown that all existing approaches have advantages and disadvantages, an overview of which are shown in Table 4. In BioMonitor, all existing approaches will be improved and further developed in order to provide a robust toolset for filling data gaps in the bioeconomy monitoring.

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Table 4 – Comparison of advantages and disadvantages of data collection methodologies

Methodology	**Advantages**	**Disadvantages**
Output-based methodologies based on existing statistics	• Quick estimations for all sectors of the bioeconomy possible	• High uncertainty due to rough expert estimates
Input-based methodologies based on existing statistics	• Not completely relying on expert estimates; results are partly derived from linkages between inputs and outputs in the National Accounts • By tracking biomass from its origin through the value chains, resulting bio-based shares in industrial products can be checked against the actual raw material basis	• IO tables not available annually • In tracking biomass from its origin, many assumptions on the split of uses must be made along the value chain
(Industry) surveys	• Direct and detailed information from actors in the bioeconomy possible	• High efforts needed to achieve representative samples, low response rates • Survey designs change over time; studies not comparable over time
Extension of the Material Flow Monitor (MFM)	• Link between biomass supply and use trough combination of the MFM with the Eurostat Material Flow Accounts	• Only applicable if detailed SUT are available (to be tested in BioMonitor case studies)
Extension of statistical classifications	• Potentially complete, continuous and consistent data at product levels	• High efforts needed for the inclusion of just a few products • High administrative burden for data collection • Risk of reduction of classification due to trade volumes below the threshold

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7 Overview of evaluated studies

Table 5 – Overview of evaluated studies

Study	Methodology	Scope	Indicators	Time scale	Spatial scale
Budzinski et al. 2017	Multi-regional input analysis (MRIO) with EXIOBASE	German wood-based bioeconomy	Physical flows, value added, employment, GHG emissions	2007	Germany
Campanini et al. 2017, Campanini et al. 2018	Estimations based on Eurostat statistics, Input-Output-tables (only for bio-based chemicals)	Primary and manufacturing sectors, management and recovery of waste	Production value, turnover and employment	2015 and 2016	Italy
Delahaye et al. 2015, Hoekstra et al. 2015	Supply and Use Tables (Material Flow Monitor, MFM)	Supply and use of all goods within the economy	Physical material flows	2008, 2010, 2012	The Netherlands
Efken et al. 2016	Calculations and estimations based on the National Accounts and the statistic of Materials and Goods received (MGr)	Primary and manufacturing sectors	Value added at factor cost and the number of employees	2002, 2006, 2010	Germany
Ehrenfeld and Kropfhäusser 2017	Company level database	plant-based bioeconomy actors classified along NACE codes	Number, type and location of bioeconomy actors by NACE codes	2013	Central Germany
Golden et al. 2015, Golden et al. 2016	collection of statistics, interviews with experts and modelling analysis using IMpact analysis for PLANning data and software (IMPLAN)	U.S. bio-based products industry (agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest products and textiles sectors and products carrying the USDA's BioPreferred® label)	Employment and value added; direct, indirect and induced effects; amount of petroleum displaced by bio-based products	2013 and 2014	USA
Gurría et al. 2017	Sankey diagrams of biomass flows from imports, to domestic supplies, uses in the different bioeconomy sectors and exports	Biomass supply and biomass uses (in food and feed products, bio-based materials and bioenergy)	Physical material flows	2000-2016	EU-28 and Member States

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Kwant et al. 2014, Kwant et al. 2015	Calculations and estimations based on national statistics and company interviews	Primary and manufacturing sectors (up to the NACE Group level)	Turnover, value added and employment	2013	The Netherlands
Mainar-Causapé and Philippidis 2018, Fuentes-Saguar et al. 2018, Philippidis and Sanjuán 2018	Social Accounting Matrices (BioSAMs)	Primary and processing sectors	Output and employment multipliers	2010	EU-28 and Member States
Mantau et al. 2012, Mantau et al. 2015	Statistics, expert estimates	Wood from raw materials to use sectors	Physical material flows	2010	EU-27
Meijl et al. 2016	Calculations based on the Agricultural IO table of the Netherlands	Primary sector, food and feed, textiles, wood industry, pulp and paper, chemicals, energy, building/construction and R&D services	Turnover, value added and employment (direct and indirect effects)	2013	The Netherlands
Nattrass et al. 2016	Company level survey	Bio-based chemicals and composites	Production volume, turnover, employment and feedstock sources	2010-2013	EU-28, Member States
Nowicki et al. 2008	Identification of potentially bio-based products and estimation of their bio-based shares	Products from PRODCOM list	Bio-based production volumes and values	2005	EU-25
Pellerin and Taylor 2008	Estimation of bioeconomy shares in economic sectors	Sectors according to the NAICS	Contribution of the bioeconomy to GDP	2007	Canada
Piotrowski et al. 2015	Tracking of biomass from origin to end applications ("Total Biomass Flow"); Statistics, expert estimates	Sugar and starch and plant oils	Physical material flows	2013	EU-27
Piotrowski et al. 2016, Piotrowski et al. 2018	Eurostat statistics, expert estimates	16 NACE sectors (agriculture, forestry and fishing, 14 manufacturing sectors and the production of electricity)	Turnover and employment	2008-2015	EU-28 and Member States

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Ronzon et al. 2018	Eurostat statistics, expert estimates	16 NACE sectors (agriculture, forestry and fishing, 12 manufacturing sectors and the production of electricity)	Turnover, valued added and employment	2008-2015	EU-28 and Member States
Rothwell et al. 2011, Rancourt et al. 2017	Company level survey	non-conventional industrial bioproducts, which include biofuels, bioenergy, biochemicals and biomaterials	Specific questions related to bio-based products	2003, 2006, 2009 and 2015	Canada
USITC 2008	Survey	Chemical and biofuel industries	economic data	2004-2007	USA
Vandermeulen et al. 2011	Interviews with companies and federations	Companies in Flanders with bio-based production	Gross margins and employment shares of the bio-based economy	2010	Flanders
Vitunskienė et al. 2017	Identification of bio-based products in national statistics (all partly bio-based productions fully counted)	19 NACE sectors (agriculture, forestry and fishing, 12 manufacturing sectors and the manufacture of gas and waste collection, treatment and disposal activities; materials recovery)	Production value, turnover and employment	2008-2015	Lithuania

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