European Commission

JRC TECHNICAL REPORTS

The EU bio-based industry: Results from a survey

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2016

EUR 27736 EN

Joint Research Centre

JRC Science Hub
https://ec.europa.eu/jrc

JRC100357

EUR 27736 EN

ISBN 978-92-79-54969-4 (PDF)

ISSN 1831-9424 (online)

doi:10.2791/806858 (online)

How to cite: Lucy Nattrass, Clifford Biggs, Ausilio Bauen, Claudia Parisi, Emilio Rodríguez-Cerezo and Manuel Gómez-Barbero; The EU bio-based Industry: Results from a survey; EUR 27736 EN; doi:10.2791/806858

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Acknowledgements

This work is funded by the European Commission, partly by the Grant Agreement Number 341300 BISO (Bioeconomy Information System and Observatory) under the Seventh Framework Programme for Research (FP7) (see https://biobs.jrc.ec.europa.eu/). The authors would like to express their gratitude to Achem Boenke (GROW), Daniel Deybe (RTD) and the participants in the workshop organized by E4tech and the European Commission's Joint Research Centre-IPTS in Brussels on 16th September 2014 for their valuables contributions and support.

Abstract

Obtaining regular analysis and data is fundamental for policy makers and stakeholders to monitor the development of an economic sector and make the necessary decisions to maximise the benefits it generates, be they of economic, social or environmental nature. The industrial use of biomass feedstock has the potential to contribute to Europe's industrial and economic growth while significantly reducing greenhouse gas emissions, other environmental burdens, and resource dependency, through the displacement of fossil-based products with bio-based alternatives. To this end, this report contributes to quantifying and benchmarking relevant sectors in the so-called European Union Bioeconomy, the bio-based industries. It looks both at the past and future of the sector by focusing on a list of relevant bio-based products (about 70 chemicals and materials) and measuring the total population producing or about to produce these products. The report presents the result of a survey, based on a structured questionnaire launched in March 2015, of 133 companies constituting the total target population. These companies are diversity terms of size and time in the market. Some companies' operations are entirely bio-based and for some others bio-based products represent a relatively small fraction of their operations. They produce and market commodity and speciality chemicals and material goods to a wide range of sectors. Fifty companies completed the questionnaire and the bio-based products they are involved with are mostly organic acids, polymers (obtained from bio-based monomers) and surfactants. The respondents operate about 100 manufacturing plants for bio-based products mainly located in the established European chemical industry clusters. They also operate production plants in third countries, principally in North America and Asia (China, Malaysia and Singapore). The respondents total bio-based product turnovers account for €6.8 billion globally (24 companies answered) and €1.4 billion in the EU (23 companies answered). Therefore, these companies produce and sell globally, testimony of the global nature of the sector. The survey identified 20 companies using animal fats and vegetable oils, 19 companies using sugar or starch crops, and 11 companies using natural fibres. All respondents are positive about the outlook for growth in the industry. The response also indicates a rise in company activity since 2011, and there appear to be shifts in products being developed and produced, probably as a result of market testing, and technical development.

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Executive Summary

Obtaining regular analysis and data is fundamental for policy makers and stakeholders to monitor the development of an economic sector and make the necessary decisions to maximise the benefits generated, be they of economic, social or environmental nature. To this end, this report contributes, in a pioneering way, to quantifying and benchmarking a relevant economic sector within the so-called Bioeconomy.

For which sectors of the Bioeconomy is economic data lacking?

The European Union defines the Bioeconomy in its 2012 Strategy and Action Plan as the "production of biological resources and the conversion of these resources and waste streams into value added products such as food, feed, bio-based products and bio-energy". The present report focuses on the production of bio-based products by EU industry. The use of biomass feedstock in this specific sector has the potential to contribute to Europe's industrial and economic growth while significantly reducing greenhouse gas (GHG) emissions, other environmental burdens and resource dependency, through the displacement of fossil-based products with bio-based alternatives.

This report is limited to bio-based products because food/feed and bioenergy production are already established industries and therefore market data are available from different sources (e.g. EUROSTAT and FAOSTAT). At the same time, there are also some bio-based products for which this type of data already exist and are reported, such as pulp and paper; textiles; leather; fur; wood and wicker products; and pharmaceuticals. These are therefore not considered in this study.

There is an important part of an emerging Bioeconomy and bio-based industry for which economic data are still very difficult to obtain. This includes the production of bio-based chemicals, polymers and fibres.

What to measure and how to describe the EU bio-based industry?

The general objective of the study is to provide a description of the current status and evolution of the EU bio-based industry based on a list of relevant bio-based products and a survey of companies producing or about to produce these products (with turnover or employing labour in the EU). The list, which contains some 70 products, was initially compiled in a previous study commissioned by the European Commission's JRC and further refined and validated by experts in several fora, including a dedicated workshop organised by the JRC and E4tech in Brussels on 16th September 2014. The final version of the list included 21 bio-based polymers; 18 bio-based organic acids; 16 bio-based products used in surfactants, solvents, binders, plasticisers, paints/coatings and lubricants; 6 bio-based alcohols; and 10 other bio-based products.

The specific objectives of the study included when possible the quantification of business activity in the EU bio-based industry (e.g. number of companies; their size; number of companies producing a given product; turnover; number of employees) and the use of biomass in bio-based products. The study also aims to determine the drivers and constraints affecting the development of bio-based products, as well as to quantitatively and qualitatively compare the EU bio-based industry with key competitor countries.

Before engaging in the industry survey, the target population had to be identified and quantified (i.e. number of companies) following the list of products and using three main sources of information (F.O. Licht proprietary database, previous research, and contacts with sector organisations like the European Chemical Industries Council and the Bio-based Industries Consortium).

The survey targeted the total population of companies using a structured questionnaire administered mostly on-line with email follow-up. The survey was launched on 31st March 2015 and lasted for a couple of months. The questionnaire, which included more than 75 questions, was validated during the above-mentioned workshop and with a pilot survey.

Size of the target population and survey response rate

The target population consisted of 133 companies which operate at about 300 sites in the EU and have some additional assets outside the EU. They are highly diverse in terms of size, products and time in the market. Some companies' operations are entirely bio-based, whereas for some others bio-based products represent a relatively small fraction of their operations. The population includes companies producing commodity and speciality chemicals and material goods for a wide range of sectors.

Fifty companies provided a response to the survey, a response rate of 38%. Not all respondents provided a response to each question.

Description of business activities in the EU bio-based industry based on survey response

A large majority of the bio-based sector consists of private limited liability companies (67% of respondents). Both on the basis of the number of employees located in the EU in 2013 and of the annual turnover generated in the same year, most of the respondents are categorised as large companies. These employ more than 250 people and have sales exceeding €50 million annually.

As regards bio-based products, 27 companies currently produce or expect to produce bio-based polymers by 2020; 26 (companies) organic acids; 19 bio-based alcohols; 14 bio-based composites; 14 bio-based surfactants; 11 bio-based paintings and coatings; 9 bio-based lubricants; 7 bio-based binders; 6 bio-based plasticisers; and 4 bio-based solvents. In addition, 24 companies indicated that they currently produce or expect to produce "other" bio-based products by 2020 that were grouped in the previous categories. Within these categories, esters constitute the most numerous product in the group (6 companies); followed by hydroxymethyl-furfural (HMF), fatty amines, ethylene and ethylene glycol (4 companies each); and isosorbide and 'other polymer additives' (2 companies each). Other products specified were epichlorohydrin, isoprene, farnesene, para-xylene, chelating agents, carbon nanotubes (from ethanol), limonene, lignosulphonates, acetaldehyde, ethyl acetate and fatty acid amides.

Only 24 companies provided data on EU sales turnover of bio-based products. However, it is possible to observe that for the majority of these companies, these sales remained relatively stable through the 2010-2013 reporting period. However, based on information from 26 companies, total sales (fossil and bio-based) increased during the same period. When it comes to the future evolution of the industry, 89% of respondents expect that bio-based product sales will increase by 2020 (49% expect an increase of more than 100%).

Forty-one companies provided information on 100 bio-based production plants located in the EU. The majority are commercial (74 plants, including one dormant plant) and a smaller number are pilot (16) and demonstration (10) plants. The largest numbers of plants are located in Italy, followed by Germany, France, the Netherlands and Spain. Germany has the largest number of commercial (active) plants (16), whereas Italy has the largest number of pilot and demonstration plants. Most of the bio-based facilities are within or near the EU chemical industry clusters.

In addition, companies reported on bio-based production facilities located outside the EU. These are mainly located in Asia (mainly in China, Malaysia and Singapore) and North America.

Companies were asked about their total number of employees in the EU. Forty-two respondents reported a total of 220,056 employees in 2013. It is very difficult to assess how many of these are engaged in bio-based activities but the survey showed that 55% of respondents have more than 50% of their employees linked to the bio-based production. The number of employees engaged in bio-based R&D activities does not appear to represent more than 2% of the total number employed in all bio-based activities.

Relative economic size

The study attempts to assess the relative economic size of the EU bio-based industry by using data on the number of companies included in the target population (133) compared to the entire EU chemical industries sector which consists of some 29,000 companies. This bottom up approach based on survey data cannot be done when it comes to the annual turnover and number of employees due to the lack of full response on these two variables. However, previous work estimated that the annual turnover relating to bio-based chemicals and plastics in the EU was €50 billion for 2009 as compared to the figure of the EU chemical umbrella organization which account for EU €527 billion for 2013 (whole EU Chemical sector). Such activities in bio-based chemicals and plastics contributed with 150,000 jobs to the EU economy as compared to the 1.9 million employees of the total EU chemical sector[1].

Use of biomass in bio-based products

The survey identified 20 companies using animal fats and vegetable oils; 19 companies using sugar and/or starch crops; and 11 companies using natural fibres. The most commonly used vegetable oils, reported in number of companies using them, are rapeseed oil and palm oil, followed by coconut oil, soybean oil and castor oil. The types of vegetable oils and animal fats used remained consistent between 2010 and 2013, with several new users appearing in 2013.

The most commonly used natural sugar and starch feedstocks are maize, wheat and sugar beet, which are all edible feedstocks. No change in usage of these feedstocks has been observed between 2010 and 2013, except that several companies reported diversification into sugar and starch feedstocks in 2013. The most commonly used natural fibre is wood and the number of users increased between 2012 and 2013. Finally, the co-products or intermediates used as feedstock are mainly glycerol, bioethanol and chemical pulp.

Half of all respondents claim that more than 95% of their feedstock is bio-based. In general, the survey shows that the proportion of bio-based feedstock in the total feedstock used has not changed between 2010 and 2013. However, the majority of respondents expect this proportion to increase by 2020.

Finally, information on the use of domestic feedstock versus imports was provided by 28 companies, of which almost half source all bio-based feedstocks from within the EU. This supply includes a broad range of feedstocks (starch, sugar, vegetable oils, animal fats and wood fibre). Five companies declared that they import more than 95% of their bio-based feedstocks into the EU. These companies use mostly vegetable oils, but also glycerol, bioethanol, animal fats and starch crops. This ratio of imported versus domestically supplied feedstock has been constant during the period 2010-2013.

Drivers and constrains affecting the development of the industry

Target companies were asked to declare and rank the importance of a given list of drivers and constraints that affect the development of the EU bio-based industry. The most important drivers are economic (including innovation) and directly relate to the bio-based product and its contribution to the profitability of the company: improved product competitiveness; improved profitability; and development of innovative products. These drivers are followed by improved environmental performance of the product. Policy is currently ranked as the least important driver, though could become more prominent in the future.

The main constraints for the development of the bio-based industry are declared to be the availability of funds to invest in production capacity; the higher production cost of bio-based products as compared to the conventional ones; and high and/or variable feedstock prices. The existence of products and/or process patents, or other intellectual property issues, and the barriers for achieving product certification, while important for

many companies, are ranked lowest on the list of constraints by the surveyed companies.

Comparison with EU competitors

The study has, for the first time, tried to compare the EU bio-based industry with the USA, Canada, China, Brazil and Malaysia, following the recommendation of experts and existing reports that point to these countries as leaders in this sector (based on existing production capacity; planned production capacity; industrial innovation; the status of complementary industries - e.g. biofuels -; and the availability of feedstock). Based on desk research, the EU compares favourably to other countries on many important indicators, with some limitations in feedstock availability and the current level of commercial activity.

Canada (in 2009) and the USA (in 2008 and 2015) carried out similar surveys of the bio-based sector, but due to the lack of harmonisation in the definition of the industries, scope, indicators measured and methodology followed, direct comparisons are not reliable using primary information.

Limitations and recommendations

The survey is not able to provide a fully quantitative picture of the status and evolution of the EU bio-based industry. This is mainly due to the high number of products and their diversity; the amount of data that needs to be collected and the difficulty for the respondents to assemble it; and the incomplete response rate. At the same time, it is not possible to quantitatively compare the EU bio-based industry with important competing countries like the USA, China and Brazil due to the lack of harmonisation in the scope and methodologies between the existing country reports. However, the survey conducted in this study provides an important first step in a systematic approach to quantifying the EU bio-based economy and a good starting point for future surveys aiming to provide a fuller picture.

1. Introduction

The use of biomass feedstocks in industry has the potential to contribute to the European Union's (EU) industrial and economic growth while significantly reducing greenhouse gas (GHG) emissions, other environmental burdens, and resource dependency, through the displacement of fossil-based products with bio-based alternatives. This was recognised in the 2012 European Bioeconomy Strategy and Action Plan[2], which outlined the importance of the Bioeconomy for Europe and the potential to contribute to a number of EU priorities and initiatives including Innovation Union, Resource Efficient Europe, and moving to a low carbon economy. The Strategy built on existing programmes for funding research and innovation, including the Seventh Framework Programme for Research and Technology Development (FP7) and Horizon 2020, and initiatives such as the Lead Market Initiative on Bio-based Products[3].

The Strategy and Action Plan highlighted the need to characterise the size and evolution of the bio-based industry within the EU, in order for policy makers and other stakeholders to be able to monitor, and help shape or support the future of the industry. The Bioeconomy Information Systems and Observatory (BISO) was set up to provide regular analysis and data to help monitor the development of the Bioeconomy, to provide forward looking tools, and to contribute to future strategy updates. The role of the BISO is vital in monitoring and maximising the impact of activities aimed at developing markets, and of programmes to increase investment in research and innovation, including Horizon 2020, national programmes and Public Private Partnerships. Without reliable data, the importance of bio-based industrial products to the EU economy will remain uncertain, and their full potential and benefits will not be realised.

Biomass feedstocks are primarily utilised in three main sectors of the economy: food and feed, energy, and industry. Reliable statistics are already collected in a number of official databases for the volumes and values of the food and feed, and energy markets (e.g. EUROSTAT, FAOSTAT). However, little economic data exists for industrial uses of biomass, and there are no official European databases in this area. Previous research broke down bio-based economic activities into NACE classifications demonstrating the multitude of industry sectors that belong wholly or partly to the Bioeconomy[4]. This research mapped and analysed the most relevant databases available for information on the Bioeconomy, and revealed that there are no specific statistical data available for bio-based products, and that it is not possible in infer the amount of bio-based products from the available databases, due to there being no linkage between raw materials and products.

Information on the production of materials from biomass feedstocks does exist, but is often incomplete, disparate, or not sufficiently detailed.

Information on the availability and production of crops within EU Member States is available from EUROSTAT databases, and various assessments of current and future available biomass have been carried out[5]. Biomass use in the food and feed and bioenergy sectors is already well-documented, and therefore information about biomass use outside of these sectors could be inferred by further analysis. Several initiatives have been undertaken to map the flows of biomass into various markets. Nova-Institut estimated the non-wood biomass use in the EU27 in 2007 at 266 million tonnes, of which 6% was attributed to material use. These estimates were based on data from EUROSTAT and the Directorate-General for Trade[6]. The Bio-TIC project has further elaborated on biomass material flows in the EU, providing estimates of the use of plant oils, sugar and starch crops in the EU in 2013 (http://www.industrialbiotech-europe.eu/).

There are a number of databases which can give partial information on the current production and market size of the bio-based industry, such as Prodcom and the Structural Business Statistics both produced by EUROSTAT.

Prodcom is an annual survey for the collection and dissemination of statistics on the production of goods in the EU, reporting on production volumes and value. Prodcom only refers to production data, and Europroms refers to the combination of Prodcom with external trade data, again reporting quantities and value at both EU and Member-State level. Previous research illustrated that almost 70 products registered in Prodcom are made completely or partly from bio-based fats[4]. However, Prodcom does not differentiate between bio-based and non-bio-based products. In addition, the Prodcom database does not include information on enterprises with less than 20 employees potentially excluding many small companies and start-ups in the emerging bio-based industries.

Structural Business Statistics (SBS) include data on industry, construction, trade and services in the EU for each NACE activity classification. Data available from SBS includes employment, salaries, and value added, each broken down by industry, though data for some categories is incomplete or estimated. Generally SBS does not include data on products as this is covered by Prodcom. SBS includes data on the structure, conduct and performance of businesses, reported for the EU-27 and individual Member States, with subsets available for European regions and according to the size of enterprises. The information contained within SBS is therefore more detailed than national accounts. However the NACE classifications do not differentiate between bio-based and non-bio-based sectors so the information could not provide sufficient granularity with respect to the Bioeconomy.

Overall these databases have limited use for gathering data on the bio-based industry as biomass-derived products often form an unspecified fraction of database product categories. The lack of a link between information on the origin of the raw materials, the amount of industrial bio-based products, and the products they end up in constitutes a fundamental problem of monitoring the Bioeconomy.

There are many publication detailing which companies are developing and investing in bio-based products and the stage of development of the products, including IEA Bioenergy Task 42 Bio-based Chemicals - value added products from biorefineries[7], Green building blocks for bio-based plastics[8], and Technology development for the production of bio-based products from biorefinery carbohydrates—the US Department of Energy's "Top 10" revisited[9]. However, these reports do not give sufficient granularity or the data required to monitor the status and evolution of the bio-based industry.

There is a clear research need to collect and analyse data on the Bioeconomy in the EU in general and on the bio-based industry in particular, in order to understand their evolution, support their development and gain from the associated benefits. The information collected must be comprehensive, detailed, and based on the current EU market situation.

Previous research has assessed how an EU framework for data collection on the economic impacts of the Bioeconomy could be created[4]. It proposes two methods to address this research need. The first is the "bio-based share approach" which proposes to use data currently reported within existing EU database categories, calculating the bio-based share within these categories. The second proposed method is to build up an entirely new statistical database, comprising only bio-based products. The second approach may provide more exact information and this it therefore the basis of the present study.

It will take time to implement an EU-wide reporting of Bioeconomy indicators. This study therefore provides a first step in addressing the information gap. The general objective is to provide a description of the current status and evolution of the EU bio-based industry by focusing on a list of relevant bio-based products and with a survey of companies producing or about to produce these products (with turnover or employing labour in the EU).

The specific objectives of the study are to:

1. Provide a description of the business activity in the EU bio-based industries.
2. Quantitatively describe the use of biomass in bio-based products.
3. Determine the drivers and constraints affecting the development of bio-based products by the EU industry.
4. Quantitatively assess the impact of the EU bio-based industry on the EU economy.
5. Quantitatively and qualitatively compare the EU bio-based industry with key EU competitor countries.

A similar need for market information has been identified outside of the EU. However, only a few research projects and surveys have been carried out aiming to, for example, quantify the value of the Bio-economy, and understand the competitiveness of the industries that adopt new bio-related processes and procedures.

2. Scope

For the purpose of this study and based on consultation with experts (including members of the Renewable Raw Materials group), EU companies are defined as those producing a turnover or employing labour in the EU which may have production facilities not only in this region but elsewhere as well.

The Bioeconomy encompasses the production of renewable biological resources and their conversion into food, feed, bio-based products and bioenergy. This study is confined to the production of bio-based products. The production of food, feed and bioenergy are outside the scope of the study as data relating to these sectors is reported under existing frameworks and in a number of official databases (e.g. EUROSTAT, FAOSTAT). For the purpose of this study, the bio-based industries refer to the production of chemicals, polymers and fibres produced from renewable biological resources, excluding biofuels.

Some material products are identified as outside of the scope of this study because data relating to these existing industries is reported elsewhere. This includes pulp and paper, textiles, leather, fur, wood and wicker products, food and feed additives, and pharmaceuticals. Established wood industry products such as rayon, viscose, medium-density fibreboard (MDF) and oriented strand board (OSB) are therefore out of scope. In addition pine chemicals such as rosin, linoleum, and turpentine, which are established products derived from crude tall oil, which is a co-product of pulp and paper manufacture, are also outside of the scope of the study.

Also, all chemical substances most commonly used as biofuels are considered out of scope, as whilst these products may be used directly in non-fuel applications or may be used as an intermediate in the production of bio-based materials, data relating to production capacity, volumes, revenue and investment is already reported elsewhere. Where these substances are used as inputs to the production of other chemical and material products, the derived products are within the scope of this study; for example the conversion of ethanol to ethylene. In this case, ethanol is considered as a feedstock for the production of ethylene.

Finished goods and products derived from bio-based products (including formulations and material products) are outside of the scope of this study. The study does therefore not extend to companies using bio-based chemicals and materials in the next stages of the value chain.

3. Methodology

The methodological approach employed in this study consisted in the following steps, described in detail in the following sections:

- Definition of a list of relevant bio-based products within the scope of the study, validated through expert consultation.
- Definition and identification of the target population (EU companies) representing the universe of the study.
- Preparation of a structured questionnaire, validated through expert consultation.
- Pilot survey to validate the questionnaire and survey procedure.
- Final survey on the full target population of bio-based companies.
- Reporting results and analysis.

3.1. Defining the product list

The list of products in the scope of the present study was drafted based on an earlier one included in Annex III of the study Methodology framework for the Bioeconomy Observatory[4] (Key products for a bio-based database). This study was commissioned by the European Commission and was finalized in January 2015. Here, the authors used the following criteria to define which key products should be on the list:

- The exclusion of food and feed, energy, pharmaceuticals and traditional, established, low innovation industries.
- The existence of EU production facilities at greater than R&D/pilot scale, i.e. those products made at near-commercial or commercial volumes within Europe.

For the purpose of the present study, this initial list of products was reworked and again several times consulted with experts and stakeholders including on a workshop that was held in Brussels on 16th September 2014. Twenty-one invited delegates attended. During the workshop, no products were removed, and some products were added. Some of the categories were modified to allow respondents to improve accuracy and remove unnecessary restrictions to the scope: building blocks were removed as not all of the products included under this category are used as monomers or intermediates for other chemical products, this was replaced with organic acids, alcohols, and other; materials and composites were edited to composite materials; and paints, lacquers and coatings, surfactants, and lubricants were grouped under the heading 'bio-based products used in the following applications', in order to differentiate between the 'named' products and an application based list, this also includes bio-based products used in a broader range of applications to be included, for example as a solvent in pesticide products.

No appropriate representative of the pesticides industry was present to comment on the inclusion or exclusion of biopesticides, although nova-Institute indicated that in previous research surfactants were identified as the most important component of pesticide products, from the perspective of bio-based ingredients. These are now included as a more general category in the revised list. Biopesticides refers to microbial and biochemical active ingredients for use in pesticide applications. Microbial biopesticides are derived from various microorganisms including bacteria, fungi, viruses and protozoa, and/or the metabolites they produce. Biochemical pesticides are naturally occurring substances that typically control pests via non-toxic mechanisms. They include plant extracts and pheromones, and also synthetic compounds that are structurally and functionally similar to naturally occurring substances. Whilst biotechnology is playing an important role in the production of more targeted active ingredients, the conversion of biomass to pesticides is not reported as a significant area of research and development. It was therefore felt that the survey, being focused on the production of chemical and material products from biomass, was not relevant to the sector.

In addition to the edits highlighted above, rayon was raised as a product with a large number of EU producers, however, there are existing market reports relating to the industry. The addition of more broad uses of pine chemicals was also raised, however, these applications fall outside of the initial scope as outlined in the technical specification for the study.

The full final list of products is presented in Annex I and includes the following product categories:

- Organic acids
- Alcohols
- Polymers:
  - Derived from natural polymers
  - Derived from monomers
- Composite materials
- Bio-based products used in the following applications
  - Surfactants
  - Solvents
  - Binders
  - Plasticisers
  - Paints/coatings
  - Lubricants
- Other products not included in the previous categories

Figure 1 below illustrates the specific products included in the scope of this study within the corresponding value chain.

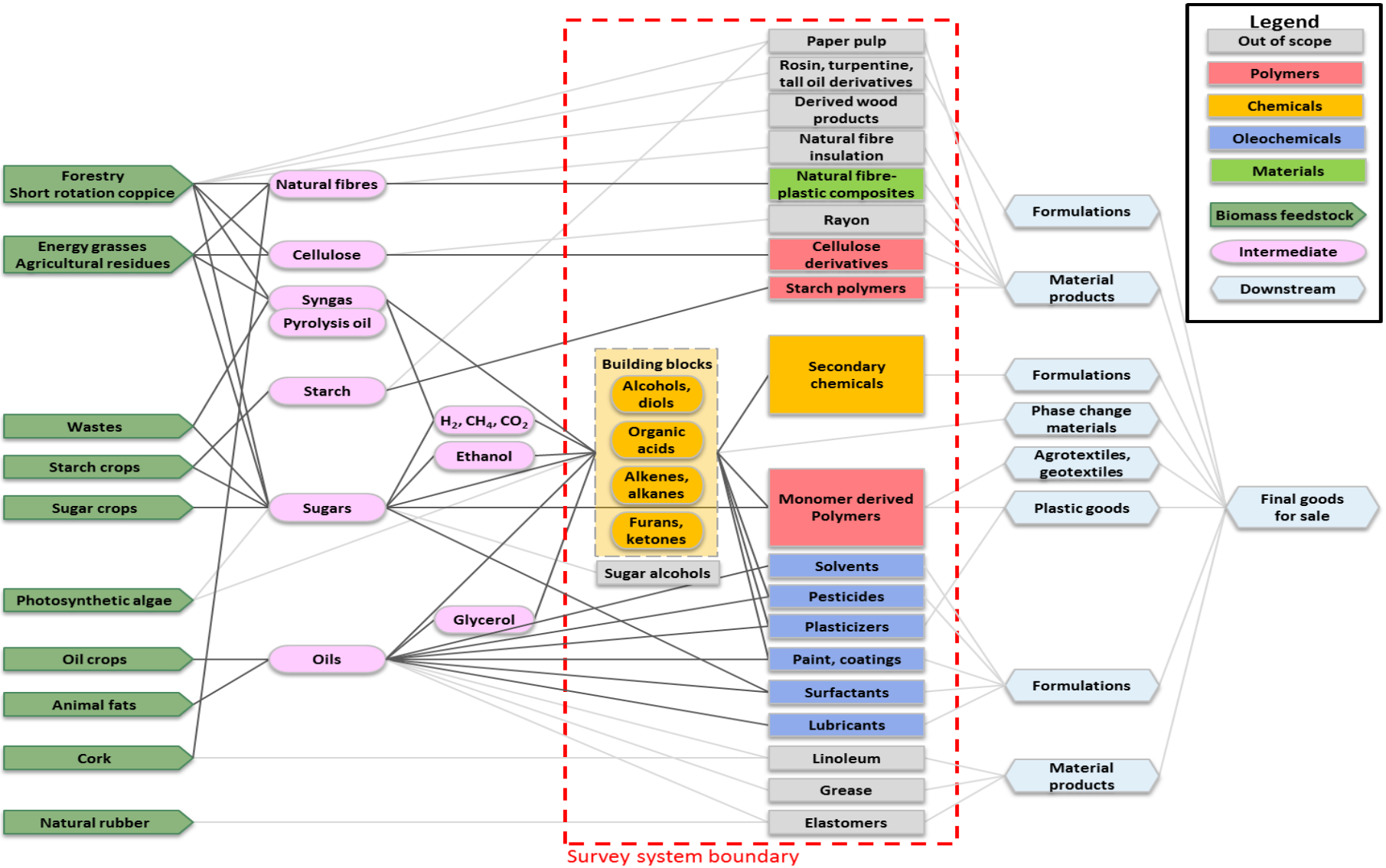


Figure 1: Products in the scope of the study and their value chains

3.2. Building a database of companies in the EU bio-based industries

The target population was identified using three main sources of information. Firstly, information on bio-based chemical industry plants was obtained from the F.O. Licht proprietary database. Using information on the name and location of each plant, desk research was carried out to identify:

- Parent company name
- Operating company name
- The identity of any joint venture partners or major shareholders/investors
- The status of the facility, i.e. whether the location specified serves mainly as:
  - a company headquarters (office);
  - production factory site;
  - predominantly a research and development site; or
  - a demonstration plant.
- Location:
  - Country
  - City / Region
- Product category and types, including rudimentary information relating to the types of product produced, (e.g. oleochemicals, polymers, organic acids, composite materials, etc). The information obtained in this way is often limited due to the information made publicly available and the varied operations of many operators. However, the information serves primarily to ensure adequate coverage of the target population across product sectors.
- Company website;
- Company or site address and telephone number;
- Contact details, including
  - Name,
  - job title,
  - telephone number,
  - email address.

Additional companies were identified from a number of sources, including previous research[4] and information from producer organisations including the European Chemical Industries Council (Cefic) and the Bio-based Industries Consortium (BIC).

One-hundred and fifty-one (151) companies was the first estimate of the target population (see Table 1). Companies were contacted directly to identify appropriate contacts for distribution of the survey questionnaire. Further investigation through desk research and following up direct leads facilitated the identification of parent or holding companies, as well as the identification of companies which had merged with others, ceased operations at particular sites, become insolvent or were identified as 'out of scope', i.e. not operating within the EU or producing products which fall outside the scope of this study (18 companies).

3.3. Drafting the questionnaire

The initial questionnaire was adapted from the same study above-mentioned, Methodology framework for the Bioeconomy Observatory[4]. This was adapted to the format of a structured questionnaire to be administered using internet based survey software (SurveyMonkey) and an Excel sheet.

The initial questionnaire was amended through expert consultation during above-mentioned stakeholder workshop of 16th September 2014 and the feedbacks received

during the pilot survey (see next section). The final questionnaire, used in the survey is provided in Annex II.

3.4. Pilot survey

A pilot survey was launched on 14th November 2014 to 20 companies out of the initial 151 previously indicated.

In order to meet the initial requirements of the study, a two phase survey process was designed, in which an on-line survey was supplemented by the submission of other questions in an Microsoft excel filed (tailored-part of the questionnaire) sent out to survey respondents to gather specific information relating to individual products.

In total, 7 responses to the online survey were submitted, of which two were incomplete with insufficient data provided to facilitate analysis. Thus the final response rate to the online pilot survey questionnaire was considered to be 5 responses (response rate of 25%) and two companies indicated that they did not wish to participate.

Five phase 2 question sets were subsequently sent out and three responses were received, of which one was complete; one incomplete with insufficient data provided to facilitate analysis; and one was a specific response indicating that the respondent did not wish to participate.

Specific requests for feedback on the survey and questionnaire were made by phone and email. This included both companies that did respond to the questionnaire and those that did not. In addition, informal feedback comments were noted when contact was made with companies throughout the survey period while trying to generate responses to the survey, i.e. follow-up telephone calls to check contact information, receipt of emails, and general reminders.

The main comments received related to concerns over:

- Time required to complete the survey;
- Confidentiality / commercial sensitivity of data requested;
- Unwillingness to take responsibility for providing information (e.g. in case of repercussions) or to delegate this responsibility
- Unclearness for certain respondents about the aims and objectives of the survey.

3.5. Final survey

Feedbacks from respondents to the pilot phase were taken into account to improve the survey strategy and the increase the response rate, in particular by improving stakeholder engagement, providing assurance regarding the confidentiality of the information supplied, and reducing the time and resource required to complete the survey. The communication approach in the survey invitation was improved, some amendments were included to improve the survey protocol and the survey questions were revised in order to enable the full questionnaire to be completed online in one stage. Specifically, questions that generated a relatively low response rate were removed. Additionally, the questions that were directed to a product-specific basis were included in the same questionnaire where respondents were requested to quantify the data on the basis of all bio-based products (in-scope) produced by the company.

The final version of the revised questionnaire was administered to the whole target population on the 31st March 2015.

Out of the 133 companies addressed, 61 reacted when receiving the questionnaire. However, 11 of those indicated their unwillingness to participate to the survey (due mainly to confidential issues) and 50 participants provided the data, giving an overall response rate of 38% (Table 1). The group of 50 also includes participants that provided their answers during the pilot phase of the survey and others that sent their data per e-

mail, i.e. not completed as required by the questionnaire. Therefore, the figures reported in the results do not represent the whole group of 50 companies but the participants who have provided data for each specific question. Most of the respondents did not answer all questions.

Table 1: Response rate description in the survey to the EU bio-based industry

Initial population	**151**
Out of scope*	18
Final population	**133**
Total responses received	61
of which positive	**50**
of which negative**	11
Response rate (of positive responses)	**38%**

Note: *subsequently discovered through responses and contact, **refusal to participate to the survey

Similar surveys in the United States and Canada have taken an, *a priori*, comparable approach. Statistics Canada's Bioproducts Production and Development Survey 2009 targeted all companies in Canada that use renewable feedstocks to develop or produce industrial bioproducts[10]. The survey identified 208 companies engaged in the production or development of bioproducts of which 59% responded. The United States International Trade Commission's Study on Industrial Biotechnology: Development and Adoption by the U.S. Chemical and Biofuel Industries distributed 1,800 questionnaires to chemical and liquid fuel producers and achieved a response rate of 67%[11]. The results of these surveys are taken into consideration in this study for benchmarking with the EU results.

4. Results

The results of the study are presented and discussed in the following sections. In addition, Annexes III and IV detail the results of the survey.

4.1. Description of the population

As illustrated in Table 1, the initial target population consisted of 151 companies operating in the bio-based industries and invited to participate in the survey. These companies control at least 300 subsidiary companies and factory sites in the EU and some have additional assets outside the EU. Of the 151 companies invited to participate in the survey, 18 companies failed the screening questions which were designed to disqualify companies 'out of scope', i.e. not producing one of the specified list of products, and/or not employing staff in the EU. After this, the final target population comprised 133 companies.

The target population includes small, medium and large enterprises; long established companies and new companies; and companies whose operations are entirely bio-based and those for whom bio-based products represent a relatively small fraction of operations. It includes companies producing commodity and speciality chemicals and material goods into a wide range of sectors. Due to the diversity of the target population and the relatively small number of companies, it is appropriate to take a census approach to survey the target population, requesting a response from each individual company.

As it will be shown in the following sections, the location of the majority of bio-materials facilities seems to occur within or near the European chemical industry clusters illustrated in Figure 6. The chemicals industry in Europe is largely characterised by these

clusters of activity, as being located near other chemicals companies enables easier access to specialised suppliers and service providers, and can facilitate industry learning and ideas-sharing[12]. These benefits also apply to the bio-based products industry, as established chemicals companies are able to apply innovative solutions to move existing operations towards greater utilisation of bio-based feedstocks. In addition, start-up companies in the bio-based products sector are likely to benefit from the infrastructure and knowledge-base available in existing chemical industry clusters. As with the European chemical industry, it will be seen that the location of production plants for the bio-based industry is concentrated around the three main European ports of Rotterdam, Hamburg and Antwerp.

Production facilities in northern Denmark, Sardinia, Bulgaria and southern England appear to have been developed without the support of existing chemical industry infrastructure, suggesting that the bio-based industry can expand beyond the geographical scope of the European fossil-based chemicals industry.

Figure 2: Location of major chemical parks in Europe. Colours: grey – no ECSPP members on park, orange – ECSPP members on park

Source: European Chemical Site Promotion Platform (ECSPP)

4.2. Description of the sample

Mimicking the description of the population, responses were received from a range of company types including large, medium and small enterprises; long established companies and new companies; and companies whose operations are entirely bio-based and those for whom bio-based products represent a relatively small fraction of operations. However, due to the diversity of the target population in terms of company size, products, and market sectors, and the relatively small number of companies from

the target population that responded to the survey, it is not appropriate to extrapolate the survey responses to the full population size.

Regarding the companies' structure, 48 companies provided information on the ownership structure of the company, of which 32 companies are private limited liability companies, 15 companies are public limited companies, and 1 company identified as a not-for-profit organisation. 16 of the 48 companies identified as subsidiaries of larger companies, and 5 identified as a joint venture (between two or more companies).

In the EU, organisations may be categorised based on the number of employees or annual revenue. The European Commission defines micro, small, medium and large enterprises on the basis of the number of employees as follows:

- A microenterprise is defined as an enterprise which employs fewer than 10 persons.
- A small enterprise is defined as an enterprise which employs fewer than 50 persons.
- A medium-sized enterprise is defined as an enterprise which employs fewer than 250 persons.
- A large enterprise is thus assumed to employ more than 250 people.

In total 42 companies provided information on the number of employees in 2013. On this basis, 22 large enterprises were identified in the survey, 9 medium enterprises, 6 small enterprises, and 5 micro enterprises. Large companies are the biggest group but it is also heterogeneous, including 8 companies with <1000 employees, 5 companies with between 1001 and 5000 employees and 9 companies with more than 10,000 employees (Figure 3).

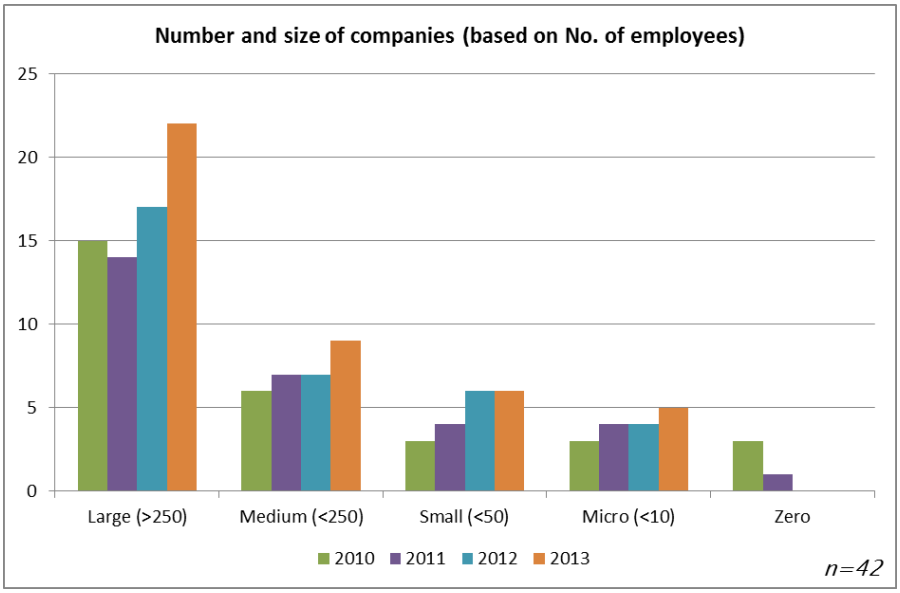


Figure 3: Types of respondent companies based on number of employees within the EU, between 2010 and 2013

Source: EU bio-based industries survey

Alternatively, the European Commission defines micro, small, medium and large enterprises on the basis of annual sales revenue as follows:

- A microenterprise is defined as an enterprise whose annual turnover does not exceed €2 million.
- A small enterprise is defined as an enterprise whose annual turnover does not exceed €10 million.
- A medium-sized enterprise is defined as an enterprise whose annual turnover does not exceed €50 million.

- A large enterprise is thus assumed to have an annual turnover exceeding €50 million.

The EU bio-based industries survey collected information on the total annual sales turnover of the companies in the EU, and the bio-based products annual sales turnover worldwide. In total 26 companies provided information on the total sales turnover in the EU in 2013. On this basis, 16 large enterprises were identified, 1 medium enterprises, 2 small enterprises, and 7 micro enterprises (including 4 companies who indicated sales revenues of zero) (Figure 4).

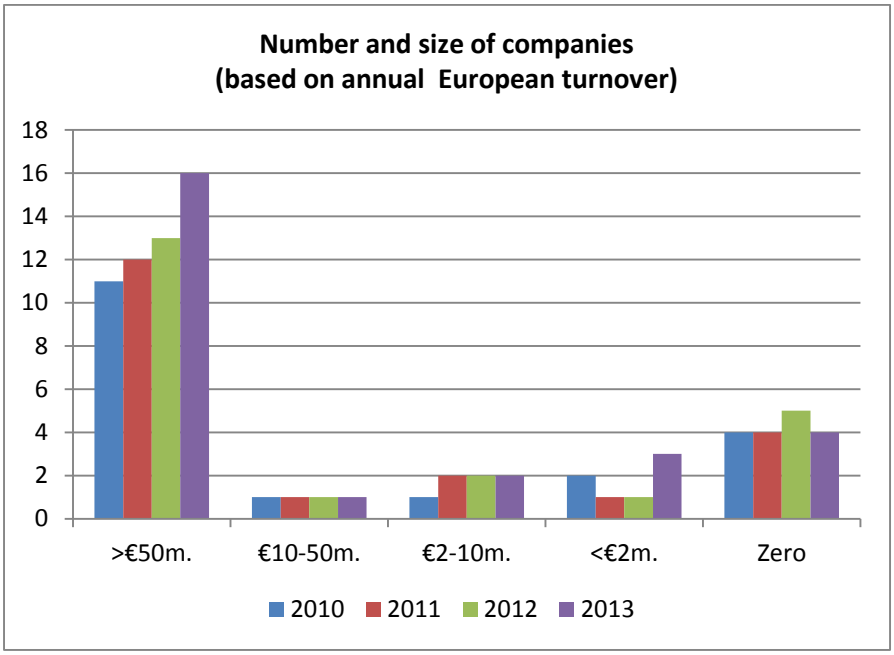


Figure 4: Types of companies based on annual turnover of all products in the EU, between 2010 and 2013

Source: EU bio-based industries survey

In summary, the distribution of company's size and structure seems to be heterogeneous enough to consider the sample as representative of the whole population.

Geographical distribution of companies in the sample is detailed in the following sections. Countries with the strongest bio-based activities in place like Germany, the Netherlands and Italy are well represented and the rest of companies are distributed in different countries. Therefore, the sample is kind of representative in terms of geographical area covered.

4.3. Description of the business activity in the EU bio-based industries

Products

The survey collected information from all the 50 companies on the types of products produced or expected to be produced by 2020. As reported in Figure 9, the bio-based products indicated by most respondents are organic acids, polymers (obtained from bio-based monomers) and surfactants. This figure shows in one picture the products that are currently in the market and/or expect to be by 2020. If we compare the products currently produced with the ones expected to be produced in 2020, there is a general growing trend in terms of number of products, but not concerning all of them (see Annex III for detailed analysis).

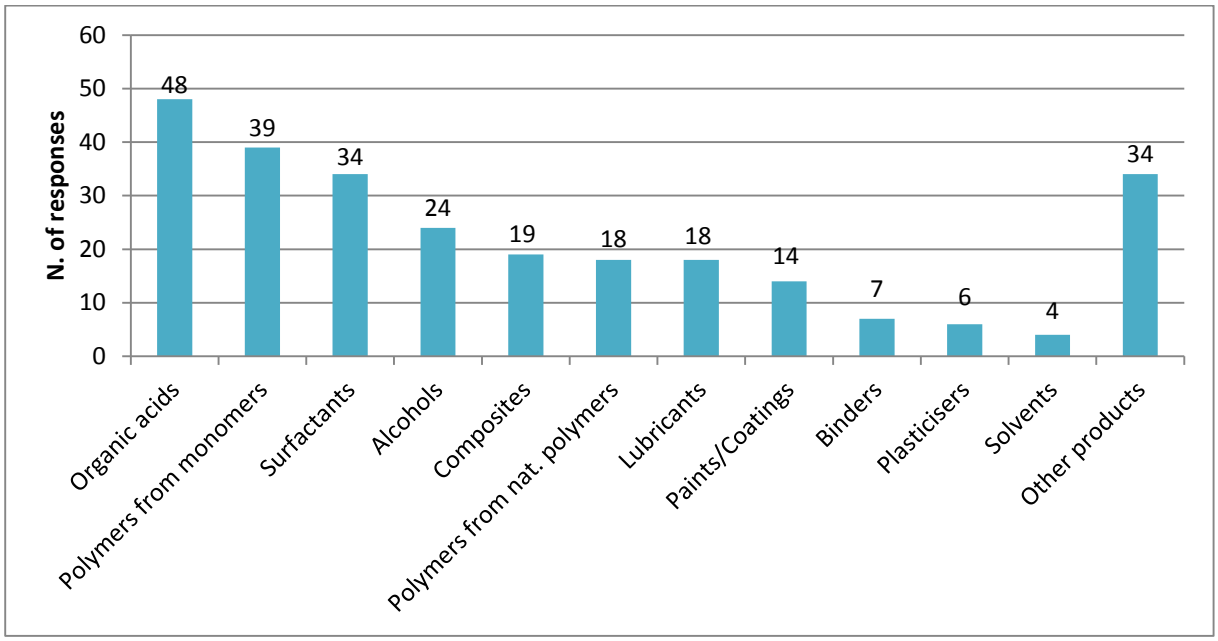


Figure 5: Number of times companies report they currently produce and/or expect to produce bio-based products by 2020

Source: EU bio-based industries survey

Note: 50 respondents. In this figure each specific organic acid, for example, counts one. 48 organic different organic acids are currently produced or will hit the market by 2020. Figure A25 of Annex III, all organic acids, for example, indicated by the same company count as one.

If we count both the currently produced and the expected bio-based products, 284 products have been indicated in total by the 50 respondents (i.e. between 5 and 6 per company in average). While some companies only indicated 1-2 products, others indicated up to 20 products, and often belonging to different product categories. This variety makes the overall data analysis very complex, since most indicators have been asked for the whole bio-based sector within the company, and not specifically per product.

The most frequently indicated products, mostly chemicals, are illustrated in Figure 6, which presents the number of companies that currently produce or expect to produce the product by 2020. This includes a range of speciality (or functional) chemicals, oleochemicals, polymers, and chemical building blocks. Many of these are established products, such as fatty acids and fatty acid esters, paint additives, polymeric surfactants, starch polymers, and wood–plastic composites. However, a number of these products currently have few producers, but more companies report that they expect to begin production by 2020. For PBS and HMF, no current producers were identified but four companies indicated they expect to produce by 2020. For FDCA and PHAs, two

companies indicated that they currently produce these products, and five companies indicated that they expect to produce these products in 2020. In addition, three companies expect to begin production of levulinic acid, n-butanol and propylene glycol by 2020.

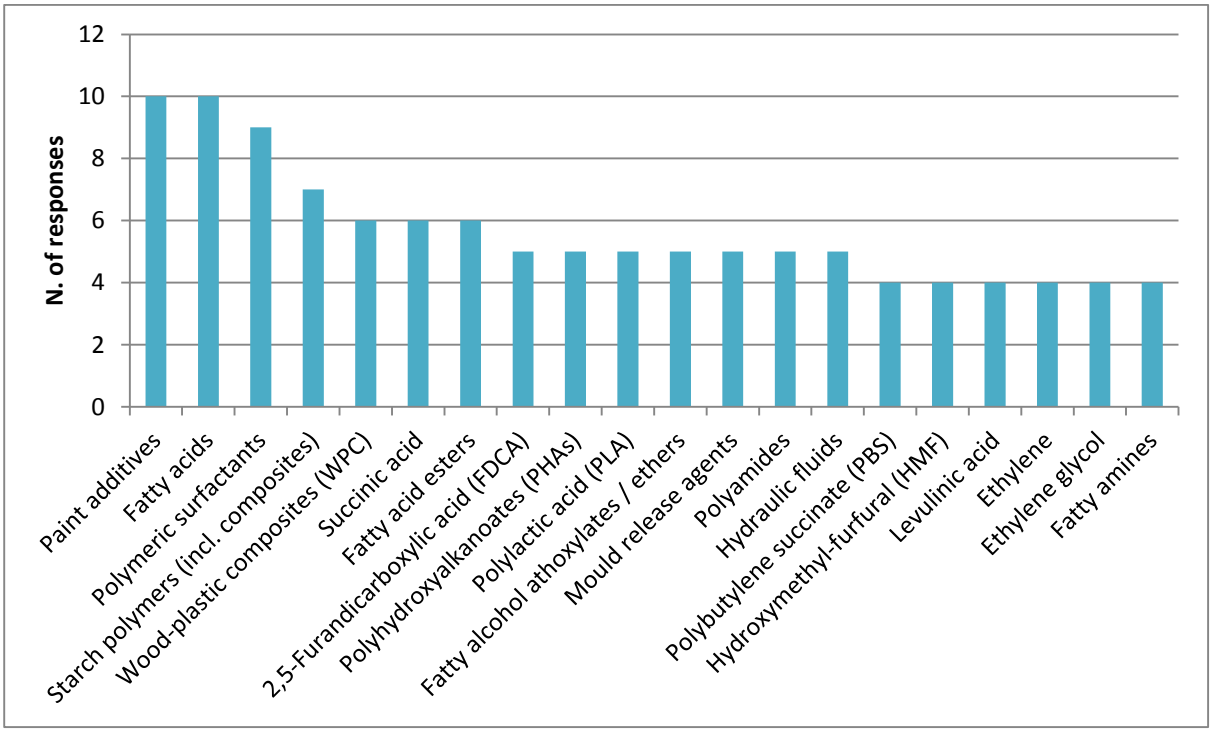


Figure 6: Bio-based products most frequently indicated by the survey respondents

Source: EU bio-based industries survey

A detailed breakdown of the individual products is provided in Annexes III and IV, while here we discuss the trends.

Figure 7 ranks the type of organic acids that are most commonly produced or expected to be produced by 2020. 23 companies currently produce or expect to produce fatty acids of various types; however the survey did not collect information on the expected evolution of fatty acid production to 2020. The most common products stearic acid, oleic acid, and palmitic acid are produced by the saponification of vegetable oils and animal fats and used in the production of soaps, cosmetics, detergents, and release agents.

Other organic acids include succinic acids, FDCA, and levulinic acid. These chemical building blocks are all expected to see an increase in the number of producers to 2020, though the production of these bio-based products is not yet at full commercial scale globally. There are several succinic acid producers in the EU and the rest of the world, increasing production capacity to near commercial scale. The product is a drop-in replacement for petrochemical succinic acid and adipic acid in some applications, and is used in the production of resins, plasticisers and biodegradable polymers. Production routes for FDCA are at pilot scale, but several technology developers expect to increase production capacities. The largest market for FDCA is the production of PEF, which may substitute for PET. PEF is more than a substitute for PET as it has superior properties, but may be used in existing polymerisation units, and therefore has the benefits of a drop-in product. Production processes for levulinic acid are at demonstration stage and production capacities are expected to scale up to 2020. Bio-based levulinic acid may substitute the petrochemical product for use in food, pharmaceutical, and personal care applications. For each of these leading products, the industry expectation is that the development of the bio-based routes will lead to market growth and an increasing range of applications. Production of a number of other products, whose bio-based production routes are at pre-commercial stages of development, is expected to increase in the EU,

including acrylic acid, terephthalic acid, and methacrylic acid. Decrease in production activity is expected for lactic acid and acetic acid, bio-based products that are produced at full commercial scale globally. The survey indicates an expected increase in the number of bio-based organic acids to 2020, and this is consistent with industry activity in Europe and the rest of the world and the number of new bio-based production routes in development[13].

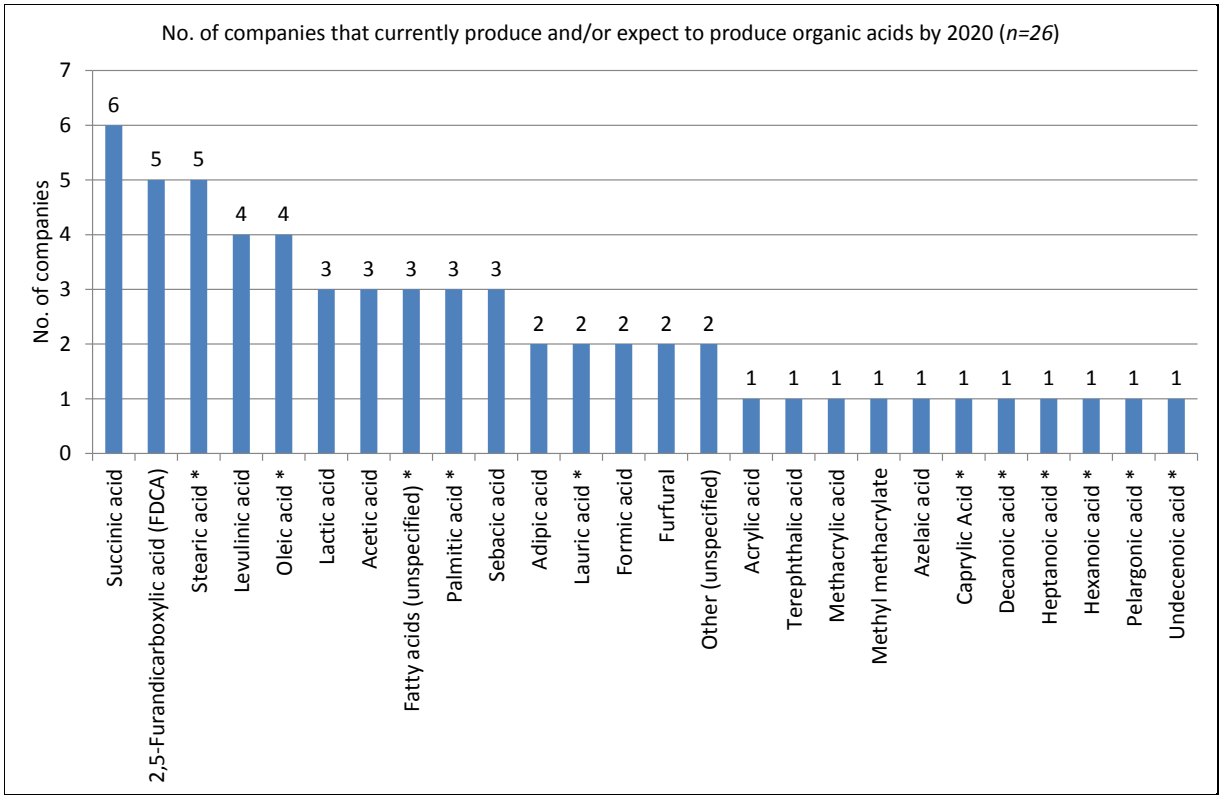


Figure 7: Number of companies that currently produce and/or expect to produce organic acids by 2020

Source: EU bio-based industries survey.

Note: * indicates types of fatty acids (23 companies in total).

Figure 8 ranks the type of alcohols that are most commonly produced or expected to be produced by 2020. The most common products are fatty alcohols, n-butanol, PDO and propylene glycol. The survey did not collect information on the expected evolution of the fatty alcohols. The survey results indicated growth in the number of producers of n-butanol, PDO and propylene glycol, resulting in a greater number of bio-based alcohols in the market. Again, this is reflective of the emerging nature of the bio-based production routes to these products [13].

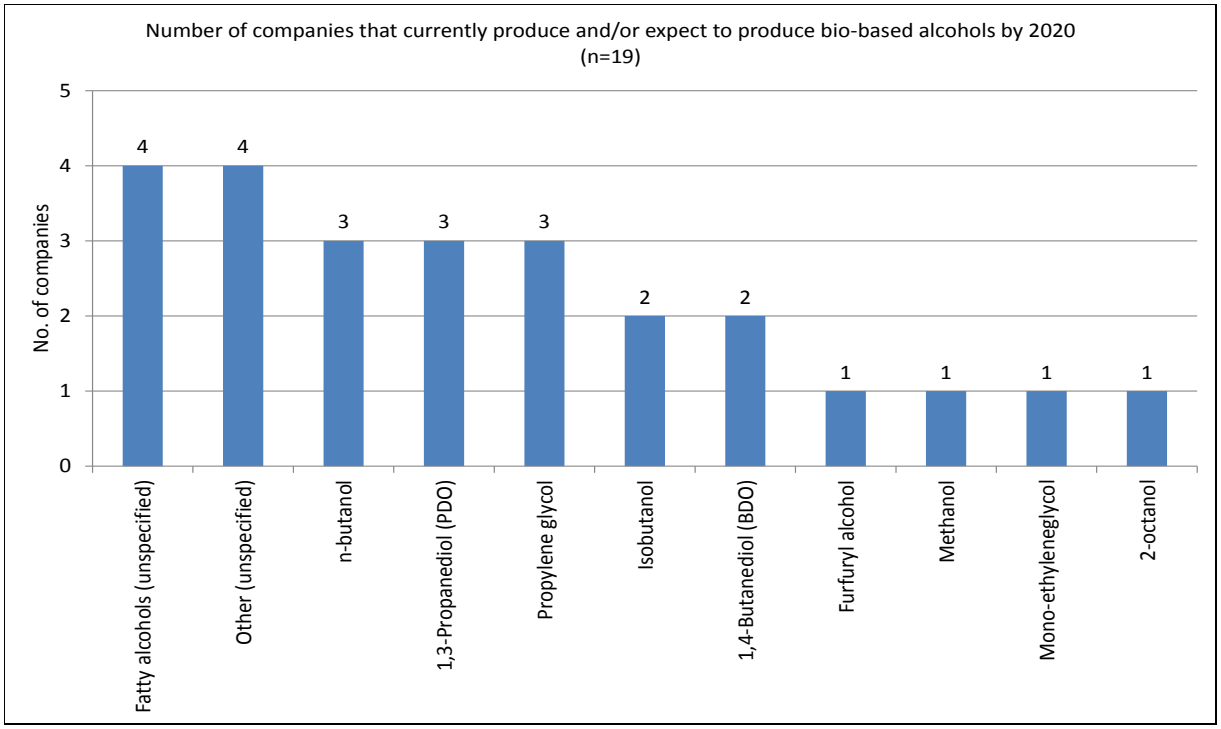


Figure 8: Number of companies that currently produce and/or expect to produce bio-based alcohols by 2020

Source: EU bio-based industries survey.

Of the companies that currently produce or expect to produce bio-based polymers by 2020, more than 90% currently produce or expect to produce bio-polymers from monomers (Figure 9), and 45% currently produce or expect to produce bio-based polymers from natural polymers (Figure 10). For this we can see that there is significant overlap with many companies producing both polymers from monomers and natural polymers. The natural polymers are dominated by starch polymers and this is supported by figures from a comprehensive study of the bio-based polymer industry[14]. In terms of production capacity, Europe is a leading producer of starch polymers, and capacity for the production of plastics is dominated by starch polymers in Europe and is expected to remain so until at least 2020.

Regarding polymers derived from monomers, the most common products are PHAs, polyamides and PLA. Europe is reported as a strong contributor to global production of polyamides[14], although the survey indicates a reduction in the number of producers to 2020. PHA and other emerging products such as PBS (which are currently produced at demonstration scale) are expected to increase in Europe to 2020. Interestingly whilst the number of producers of lactic acid is expected to reduce in Europe to 2020, the number of producers of PLA is expected to increase; this may reflect that innovation remains in the production of PLA rather than the lactic acid. PHA, PLA and PBS are not used as drop-in replacements for petrochemical products; rather their market is linked to certain properties such as biodegradability. Trends in the production for plastics in Europe differ to the rest of the world, where growth in the last two years has been dominated by drop-in products. European Bioplastics estimate that production capacity in Europe will continue to increase to 2017, but at a much slower pace than in South America and Asia, so that the European share of the market will reduce to around 7%.

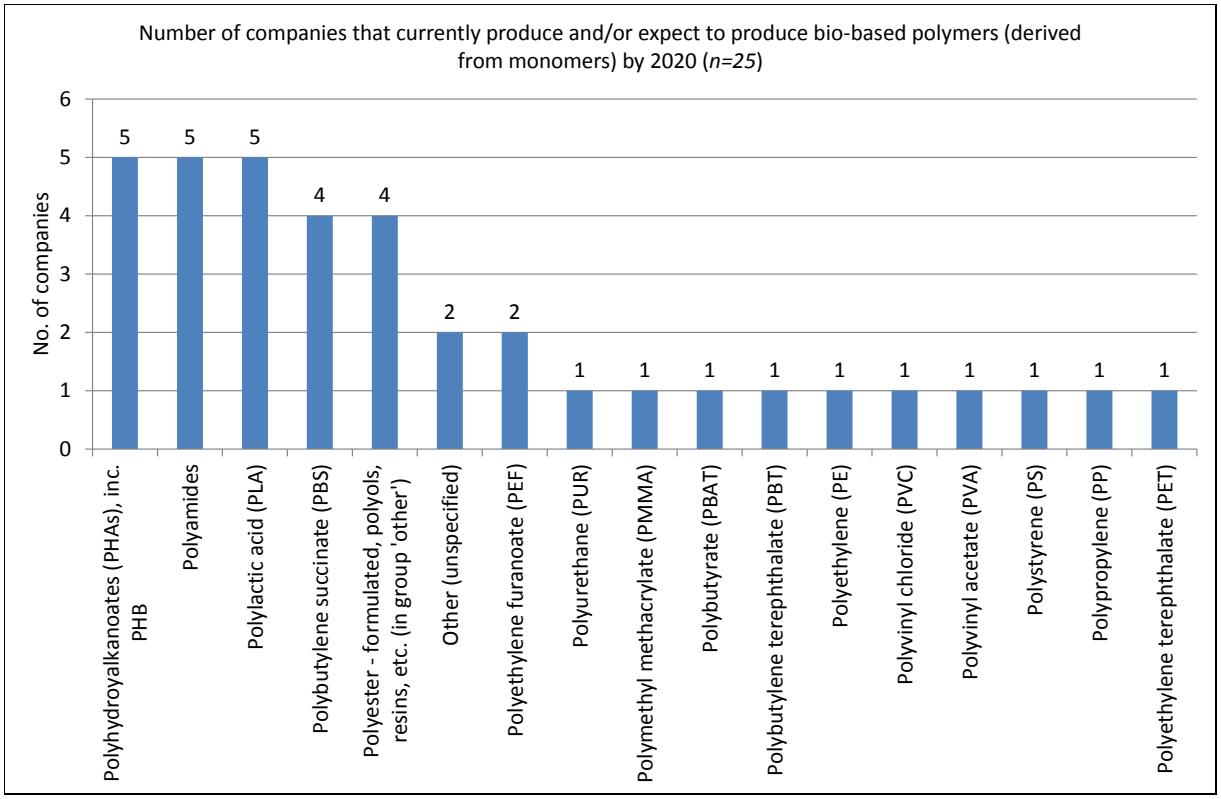


Figure 9: Number of companies that currently produce and/or expect to produce bio-based polymers (derived from monomers) by 2020

Source: EU bio-based industries survey.

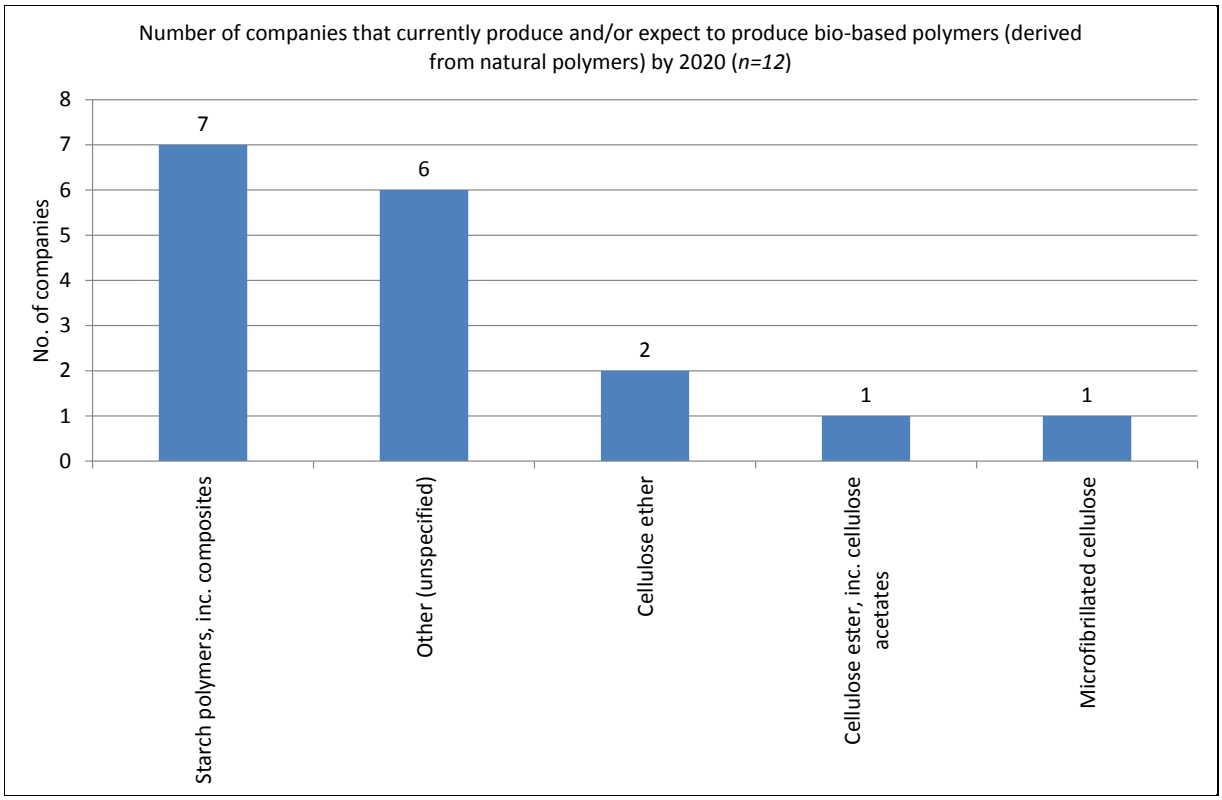


Figure 10: Number of companies that currently produce and/or expect to produce bio-based polymers (derived from natural polymers) by 2020

Source: EU bio-based industries survey.

Other products are dominated by surfactants, primarily polymeric surfactants. The survey responses indicate that number of producers of polymeric surfactants is expected to remain stable to 2020, whilst many of the other surfactant products are expected to reduce in the number of producers out to 2020 (see Annexes III and IV for a detailed break-down).

Production facilities

Forty-two companies reported they have bio-based production facilities in the EU, 7 do not and 1 did not answered. Forty-one companies provided information on 100 bio-based production plants located in the EU. The majority of these EU-based plants reported were commercial plants (74 plants including one dormant plant), and a smaller number of pilot (16) and demonstration (10) plants. Figure 11 illustrates the location of the production facilities in the EU in terms of country. The largest numbers of plants are located in Italy, Germany, France, Netherlands and Spain. Germany has the largest number of commercial plants and Italy has the largest number of pilot and demonstration plants.

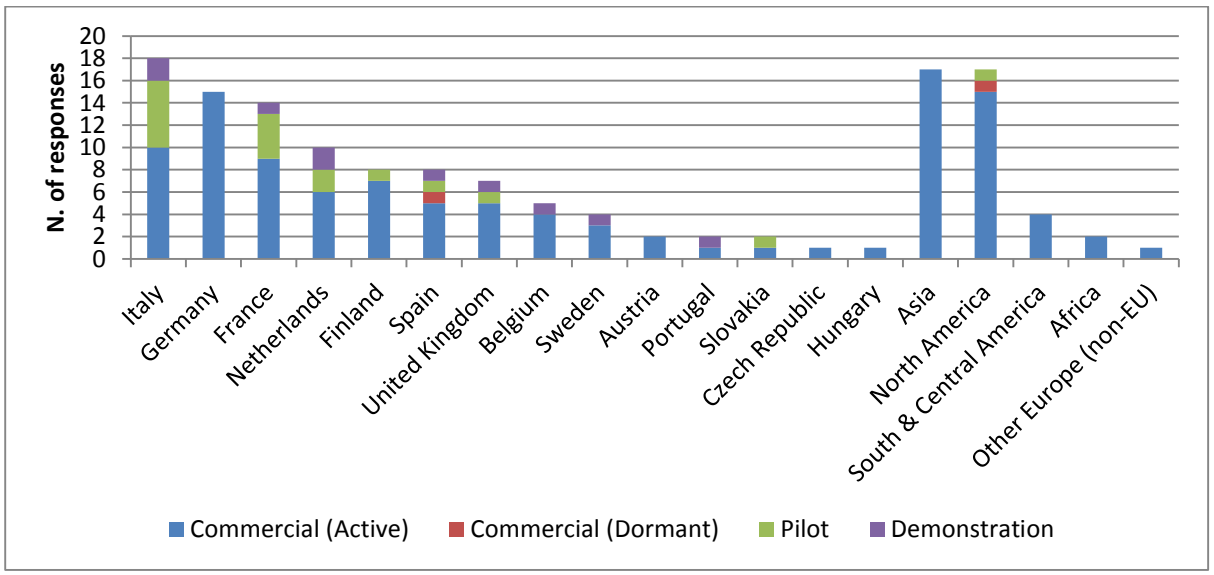


Figure 11: Status and location of bio-based production facilities in the EU

Source: EU bio-based industries survey.

Of the survey respondents, 21 companies indicated that they have bio-based production facilities outside the EU, of which 18 companies provided information on 41 separate plants. The majority were commercial plants (40 plants including one dormant plant). Their location is also shown in Figure 11. The largest number of plants is located in Asia and North America. Within Asia, the greatest number of plants was located in China (5), Malaysia (3) and Singapore (3).

Back to Europe, the location of all facilities (headquarters, R&D, demonstration and production) obtained via desk research and the survey response for the 133 companies is illustrated in Figure 12. The target population of this study shows a similar distribution as the main European chemical industry clusters shown in Figure 2.

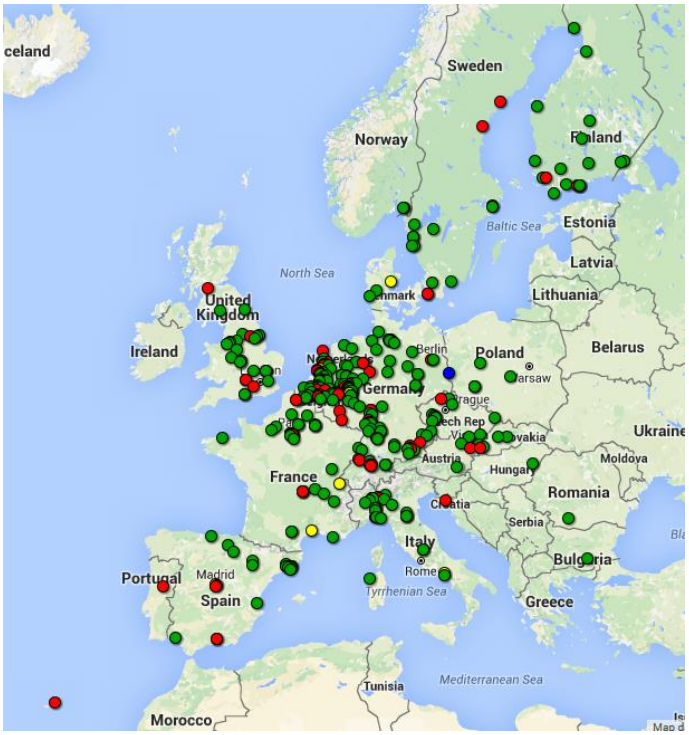


Figure 12: Location of the target population premises within the EU, showing headquarters (red), R&D sites (yellow), demonstration plants (blue) and production plants (green).

Source: EU biobased industries survey

Respondents indicated that the main reasons for choosing the facilities' location are related to feedstock availability and to proximity to already existing activities, both commercial and R&D, and this is valid both for facilities inside and outside the EU (Figure 13 and see the detailed answers in Annex III).

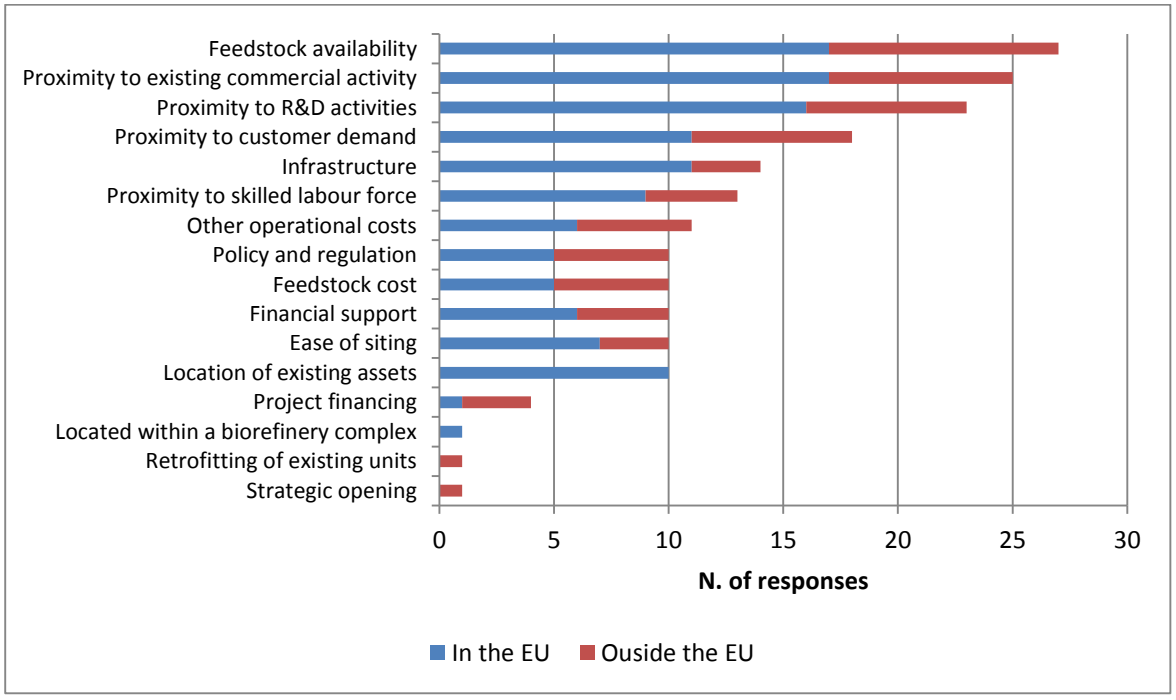


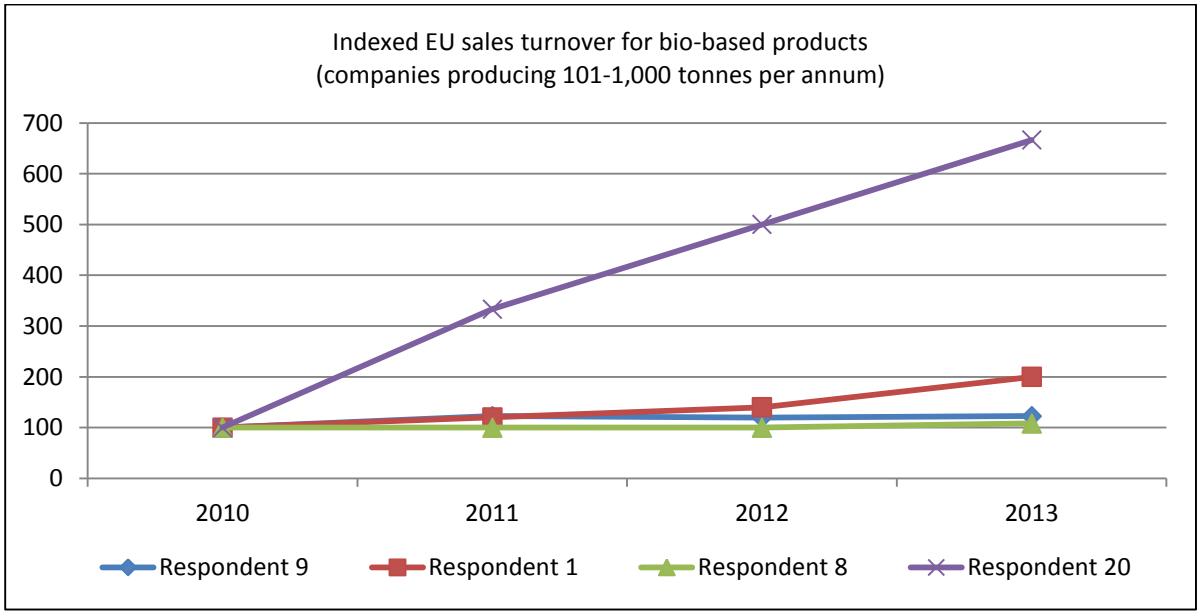
Figure 13: Reasons for choosing the facilities' location in the EU and outside the EU (N. of respondents: 35 in the EU, 16 outside)

Unfortunately, the survey data do not allow us to identify which products are produced at which locations. Similarly, it does not allow us to identify which feedstocks are used at which locations.

Production and sales

The European Commission communication Innovating for Sustainable Growth: A Bioeconomy for Europe[2], estimated that the European Bioeconomy has an annual turnover of €2 trillion, including the agriculture, forestry, fisheries, food and pulp and paper industries, as well as parts of the chemical, biotechnological and energy industries. The annual turnover relating to bio-based chemicals and plastics in the EU was estimated at €50 billion for 2009. It is not possible to verify this estimate based on the EU bio-based industries survey due to the incompleteness of the data set. Only 24 companies provided data on the global sales turnover for bio-based products (€6.8 billion in 2013), and 23 companies provided data on the EU sales turnover of bio-based products (€1.8 billion in 2013).

Despite the incompleteness of the data set, it is possible to observe the following trends for the respondents who provided a complete data set (2010 – 2013). European sales of all products (fossil and bio-based) increased from 2010 to 2013, whilst global and EU sales turnover for bio-based products remained relatively stable throughout the reporting period. Individual company performance over the reporting period may be assessed in order to establish any trends (Figure 14). For the majority of companies, EU sales of bio-based products have remains relatively stable between 2010 and 2013, with a medium and large producers seeing sales reduce. There are examples of high growth rates in both small and larger companies, of up to 600%. Two companies display strong growth, and they each produce a range of products from different product categories (including composites, chemical building blocks, surfactants and binders), these companies both utilise wood feedstocks among others.



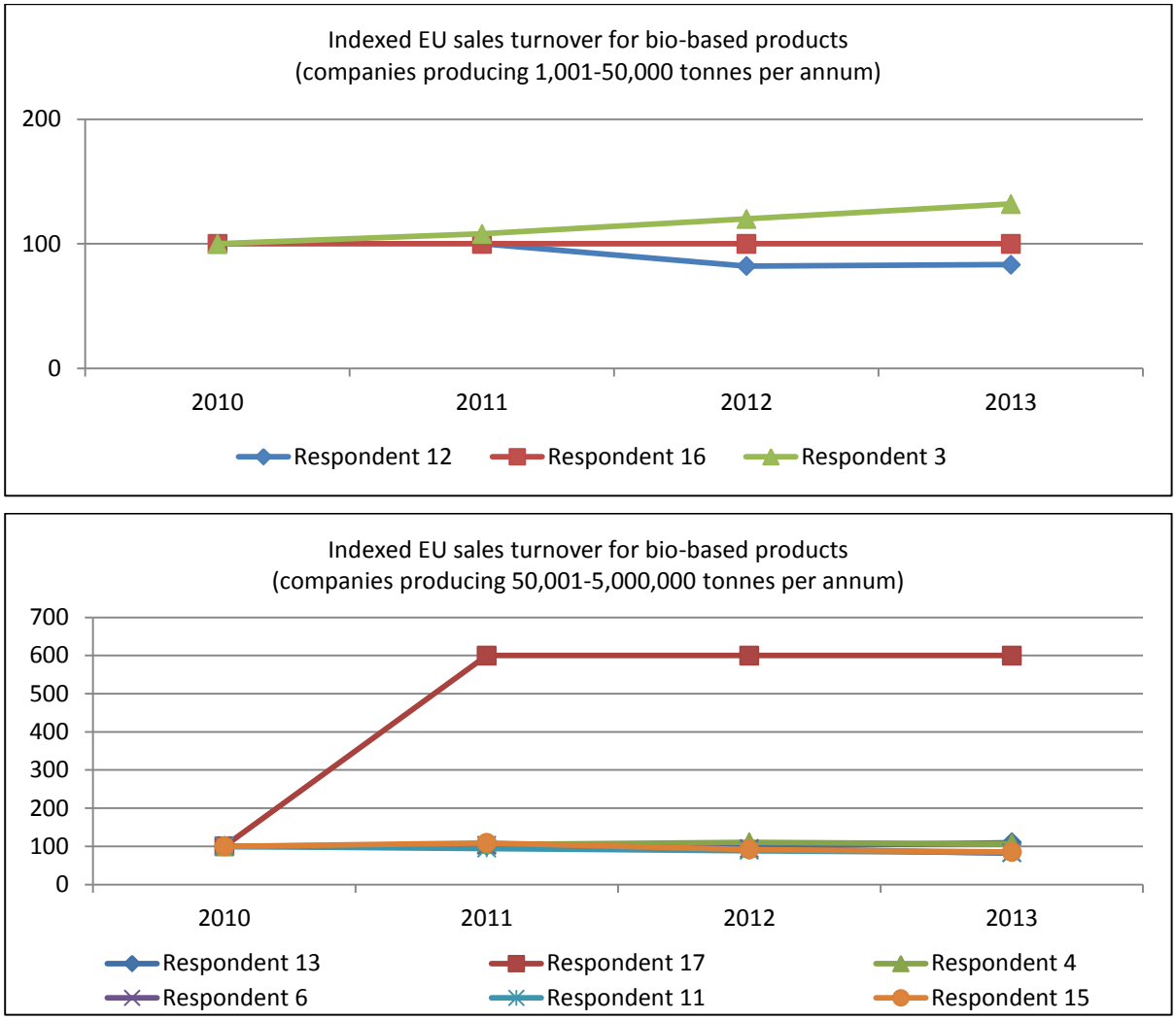


Figure 14: Indexed EU sales turnover for bio-based products, illustrated based on size of production

Source: EU bio-based industries survey.

Survey respondents expect future revenues to increase, 89% of companies expect global bio-based sales revenues to increase by 2020, with 53% of companies expecting an increase in revenues of more than 100%. Similarly, for European sales turnover of bio-based products, 89% of respondents expect an increase to 2020, including 49% who expect an increase of more than 100%.

Total production of bio-based products in the EU declined between 2010 and 2013 from 6.9 million tonnes to 6.3 million tonnes, for the limited number of respondents who provided data for each year (20 respondents). Individual company performance over the reporting period may be assessed in order to establish any trends (Figure 15).

The large producers display modest growth in EU production of bio-based products, and in one case significant decline. Small companies (with production of up to 100 tonnes in 2010) have demonstrated high growth rates in all cases, and in some cases up to 900%. This had been achieved by small enterprises dedicate to the production of bio-based products, and large enterprises with extensive petrochemical profiles.

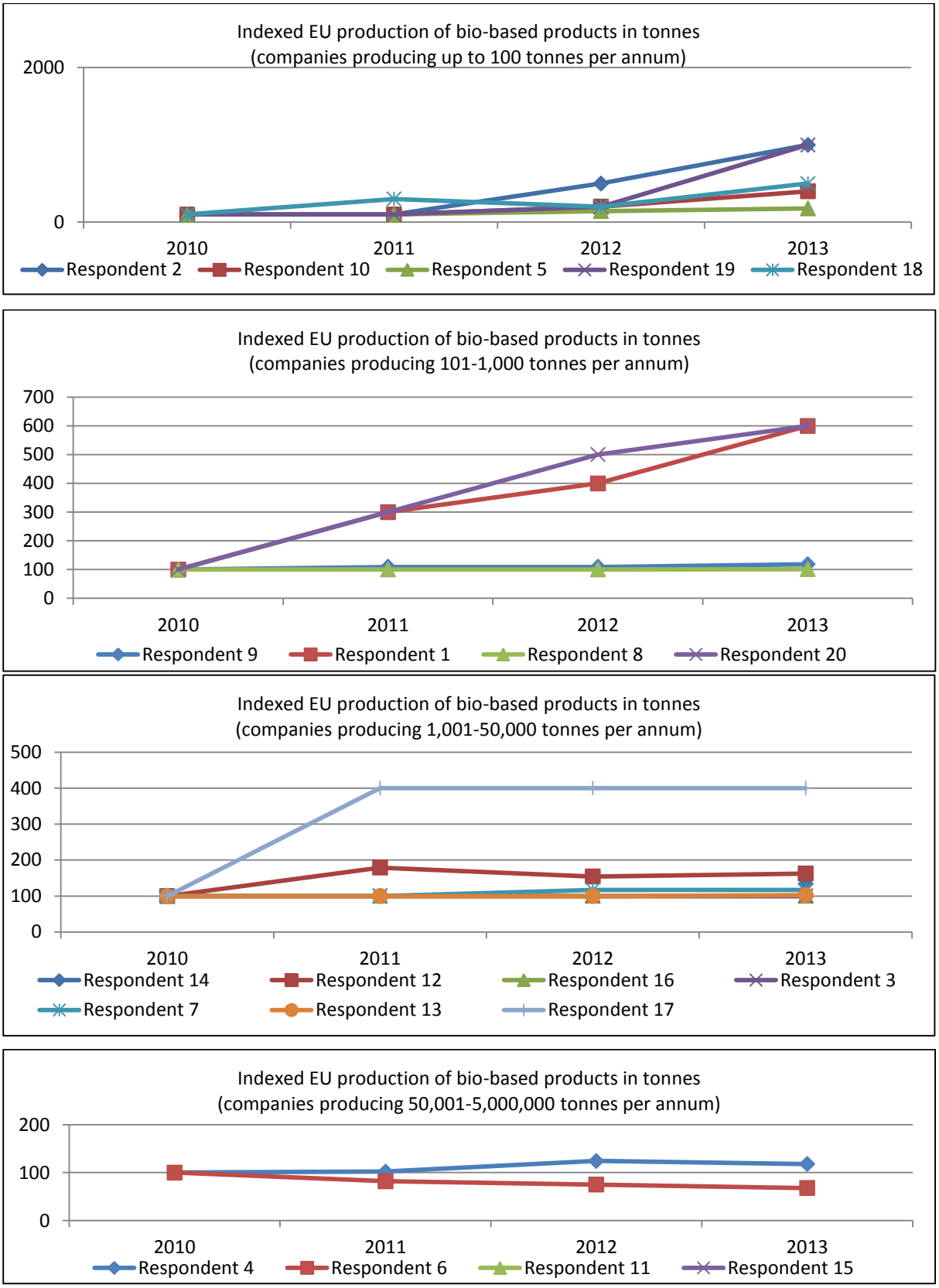


Figure 15: Indexed EU production of bio-based products in tonnes, illustrated based on size of production

Source: EU bio-based industries survey.

The proportion of EU bio-based output sold within the EU declined between 87% in 2010 to 82% in 2013, although the majority of companies reported no change in the proportion of their products sold in the EU.

Employment

The EU bio-based industries survey captures data on a limited number of companies and it is therefore not comparable to previous industry wide estimates. Within 43 companies operating in the bio-based industries it identified that the total number of employees within the EU was over 220,000 in 2013. More than 99% of the total jobs exist within large organisations (with more than 250 employees in the EU). Thirty-three companies provided an indication of the number of employees working in bio-based activities, with a total of 2,334 employees in 2013. Eleven companies stated that 100% of their employees were involved in bio-based activities, including several large organisations with more than 250 employees. The majority of companies indicated that the percentage of employees engaged in bio-based activities was greater than 50% (19 out of 35 companies) (Table 2), and the majority of the jobs identified are therefore within companies in which bio-based activities represent a major share of the business activity.

Table 2: Proportion of total employees engaged in bio-based activities (No. of companies)

	Number of companies			
Proportion of employees in bio-based activities	**2010**	**2011**	**2012**	**2013**
>50%	11	12	14	19
25% to 49%	1	1	1	2
10% to 24%	4	5	4	6
<10%	10	7	8	8

Source: EU bio-based industries survey.

Figure 16 shows the trends of number of employees in bio-based activities in the EU. It is illustrated that there was an increasing trend in the number of employees employed in bio-based activities, with the exception of companies producing more than 50,000 tonnes of bio-based products. This is comparably with the trends in output and turnover.

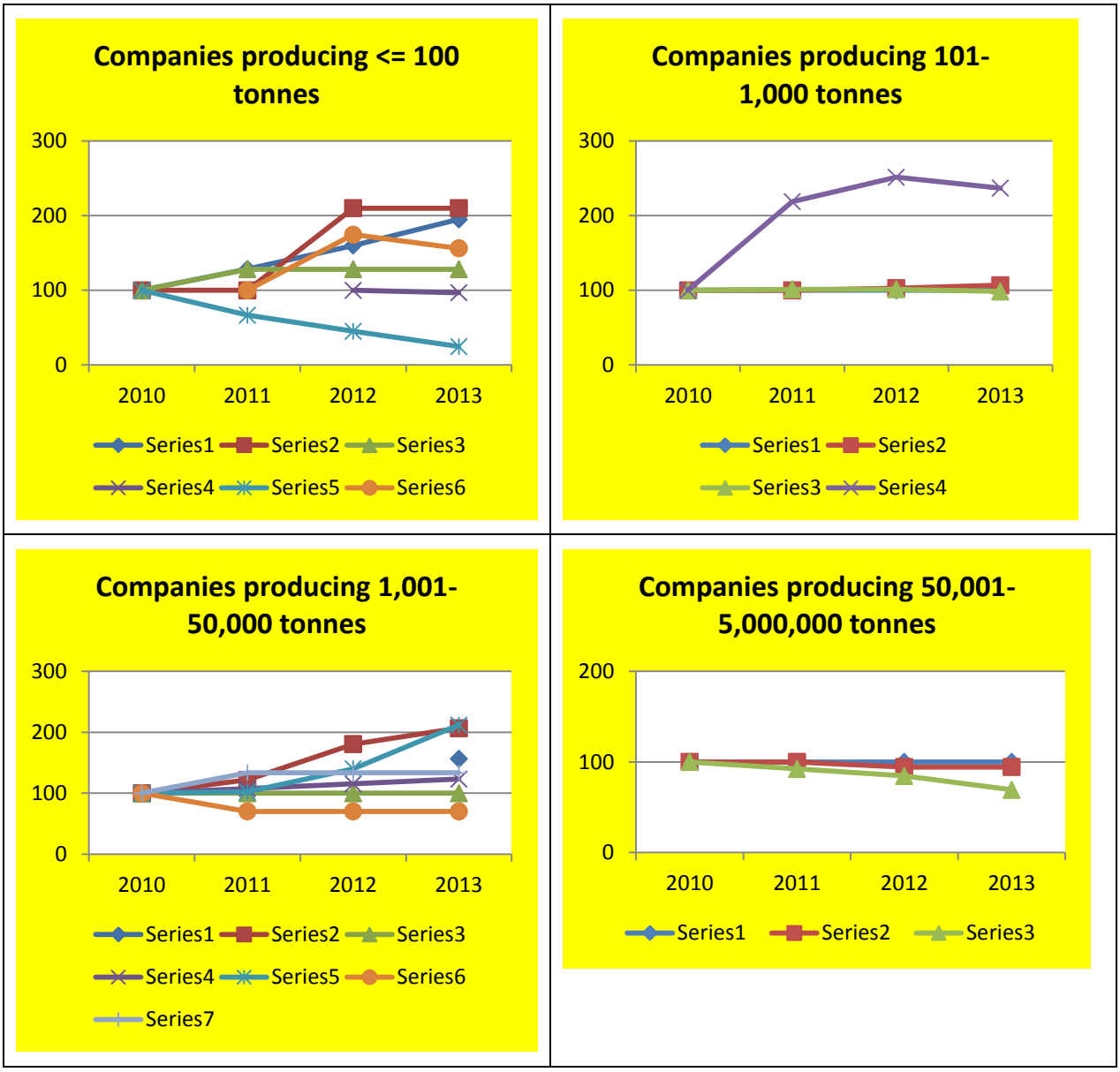


Figure 16: Trends of number of employees in bio-based activities in the EU. Index = 100 in 2010. Companies are classified according to their annual output in tonnes

Source: EU bio-based industries survey.

Research and Development

The survey requested an indication of the percentage of employees active in research and development, analysis of these results indicates that 3,237 employees working on research and development of bio-based products in 2013 within 33 companies. This figure is greater than the number of jobs identified in the bio-based industries in the EU, due to a different set of respondents, and therefore not comparable. A major challenge with data collected on jobs and R&D is that companies producing a range of bio-based products in scope and out of scope for the survey, in most cases have not made an appropriate estimate for only the products in scope.

However, again an attempt can be done by illustrating the trend of number of employees in R&D activities related to bio-based products as reported by the respondents classified in terms of production in tonnes. In general terms, respondents seems to have either increase or maintain the number of employees in R&D during the 2010-2013 period,

except for companies producing more than 50,000 tonnes which either maintain the number or decrease it.

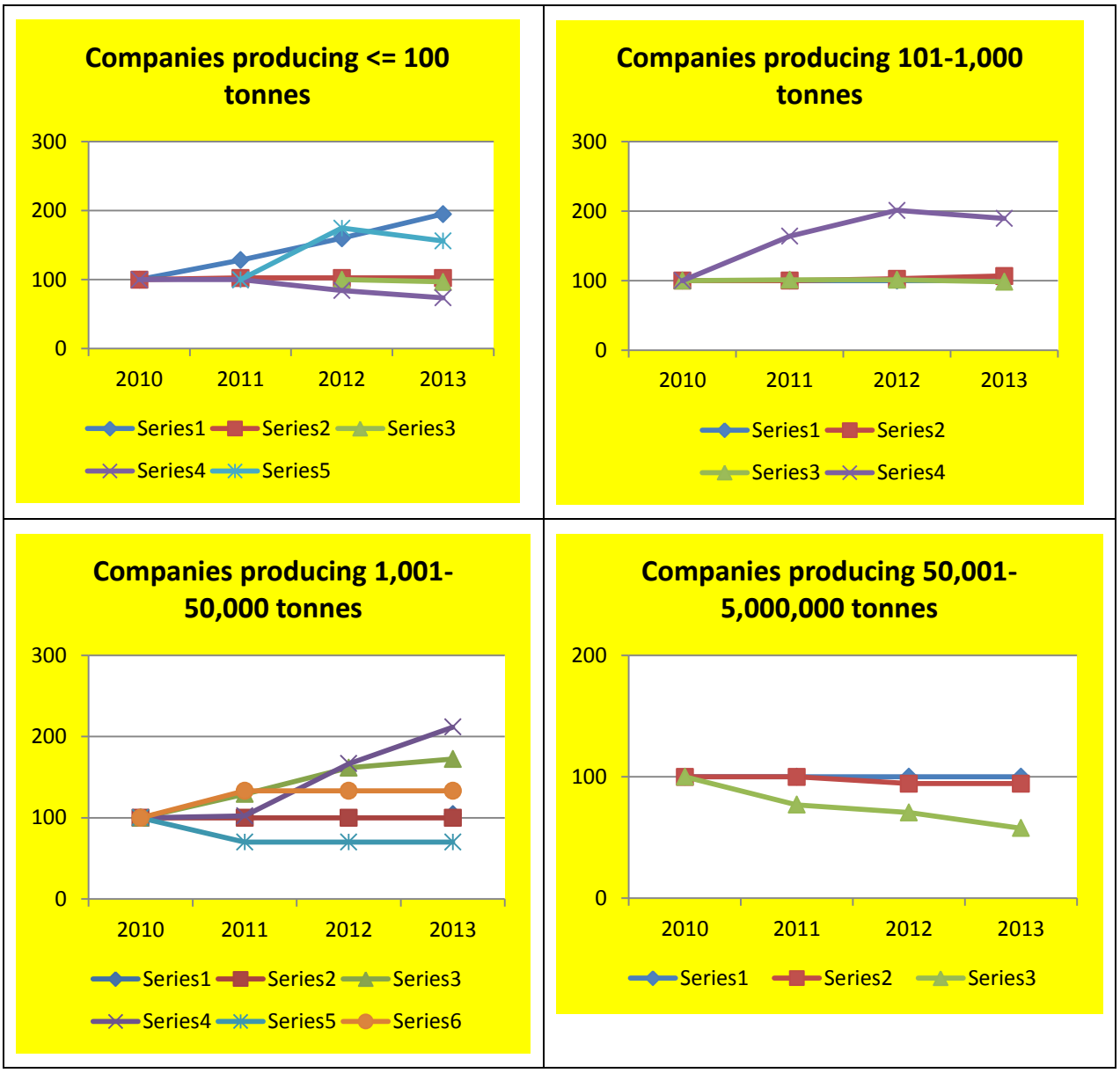


Figure 17: Trends of number of employees in R&D activities related to bio-based products in the EU. Index = 100 in 2010. Companies are classified according to their annual output in tonnes

Source: EU bio-based industries survey.

The survey did not collect data on private capital investment into bio-based products, but did collect information on public funding. 55% of survey respondents indicated that they have received public funding since 2010 indicating investment in research, development and demonstration. Interestingly 45% of companies indicated that they have not received public funding, which indicate that there is a mature, competitive bio-based products sector, and that public funding is directed at finding the next generation of products.

A total of €120 million of public funding was awarded to respondents between 2010 and 2013, the total annual awards increased between 2010 and 2013. Responses indicate that there are a wide range of national and EU funding initiatives, highlighting the

importance of ensuring complementarity and maximising synergies between funding programmes.

Costs

According to the survey respondents, the average contribution (%) of various cost categories to production costs for bio-based products produced in the one shown in Figure 18. It illustrates that the biggest determinants of the overall production costs is the biomass feedstock, in line with what was stated in the analysis of constraints. However, there are large variations between companies and these figures have to be considered cautiously.

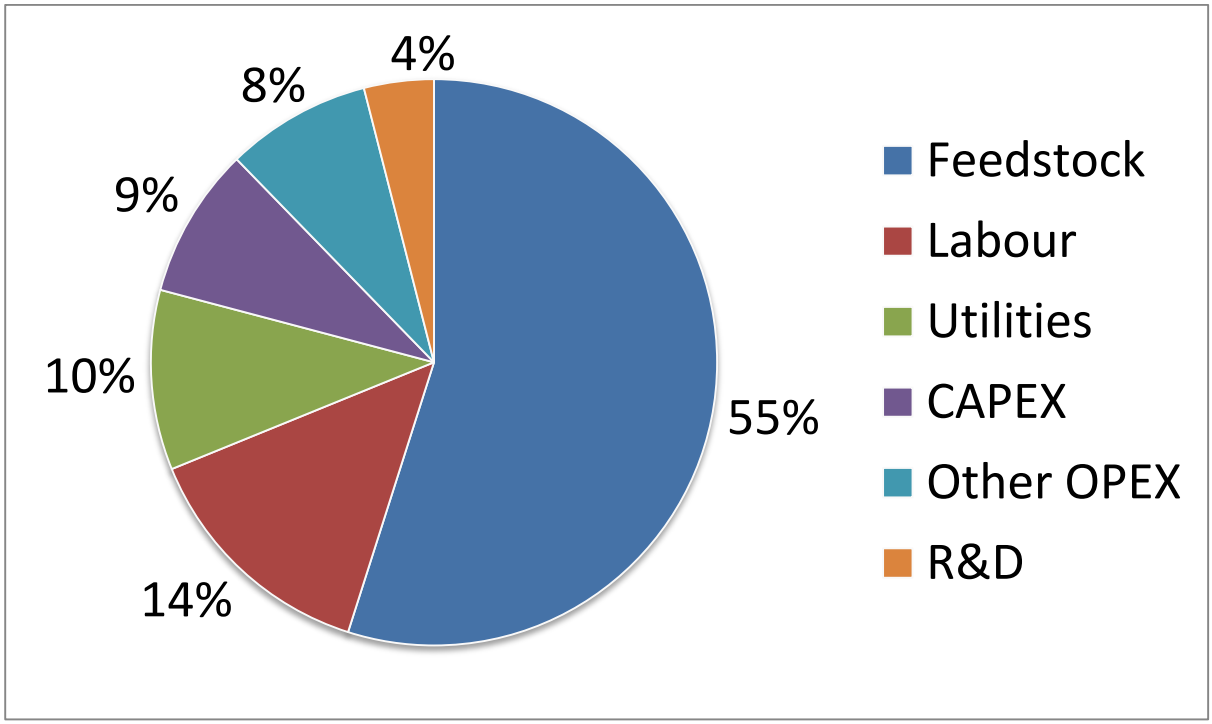


Figure 18: Average cost distribution for companies over the period 2010-2013

Source: EU bio-based industries survey.

4.4. Use of biomass in bio-based products

According to the participants to the survey, the most used source of feedstock to produce bio-based products in the EU is vegetable oils (Figure 19), which can be explained by the fact that most products in the list are oleochemicals, like surfactants, lubricants and solvents. Nine-teen companies reported they use vegetable oils, 16 starch and 14 alcohols. Obviously, the same company can use and combine more than one feedstock.

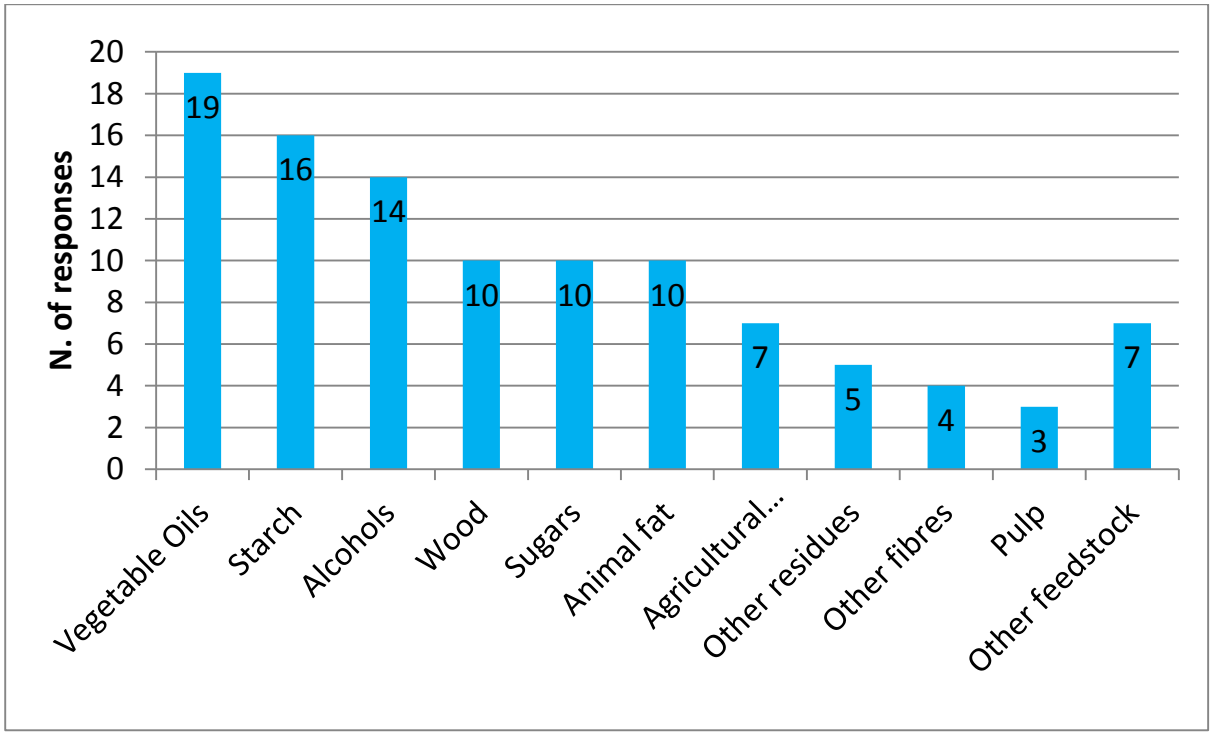


Figure 19: Feedstock sources indicated by respondents for the production of bio-based products

Source: EU bio-based industries survey.

The survey has not collected information on the quantities of feedstocks used or on feedstock use on an individual product basis, due to the large number of products, the complexity of the questionnaire, and the ability of respondents to collect specific information. It may however, made a number of observations based on the responses. The survey has identified 20 companies using animal fats and vegetable oils (there is only one user of animal fats that does not also use vegetable oils), 19 companies using sugar or starch crops, and 11 companies using natural fibres.

The most commonly used vegetable oils are rapeseed oil, and palm oil, followed by coconut oil, soybean oil and castor oil. All of these products are edible with application in the food and feed sectors. Of the 20 companies identified as using vegetable oils and animal fats, 18 use edible vegetable oils, 9 use a combination of edible vegetable oils and animal fats, and 2 companies specify only feedstocks that do not compete with the food industry (algae oils and animal fats) – these companies are both small enterprises (fewer than 50 employees), and new bio-based product producers, indicating that they started consuming feedstocks in 2013. Whilst the survey has not collected data on the volumes of each feedstock used, it appears that companies are consistent in the types of vegetable oil and animal fats used between 2010 and 2013; the survey has not identified any changes in feedstocks used between years, except in the case of several new users of vegetable oils and animal fats in 2013.

The most commonly used sugar and starch feedstocks are maize, wheat, and sugar beet, all edible feedstocks which may compete with the production of food and feed. Data on the quantities of each type of feedstock has not been collected, but companies seem to be consistent in their use of sugar and starch feedstocks – we have not observed changes in feedstocks between 2010 and 2013, except several companies have reported diversification of sugar and starch feedstocks in 2013. In total 19 companies reported using sugar and starch feedstocks, of which 17 companies use edible feedstocks, only 1 company specified that it used only lignocellulosic sugars, and 1 company uses dextrose. The use of agricultural residues has increased between 2010 and 2013 although it is not specified if this is lignocellulosic material.

The most commonly used natural fibre is wood, and the number of users has increased between 2012 and 2013. Companies have generally been consistent in the fibre feedstocks which they have used between 2010 and 2013, with the exception of several new users which seem to have emerged in 2013. The new users include micro enterprises and large enterprises.

Regarding the use of industry co-products or intermediates, 9 companies indicated they use glycerol as a feedstock, 3 of which are micro or small enterprises who have started using glycerol in 2012. The survey has also identified 7 users of bioethanol, 2 users of chemical pulp as a feedstock for bio-based materials (both pulp and paper companies) and no users of biomethanol.

Information on the use of domestic feedstock versus imports was provided by 28 companies, of which almost half source all bio-based feedstocks from within the EU, including a broad range of feedstocks (starch, sugar, vegetable oils, animal fats and wood fibre). 5 companies import more than 95% of their bio-based feedstocks into the EU; these companies use mostly vegetable oils, but also glycerol, bioethanol, animal fats and starch crops. The majority of companies have been consistent in the ratio of domestic and imported feedstocks, notably 2 large producers of bio-based products have increased the proportion of feedstock imported into the EU, including glycerol.

Information on the proportion of bio-based feedstocks in total feedstock use was provided by 30 companies, of which almost 50% claim more than 95% of their feedstock is bio-based. The profile of these companies vary widely, including micro to large enterprises, utilising fermentation, catalytic, and other processes to produce bio-based products from starch and sugars, vegetable oils and animal fats, ethanol, glycerol and other alcohols. The proportion of bio-based feedstocks in total feedstock use for individual companies is largely consistent between 2010 and 2013, and the increase illustrated in Figure 20 is due to new producers reporting only for 2012 and/or 2013. However, the majority of respondents expect that the proportion of bio-based feedstock in total feedstock use will increase to 2020. According to most respondents (68.4%), the contribution of bio-based feedstock to total feedstock use is likely to increase by 2020. According to the 23.7% of respondents the increase will be higher than 100%.

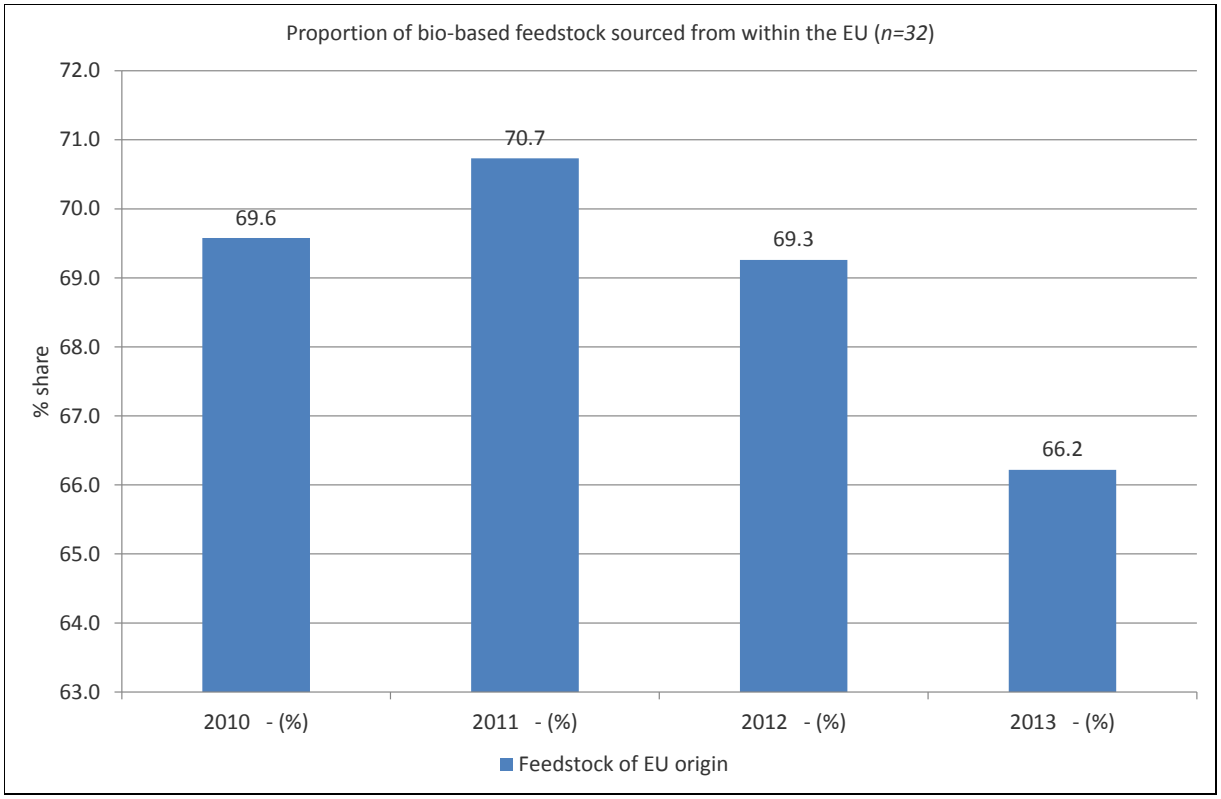


Figure 20: Proportion of bio-based feedstock sourced from within the EU

Source: EU bio-based industries survey.

Feedstock availability was cited as a key reason for selecting the location of bio-based production facilities in the EU by approximately 50% of respondents, and is the most important factor alongside proximity to existing commercial activities. The profile of the companies stating feedstock availability as a key location factor vary widely, these companies use a broad range of feedstocks, sourced from the EU and imported into the EU.

The data collected by the EU bio-based industry survey does not enable us to quantify the total use of bio-based feedstocks in the EU. However, detailed quantitative analysis of feedstock use has been carried out for some feedstock types in other projects. The Bio-TIC project provides an estimate of the use of plant oils and sugar and starch crops for material uses in the EU in 2013. The use of starch and sugar for material uses is estimated at 2 million tonnes in 2013, dominated by fermentation products, solvents, and starch blends. This compares to annual production of 16.4 million tonnes of crystallised sugar for food application, 7.8 million tonnes used in the production of ethanol, and 1.5 million tonnes used in paper products. The domestic supply of starch crops was estimated at 329 million tonnes in 2013, of which 299 million tonnes were used in the production of food and feed, and 22 million tonnes for starch production, to supply numerous industries.

Bio-TIC estimate that 1.2 million tonnes of plant oils were used in production of materials in the EU in 2013, including 0.5 million tonnes in paintings and coatings, 0.4 million tonnes for surfactants, 0.15 million tonnes for lubricants and 0.1 million tonnes for polymer production. This compares to 10 million tonnes of plant oils used in the production of biofuels, and 13.6 million tonnes in food and feed applications.

4.5. Drivers and constraints affecting the development of bio-based products by the EU industry

According to the respondents of the EU bio-based industries survey, the most important drivers for the development of bio-based products within the EU are improved product competitiveness (with 93% of companies rating this as an important driver), improved profitability (89%), sales growth potential (89%), development of innovative products (87%), improved product properties or performance (84%), and improved environmental performance (82%), as shown in Figure 21. Where respondents were able to indicate an unlimited number of drivers, the majority of pre-defined options were rated as important by more than 50% of respondents, including potential to increase market share, market demand increase, sustainability goals, production related to current competencies, availability of public funding, and product diversification. This illustrates a diversity of drivers behind bio-based product development associated with different value propositions and the potential to innovate.

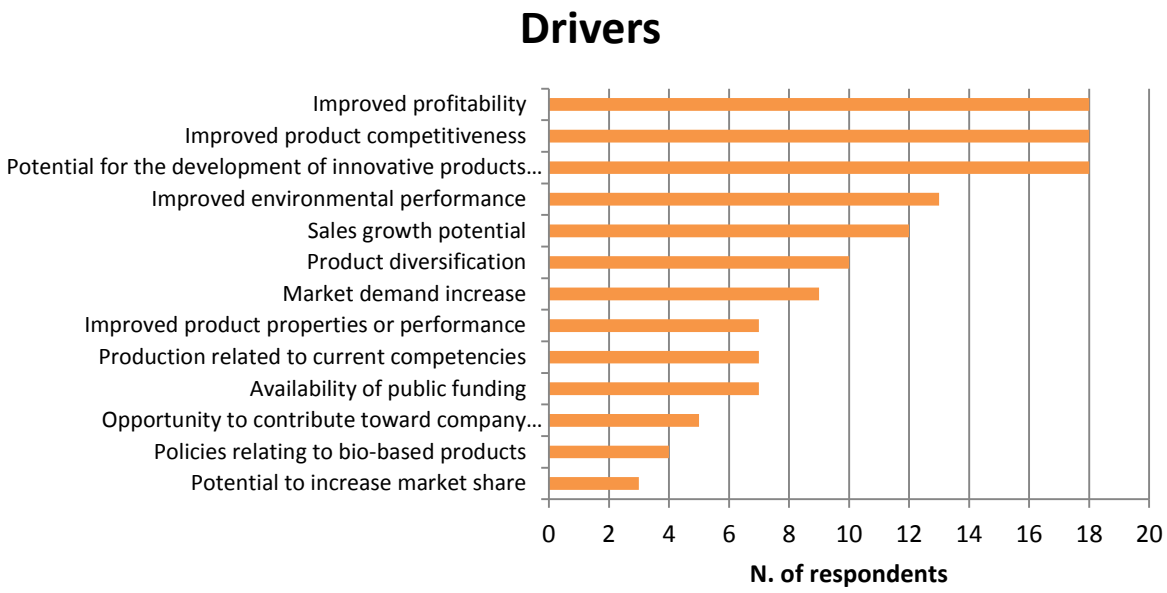


Figure 21: Ranking the most important drivers for the development of bio-based products

Source: EU bio-based industries survey.

The response from the EU bio-based industries is in close agreement to the most important reasons for evaluating or pursuing Industrial Biotechnology, from companies surveyed in the US, specifically the most important reasons identified were to improve profitability, sales growth potential, and to improve competitiveness[11]. In Canada, the most important factors which influence the development of bio-based products cover similar themes, although the relative importance of these factors differs from the EU and US results. In the Canadian survey, respondents associated greater importance to increasing product range (74% of respondents) and less companies associated bio-based products with improved economics (38% of companies stated using biomass to reduce production costs)[10].

According to respondents of the EU bio-based industries survey, the most important constraints for the development of bio-based products are the availability of funds to invest in production capacity (with 74% of companies rating this as an important constraint), higher production costs compared to existing fossil based alternatives (72%), and increased or variable feedstock costs (70%), as shown in Figure 22. Where respondents were able to indicate an unlimited number of constraints, the availability of funds for necessary R&D, increased capital costs and technology maturity or risk

associated with new process development where identified as important constraints by more than two-thirds of respondents.

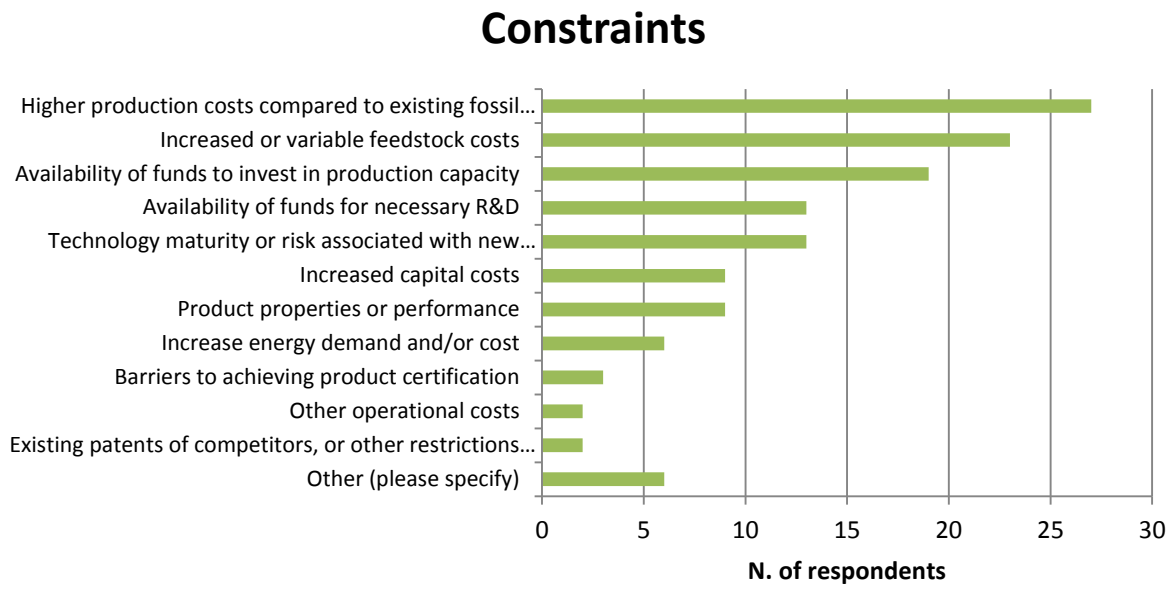


Figure 22: Ranking the most important constraints for the development of bio-based products

Source: EU bio-based industries survey.

The issues of competitive production costs is rated as very high importance in both the drivers and constraints to the development of bio-based products, indicates that for successful or emerging products cost competitiveness is a key part of the value proposition, whilst for products still under development it is very important that the production costs become more competitive with the existing products in order for these products to achieve any market share.

The Bio-TIC project (2014)[15, 16] has done considerable work recently in identifying regulatory and non-technological hurdles that may inhibit innovation and prevent the realisation of the market and technological potential of industrial biotechnology in Europe. The key Bio-TIC sectors include bio-based chemical building blocks, plastics, and surfactants (alongside advanced biofuels and CO utilisation). The Bio-TIC non-technological roadmap is based on an extensive literature study and the subsequent stakeholder discussion of its findings during eight regional workshops and more than 60 expert interviews. Several barriers affecting the bio-based industries were highlighted, including:

- Feedstock related barriers: the logistics of securing large quantities of biomass feedstocks all year round, and the availability of feedstock at affordable prices
- Investment barriers and financial hurdles: the availability of project capital (specifically limited public funding for R&D and scale-up activities, and limited access to finance for SMEs, spin-offs and start-up companies), and the perception of high investment risk.
- Poor public perception and awareness of industrial biotechnology and bio-based products.
- Demand side policy barriers: an absence of incentives or efficient policies. There is no framework in Europe to promote bio-based products, and a wide variety of ecolabels and no standards for sustainable and bio-based products.
- Other barriers: including barriers related to human resources (the availability of personnel with the right skills and curricula), collaboration efficiency (insufficient

knowledge exchange), intellectual property, and sustainability (no coherent policy framework for sustainability).

More specifically, for chemical building blocks, the core issue appears to be the lack of general interest in production of bio-based chemical building blocks, whether it is expressed by low levels of investment, or a lack of demand side policy drivers or financial incentives for biochemicals. Demonstration scale-up activities are expensive, and in many cases not being carried out due to the lack of a clear economic case versus the fossil chemical counterfactual. Whilst for polymers, the business case is mainly faced with problems related to price (vs. fossil substitutes), a lack of critical mass due to immature value chains, and no real regulatory support to foster their competitiveness. A lack of recycling systems for new polymers, poor public awareness and the need for clear standards/definitions are also hampering the sector.

Similar themes regarding the barriers to the development of bio-based products are reported in other regions. In Canada, more than half of companies rated the lack of financial capital as a barrier to production and development of bio-based products as high, and 42% of companies rated the cost of biomass as a barrier to production and development as high.

The cost and timeliness of regulatory approval was also rated as a high barrier by over half of companies in Canada, whilst few companies ranked barrier relating to product certification or approval as one of the three most important barriers (6.5%). However, industry wide perspectives, such as those presented by the Bio-TIC project, indicate a lack of demand side policies as a barrier.

In the US, companies rated the following impediments to the commercialisation of bio-based products as most significant: feedstock price, lack of capital (debt or equity), a high level of risk in relation to profit potential, and final product not cost competitive. These key factors are in very close agreement to those indicated by the EU bio-based industries survey.

4.6. Impact of the EU bio-based industry on the EU economy

The impact of the EU bio-based industry on the EU economy may be quantified by indicators such as the number of companies operating in the industry, the number of jobs, and sales revenues. This study focussed on those sections of the chemicals and materials industries that convert biomass feedstocks to primary products (or intermediates). The impacts may be defined as the direct jobs and revenues generated by these organisations, or the impacts may extend beyond the conversion of biomass feedstock to primary products (or intermediates) to include benefits to the upstream industries from additional markets for agricultural, forestry and waste materials, and the downstream industries, utilising the bio-based products in added value applications, for example the construction sector, textiles, automotive, among many others.

Several studies have attempted to estimate the impact of the EU bio-based industry on the EU economy. Figures cited in the European Bioeconomy Strategy and Action Plan, (from The Knowledge Based Bio-Economy in Europe, 2010) estimate that the annual turnover relating to bio-based chemicals and plastics in the EU was €50 billion for 2009, and that such activities contributed 150,000 jobs to the EU economy[1].

More recent estimates based on EUROSTAT data for 2011[17] provides a comparable estimate for the manufacture of chemicals, chemical products, and plastics. Based on the assumption that the bio-based industry represents 5% of the European chemicals industry, they estimate that the turnover in the EU relating to the production of bio-based chemicals, chemical products, and plastics was 76 billion EUR in 2011 and that the number of jobs in the manufacture of bio-based chemicals, chemical products and plastics was 60,000 in 2011. The number of additional jobs in the agricultural sector in the supply of feedstock is estimated at 30,000 – 60,000, bringing the total number of jobs to between 90,000 and 120,000.

In order to contextualise the size of the bio-based industries, we may compare this to the EU chemicals industry. According to data and analysis produced by CEFIC, the EU chemicals industry is a long established industry, established over 150 year ago, which includes approximately 29,000 companies[18]. The EU chemicals industry generated a turnover of €527 billion in 2013. Over the last two decades EU chemical sales have almost doubled, however since 2011 there has been a slight decline in sales (2.7% between 2011 and 2012, and 1.6% between 2012 and 2013). Between 2010 and 2013, the ratio of sales within the EU vs Extra-EU exports has remained relatively stable with around three-quarters of sales within the EU. The number of employees employed directly by the EU chemical industry has remained unchanged since 2010 at 1.2 million people. Regarding growth, absolute capital spending and the intensity of capital spending as a percentage of sales has remained flat between 2010 and 2013 (at an average of €18 billion per year), while spending on R&D has seen a small increase in absolute terms, but flat as a percentage of sales (at 1.6%).

The bio-based industries have been compared to the paper and pulp industry and the biofuels industry in previous reports. According to the KBBE, the annual turnover for the biofuels industry in the EU was €6 billion for 2009, and the industry contributed 150,000 jobs to the EU economy[1]. This indicates that whilst the two industries employ an equal number of people across the EU, the value added to the economy for each jobs within the chemical and materials sectors is eight times greater. Both the bio-based industries and the biofuels industries are dwarfed by the paper and pulp industry, which is estimated to contribute €375 billion to the economy in 2009, and contribute 1.8 million jobs.

The EU bio-based industries survey collected data on the number of employees working on bio-based activities from 36 companies, out of a target population of 133 companies (27% response rate). The survey identified 2,334 employees directly employed in bio-based activities. Also, 23 companies (17% response rate) provided data on the sales turnover in the EU of bio-based products, estimated at about €1.4 billion. These figures seem to indicate lower direct employment and turnover figures compared to the top-down estimates from the studies mentioned above. However, the partial nature of the survey means it is difficult to provide an overall indication of the economic impacts and how they compare to the high-level top-down estimates. Furthermore, there will be additional benefits realised in the production of value added consumer products.

4.7. Comparison of the EU bio-based industry with key EU competitor countries

Europe is seen as a global leader in various fields of biosciences and technologies, with a competitive edge in industrial biotechnology (IB) for enzyme, chemical, food and feed ingredients production. For example, 64% of all enzyme companies operate from within the EU[19]. Europe has good availability of biomass feedstocks, with advanced practices in the areas of agriculture, forestry and wastes. There are world leading bio-based technology companies operating in the EU, with a range of bio-based products already in the market, as demonstrated by the survey results, and an increasing portfolio of products anticipated to develop to 2020.

However, according to EuropaBio a wide range of countries have introduced Bioeconomy policies (Figure 23), and nations such as the US, China, Canada, Japan, and India are rapidly adopting industrial biotechnology [2]. The conditions for investment have been reported to be more attractive in the US and China (in particular for demonstration activities), with examples of EU technology being deployed there[15, 16].

The urgency of commercialising EU research has been recognised within the EU, and has led to the establishment of the Bio-based Industries Consortium (BIC), and the Bio-Based Industries (BBI) Public-Private Partnership with the EU Horizon 2020 programme. These efforts and significant investment sums (€3.8billion) are looking to build new supply chains, scale-up research to flagship biorefineries, plus develop markets and

policies for the products made[15, 16]. The impact of these programmes are not fully realised in the industry today.

For the purposes of this study the US, China and Brazil are compared as competitor regions. These regions are reported to be leaders in the bio-based industry, based on existing production capacity, planned production capacity, industrial innovation, the status of complementary industries (for example biofuel production), and the availability of feedstock. Canada and Malaysia both have existing bio-based industries, but feature less prominently in reported commercialisation strategies of new developers, and are also discussed below.

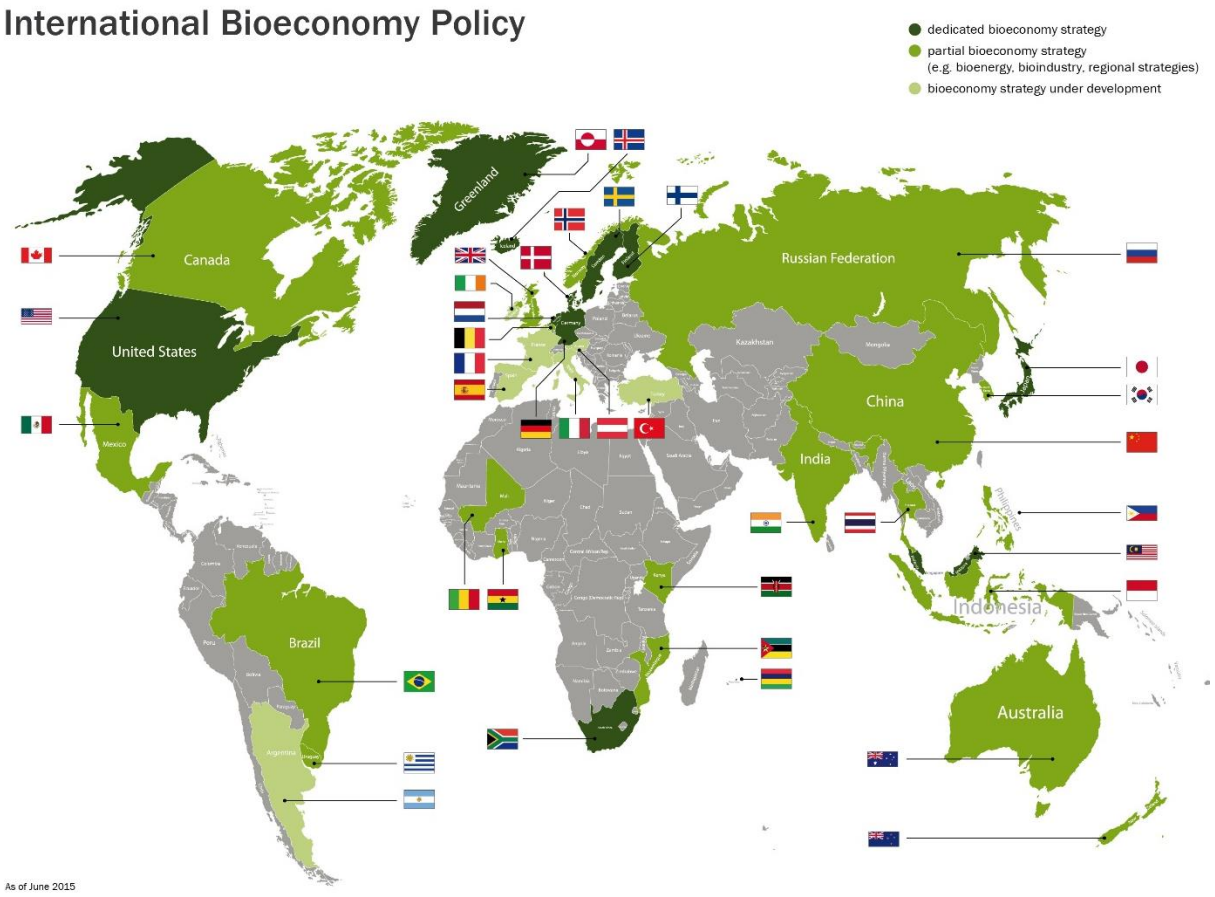


Figure 23: Countries which have dedicated or partial bioeconomy strategies

Source: German Bioökonomierat (Bioeconomy Council)

An outline of the current state of the bio-materials industry in each of these countries is given, focussing on the policy and financial support provided by the government, and assessing the available information on production capacity. However information on the production volumes and the value of the bio-based industries is not published for each country of interest, additionally the methodologies used to report on the size of the industry is different for each country, making direct comparisons between datasets challenging due to differences in the scope of products included. The limited availability of information for some key producing regions such as China, Brazil, and Malaysia represents a key data gap in the ability to quantitatively compare the EU bio-based industry to the rest of the world.

Canada

Canada has an abundance of natural resources, which presents opportunities for the development of the Bioeconomy. However despite initiatives at the province level in Alberta, British Columbia and Ontario there is no specific federal government strategy for

the promotion or support of the bio-based sector, which may be impeding its development[20]. Financial support appears to be limited to biofuels, through the Next-generation Biofuels Fund.

Canada has published data on the bio-based industry. Statistics Canada published the Bioproducts Production and Development Survey in 2009, the third survey on bioproduct activity. Similar to the EU bio-based industry survey, the Bioproducts Production and Development Survey targeted all firms in Canada that use biomass feedstocks to develop or produce industrial bioproducts, and focussed on non-conventional products (excluding food, feed, medicines, wood composite products and traditional bioproducts). The scope includes the products included in the EU survey, and additionally biofuels and pesticides.

The Survey reported that, in 2009, 208 firms were engaged in the production or development of bioproducts. Those companies reported total sales revenues of CAD14.9 billion (2009) and sales revenues from bioproducts of CAD1.3 billion (2009). Spending on R&D activities for bioproducts or biomass totalled CAD74 million (2009). However, although these figures indicate an industry with good potential, they demonstrate a decline from 2003[21].

USA

In the USA the 2002 Farm Bill created the BioPreferred program in order to increase the purchase and use of bio-based products, and in February 2012 President Obama issued a Presidential Memorandum outlining steps to take greater advantage of the BioPreferred Program, aiming to significantly increase federal procurement of bio-based products. Furthermore in April 2012, the Obama administration launched the "National Bioeconomy Blueprint". This is a national strategy laying out objectives to help achieve the full potential of the US Bioeconomy and highlighting achievements towards these objectives. This blueprint emphasised the importance of the Bioeconomy both as a growth industry for America and also for its value to society as a whole. The five strategic objectives which are identified focus on R&D, transition from lab to market, reforming regulations, training the workforce, and the development of collaborations and public-private partnerships.

Specific policy support for the bio-based products industry in the US comes from the BioPreferred Program, which includes a voluntary labelling initiative for biobased products and a procurement requirement for federal agencies and their contractors to increase the purchase and use of biobased products. For financial support, the USDA Biorefinery, Renewable Chemical, and Biobased Product Manufacturing Assistance Program (formally called the Biorefinery Assistance Programme) gives loan guarantees of up to $250 million for the development of advanced biofuels, renewable chemicals and biobased product manufacturing. However the scope of this fund was only increased from advanced biofuels to include alternative chemical products in mid-2015. This revised fund has $200 million mandatory funding over three years, with discretionary funding of up to $375 million over five years[22]. In addition the Integrated Biorefineries programme provides funding to support crop establishment, although this is primarily focussed on the energy-use of biomass.

One of the first large US surveys into the Bioeconomy was conducted in 2008 by the US International Trade Commission and was based largely on data collected directly from the industry via survey, relating to the years 2004 to 2007.

A 2015 study for the USDA provides more up-to-date data, and suggests the US bio-economy, and bio-based products sector in particular, has grown in the past seven years. Information was gathered from three main sources: interviews with government and industry experts, statistics from government agencies and published literature, and economic modelling using IMPLAN modelling software. The following overarching sectors are taken as contributing to the bio-based economy: agriculture and forestry, biorefining, bio-based chemicals, enzymes, bioplastic bottles and packaging, forest

products and textiles. This report excluded energy, livestock, food, feed and pharmaceuticals products.

The study indicates that the total contribution of the bio-based products industry to the US economy in 2013 was $369 billion, with 4 million people employed either directly or indirectly.

The bio-based chemicals sector (defined as a chemical derived or synthesised in whole or in part from biological materials), which included plastics such as PHA and PLAs, biolubricants, biosolvents and dyes was estimated to contribute around $5 billion directly and $17.4 billion in total, considering multiplier effects, to the US economy in 2013, employing 22,950 people directly and 133,000 people when considering direct, indirect and induced employment. The entire chemicals sector was estimated to be 4% biobased.

The EU bio-based economy survey results presented in this study indicate that value and direct employment figures for the US and EU bio-based chemicals sectors could be of the same order of magnitude.

China

In China's 12th 5-year plan (laid out in 2011), biotechnology was one of their seven priority industries, although this was primarily focussed on drugs and medical technology[23]. The plan overall focussed on more sustainable development, rather than simply rapid growth, and considered the introduction of several environmental measures such as goals to limit GDP CO_2 intensity, pollution limits, and new resource use and environmental taxes, which are likely to stimulate the bioeconomy[24].

Financial support for the development of bio-based chemicals and materials has been sourced from the Knowledge Innovation Program of the Chinese Academy of Sciences (from 1998 to 2010), and the National High Technology Research and Development Program of China (863 Programme) which began in 1986.

No public government statistics or national data relating to the bio-based industry in China is available. Nevertheless, significant production capacity is being built at commercial scale, by both Chinese and International companies, who are attracted to China by low production and labour costs. Examples of such companies include Cardia Bioplastics, Hiusan Biosciences and Hexing Chemical[25]. Bioplastic materials produced in China include PBAT, PLA, PHA, PVA, PPC, and the combined existing production capacity has been estimated at about 85,000 tonnes per annum[26].

Brazil

With a strong agricultural sector and well-established ethanol production industry, Brazil is well-placed to move into the emerging bio-materials sector. Brazil has a number of innovation policies in place and innovation is supported by the National Bank for Social Development (BNDES) and the Funding Authority for Studies and Projects (FINEP). In addition EMBRAPA (Brazilian Agricultural Research Corporation) has long supported the use of biotechnology in agriculture. Biotechnology was identified as a national strategic priority in 2003 and formally supported in the 2007 decree, Política de Desenvolvimento da Biotecnologia, which also established the National Biotechnology Committee[27].

The development of the biomaterials sector in Brazil is closely linked to the established bioethanol production from sugarcane industry. This is evidenced by the dual-purpose funding of the Joint Support Plan for Industrial Technological Innovation in Sugarcane-based Ethanol and Chemical Sectors (PAISS) which focuses on innovation in both the agricultural and processing aspects of the sugarcane industry. Alongside the production of second-generation bioethanol and new gasification technologies, PAISS focuses on funding the development of new sugarcane products outside of the biofuels sector. PAISS has supported R$ 2.5 billion of projects to date.

Although there is no country-wide survey or inventory of bio-based materials plants in Brazil, there are several large enterprises in this sector including the Braskem bio-based

polyethylene plant, Cardia Bioplastics plant in São Paulo, the planned Moore Capital PHA production plant, and PHB Industrial S.A.

Malaysia

In 2005 Malaysia launched the National Biotechnology Policy (NBP) to develop agriculture, healthcare and industrial manufacturing, with the Malaysian Biotechnology Corporation (BiotechCorp) primarily responsible for its implementation. BiotechCorp has formed strategic partnerships with Italian, Belgian and German bio-based industry developers, with a view of Malaysia as a growing hub for the bioeconomy in South-East Asia[28].

In 2009 Malaysia introduced an accreditation scheme for qualified international and Malaysian biotechnology companies, called Bionexus. Bionexus companies benefit from support and significant funding such as 100% tax exemption for 10 years and double deductions on R&D expenditure[29]. In addition, Bionexus companies are able to access funding from the Biotechnology Commercialisation Fund.

Focusing more specifically on bio-based feedstocks, the Bioeconomy Transformation Programme (BTP) was launched in 2012, providing a government platform to channel private sector investment into bio-based industries[30], specifically targeting the production of biofuels, bioplastics and bio-based chemicals. By 2014 the BTP had identified and approved 25 bio-economy 'trigger' programmes which it was supporting.

Finally, the National Biomass Strategy launched in 2013 recognises the importance of both bio-based chemicals and bio-fuels to leveraging the most value from Malaysia's biomass resources.

Despite such strong government support for the bio-economy in Malaysia, there is no overall inventory of bio-based products plants. Nevertheless, there are developments in this sector including the SIRIM Berhad PHA plant, the planned Johor bio-refining plant, and the Arkema and CJ Cheiljedang thiochemicals from sugars plant.

Country Comparison

The heat-map shown in Figure 24 compares the bio-based products sector in the five selected countries to that of the EU. Europe compares favourably to the other countries on all indicators, with some limitations in feedstock availability and current level of commercial activity. It should however be noted that it was not possible to fully quantitatively assess the current level of commercial activity due to a lack of data, and varied definitions of the 'bio-economy'.

	Feedstock Availability	Government Strategy	Government Financial Support	Current Status of Bio-based Industries
EU	EU has a large forestry sector and good levels of grain and vegetable oil production and residues	2012 - Bioeconomy Strategy and Action Plan	US$ 4.1 billion for renewable biobased economy between 2014-2024 through Horizon 2020 and industry matched funding.	Strong forestry sector. Good bio-based products sector - Europe accounts for around one-quarter of bio-based plastic production capacity. Good R&D and innovation.
USA	USA is in the global top three for production of wheat, maize, sugar-beet and soybean, and has a large forestry	2002 - BioPreferred Programme - 2012 – National Bioeconomy Blueprint	Up to US$575 million via the USDA Biorefinery Assistance Program. Also fuding through the Integrated Biorefineries Program.	Strong agricultural, forestry and biofuels sector. Bio-based products sector is established, from R&D through to commercial plants, including chemical building blocks, plastics and lubricants.
Canada	Canada has large grain production and large forestry sector.	No government bioeconomy strategy but activities at Province level	At least $90 million committed under the current NextGen Biofuels Program, but no support for bio-materials	Strong agricultural and forestry sector and good biofuels industry, but limited bio-products activity.
China	China is largest wheat producer in the world, third largest producer of sugar-cane and has a large forestry sector	2011 - 12th 5-year plan - biotechnology one of seven 'priority industries', but no specific bioeconomy strategy	Loans and grants available are part of wider science / technology innovation funding	Strong agricultural and forestry sectors. Many demonstration and commercial bio-products plants, including chemical building blocks and plastics. Innovation capacity growing.
Brazil	Brazil is largest sugar-cane producer in the world, large soybean producer, and has a large forestry sector.	2007 Biotechnology development policy (Decreto no 6041, Anexo Política de Desenvolvimento da Biotecnologia; Decreto Nº 6.041) established National Biotechnology Committee	US$630 million committed under PAISS Industry and PAISS Agriculture	Strong agricultural, forestry and bioethanol sector. Several commercial-scale bioproducts plants. Limited diversity in national bio-based industry.
Malaysia	Second-largest global producer of palm-oil.	2005 – National Biotechnology Policy, including the Bioeconomy Transformation Programme and the Bionexus Companies Programme. 2011 - National Biomass Strategy to 2020	Malaysia has supported the development of 225 BioNExus-status companies with approved investment of US$761 million since 2005	Strong agricultural sector, particularly in relation to palm oil. Several demonstration and commercial bio-products plants.

Figure 24: Comparison of bio-economy across a number of countries, with focus on bio-based materials

Source: Different sources.

5. Conclusions

The census survey of the EU bio-based industries aimed to provide a description of the current status of the industry, to allow the JRC to monitor and analyse developments in the industry in Europe. The population is diverse in terms of company size, products, and markets supplied and therefore to provide a comprehensive description of the industry requires a full response. Feedback from the target population and other industry stakeholders has clearly indicated that there are major barriers to collecting the required data. The two main comments relate to concerns over the amount of time and resource required to collect such data and the availability of the data required (within the company), and also the commercial sensitivity of the data. This has clearly had an impact on the response rate and on the quality of some responses, particularly with open-ended questions to which respondents are required to input data or information which the respondent may have difficulty in researching or obtaining from within a large and diverse company structure. In addition, unless there is a clear value to the company from responding to the survey, or a legal obligation, companies will be hesitant to dedicate time and resources to responding. Developing statistical information, in particular in a novel, varied and competitive sector like the bio-economy will inevitably require a protracted effort and continuous engagement with the industrial community.

Nevertheless, this survey obtained a response from almost half the target population, which though somewhat lower is not dissimilar to that of similar exercises carried out in North America. While the overall response rate was insufficient to provide a comprehensive picture of the sector, it does provide some important insights. In order to gain a more comprehensive insight into specific companies or sub-sectors of the bio-based industry, follow-up (face-to-face) interviews with stakeholders could potentially be undertaken. Also, using the data gathered in this project and making analysis based on it publicly available could encourage other industry players to participate in future surveys.

The response illustrates that there are a diverse set of active players ranging from large to micro companies, developing and producing a wide range of products from a wide range of feedstocks. The companies that responded to the survey report total bio-based product turnovers of the order of €6.8 billion globally and €1.4 billion in the EU. All respondents are positive about the outlook for growth in the industry. The response also indicates a rise in company activity since 2011, and there appear to be shifts in products being developed and produced, probably as a result of market testing, and technical development. The active European companies produce and sell globally, testimony of the global nature of the sector.

Many of the companies are engaged in R&D activities in different parts of the world, meaning that there is probably competition to attract R&D investment to the EU, but also that there is potential for companies to capitalise on synergies from R&D being carried out and funded in different regions. Proximity to R&D appears to be a very important factor in determining early production location, alongside resource availability, existing infrastructure and proximity to market demand. Therefore, remaining competitive as a location for R&D is likely to have additional benefits in terms of promoting the manufacture of bio-based products in the EU.

Improved profitability and improved product competitiveness, along with the development of innovative products, were cited as the three most important drivers for the development of bio-based products, indicating a relatively market driven sector. This indicates that there is a need to understand: the potential for cost reduction of certain routes and how to support this cost reduction; the availability and price of feedstock given competing uses; the R&D requirements and how to provide effective and targeted funding. Responses suggest a diversity of drivers associated with different value propositions (performance, competitiveness, environmental) and the potential to innovate. Factors such as policies relating to bio based products were given less prominence. Nevertheless, the sector could be enhanced by policy support, for example

in the area of environmental performance of bio-based products relative to alternatives. These are key to providing positive future conditions for competitive bio-based products. Public funding is important to most respondents, with sources of funding ranging from pan-European to regional and local.

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Annex I: List of products in the scope

Organic acids

- **Succinic acid**
- **Adipic acid**
- **Lactic acid**
- Itaconic acid
- **Acetic acid**
- Citric acid
- **Lauric acid**
- **Sebacic acid**
- **Formic acid**
- **Levulinic acid**
- **2,5-Furandicarboxylic acid (FDCA)**
- **Acrylic acid**
- 3-hydroxypropionic acid (3-HPA)
- Glutamic acid
- **Terephthalic acid**
- **Furfural**
- **Methacrylic acid**
- **Methyl methacrylate**

Alcohols

- **n-butanol**
- **Isobutanol**
- **1,4-Butanediol (BDO)**
- **1,3-Propanediol (PDO)**
- **Propylene glycol**
- **Furfuryl alcohol**

Polymers

- **Derived from natural polymers**
  - **Cellulose ester, inc. cellulose acetates**
  - **Cellulose ether**
  - **Starch polymers, inc. composites**
- **Derived from monomers**
  - **Polyhydroyalkanoates (PHAs), inc. PHB**
  - **Polyamides**
  - **Polyurethane (PUR)**
  - **Polylactic acid (PLA)**
  - **Polyethylene furanoate (PEF)**
  - **Polybutylene succinate (PBS)**
  - Polycarbonates (PC)
  - **Polymethyl methacrylate (PMMA)**
  - Polybutadiene (PBD)
  - **Polybutyrate (PBAT)**
  - **Polybutylene terephthalate (PBT)**
  - **Polyethylene (PE)**
  - **Polyvinyl chloride (PVC)**
  - **Polyvinyl acetate (PVA)**
  - **Polystyrene (PS)**
  - **Polypropylene (PP)**

- Polyethylene glycol (PEG)
- **Polyethylene terephthalate (PET)**

Composite materials

- **Wood-plastic composites (WPC)**
- **Cork reinforced plastics**
- **Other natural fibre reinforced plastics**

Others

- **Hydroxymethyl-furfural (HMF)**
- **Epichlorohydrin**
- **Isoprene**
- **Isosorbide**
- **Farnesene**
- **Fatty amines**
- **Ethylene**
- Acetone
- **Ethylene glycol**
- **Para-xylene**

Other bio-based products used in the following applications:

- **Surfactants**
  - **Fatty alcohol ethoxylates/ethers**
  - **Fatty alcohol ether sulfates**
  - **Fatty alcohol sulfates**
  - **Ester quats**
  - **Alkyl polyglucosides**
  - Lipopeptides and digopeptites
  - **Glycolipids, inc. sophorolipids**
  - **Polymeric surfactants**
- **Solvents**
- **Binders**
- **Plasticisers**
  - **Phthalate esters**
- **Paints/coatings**
  - **Paint additives**
  - **Printing colours**
- **Lubricants**
  - **Mould release agents**
  - **Chain & bearing lubricants**
  - **Hydraulic fluids**

Annex II: On-line questionnaire

1. Introduction

This survey aims to collect data on the current status and expected evolution of the bio-based industry within the EU. Results of the survey will input to the JRC Bio-economy Information System Observatory.

This survey is part of a wider **Study of the EU Bio-based Industry**; commissioned by the European Commission's Joint Research Centre and carried out by E4tech and Agra CEAS Consulting. The study aims to provide a comprehensive analysis of business activity to assist the JRC in monitoring and analysing developments in the bio-based industry in Europe, specifically addressing gaps in the existing data resources.

The study will establish, for the first time, transparent market data which will improve the sector's visibility and support investment decisions and policy actions.

2. Instructions

The online survey may be accessed here https://www.surveymonkey.com/r/NR3QWNK

We strongly recommend that you review the questions in advance to gather any information required prior to submitting your response online. This pdf copy of the questionnaire is provided for this purpose.

It is not possible to save your online response to resume at a later date and therefore the online survey should be completed in one session.

Should you experience any technical difficulties in completing and submitting the online survey, please do not hesitate to contact Clifford.Biggs@ceasc.com.

3. Key definitions

For the purpose of this survey 'bio-based' products relate to products derived in whole or in part of biological products from biomass (including plant, animal, and marine or forestry materials).

The focus of the survey is on addressing gaps in the existing data resources, and therefore includes the material use of biomass, excluding food, feed and bio-energy. Other existing bio-based industries are also considered out of scope of this study because data relating to these existing industries is reported elsewhere. This includes pulp and paper, textiles, leather, fur, wood and wicker products, and pharmaceuticals.

A brief description of the bio-based products included in the scope of the survey is outlined below.

4. Product Scope

The survey aims to collect data on the current status and expected evolution of the bio-based industry within the EU.

This survey is part of a wider **Study of the EU Bio-based Industry**, which will assist the JRC in monitoring and analysing developments in the bio-based industry in Europe, *specifically addressing gaps in the existing data resources*.

The production of food, feed and bio-energy are outside the scope of the study, as data relating to the production and value of these sectors is reported under existing frameworks. The study focuses on the material use of biomass, including chemicals, polymers, and fibres.

Some material products are defined as *outside of the scope* of this study because data relating to these existing industries is reported elsewhere. This includes pulp and paper, textiles, leather, fur, wood and wicker products, and pharmaceuticals. The JRC is concerned about the impacts on existing industries, and the study will report on potential impacts.

5. Survey scope

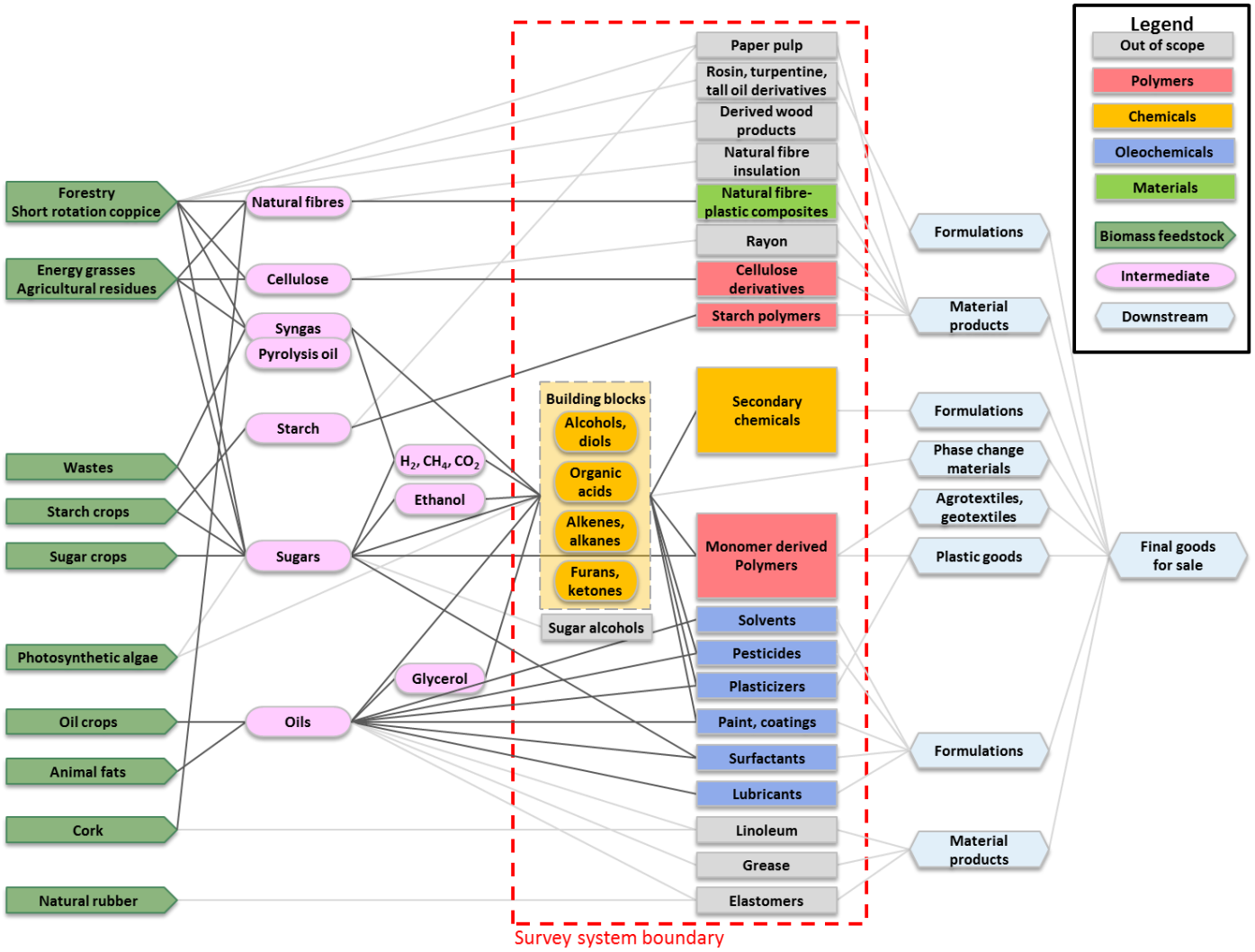
The following simplified value chain diagram is provided to give an indication of the products included in the scope of the survey. For the avoidance of doubt, a more detailed list of products is included in the initial screening questions.

Chemical substances most commonly used as *biofuels* are considered *outside of the scope* of this survey (e.g. ethanol, FAME and HVO). Whilst these products may be used directly in non-fuel applications or may be used as an intermediate in the production of bio-based materials, data relating to production capacity, production volumes, revenue and investment, is already reported elsewhere.

However, where these substances are intermediates for the production of other chemical and material products, the *derived products* are within the scope of this survey; for example the conversion of ethanol to ethylene. In this case, ethanol will be considered a feedstock for the production of ethylene.

The production of biofuels also leads to co-products, for example glycerol from the production of FAME, and carbon dioxide from the production of ethanol. These co-products may be utilised in the production of chemical and material products. As the production of biofuel is outside of the scope of the survey, the production of biofuel co-products is also outside of the scope of the survey. Chemicals and materials *derived from biofuel co-products* are however *within the scope* of the survey. In this case, the biofuel co-product will be considered a feedstock for the bio-based industry, to avoid duplicating and potentially double counting the impacts of biofuel manufacturing capacity.

If you have any further questions regarding the scope of the survey please do not hesitate to contact Lucy.Nattrass@E4tech.com.


Legend
Out of scope
Polymers
Chemicals
Oleochemicals
Materials
Biomass feedstock
Intermediate
Downstream
Forestry
Short rotation coppice
Energy grasses
Agricultural residues
Wastes
Starch crops
Sugar crops
Photosynthetic algae
Oil crops
Animal fats
Cork
Natural rubber
Natural fibres
Cellulose
Syngas
Pyrolysis oil
Starch
Sugars
Oils
H_2, CH_4, CO_2
Ethanol
Glycerol
Building blocks
Alcohols, diols
Organic acids
Alkenes, alkanes
Furans, ketones
Sugar alcohols
Paper pulp
Rosin, turpentine, tall oil derivatives
Derived wood products
Natural fibre insulation
Natural fibre-plastic composites
Rayon
Cellulose derivatives
Starch polymers
Secondary chemicals
Monomer derived Polymers
Solvents
Pesticides
Plasticizers
Paint, coatings
Surfactants
Lubricants
Linoleum
Grease
Elastomers
Formulations
Material products
Formulations
Phase change materials
Agrotextiles, geotextiles
Plastic goods
Formulations
Material products
Final goods for sale
Survey system boundary

6. Contact Information

***Q1. Please provide contact details for your company and for the person responsible for completing this questionnaire.**

- Company name
- Address
- Country
- Company telephone number (incl. country code)
- Company email address
- Company website
- Person to be contacted regarding this questionnaire
- Job role or title (e.g. Director)
- Contact telephone number and extension (incl. country code)
- Contact email address

ANSWER: insert information

Continue survey; go to **Screening**

7. Screening

***Q2. Does your company do ANY of the following:**

(1) generate sales turnover OR employ people <u>in the EU</u> at present?

OR

(2) expect to generate sales turnover OR employ people <u>in the EU</u> by 2020?

ANSWER: YES – continue survey; go to **Screening (2)**

ANSWER: NO – **<u>Exit survey</u>**.

8. Screening (2)

***Q3. Does your company currently produce, or expect to produce by 2020, ANY of the following bio-based products?**

- Organic Acids
- Alcohols (excluding ethanol)
- Polymers derived from natural polymers, or monomers
- Composite Materials
- Others from the following list:
    - Hydroxymethyl-furfural (HMF)
    - Epichlorohydrin
    - Isoprene
    - Isosorbide
    - Farnesene
    - Fatty amines
    - Ethylene
    - Acetone
    - Ethylene glycol
    - Para-xylene
- Others for use in the following applications:
    - Surfactants
    - Solvents
    - Binders
    - Plasticisers
    - Paintings/coatings
    - Lubricants

ANSWER: YES – continue survey; go to **Organic acids**

ANSWER: NO – **Exit survey**.

9. Organic acids

***Q4. Does your company currently produce bio-based organic acids, or expect to produce any by 2020?**

ANSWER: YES – continue survey; go to **Organic acids (2)**

ANSWER: NO – continue survey; go to **Alcohols**

10. Organic acids (2)

***Q5. Please select all the bio-based organic acids which your company currently produces, and those which it expects to produce by 2020.**

If the product is both currently produced and expected to be produced in 2020, please select both columns.

ANSWER: Tick all that apply

	Currently produced	Expect to produce by 2020
Succinic acid Adipic acid Lactic acid Itaconic acid Acetic acid Citric acid Lauric acid Sebacic acid Formic acid Levulinic acid 2,5-Furandicarboxylic acid (FDCA) Acrylic acid 3-hydroxypropionic acid (3-HPA) Glutamic acid Terephthalic acid Furfural Methacrylic acid Methyl methacrylate Other (please specify)		

For other, please specify:	

If a product or products is not included in this list, please contact Lucy.Nattrass@e4tech.com

Continue survey; go to **Alcohols**

11. Alcohols

***Q6. Does your company currently produce bio-based alcohols, or expect to produce any by 2020?**

ANSWER: YES – continue survey; go to **Alcohols (2)**

ANSWER: NO – continue survey; go to **Polymers**

12. Alcohols (2)

***Q7. Please select all the bio-based alcohols which your company currently produces, and those which it expects to produce by 2020.**

If the product is both currently produced and expected to be produced in 2020, please select both columns.

ANSWER: Tick all that apply

	Currently produced	Expect to produce by 2020
n-butanol Isobutanol 1,4-Butanediol (BDO) 1,3-Propanediol (PDO) Propylene glycol Furfuryl alcohol Other (please specify)		

For other, please specify:	

If a product or products is not included in this list, please contact Lucy.Nattrass@e4tech.com

Continue survey; go to **Polymers**

13. Polymers

***Q8. Does your company currently produce bio-based polymers, or expect to produce any by 2020?**

ANSWER: YES – continue survey; go to **Polymers (2)**

ANSWER: NO – continue survey; go to **Composite materials**

14. Polymers (2)

***Q9-10. Please select all the bio-based polymers which your company currently produces, and those which it expects to produce by 2020.**

If the product is both currently produced and expected to be produced in 2020, please select both columns.

ANSWER: Tick all that apply

	Currently produced	Expect to produce by 2020
Q9. Derived from natural polymers Cellulose ester, inc. cellulose acetates Cellulose ether Starch polymers, inc. composites Other (please specify) **Q10. Derived from monomers** Polyhydroyalkanoates (PHAs), inc. PHB Polyamides Polyurethane (PUR) Polylactic acid (PLA) Polyethylene furanoate (PEF) Polybutylene succinate (PBS) Polycarbonates (PC) Polymethyl methacrylate (PMMA) Polybutadiene (PBD) Polybutyrate (PBAT) Polybutylene terephthalate (PBT) Polyethylene (PE) Polyvinyl chloride (PVC) Polyvinyl acetate (PVA) Polystyrene (PS) Polypropylene (PP) Polyethylene glycol (PEG) Polyethylene terephthalate (PET) Other (please specify)		

For other, please specify:	

If a product or products is not included in this list, please contact Lucy.Nattrass@e4tech.com

Continue survey; go to **Composite materials**

15. Composite materials

***Q11. Does your company currently produce bio-based composite materials, or expect to produce any by 2020?**

ANSWER: YES – continue survey; go to **Composite materials (2)**

ANSWER: NO – continue survey; go to **Other bio-based products**

16. Composite materials (2)

***Q12. Please select all the bio-based composite materials which your company currently produces, and those which it expects to produce by 2020.**

If the product is both currently produced and expected to be produced in 2020, please select both columns.

ANSWER: Tick all that apply

	Currently produced	Expect to produce by 2020
Wood-plastic composites (WPC) Cork reinforced plastics Other natural fibre reinforced plastics Other (please specify)		

For other, please specify:	

If a product or products is not included in this list, please contact Lucy.Nattrass@e4tech.com

Continue survey; go to **Other bio-based products**

17. Other bio-based products

***Q13. Does your company currently produce any other bio-based products, or expect to produce any by 2020?**

ANSWER: YES – continue survey; go to **Other bio-based products (2)**

ANSWER: NO – continue survey; go to **Company information**

18. Other bio-based products (2)

Q14-20. Please select all the other bio-based products which your company currently produces, and those which it expects to produce by 2020.

If the product is both currently produced and expected to be produced in 2020, please select both columns.

ANSWER: Tick all that apply

	Currently produced	Expect to produce by 2020
Q14. Surfactants Fatty alcohol ethoxylates/ethers Fatty alcohol ether sulfates Fatty alcohol sulfates Ester quats Alkyl polyglucosides Lipopeptides and digopeptites Glycolipids, inc. sophorolipids Polymeric surfactants Other (please specify)		
Q15. Solvents Other (please specify)		
Q16. Binders Other (please specify)		
Q17. Plasticisers Phthalate esters Other (please specify)		
Q18. Paints/coatings Paint additives Printing colours Other (please specify)		
Q19. Lubricants Mould release agents Chain & bearing lubricants Hydraulic fluids Other (please specify)		
Q20. Others Hydroxymethyl-furfural (HMF) Epichlorohydrin Isoprene Isosorbide Farnesene Fatty amines Ethylene Acetone Ethylene glycol Para-xylene Other (please specify)		

For other, please specify:	

If a product or products is not included in this list, please contact Lucy.Nattrass@e4tech.com

Continue survey; go to **Company information**

19. Company information

Q21. What is the ownership structure of your company?

- Public limited liability company
- Private limited liability company
- Other
- If other, please specify

ANSWER: tick the most appropriate definition

Q22. Is your company a subsidiary of a larger company?

- YES
- NO
- If YES, please specify the parent company name.

ANSWER: tick the most appropriate definition

Q23. Is your company a joint venture?

- YES
- NO
- If YES, please specify joint venture company name(s).

ANSWER: tick the most appropriate definition

Continue survey; go to **Production facilities in EU Member States**

20. Production facilities in EU Member States

***Q24. Does your company have bio-based production facilities in the EU?**

ANSWER: YES – continue survey; go to **Production facilities in EU Member States (2)**

ANSWER: NO – continue survey; go to **Production facilities outside the EU.**

21. Production facilities in EU Member States (2)

Q25-26: Please provide details of your company's bio-based production facilities in the EU;

- Status
- Location (Member State)
- Location (Region / town)

Please use one row per facility. When you have included all EU facilities, you can leave remaining rows blank.

ANSWER: Insert information

	Q25(a). Status	Q25(b). Country	Q26. Region/town
1	e.g. Pilot	e.g. Austria	
2	e.g. Demonstration	e.g. Belgium	
3	e.g. Commercial (active)	e.g. Bulgaria	
4	e.g. Commercial (dormant)	e.g. Croatia	
5			
6			
7			
8			
9			
10			

If your company has more than 10 production facilities in the EU, please contact clifford.biggs@ceasc.com

Continue survey; go to **Production facilities in EU Member States (3)**

22. Production facilities in EU Member States (3)

Q27. What were the key reasons for selecting the location of the facilities listed above?

ANSWER: tick all that apply

Factors	Tick if applicable
Policy and regulation (e.g. policies to promote the use of bio-based products or industrial development, environmental regulations, etc.)	
Financial support (e.g. availability of production subsidies, market incentives and/or capital grants, etc.)	
Project financing (e.g. availability and/or terms of project finance)	
Proximity to customer demand (e.g. business customer and/or final consumer)	
Feedstock availability	
Feedstock cost	
Other operational costs (e.g. energy, other consumables, wages, etc.)	
Proximity to R&D activities	
Proximity to existing commercial activity	
Proximity to skilled labour force	
Ease of siting (e.g. brownfield/greenfield site, planning requirements)	
Infrastructure (e.g. waste treatment infrastructure)	
Other (please specify)	

For other, please specify:	

Continue survey; go to **Production facilities outside the EU**

23. Production facilities outside the EU

***Q28. Does your company have bio-based production facilities outside the EU?**

ANSWER: YES – continue survey; go to **Production facilities outside the EU (2)**

ANSWER: NO – continue survey; go to **Industry associations**

24. Production facilities outside the EU (2)

Q29-30: Please provide details of your company's bio-based production facilities outside the EU;

- Status
- Location (Continent)
- Location (Country)

Please use one row per facility. When you have included all non-EU facilities, you can leave remaining rows blank.

ANSWER: Insert information

	Q29(a). Status	Q29(b). Continent	Q30. Country
1	e.g. Pilot	e.g. Other Europe (non-EU)	
2	e.g. Demonstration	e.g. North America	
3	e.g. Commercial (active)	e.g. South & Central America	
4	e.g. Commercial (dormant)	e.g. Asia	
5		e.g. Oceania	
6		e.g. Africa	
7			
8			
9			
10			

If your company has more than 10 production facilities outside the EU, please contact clifford.biggs@ceasc.com

Continue survey; go to **Production facilities outside the EU (3)**

25. Production facilities outside the EU (3)

Q31. What were the key reasons for selecting the location of the facilities listed above?

ANSWER: tick all that apply

Factors	Tick if applicable
Policy and regulation (e.g. policies to promote the use of bio-based products or industrial development, environmental regulations, etc.)	
Financial support (e.g. availability of production subsidies, market incentives and/or capital grants, etc.)	
Project financing (e.g. availability and/or terms of project finance)	
Proximity to customer demand (e.g. business customer and/or final consumer)	
Feedstock availability	
Feedstock cost	
Other operational costs (e.g. energy, other consumables, wages, etc.)	
Proximity to R&D activities	
Proximity to existing commercial activity	
Proximity to skilled labour force	
Ease of siting (e.g. brownfield/greenfield site, planning requirements)	
Infrastructure (e.g. waste treatment infrastructure)	
Other (please specify)	

For other, please specify:	

Continue survey; go to **Industry associations**

26. Industry associations

***Q32. Is your company a member of any chemical or bio-based industry association?**

ANSWER: YES – continue survey; go to **Industry associations (2)**

ANSWER: NO – continue survey; go to **Research and development**

27. Industry associations (2)

Q33-34: Is your company a member of any chemical or bio-based industry associations?

ANSWER: tick all that apply

Q33. EU Level Association

- AEBiom European Biomass Association
- APAG European Oleochemicals and Allied Products Group Plastics Europe
- BIC Bio-based Industries Consortium
- CEFIC European Chemical Industry Council
- CIRFS European Man-Made Fibres Association
- EB European Bioplastics
- EERA European Energy Research Alliance
- EFB European Federation of Biotechnology
- EFCC Federation for Construction Chemicals
- ERRMA European Renewable Resources and Materials Association
- EuropaBio European Association for Bio-industries
- PE Plastics Europe
- Other (please specify)

For other, please specify:	

Q34. Member State level (Member State mentioned first)

- **AT** FCIO Fachverband der Chemischen Industrie Österreichs
- **BE** Essenscia Belgian Federation for Chemistry and Life Sciences Industries
- **BE** VALBIOM Valorisation de la Biomasse asbl.
- **BG** BKTDCP Branshova Kamara Turgovskite Drujestva Chimicheskata Promishlenost
- **HR** UKI Udruzenje Kemijske Industrije
- **CZ** SCHP Association of Chemical Industry of the Czech Republic
- **DK** PI Procesindustrien
- **EE** EKL Eesti Keemiatoostuse Liit

- **FI** KT RY Kemianteollisuus ry
- **FR** ACDV Association Chimie du Végétal
- **FR** ADEME Agence de l'Environnement et de la Maîtrise de l'Energie
- **FR** UIC Union des Industries Chimiques
- **DE** DIB Deutsche Industrievereinigung Biotechnologie
- **DE** FNR Fachagentur Nachwachsende Rohstoffe e.V.
- **DE** VCI Verband der Chemischen Industrie e.V.
- **EL** HACI Hellenic Association of Chemical Industries
- **HU** MAVESZ Hungarian Chemical Industry Association
- **IE** IPCMF PharmaChemical Ireland
- **IT** FEDERCHIMICA Federazione Nazionale dell'Industria Chimica
- **IT** INNOVHUB Stazioni Sperimentali per l'industria
- **LV** LKUFUA Latvijas Kimijas Un Farmacijas Uznemeju Asociacija
- **LT** LCPIA Lietuvos Chemijos Pramones Imoniu Asociacija
- **NL** VNCI Vereniging van de Nederlandse Chemische Industrie
- **PL** PIPC Polish Chamber of Chemical Industry
- **PT** APEQ Associação Portuguesa das Empresas Químicas
- **RO** APDCR Romanian Chemicals Producers and Distributors Association
- **SK** ZCHFP Zväz chemického a farmaceutického priemyslu Slovenskej republiky
- **SI** GZS Chamber of Commerce and Industry of Slovenia Dimiceva
- **ES** FEIQUE Federacion Empresarial de la Industria Quimica Espanola
- **SE** IKEM Innovation and Chemical Industries in Sweden
- **UK** CIA Chemical Industries Association
- Other (please specify)

For other, please specify:	

Continue survey; go to **Research and development**

28. Research and development

***Q35. Does your company carry out R&D activities for bio-based products <u>in the EU</u>?**

ANSWER: YES

ANSWER: NO

Continue survey; go to **Research and development (2)**

29. Research and development (2)

***Q36. Does your company carry out R&D activities for bio-based products <u>outside the EU</u>?**

ANSWER: YES – continue survey; go to **Research and development (3)**

ANSWER: NO – continue survey; go to **Drivers for development**

30. Research and development (3)

Q37. In which regions <u>outside the EU</u> does your company have R&D activities for bio-based products?

- Other Europe (non-EU)
- North America
- South & Central America
- Asia
- Oceania
- Africa

ANSWER: tick all that apply.

Continue survey; go to **Drivers for development**

31. Drivers for development

Q38. From the list, please indicate the importance of the following DRIVERS for the development of bio-based products by your company.

ANSWER: tick the relative importance of each driver

		not important at all	not very important	neutral	important	very important
1	Improved profitability					
2	Improved product competitiveness					
3	Improved environmental performance					
4	Improved product properties or performance					
5	Potential for the development of innovative products with improved properties or performance					
6	Product diversification					
7	Market demand increase					
8	Sales growth potential					
9	Potential to increase market share					
10	Contribution toward company sustainability goals					
11	Production related to current competencies					
12	Availability of public funding					
13	Policies relating to bio-based products					
14	Other (please specify)					

For other, please specify:	

Continue survey; go to **Drivers for development (2)**

32. Drivers for development (2)

Q39. From the list, please indicate the 3 (THREE) MOST IMPORTANT DRIVERS for development of bio-based products by your company

- Improved profitability
- Improved product competitiveness
- Improved environmental performance
- Improved product properties or performance
- Potential for the development of innovative products with improved properties or performance
- Product diversification
- Market demand increase
- Sales growth potential
- Potential to increase market share
- Contribution toward company sustainability goals
- Production related to current competencies
- Availability of public funding
- Policies relating to bio-based products
- Other (please specify)

ANSWER: tick the three (3) most important

For other, please specify:	

Continue survey; go to **Constraints on development**

33. Constraints on development

Q40. From the list, please indicate the importance of the following CONSTRAINTS on the development of bio-based products by your company

ANSWER: tick the relative importance of each driver

		not important at all	not very important	neutral	important	very important
1	Higher production costs compared to existing fossil based alternatives					
2	Increased capital costs					
3	Increased or variable feedstock costs					
4	Increase energy demand and/or cost					
5	Other operational costs					
6	Availability of funds to invest in production capacity					
7	Availability of funds for necessary R&D					
8	Technology maturity or risk associated with new process development					
9	Existing patents of competitors, or other restrictions relating to existing IP					
10	Product properties or performance					
11	Barriers to achieving product certification					
12	Other (please specify)					

For other, please specify:	

Continue survey; go to **Constraints on development (2)**

34. Constraints on development (2)

Q41. From the list, please indicate the 3 (THREE) MOST IMPORTANT CONSTRAINTS on the development of bio-based products by your company

- Higher production costs compared to existing fossil based alternatives
- Increased capital costs
- Increased or variable feedstock costs
- Increase energy demand and/or cost
- Other operational costs
- Availability of funds to invest in production capacity
- Availability of funds for necessary R&D
- Technology maturity or risk associated with new process development
- Existing patents of competitors, or other restrictions relating to existing IP
- Product properties or performance
- Barriers to achieving product certification
- Other (please specify)

ANSWER: tick the three (3) most important

For other, please specify:	

Continue survey; go to **EU employees**

35. EU employees

Q42. What was the total number of employees in your company in the EU?

ANSWER: insert information

Year	Insert number of employees
2010	
2011	
2012	
2013	

Q43. What share (%) was employed in bio-based activities in the EU?

ANSWER: insert information

Year	Insert % employed in bio-based activities
2010	
2011	
2012	
2013	

Q44. What share (%) was involved in R&D activities related to bio-based products in the EU?

ANSWER: insert information

Year	Insert % employed in bio-based R&D
2010	
2011	
2012	

2013	

Continue survey; go to **Production**

36. Production

Q45. What types of processes does your company use for the production of bio-based products in the EU?

ANSWER: tick all that apply

Fermentation	Enzymatic	Catalytic	Other (please specify)

For other, please specify:	

Q46. What was your company's total annual output (in tonnes) of bio-based products in the EU?

ANSWER: insert information

Year	Insert quantity in tonnes
2010	
2011	
2012	
2013	

Q47. What share (%) of EU bio-based product output was sold in the EU?

Year	Insert %
2010	
2011	

2012	
2013	

Q48. How is the share (%) of bio-based product output sold <u>in the EU</u> expected to change by 2020?

ANSWER: tick the most applicable

increase >100%	increase <100%	No change	Decrease	Decrease to zero

Continue survey; go to **Feedstock**

37. Feedstock

Q49-55: What type(s) of feedstock does your company use to produce bio-based products <u>in the EU</u>?

ANSWER: tick all that apply

Feedstock	2010	2011	2012	2013
Q49. Fibres				
Chemical pulp Cork Cotton fibre Flax / Hemp Jute / Kenaf Wood Other fibre (please specify)				
Q50. Sugars				
Sugar beet Sugar cane Other sugar (please specify)				
Q51. Starch				
Cassava Maize / Corn Potato				

Wheat Other starch (please specify)				
Q52. Vegetable oils				
Coconut oil Linseed oil Palm oil Rapeseed oil Soybean oil Other vegetable oil (please specify)				
Q53. Residues				
Agricultural residues Animal fat Animal proteins Other residues (please specify)				
Q54. Alcohols				
Bio-ethanol Bio-methanol Glycerol Other alcohols (please specify)				
Q55. Other (please specify)				
Other (please specify)				

For other, please specify:	

Continue survey; go to **Feedstock (2)**

38. Feedstock (2)

Q56. What share (%) of bio-based feedstock is sourced from <u>within the EU</u> (i.e. feedstock of EU origin)?

ANSWER: insert information

Year	Insert % sourced from the EU
2010	
2011	
2012	
2013	

Q57. What is the share (%) of bio-based feedstock in total feedstock use for producing bio-based products in the EU?

ANSWER: insert information

Year	Insert % bio-based feedstock in total
2010	
2011	
2012	
2013	

Q58. How is the contribution of bio-based feedstock to total feedstock use likely to change by 2020?

ANSWER: tick the most applicable

increase >100%	increase <100%	No change	Decrease	Decrease to zero

Continue survey; go to **Sales turnover**

39. Sales turnover

Q59. What was your company's total sales turnover of bio-based products worldwide?

ANSWER: insert information

Year	Insert turnover in Euros
2010	
2011	
2012	
2013	

Q60. How is total sales turnover of bio-based products worldwide expected to change by 2020?

ANSWER: tick the most applicable

increase >100%	increase <100%	No change	Decrease	Decrease to zero

Continue survey; go to **Sales turnover (2)**

40. Sales turnover (2)

Q61: What was your company's total sales turnover in the EU (i.e. fossil-based and bio-based products)?

ANSWER: insert information

Year	Insert turnover in Euros
2010	
2011	
2012	
2013	

Q62. What was your company's total sales turnover of bio-based products in the EU?

ANSWER: insert information

Year	Insert turnover in Euros
2010	
2011	
2012	
2013	

Q63. How is total sales turnover of bio-based products in the EU expected to change by 2020?

ANSWER: tick the most applicable

increase >100%	increase <100%	No change	Decrease	Decrease to zero

Continue survey; go to **Costs**

41. Costs

Q64-67. What was the approximate contribution (%) of each of the following categories to production costs for bio-based products produced <u>in the EU</u>?

ANSWER: insert information

Q64. 2010	
Feedstock	
Labour	
Utilities	
Other OPEX	
R&D	
CAPEX	
Total	100%

Q65. 2011	
Feedstock	
Labour	
Utilities	
Other OPEX	
R&D	
CAPEX	
Total	100%

Q66. 2012	
Feedstock	
Labour	
Utilities	
Other OPEX	
R&D	
CAPEX	
Total	100%

Q67. 2013	
Feedstock	
Labour	
Utilities	
Other OPEX	
R&D	
CAPEX	
Total	100%

Continue survey; go to **Public funding**

42. Public funding

***Q68. Has your company received public funding since 2010?**

ANSWER: YES – continue survey; go to **Public funding (2)**

ANSWER: NO – **Exit survey.**

43. Public funding (2)

Q69. What was the total value (in Euros) of public funding received?

ANSWER: insert information

Year	Insert funding value in Euros
2010	
2011	
2012	
2013	

Q70. What was the name(s) of the programme from which public funding was received?

ANSWER: insert information

Year	Insert name of funding programme
2010	
2011	
2012	
2013	

Q71. Was the public funding programme from which funds were received part of an 'EU Framework Programe'?

ANSWER: insert information

Year	Select option
2010	YES / NO / Don't know
2011	YES / NO / Don't know

2012	YES / NO / Don’t know
2013	YES / NO / Don’t know

End of survey

Annex III: Detailed answers

This section presents an analysis of the data submitted in response to the survey questions.

1. Bio-based products

Q4, Q6, Q8, Q11 and Q13. Does your company currently produce bio-based organic acids (Q4.), alcohols (Q6.), polymers (Q8.), composite materials (Q11.) or other (Q13.), or expect to produce any by 2020?

Figure A25 shows the number of companies which either currently produce and/or expect to produce bio-based products by 2020. The results are summarised as follows:

- (Q4.) 26 companies (52.0%) currently and/or expect to produce organic acids;
- (Q6.) 19 companies (38.0%) currently and/or expect to produce bio-based alcohols;
- (Q8.) 27 companies (54.0%) currently and/or expect to produce bio-based polymers;
- (Q11.) 14 companies (28.0%) currently and/or expect to produce bio-based composite materials;
- (Q13.) 37 companies (74.0%) currently produce or expect to produce other bio-based products. This category is further disaggregated by subsequent questions into the following sub-categories:
    - (Q14.) 14 companies (28%) currently and/or expect to produce surfactants;
    - (Q15.) 4 companies (8%) currently and/or expect to produce solvents;
    - (Q16.) 7 companies (14%) currently and/or expect to produce binders;
    - (Q17.) 6 companies (12%) currently and/or expect to produce plasticisers;
    - (Q18.) 11 companies (22%) currently and/or expect to produce paints/coatings;
    - (Q19.) 9 companies (18%) currently and/or expect to produce lubricants;
    - (Q20.) 24 companies (48%) currently and/or expect to produce other bio-based products (note for further details of specific products currently produced, please refer to the analysis of responses to Q20 below).

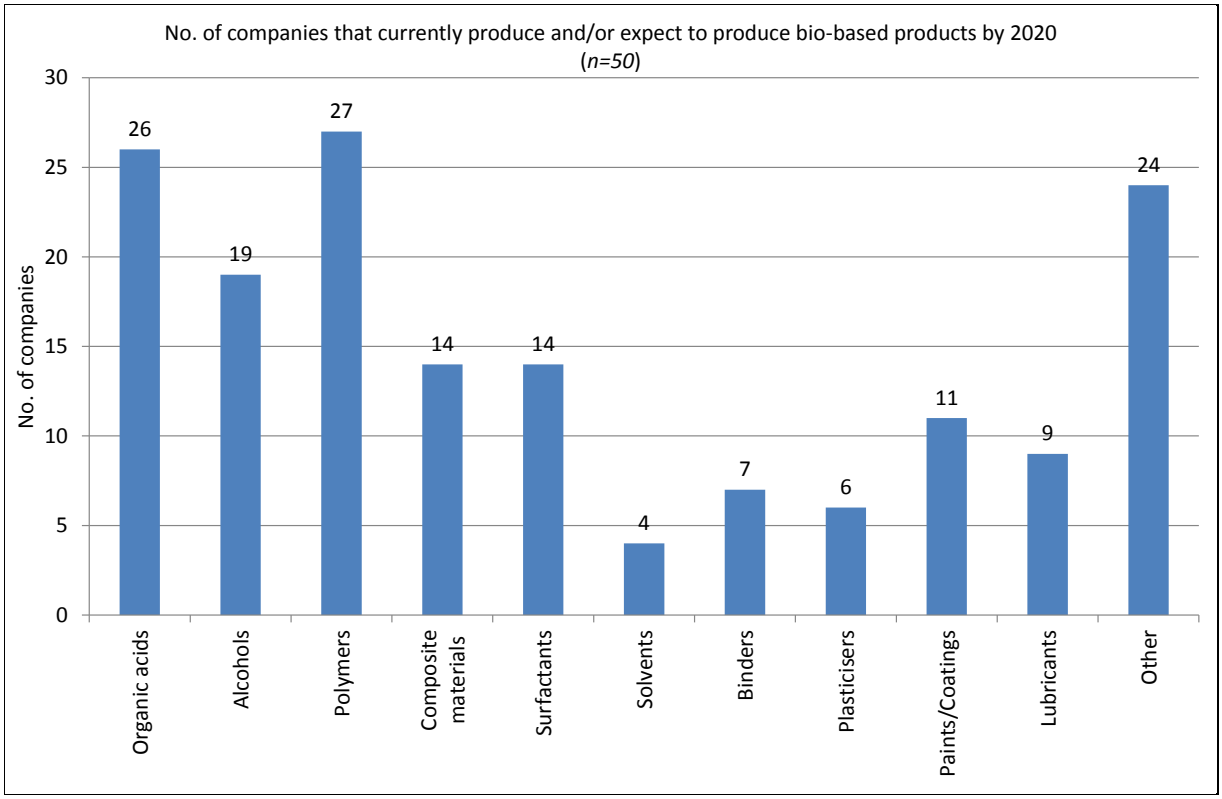


Figure A25: Number of companies that currently produce and/or expect to produce bio-based products by 2020

Source: EU bio-based industries survey.

Q5. Please select all the bio-based organic acids which your company currently produces, and those which it expects to produce by 2020. If the product is both currently produced and expected to be produced in 2020, please select both columns.

26 companies indicated that they current produce or expect to produce **organic acids** by 2020. Figure A26 ranks the type of organic acids that are currently produced or are expected to be produced by 2020. Of this total, 23 companies either currently produce and/or expect to produce fatty acids of various types, of which stearic (5 companies), oleic (4 companies) and palmitic (3 companies) acids are ranked as the three highest in terms of the number of companies indicating current or expected production. In terms of individual products, as illustrated in the chart below, succinic acid (6 companies) is ranked highest in terms of the number of companies indicating current or expected production; followed by 2,5-furandicarboxylic acid (FDCA) and stearic acid (5 companies each); levulinic acid and oleic acid (4 companies each).

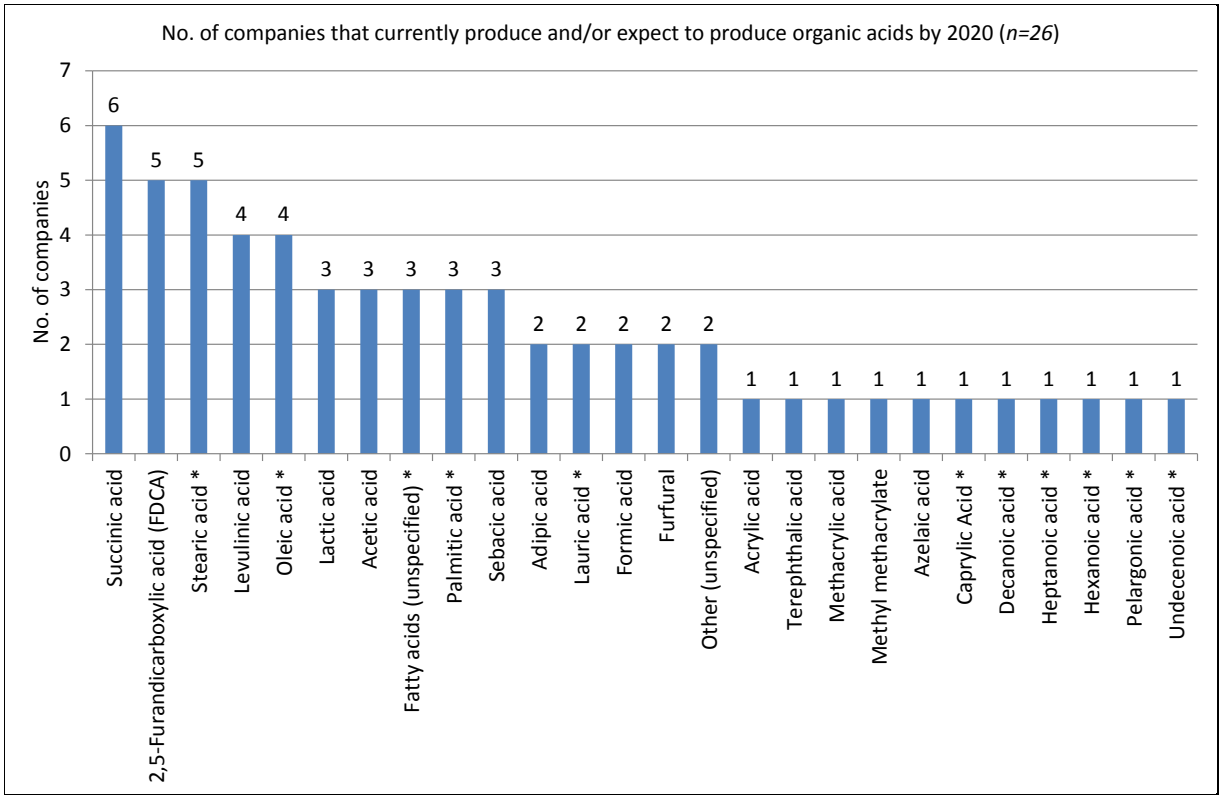


Figure A26: Number of companies that currently produce and/or expect to produce organic acids by 2020

Note: * indicates types of fatty acids (23 companies in total).

Source: EU bio-based industries survey.

Figure A27 shows the expected change in the number of companies currently producing different types of organic acids compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing succinic acid, adipic acid, levulinic acid, 2,5-Furandicarboxylic acid (FDCA), acrylic acid, terephthalic acid, furfural acid and methacrylic acid;
- **no change** in the number of companies producing formic acid and methyl methacrylate; and
- a **decrease** in the number of companies producing lactic acid, acetic acid, lauric acid and sebacic acid.

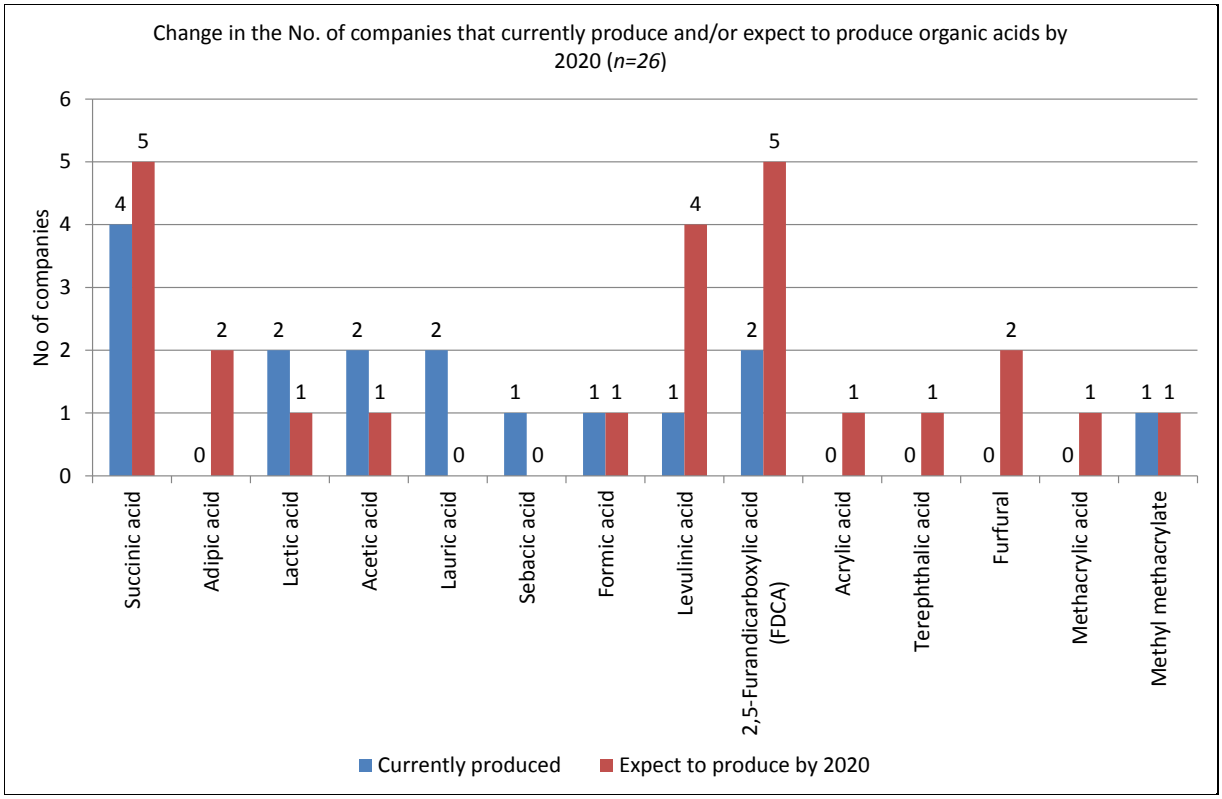


Figure A27: Change in the number of companies that currently produce and/or expect to produce organic acids by 2020

Source: EU bio-based industries survey.

Q7. Please select all the bio-based alcohols which your company currently produces, and those which it expects to produce by 2020. If the product is both currently produced and expected to be produced in 2020, please select both columns.

In total 19 companies currently produce **bio-based alcohols** or expect to product by 2020. Figure A28 ranks the type of bio-based alcohols that are currently produced or are expected to be produced by 2020. Of the other top-5 ranked products, fatty alcohols (type unspecified) ranked highest in terms of the number of companies indicating current or expected production (4 companies); followed by n-butanol, 1,3-Propanediol (PDO) and Propylene glycol (3 companies each); and isobutanol and 1,4-Butanediol (BDO) (2 companies each). 4 companies indicated that they either currently produce and/or expect to produce 'other alcohols' but did not specify products.

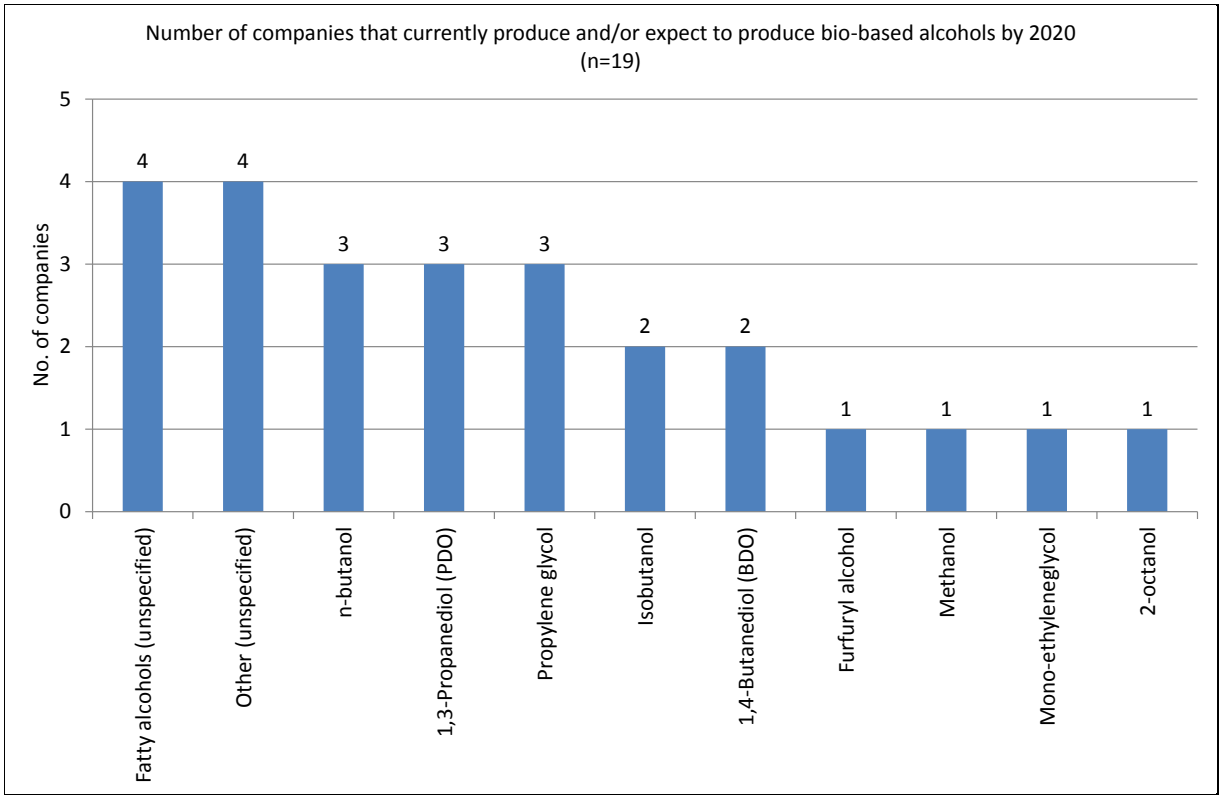


Figure A28: Number of companies that currently produce and/or expect to produce bio-based alcohols by 2020

Source: EU bio-based industries survey.

Figure A29 shows the expected change in the number of companies currently producing different types of bio-based alcohols compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest the number of companies producing all types of bio-based alcohols listed is expected to increase by 2020.

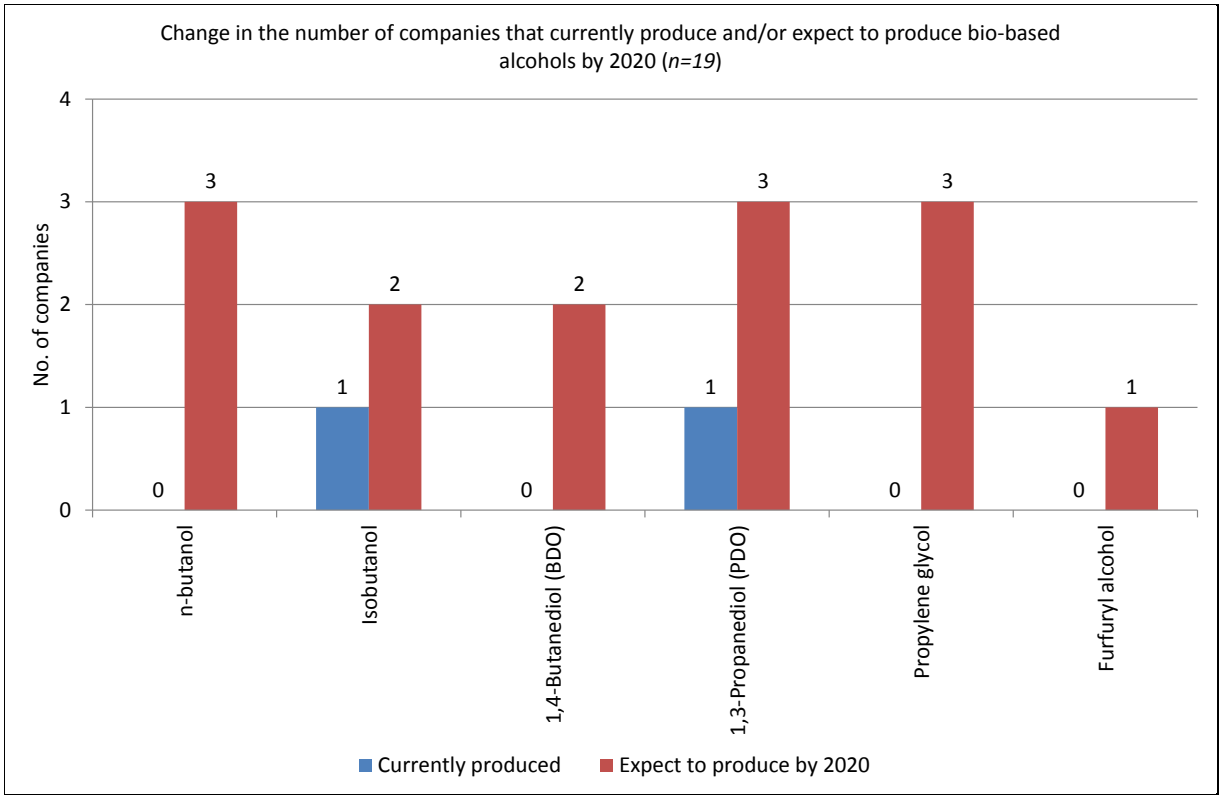


Figure A29: Change in the number of companies that currently produce and/or expect to produce bio-based alcohols by 2020

Source: EU bio-based industries survey.

Q9. Does your company currently produce bio-based polymers, or expect to produce any by 2020? - Derived from natural polymers

In total 12 companies indicated that they currently produce polymers (derived from natural polymers) or expect to produce by 2020. Figure A30**Error! Reference source ot found.** ranks the type of bio-based polymers (derived from natural polymers) that are currently produced or are expected to be produced by 2020. As illustrated, the highest ranked product is starch polymers (inc. composites) (7 companies); followed by cellulose ether (2 companies); cellulose ester (inc. cellulose acetates) and micro fibrillated cellulose (1 company each). 6 companies indicated that they either currently produce and/or expect to produce 'other' polymers but did not specify products.

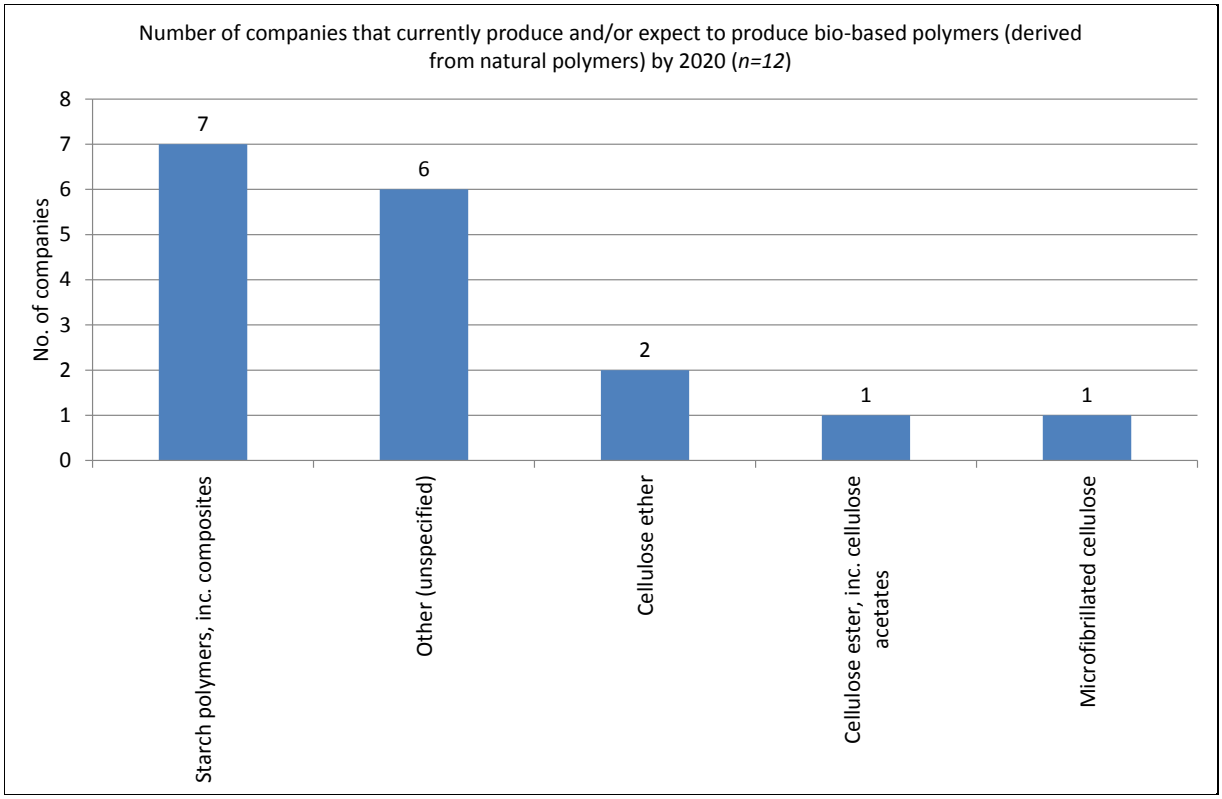


Figure A30: Number of companies that currently produce and/or expect to produce bio-based polymers (derived from natural polymers) by 2020

Source: EU bio-based industries survey.

Figure A31 shows the expected change in the number of companies currently producing different types of bio-based polymers (derived from natural polymers) compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing cellulose ether and starch polymers (inc. composites); while
- the number of companies producing cellulose ester (inc. cellulose acetates) is expected to **decrease**.

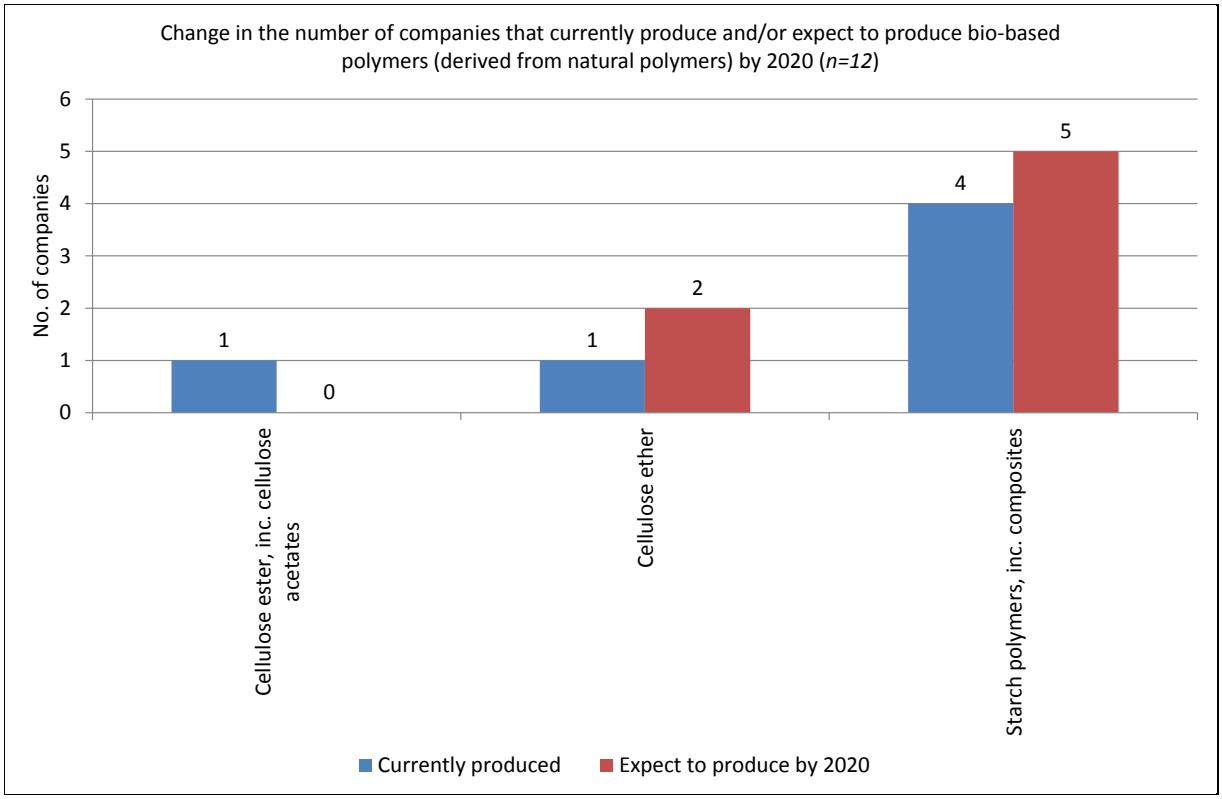


Figure A31: Change in the number of companies that currently produce and/or expect to produce bio-based polymers (derived from natural polymers) by 2020

Source: EU bio-based industries survey.

Q10. Does your company currently produce bio-based polymers, or expect to produce any by 2020? - Derived from monomers

In total 25 companies indicated that they currently produce **polymers (derived from monomers)** or expect to produce by 2020. Figure A32 ranks the type of bio-based polymers (derived from monomers) that are currently produced or are expected to be produced by 2020. Of the top-5 ranked products, 5 companies indicated that they produce or expect to produce polyhydroyalkanoates (PHAs) (inc. PHB), polyamides and polylactic acid (PLA); and 4 companies produce or expect to produce polybutylene succinate (PBS) and polyesters (inc. formulated polyesters, polyols and resins)..

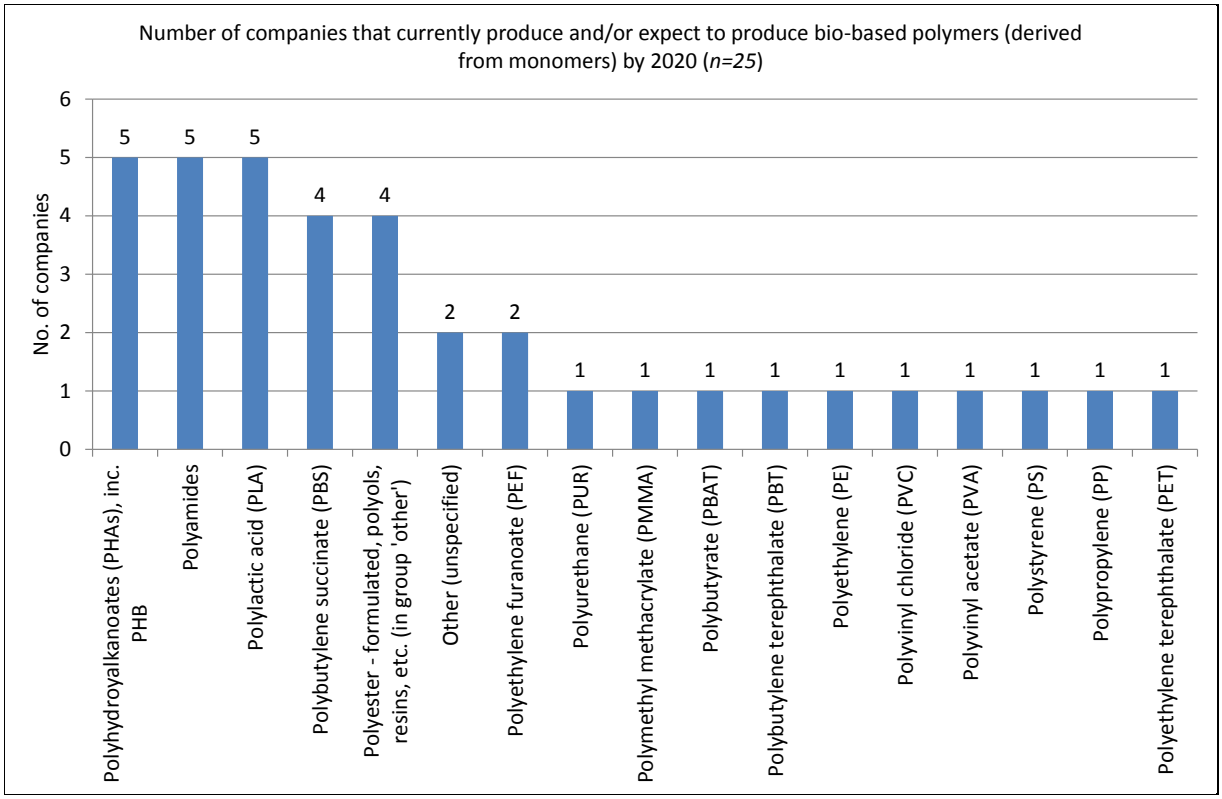


Figure A32: Number of companies that currently produce and/or expect to produce bio-based polymers (derived from monomers) by 2020

Source: EU bio-based industries survey.

Figure A33 shows the expected change in the number of companies currently producing different types of bio-based **polymers (derived from monomers)** compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing polyhydroyalkanoates (PHAs), inc. PHB, polyurethane (PUR), polylactic acid (PLA), polyethylene furanoate (PEF), polybutylene succinate (PBS), polybutyrate (PBAT), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP) and polyethylene terephthalate (PET);
- **no change** in the number of companies producing polycarbonates (PC), polymethyl methacrylate (PMMA), polybutadiene (PBD), polybutylene terephthalate (PBT), polystyrene (PS) and polyethylene glycol (PEG); and
- a **decrease** in the number of companies producing polyamides and polyvinyl acetate (PVA).

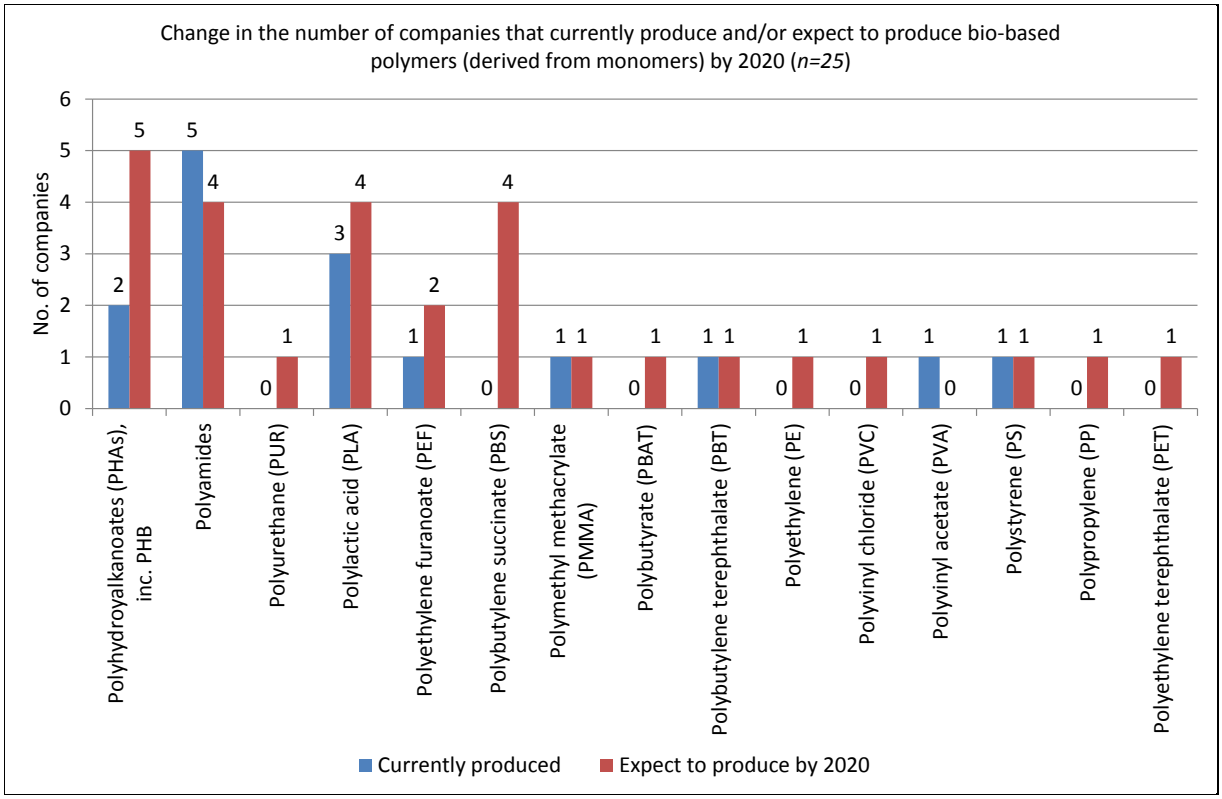


Figure A33: Change in the number of companies that currently produce and/or expect to produce bio-based polymers (derived from monomers) by 2020

Source: EU bio-based industries survey.

Q12. Please select all the bio-based composite materials which your company currently produces, and those which it expects to produce by 2020. If the product is both currently produced and expected to be produced in 2020, please select both columns.

In total 14 companies indicated that they currently produce bio-based **composite materials** or expect to produce by 2020. Figure A34 ranks the type of bio-based composite materials that are currently produced or are expected to be produced by 2020. As illustrated, the highest ranked product is other natural fibre reinforced plastics (8 companies); followed by wood-plastic composites (WPC) (6 companies); other composite materials (unspecified) (4 companies); and cork reinforced plastics (1 company).

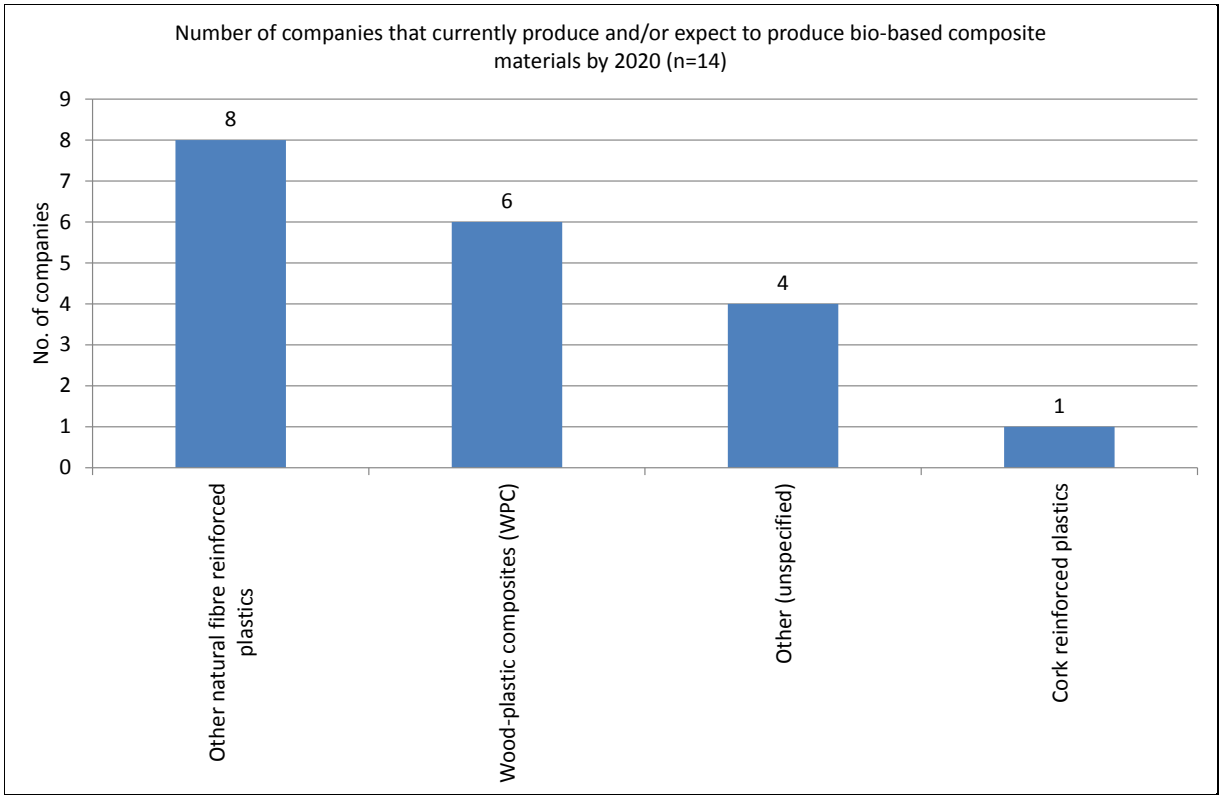


Figure A34: Number of companies that currently produce and/or expect to produce bio-based composite materials by 2020

Source: EU bio-based industries survey.

Figure A35 shows the expected change in the number of companies currently producing different types of bio-based **composite materials** compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing wood-plastic composites (WPC) and other natural fibre reinforced plastics;
- **no change** in the number of companies producing cork reinforced plastics; and
- a **decrease** in the number of companies producing other composite materials (unspecified).

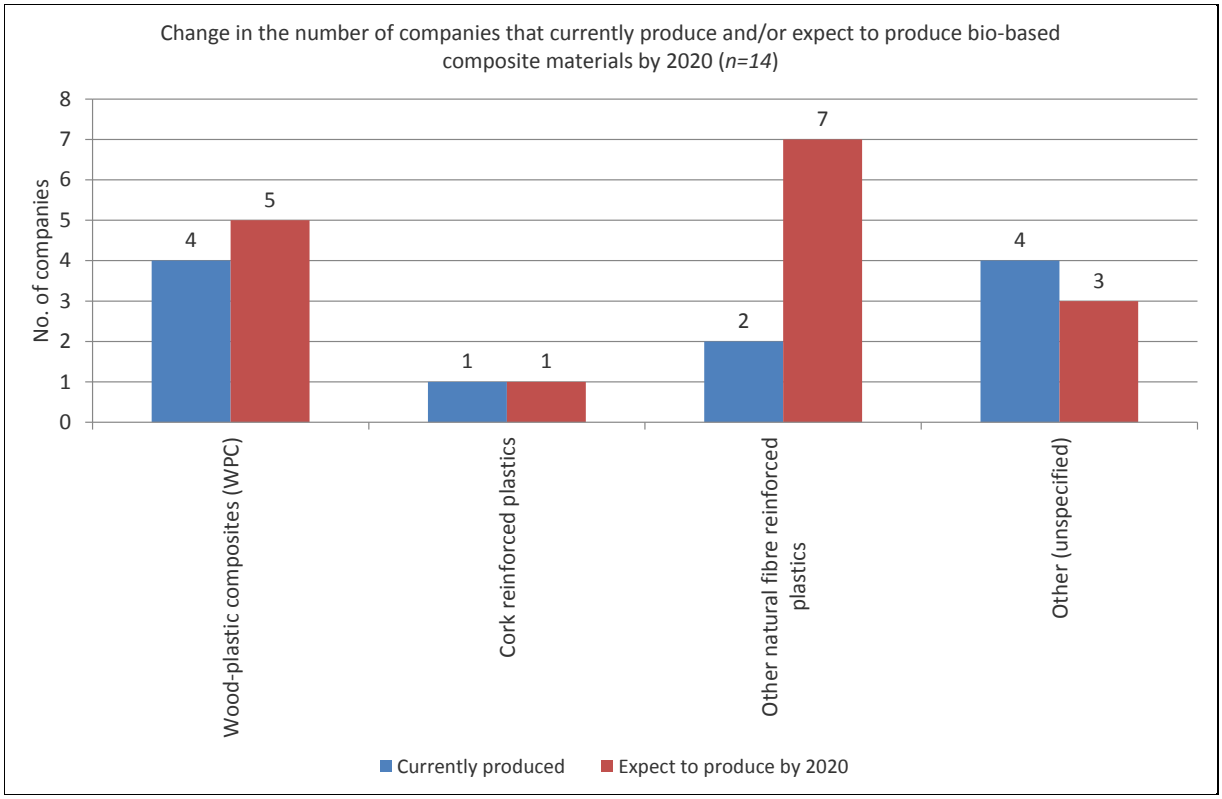


Figure A35: Change in the number of companies that currently produce and/or expect to produce bio-based composite materials by 2020

Source: EU bio-based industries survey.

Q14. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Surfactants

In total 14 companies indicated that they currently produce bio-based **surfactants** or expect to produce by 2020. Figure A36 ranks the type of bio-based surfactants that are currently produced or are expected to be produced by 2020. 9 companies indicated that they produce or expect to produce polymeric surfactants; and 5 companies produce or expect to produce fatty alcohol ethoxylates/ethers; 4 companies indicated that they produce or expect to produce ester quats; and 3 companies each indicated output of fatty alcohol ether sulphates, fatty alcohol sulphates and alkyl polyglucosides; while 2 companies each indicated output of glycolipids (inc. sophorolipids), amphoteric surfactants (betaines) and metallic soaps.

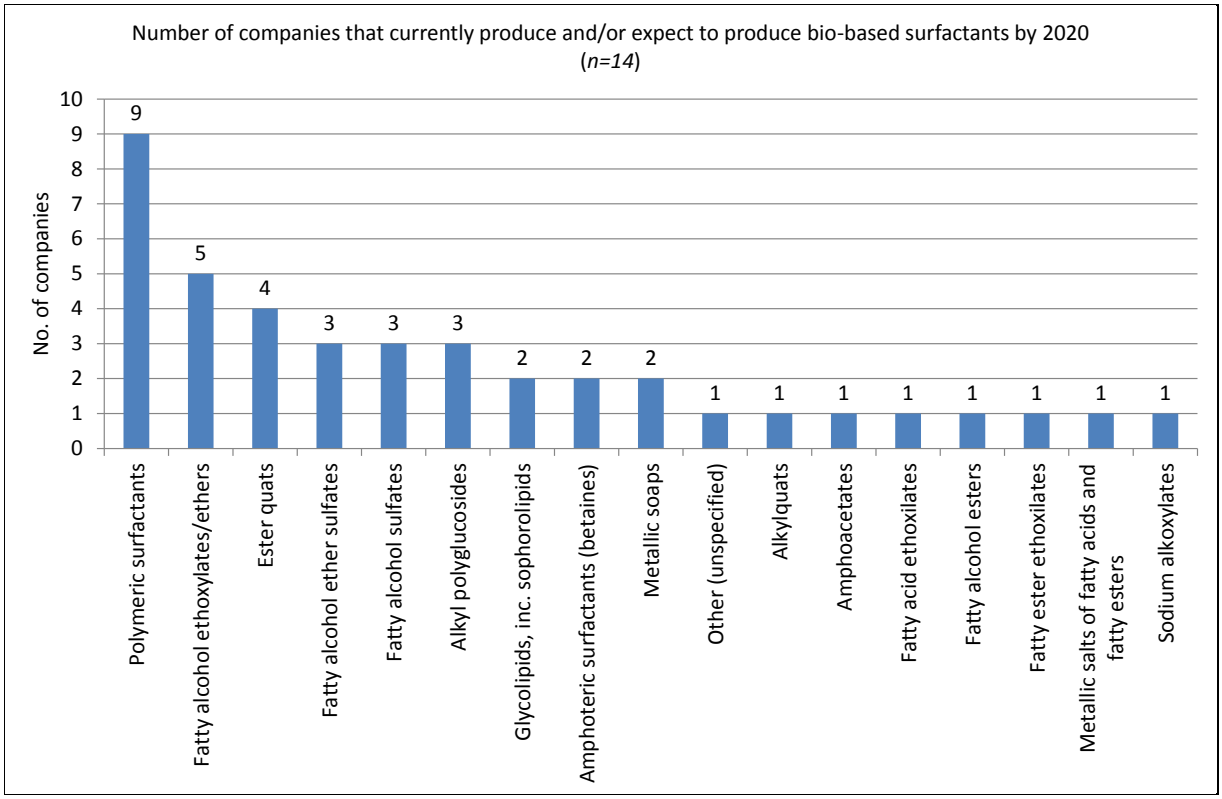


Figure A36: Number of companies that currently produce and/or expect to produce bio-based surfactants by 2020

Source: EU bio-based industries survey.

Figure A37 shows the expected change in the number of companies currently producing different types of bio-based **surfactants** compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing alkyl polyglucosides and glycolipids (inc. sophorolipids);
- **no change** in the number of companies producing lipopeptides, digopeptites and polymeric surfactants; and
- a **decrease** in the number of companies producing fatty alcohol ethoxylates/ethers, fatty alcohol ether sulphates, fatty alcohol sulphates, and ester quats.

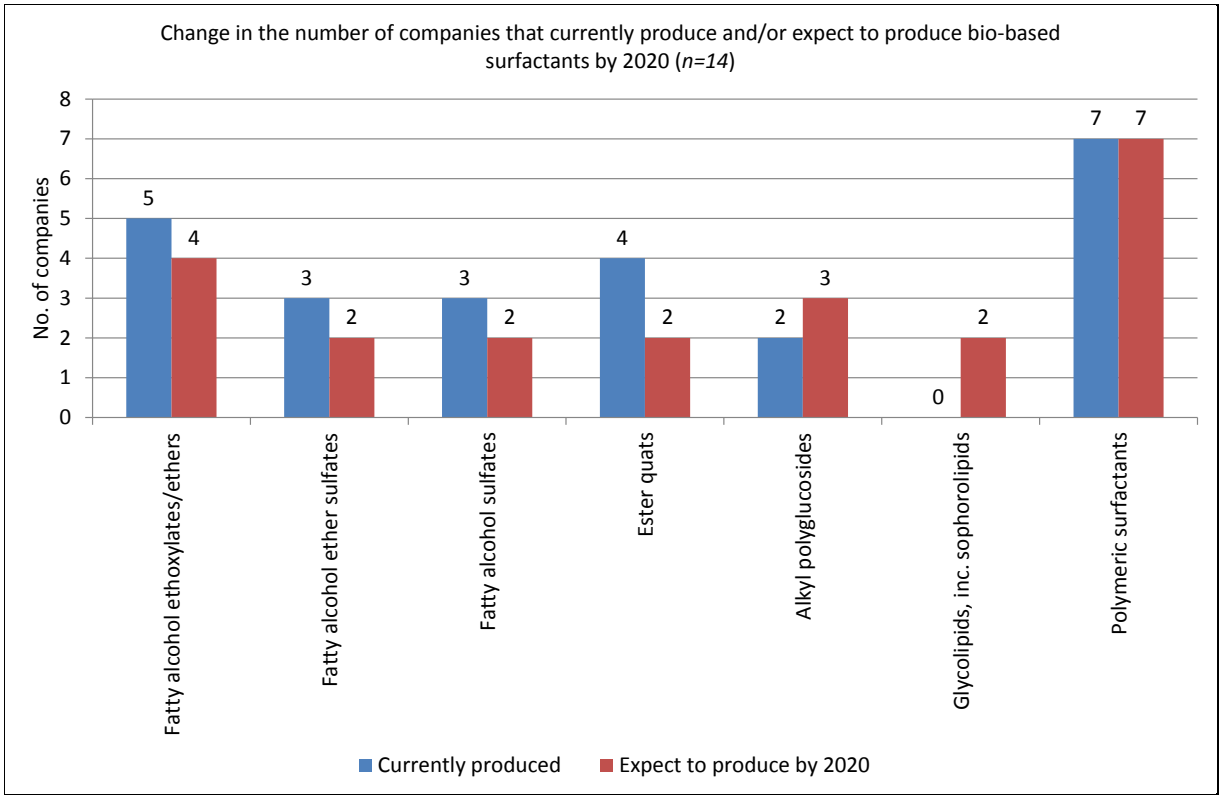


Figure A37: Change in the number of companies that currently produce and/or expect to produce bio-based surfactants by 2020

Source: EU bio-based industries survey.

Q15. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Solvents

1 company indicated that they currently produce or expect to produce methyl levulinate; while 3 companies indicated that they currently produce or expect to produce other (unspecified) **solvents**. The number of companies that expect to continue producing solvents in the future is expected to decrease. This question produced a small number of responses and therefore the results are not presented graphically.

Q16. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Binders

Figure A38 ranks the type of bio-based **binders** that are currently produced or are expected to be produced by 2020. As illustrated, 7 companies indicated that they produce or expect to produce binders, of which 2 companies each indicated output of adhesives and colloid binders; while 1 company each indicated output of pentaerytrithol and modified starches and sugar-based binders. The number of companies that expect to continue producing binders in 2020 is expected to decrease slightly.

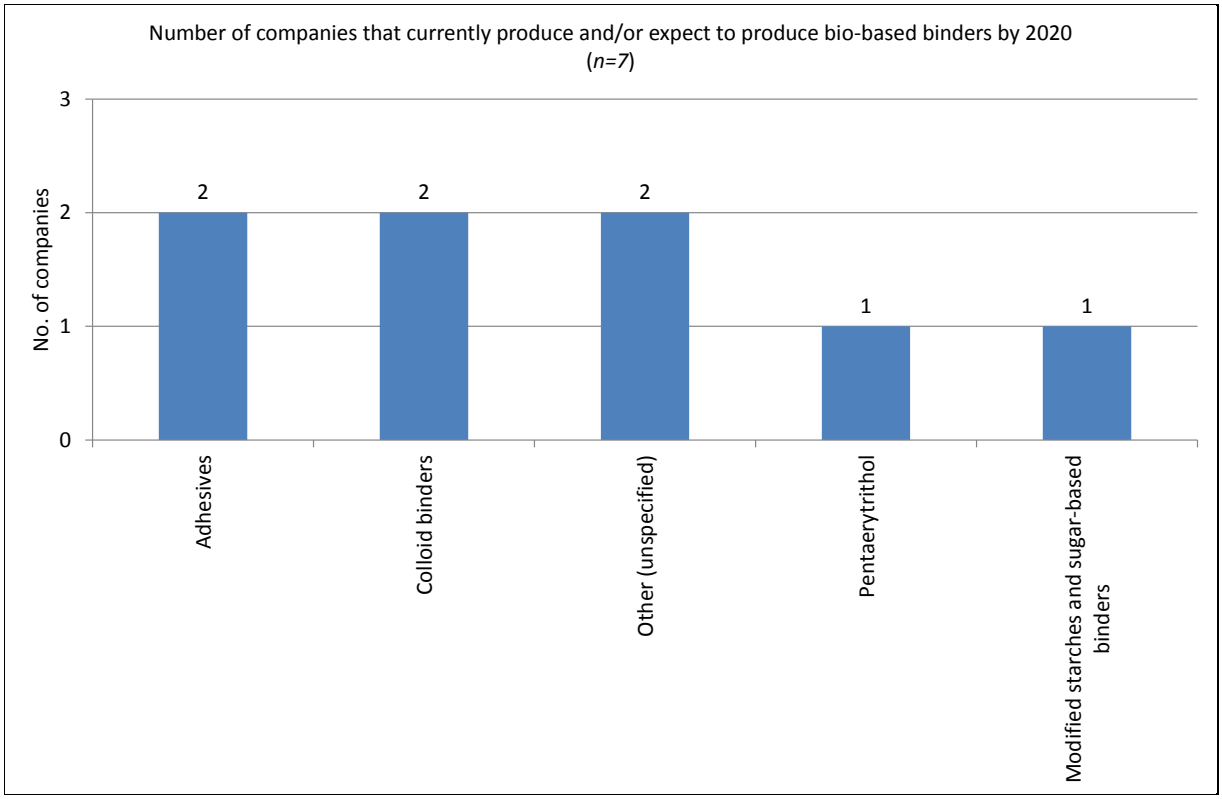


Figure A38: Number of companies that currently produce and/or expect to produce bio-based binders by 2020

Source: EU bio-based industries survey.

Q17. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Plasticisers

Figure A39 ranks the type of bio-based **plasticisers** that are currently produced or are expected to be produced by 2020. As illustrated, 6 companies indicated that they produce or expect to produce plasticisers, of which 1 company each specified phthalate esters, furanoate esters, epoxidized soya bean oil and, isosorbide diester. The number of companies that expect to continue producing binders in 2020 is expected to decrease.

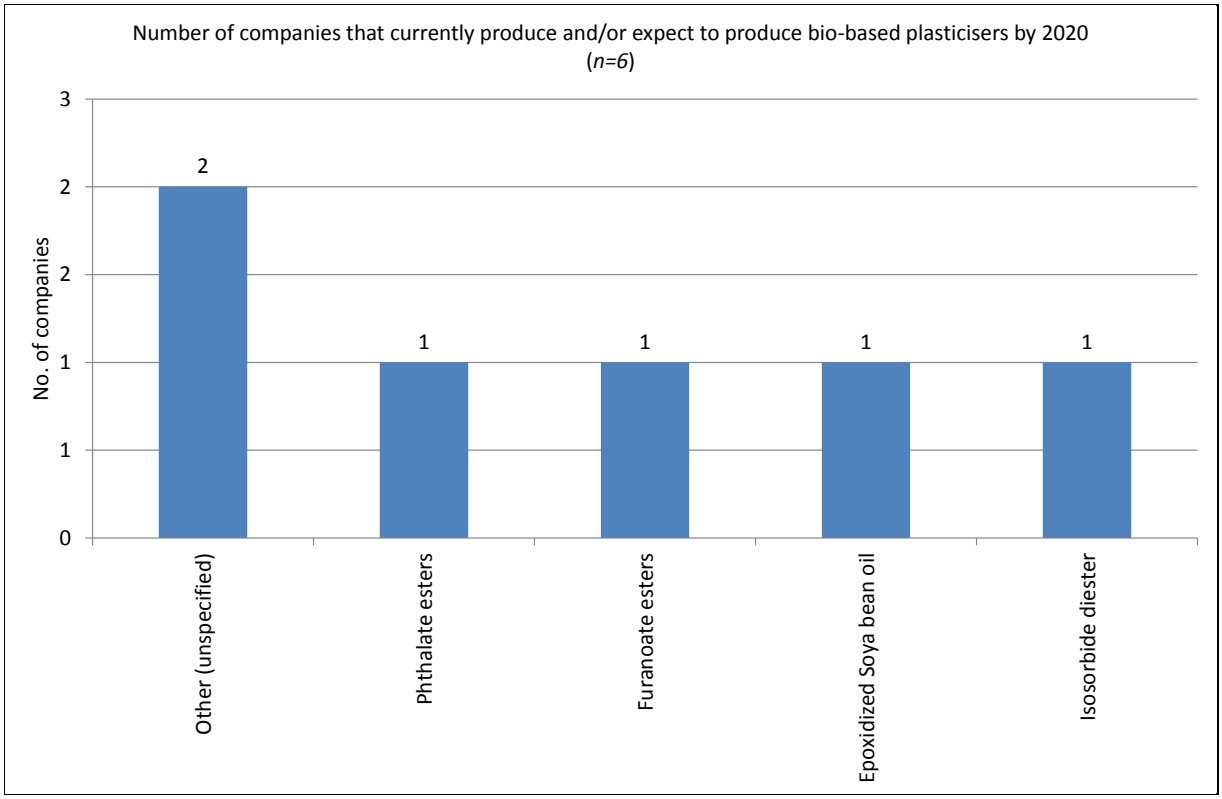


Figure A39: Number of companies that currently produce and/or expect to produce bio-based plasticisers by 2020

Source: EU bio-based industries survey.

Q18. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Paints/coatings

Figure A40 ranks the type of bio-based **paints/coatings** that are currently produced or are expected to be produced by 2020. As illustrated, 10 companies indicated that they produce or expect to produce paint additives; 2 companies produce or expect to produce resins (inc. alkyd resins); and 1 company each indicated output of printing colours, rheology additives and hybrid polymer coatings.

The number of companies that expect to continue producing printing colours is expected to increase; whereas the number of companies producing paint additives and other paints/coatings is not expected to change by 2020.

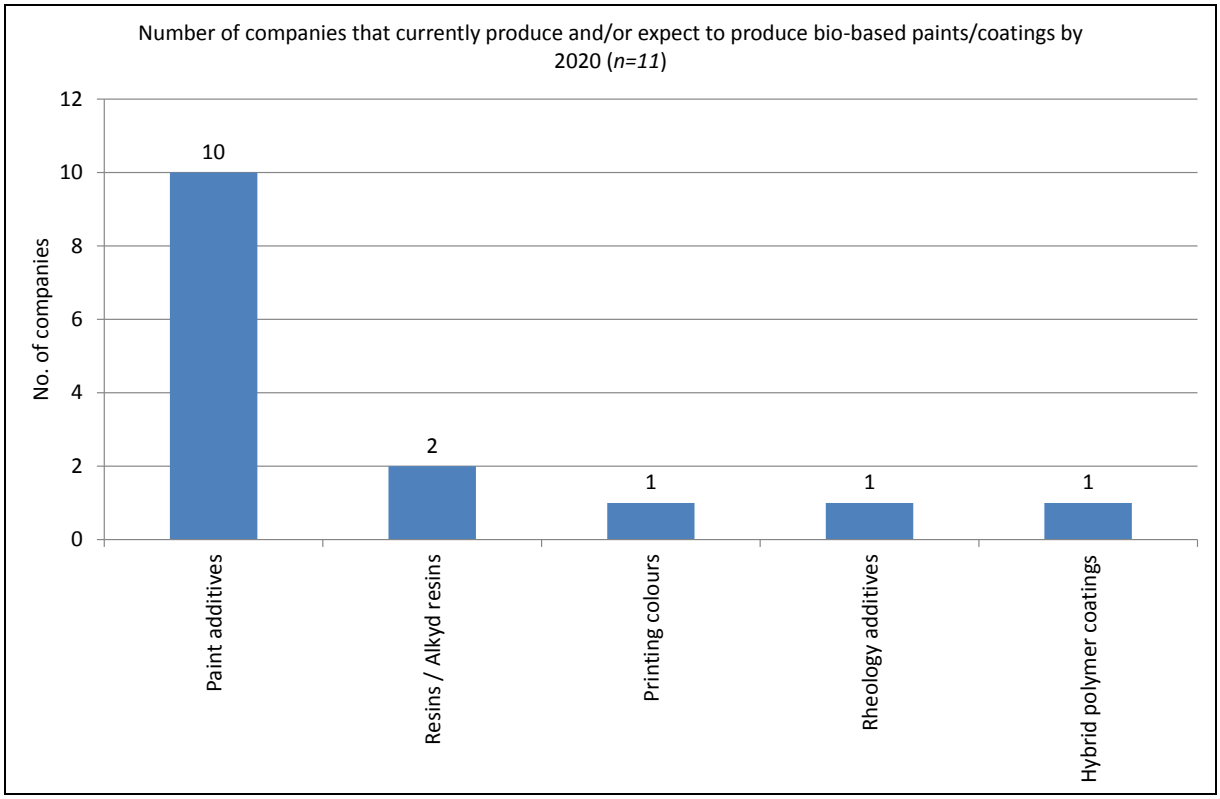


Figure A40: Number of companies that currently produce and/or expect to produce bio-based paints/coatings by 2020

Source: EU bio-based industries survey.

Q19. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Lubricants

Figure A41 ranks the type of bio-based **lubricants** that are currently produced or are expected to be produced by 2020. In total, 9 companies indicated that they produce or expect to produce lubricants, with 5 companies each indicating output of mould release agents and hydraulic fluids; and 4 companies indicating output of chain & bearing lubricants; 2 companies indicating output of additives / raw materials for lubricants; and 1 company each indicating output of metallic stearates and metal working fluids.

The number of companies that expect to continue producing mould release agents, chain & bearing lubricants and hydraulic fluids in 2020 is expected to decrease; whereas the number of other lubricant (unspecified) producers is expected to remain unchanged.

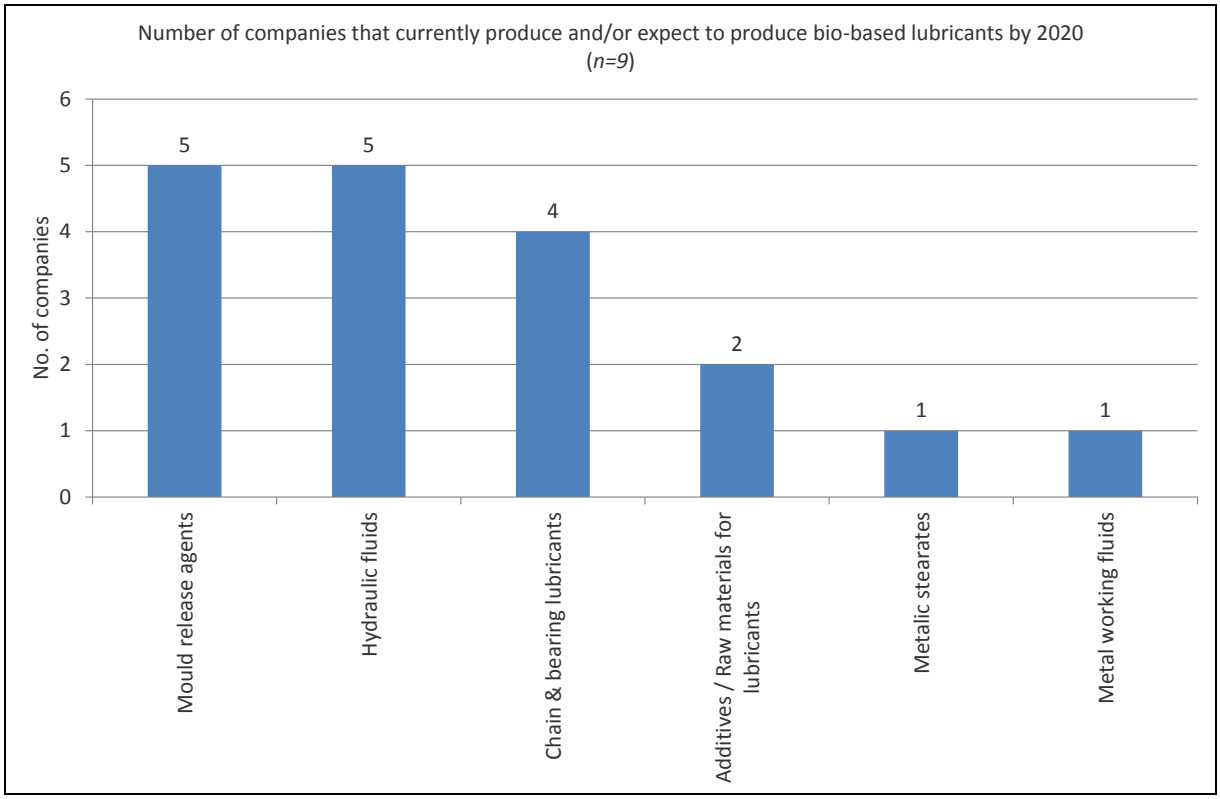


Figure A41: Number of companies that currently produce and/or expect to produce bio-based lubricants by 2020

Source: EU bio-based industries survey.

Q20. Does your company currently produce any other bio-based products, or expect to produce any by 2020? - Others

Figure A42 ranks the type of **other bio-based products** that are currently produced or are expected to be produced by 2020. 24 companies indicated that they produce or expect to produce 'other' bio-based products, of which fatty acid esters constitute the most numerous product in the group (6 companies), followed by hydroxymethyl-furfural (HMF), fatty amines, ethylene and ethylene glycol (4 companies each; and isosorbide and 'other polymer additives' (2 companies each). Other products specified were epichlorohydrin, isoprene, farnesene, para-xylene, chelating agents, carbon nanotubes (from ethanol), limonene, lignosulphonates, acetaldehyde, ethyl acetate and fatty acid amides.

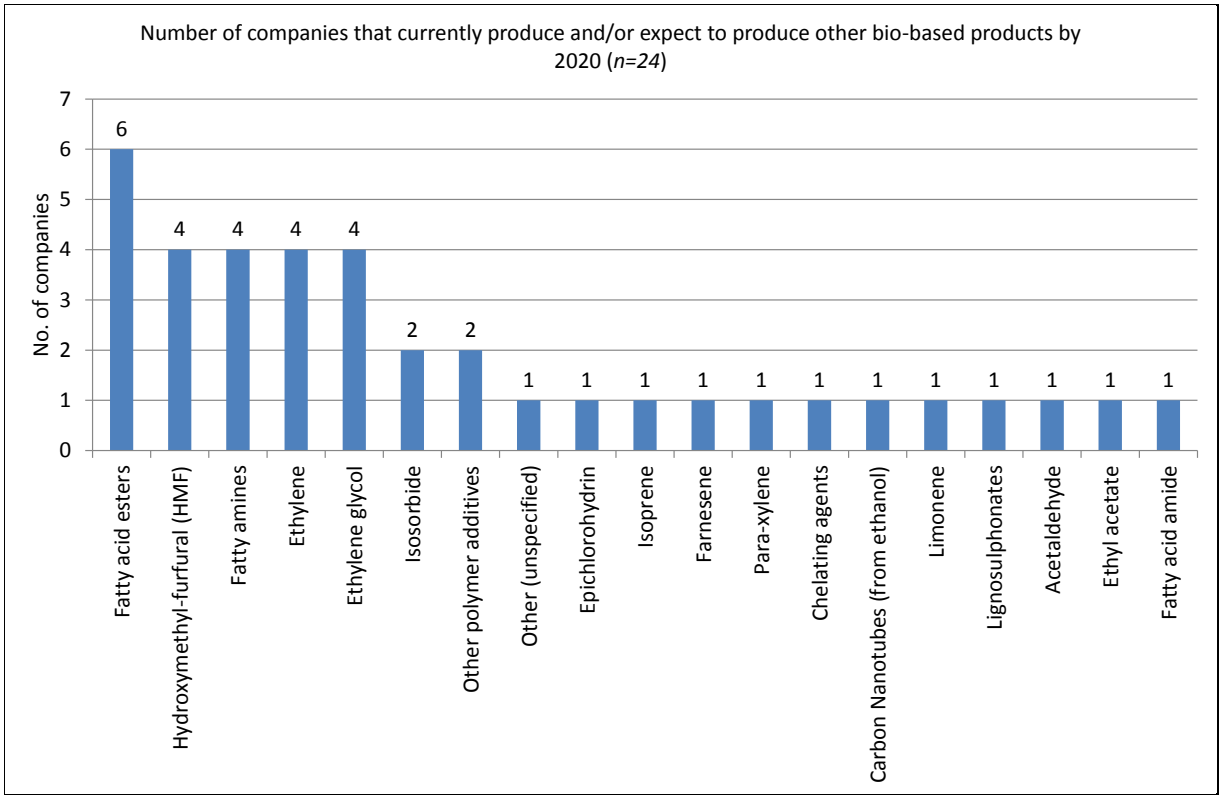


Figure A42: Number of companies that currently produce and/or expect to produce other bio-based products by 2020

Source: EU bio-based industries survey.

Figure A43 shows the expected change in the number of companies currently producing different types of **other bio-based products** compared to 2020. The question specifically asked respondents to tick both 'current' and 'by 2020' boxes if they expected to continue producing a product in the future. The results suggest:

- an **increase** in the number of companies producing hydroxymethyl-furfural (HMF), isoprene, farnesene, ethylene, ethylene glycol and para-xylene;
- **no change** in the number of companies producing isosorbide, fatty amines and acetone; and
- a **decrease** in the number of companies producing epichlorohydrin and other (unspecified) products.

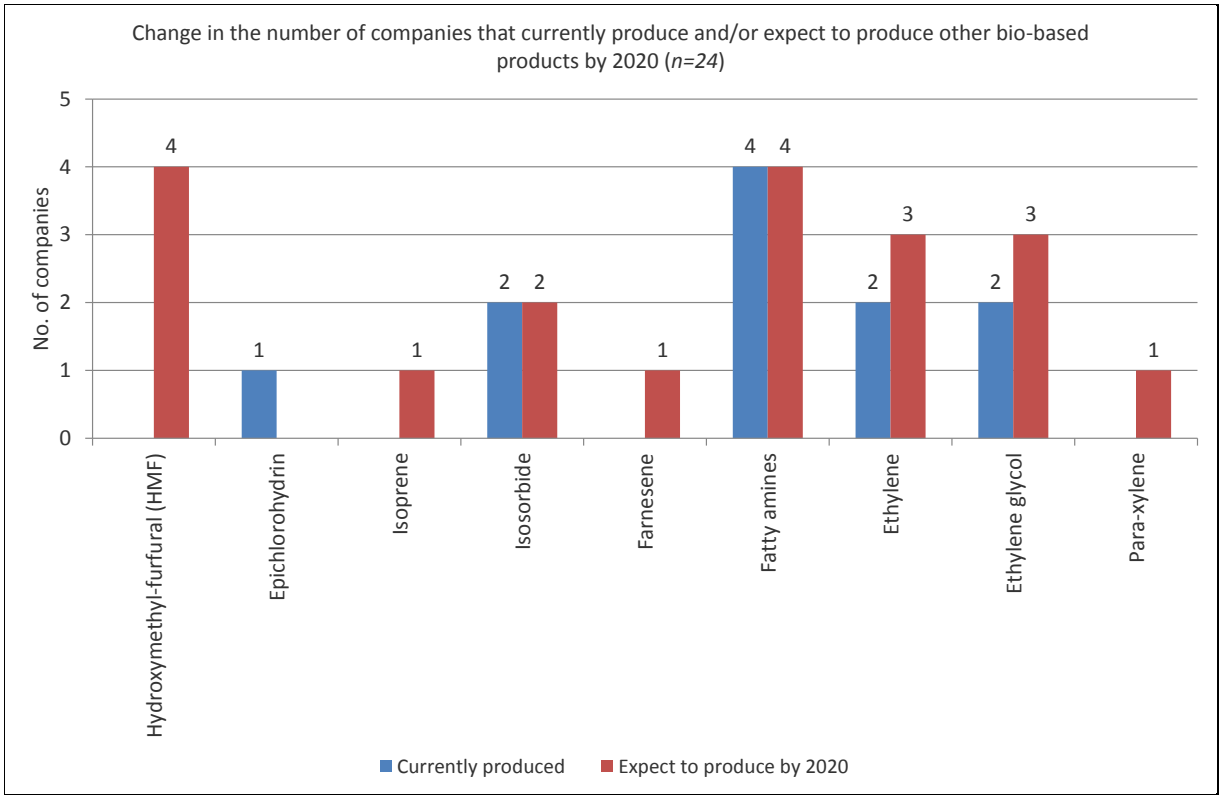


Figure A43: Change in the number of companies that currently produce and/or expect to produce other bio-based products by 2020

Source: EU bio-based industries survey.

2. Company information

Q21. What is the ownership structure of your company?

Public limited liability company:	15 (31.3%)
Private limited liability company:	32 (66.7%)
Other (not-for-profit):	1 (2.1%)
Answered question:	*48*

Q22. Is your company a subsidiary of a larger company?

Yes:	16 (33.3%)
No:	32 (66.7%)
Answered question:	*48*

Q23. Is your company a joint venture with another company?

Yes:	5 (10.6%)
No:	42 (89.4%)
Answered question:	*47*

3. Production facilities in EU Member States

Q24-26. Does your company have bio-based production facilities in the EU?

42 companies indicated that they have bio-based production facilities in the EU, of which 41 companies provided information on 100 separate plants. Of this total:

- 16 are pilot plants;
- 10 are demonstration plants;
- 73 are commercial (active) plants; and
- 1 is a commercial (dormant[1]) plant.

Figure A44 presents the status and location of bio-based production facilities in the EU based on the survey responses. The largest numbers of plants are located in Italy (18), Germany (16), France (15), Netherlands (10) and Spain (9). Germany has the largest number of commercial (active) plants (16), whereas Italy has the largest number of pilot and demonstration plants (8).

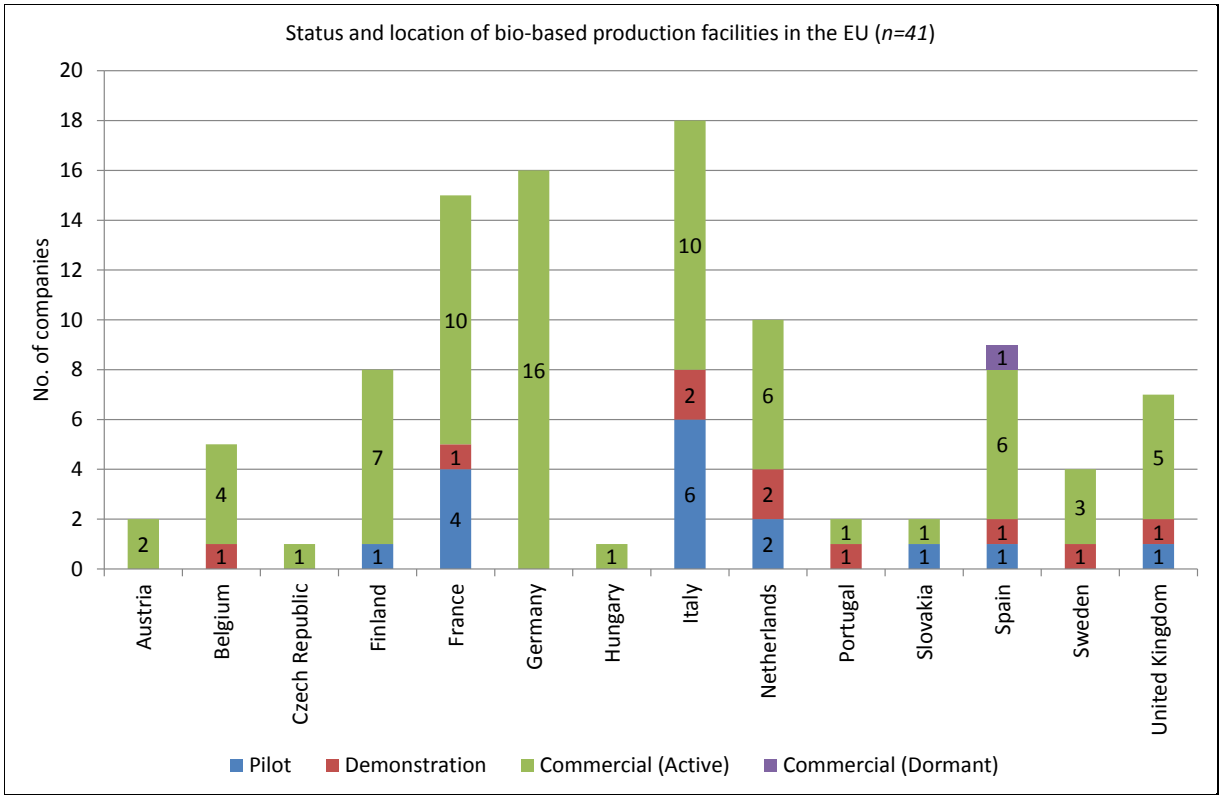


Figure A44: Status and location of bio-based production facilities in the EU

Source: EU bio-based industries survey.

Q27. What were the key reasons for selecting the location of the facilities listed above?

Figure A45 below ranks reasons for selecting the location of bio-based production facilities in the EU. In total, 35 companies responded to the question, indicating that the two main factors for site selection are feedstock availability (17 responses) and proximity to existing commercial activity (17 responses), followed by proximity to R&D

[1] i.e. not currently active; but with expectation of resuming activities when market conditions are favourable.

activities (16 responses), proximity to customer demand (11 responses) and infrastructure (11 responses).

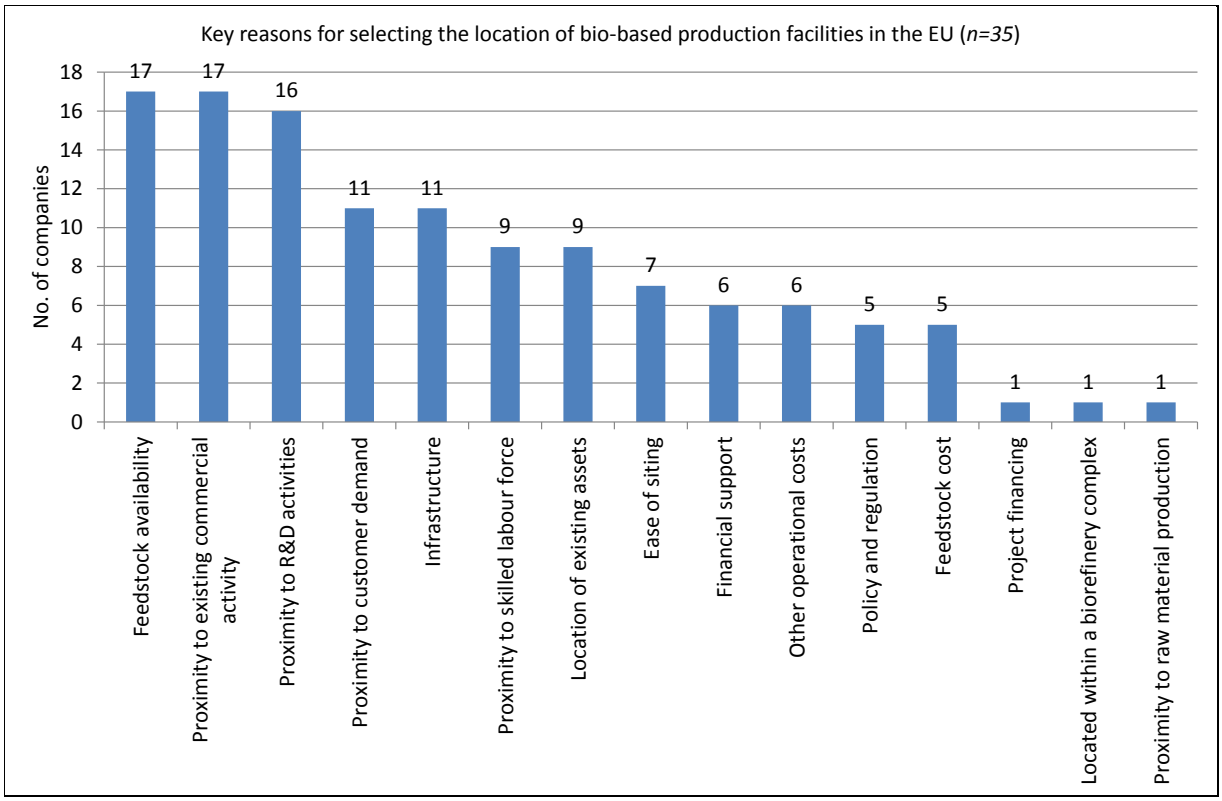


Figure A45: Key reasons for selecting the location of bio-based production facilities in the EU

Source: EU bio-based industries survey.

4. Production facilities outside the EU

Q28-30. Does your company have bio-based production facilities outside the EU?

21 companies indicated that they have bio-based production facilities outside the EU, of which 18 companies provided information on 41 separate plants. Of this total:

- 1 is a pilot plant;
- None are demonstration plants;
- 39 are commercial (active) plants; and
- 1 is a commercial (dormant[2]) plant.

Figure A46 presents the status and location of bio-based production facilities outside the EU. The largest number of plants are located in Asia (17) and North America (17), followed by South & Central America (4), Africa (2) and Other (non-EU) Europe (1).

In terms of countries, the USA has the largest number of plants (15), followed by China (5), Brazil (3), Malaysia (3) and Singapore (3).

[2] i.e. not currently active; but with expectation of resuming activities when market conditions are favourable.

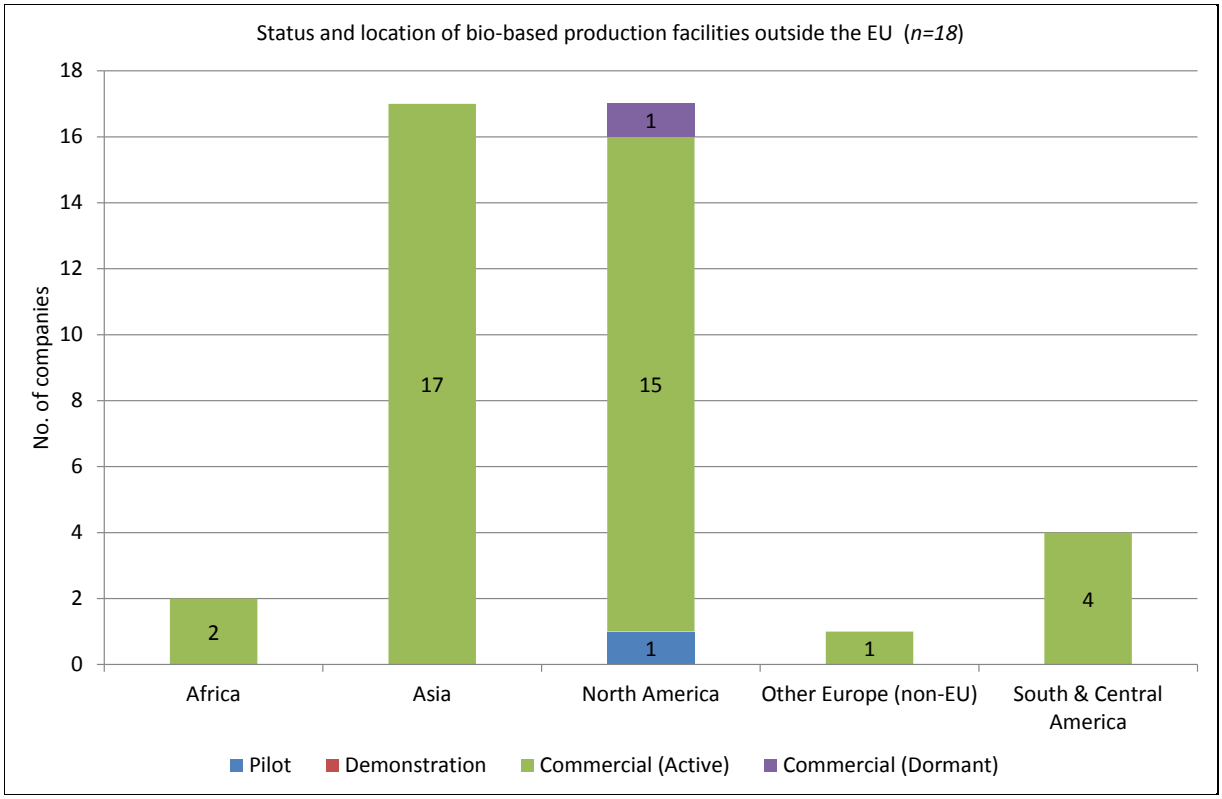


Figure A46: Status and location of bio-based production facilities outside the EU

Source: EU bio-based industries survey.

Q31. What were the key reasons for selecting the location of the facilities listed above?

Figure A47 below ranks reasons for selecting the location of bio-based production facilities outside the EU. In total, 16 companies responded to the question, indicating that the main factor for site selection is feedstock availability (10 responses); followed by proximity to existing commercial activity (8 responses); proximity to customer demand and R&D activities (7 responses each); followed by both policy and regulation and feedstock cost (5 responses each).

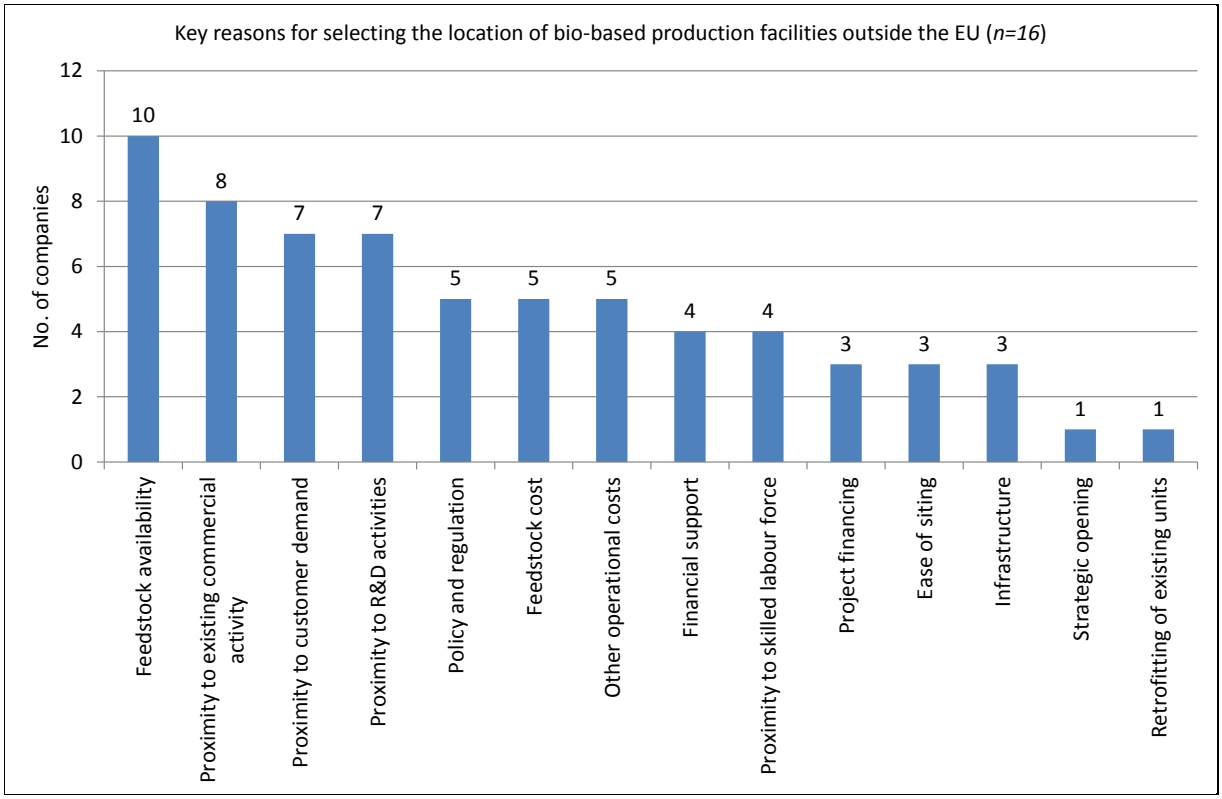


Figure A47: Key reasons for selecting the location of bio-based production facilities outside the EU

Source: EU bio-based industries survey.

5. Industry associations

Q32-34. Is your company a member of any chemical or bio-based industry association?

44 companies indicated that they are members of chemical or bio-based industry associations. Of this total, 40 companies are members of EU associations and 34 are members of Member State associations.

Figure A48 illustrates membership of EU chemical or bio-based industry associations. In terms of representing companies which responded to the survey, the 5 EU associations with the largest membership are:

- BIC - Bio-based Industries Consortium (20);
- Cefic - European Chemical Industry Council (19);
- EuropaBio - European Association for Bio-industries (11);
- APAG - European Oleochemicals and Allied Products Group Plastics Europe (9);
- Plastics Europe (8).

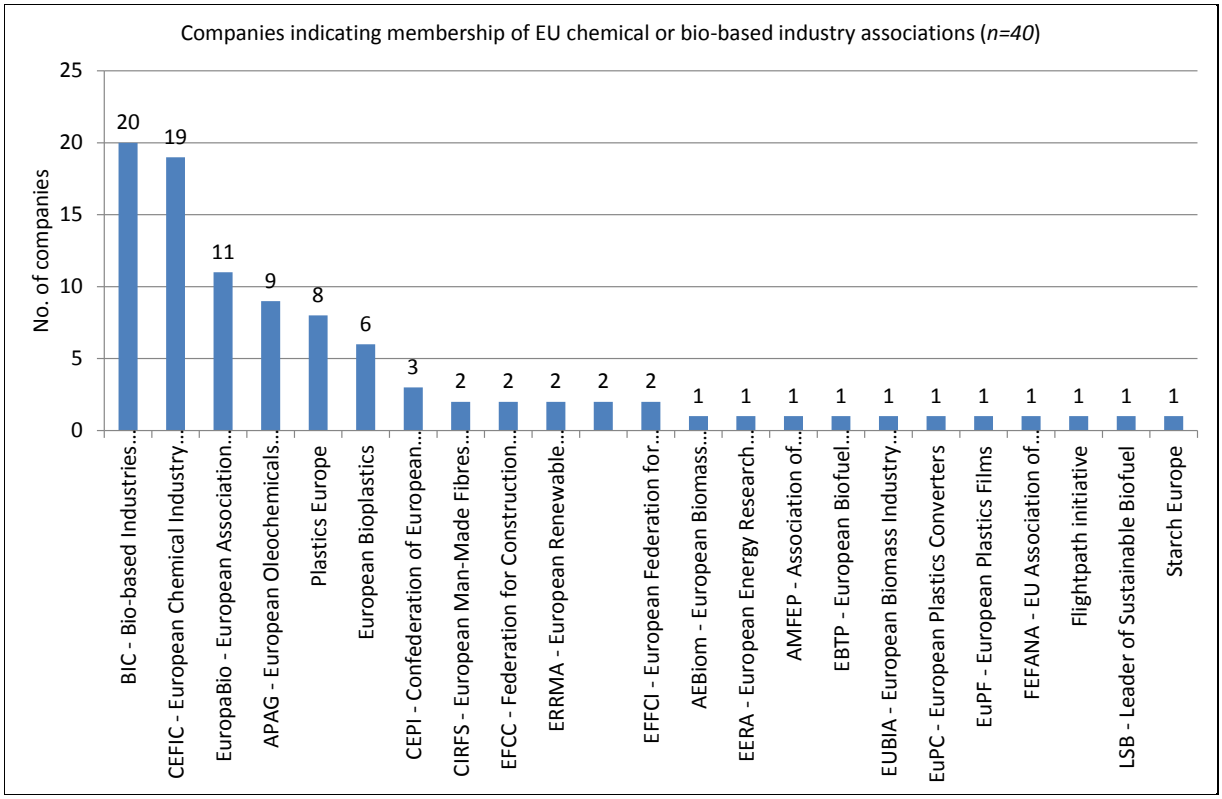


Figure A48: Companies indicating membership of EU chemical or bio-based industry associations

Source: EU bio-based industries survey.

Figure A49 illustrates membership of Member State chemical or bio-based industry associations. In terms of representing companies which responded to the survey, the 5 Member State associations with the largest membership are:

- DE - VCI - Verband der Chemischen Industrie e.V. (8);
- IT - FEDERCHIMICA - Federazione Nazionale dell'Industria Chimica (8);
- FR - UIC - Union des Industries Chimiques (6);
- NL - VNCI - Vereniging van de Nederlandse Chemische Industrie (6);
- UK - CIA - Chemical Industries Association (6).

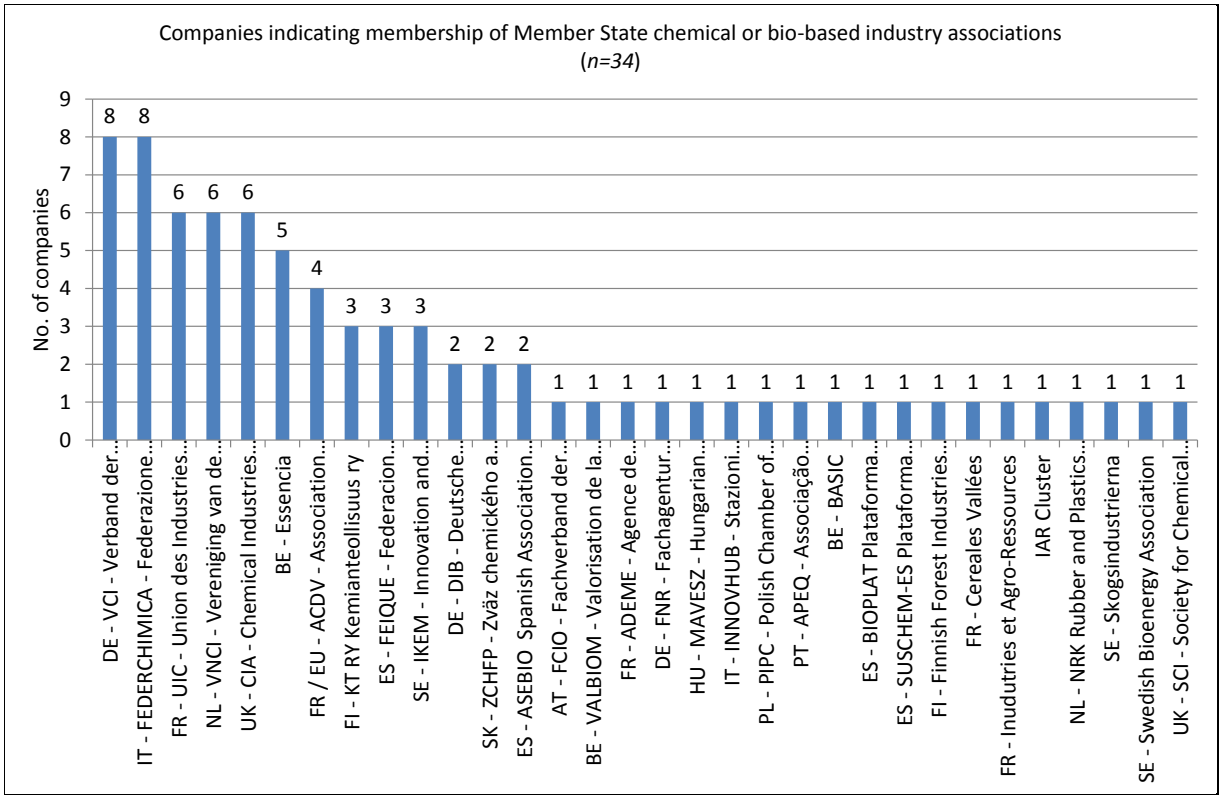


Figure A49: Companies indicating membership of Member State chemical or bio-based industry associations

Source: EU bio-based industries survey.

6. Research and development

Q35. Does your company carry out R&D activities related to bio-based products in the EU?

Yes:	43 (89.6%)
No:	5 (10.4%)
Answered question:	*48*

Q36-37. Does your company carry out R&D activities related to bio-based products outside the EU?

19 companies stated that the carry out R&D activities related to bio-based products outside the EU. Of this total, 18 provided details of the location of these activities:

- 13 companies have R&D activities in North America;
- 13 companies have R&D activities in Asia;
- 3 companies have R&D activities in Other (non-EU) Europe;
- 2 companies have R&D activities in South & Central America;
- 1 company has R&D activities in Africa; and
- no companies have R&D activities in Oceania.

7. Drivers for development of bio-based products

Q38-39. From the list, please indicate the importance of the following DRIVERS for the development of bio-based products by your company.

Figure A50 presents an assessment of the relative importance of drivers for the development of bio-based products. In total, 45 companies responded to the question, indicating that the most important drivers are improved product competitiveness (42 companies), sales growth potential (40 companies), improved profitability (40 companies), development of innovative products (39 companies) and improved product properties or performance (38 companies). Companies were also asked to provide supplementary information on other factors which they deemed important. Such factors included 'strong customer requests' and 'private funding' (1 company each). However, respondents were not asked to categorise the importance of these factors and therefore these responses are not included in Figure A50 below.

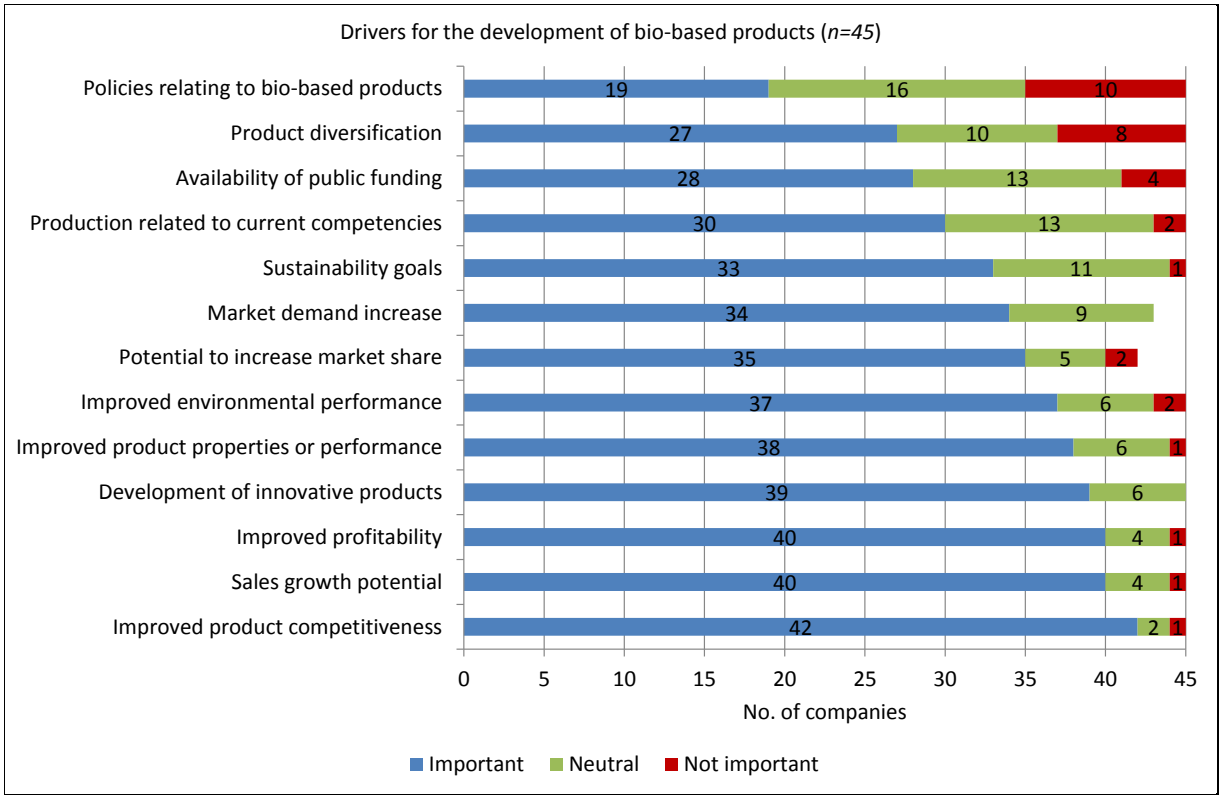


Figure A50: Drivers for the development of bio-based products

Source: EU bio-based industries survey.

When asked further to select the three most important drivers for the development of bio-based products, out of 44 companies which responded to the question, the three most important drivers selected were improved profitability (18 companies), improved product competitiveness (18 and development of innovative products (18 companies); followed by improved environmental performance (13 companies) and sales growth potential (12 companies). These results are presented in Figure A51 and broadly confirm the findings above.

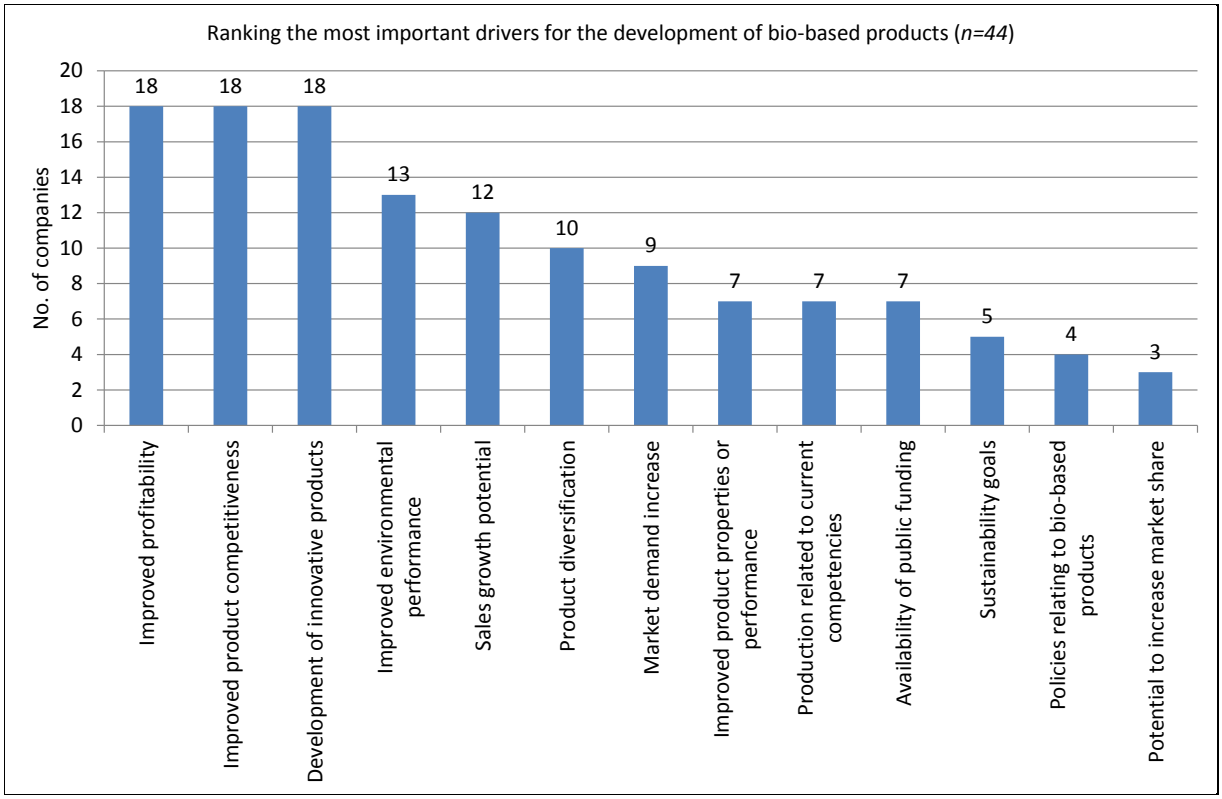


Figure A51: Ranking the most important drivers for the development of bio-based products

Source: EU bio-based industries survey.

8. Constraints on development of bio-based products

Q40-41. From the list, please indicate the importance of the following CONSTRAINTS on the development of bio-based products by your company

Figure A52 presents an assessment of the relative importance of constraints for the development of bio-based products. In total, 46 companies responded to the question, indicating that the most important constraints are higher production costs (25 companies); availability of funds to invest in production capacity (17 companies) and increased or variable feedstock costs (17 companies); availability of funds for necessary R&D (16 companies); followed by technology maturity (10 companies) and product properties or performance (10 companies). Companies were also asked to provide supplementary information on other factors which they deemed important. Such factors included 'competition with bio-energy sectors' and 'feedstock availability (competition, quality, etc.)' (3 companies each); as well as 'lack of legislative support', 'customer demand' and 'supply chain costs' (1 company each). However, respondents were not asked to categorise the importance of these factors and therefore these responses are not included in Figure A52 below.

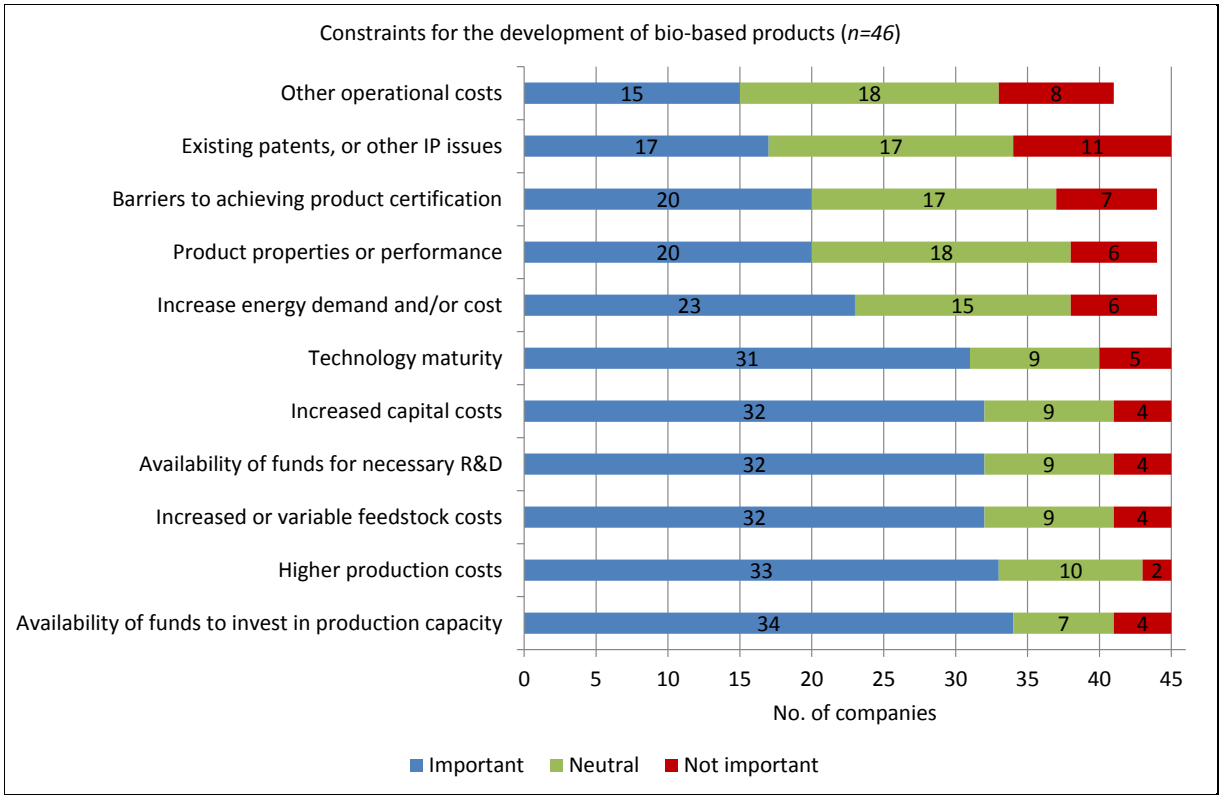


Figure A52: Constraints on the development of bio-based products

Source: EU bio-based industries survey.

When asked further to select the three most important constraints on the development of bio-based products, out of 46 companies which responded to the question, the three most important constraints selected were higher production costs (27 companies), increased or variable feedstock costs (23 companies), availability of funds to invest in production capacity (19 companies). These results are presented in Figure A53 and broadly confirm the findings above.

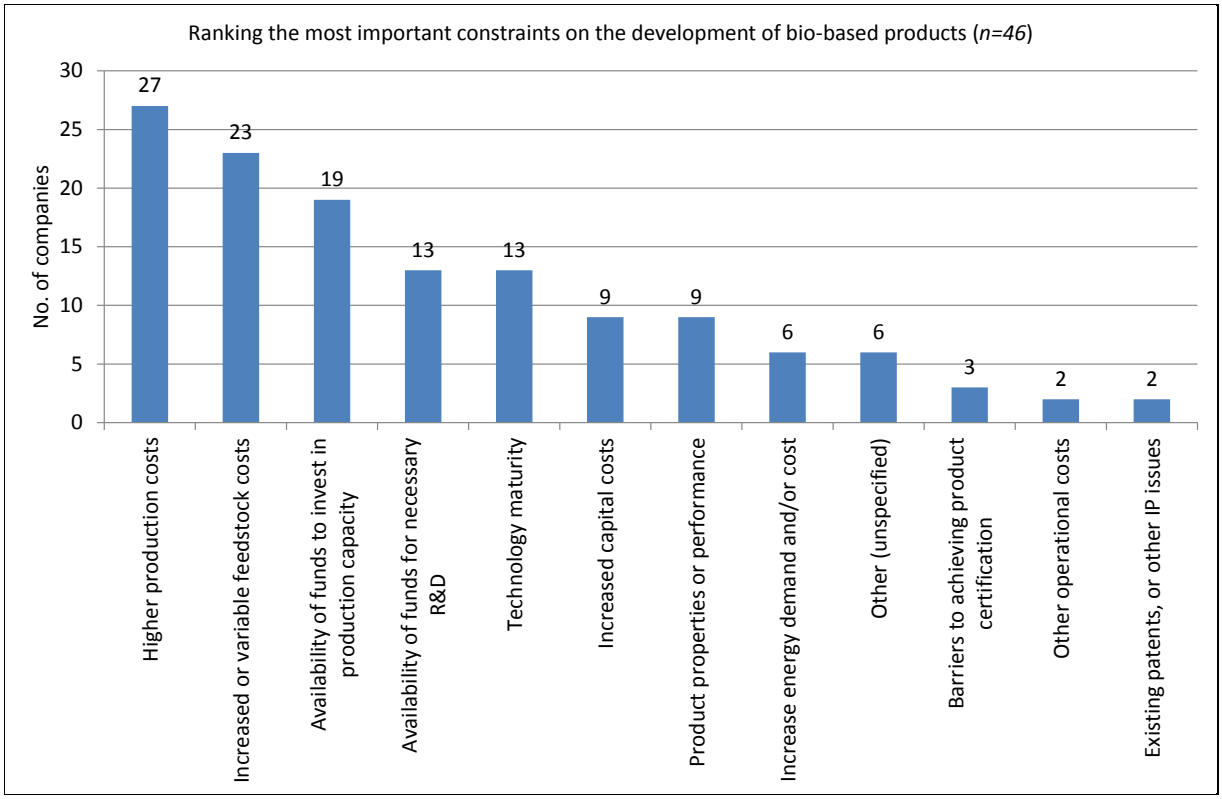


Figure A53: Ranking the most important constraints on the development of bio-based products

Source: EU bio-based industries survey.

9. EU employees

Q42. What was the total number of employees in your company in the EU?

In total, 42 companies responded to the question providing data on the number of employees between 2010 and 2013, although not all companies provided data for each year. Table A3 presents the total number of employees identified in each year and the number of companies which provided data for that year.

Table A3: Number of staff employed by bio-based companies in the EU between 2010 and 2013

2010	2011	2012	2013
109,805	110,346	189,729	220,056
n = 30	n = 30	n = 34	n = 42

Source: EU bio-based industries survey.

Q43. What share (%) was employed in bio-based activities in the EU?

35 companies provided data on the proportion of total employees employed in bio-based activities (Table A4). Cross tabulation of this data with the data on total employment numbers was used to estimate the total number of employees in bio-based activities and to calculate the annual increase in total employment (Table A5).

Table A4: Proportion of total employees engaged in bio-based activities (No. of companies)

	Number of companies			
Proportion of employees in bio-based activities	**2010**	**2011**	**2012**	**2013**
>50%	11	12	14	19
25% to 49%	1	1	1	2
10% to 24%	4	5	4	6
<10%	10	7	8	8

Source: EU bio-based industries survey.

Table A5: Increase in the number of employees engaged in bio-based activities

Increase in number of employees			
2010	**2011**	**2012**	**2013**
-	987	357	2,334
-	n = 26	n = 28	n = 36

Source: EU bio-based industries survey.

Q44. What share (%) was involved in R&D activities related to bio-based products in the EU?

32 companies provided data on the proportion of total employees involved in R&D activities related to bio-based products (Table A6). Cross tabulation of total employment numbers with the proportion of total employees involved in R&D activities related to bio-based products in the EU was used to estimate the total number of employees involved in R&D activities related to bio-based products (Table A7).

Table A6: Proportion of total employees engaged in bio-based R&D activities (No. of companies)

	Number of companies			
Proportion of employees in bio-based R&D activities	**2010**	**2011**	**2012**	**2013**
>50%	5	4	7	8
25% to 49%	2	4	4	5
10% to 24%	3	2	1	4
<10%	15	13	13	14

Source: EU bio-based industries survey.

Table A7: Increase in the number of employees engaged in bio-based R&D activities

2010	2011	2012	2013
-	87	312	3,237
-	n = 25	n = 27	n = 33

Source: EU bio-based industries survey.

10. Production

Q46. What was your company's total annual output (in tonnes) of bio-based products in the EU?

Table A8 presents average and total annual output (in tonnes) of bio-based products in the EU. 27 companies responded to this question, of which 21 provided data in each of the 4 years requested (2010, 2011, 2012, 2013) and the average and total output figures presented here are based on these 24 companies. Reported production output has remained relatively flat over the time period.

Table A8: Average and total output of bio-based products in the EU

Answer Options	Average[1]	Total[2]
2010 - (in tonnes)	31,963	671,223
2011 - (in tonnes)	47,368	994,734
2012 - (in tonnes)	42,669	896,053
2013 - (in tonnes)	55,964	1,175,235

Note: [1] Simple average and [2] total (sum) for companies which provided data for all years (2010, 2011, 2012, 2013).

Source: EU bio-based industries survey.

Q47. What share (%) of EU bio-based product output was sold in the EU?

Figure A54 presents the average share of total EU bio-based output sold in the EU over the period from 2010 to 2013. The proportion of EU output sold within the EU declined from 86.2% in 2010 to 83.2% in 2012, before increasing to 89.8% in 2013. Table A9 presents the proportion of EU bio-based product output sold within the EU. This decline in the percentage of bio-based output sold in the EU is more than compensated for by the increase in total production, indicating that the European market is also growing.

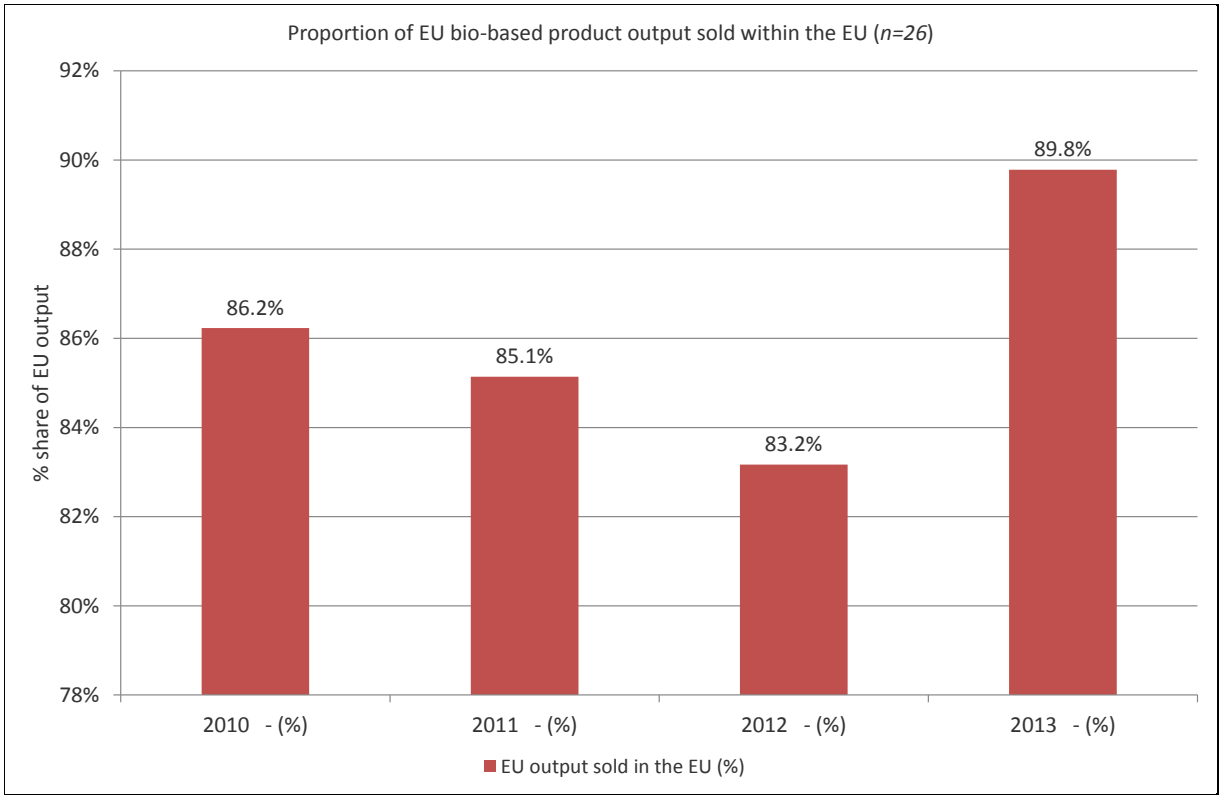


Figure A54: Proportion of EU bio-based product output sold within the EU

Source: EU bio-based industries survey.

Table A9: Proportion of EU bio-based product output sold within the EU (number of companies)

Proportion of employees	2010	2011	2012	2013
>75%	13	12	12	13
50% to 74%	2	2	1	2
25% to 49%	0	0	1	2
1% to 24%	0	0	0	0
0%	7	7	8	9

Source: EU bio-based industries survey.

Q48. How is the share (%) of bio-based product output sold in the EU expected to change by 2020?

37 companies indicated their expectation for how the share (%) of bio-based product output sold in the EU expected to change by 2020 (see Figure A55):

- 15 companies expect the share of sales in the EU to increase >100%;
- 13 companies expect the share of sales in the EU to increase <100%;
- 8 companies expect no change in the share of sales in the EU;
- 1 company expect the share of sales in the EU to Decrease;
- no companies expect the share of sales in the EU to Decrease to zero.

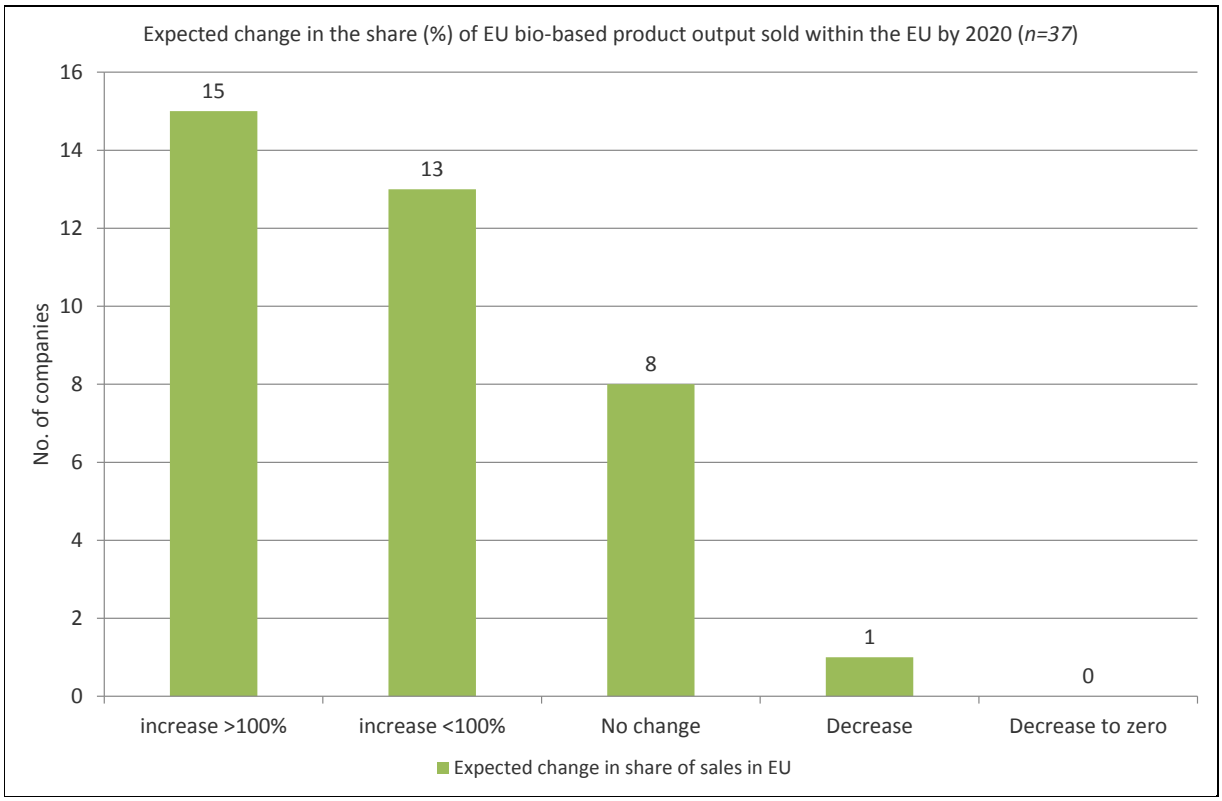


Figure A55: Expected change in the share (%) of EU bio-based product output sold within the EU by 2020

Source: EU bio-based industries survey.

11. Feedstock

Q45. What types of processes does your company use for the production of bio-based products in the EU?

Figure A56 presents the types of feedstock conversion processes used for the production of bio-based products in the EU. 40 companies provided information on the types of feedstock processes used. As illustrated, 17 companies use catalytic conversion processes, 15 use fermentation and 6 use enzymatic conversion processes. 25 companies state that they use other processes, mainly different types of chemical reactions/conversion, e.g. polymerisation, hydrolysis, esterification and pyrolysis.

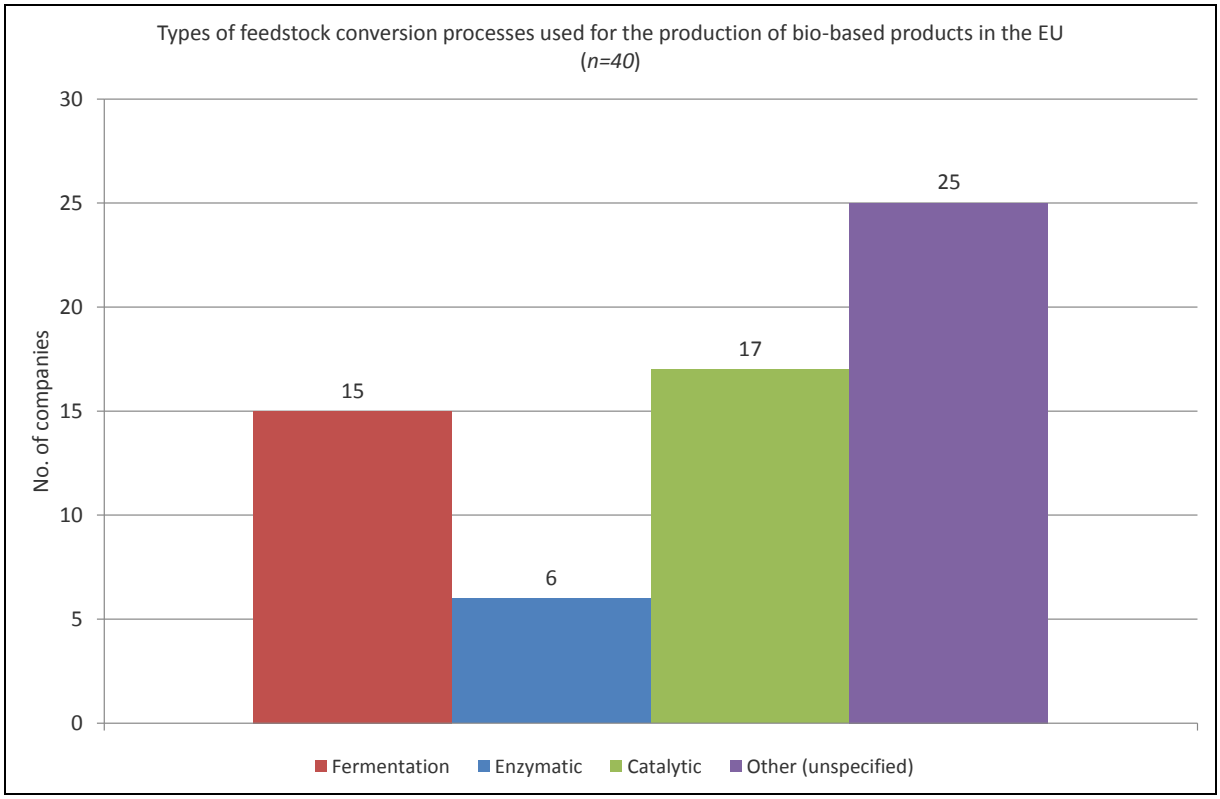


Figure A56: Types of feedstock conversion processes used for the production of bio-based products in the EU

Source: EU bio-based industries survey.

Answers to questions 45 and 49-55 are not uniquely linked; in other words, if a respondent identifies multiple feedstocks in questions 49-55 and multiple processes in question 45, it is not possible to separate out which process is used for each feedstock; consequently cross-tabbing of multiple answers creates links between feedstocks and processes which, in reality are not relevant for the company.

Q49. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Fibres

11 companies state that they use various forms of fibre as feedstock for bio-based products in the EU, of which 8 companies use wood and 2 use chemical pulp. Figure A57 illustrates the number of companies using different fibre feedstocks over the period from 2010 to 2013.

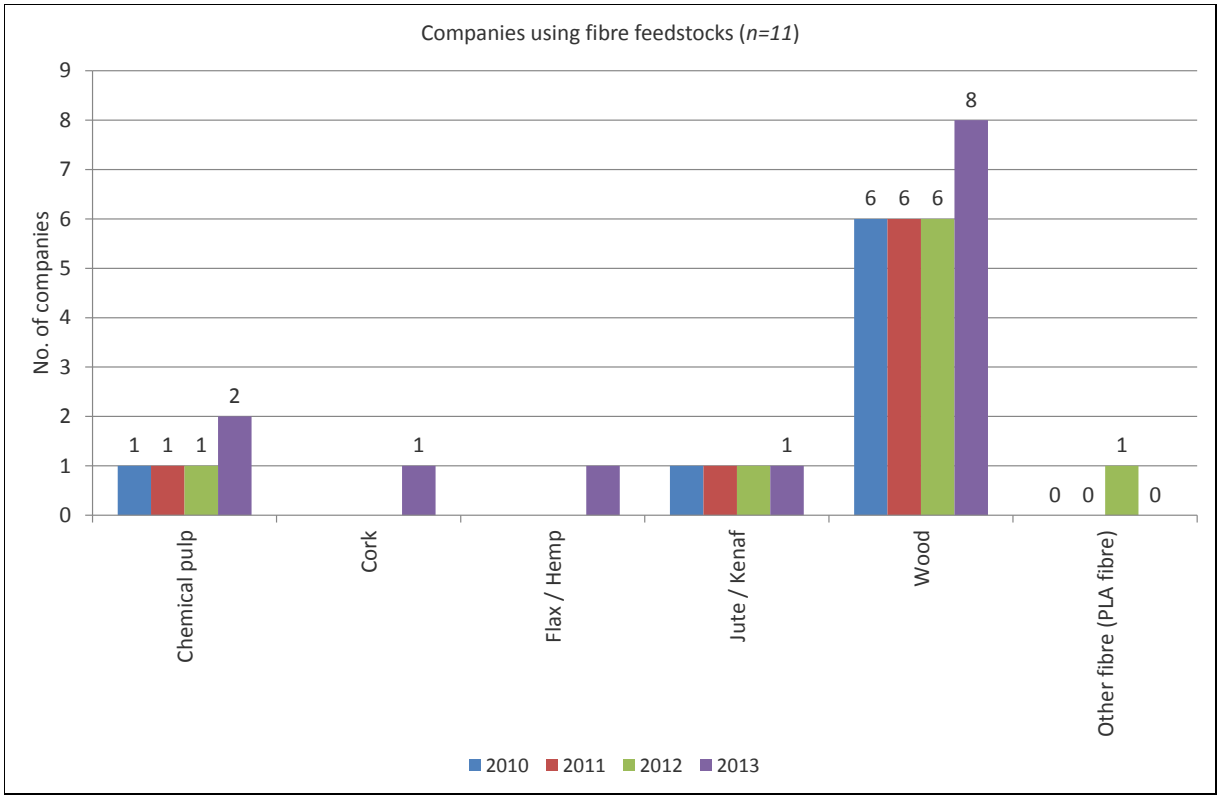


Figure A57: Number of companies using fibre feedstocks

Source: EU bio-based industries survey.

Q50. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Sugars

Figure A58 illustrates the number of companies using sugar feedstocks over the period from 2010 to 2013. In total, 9 companies state that they use various sugar feedstocks for bio-based products in the EU, of which 6 companies use sugar beet, 5 use sugar cane and 3 use other sugars[3] (including xylose and arabinose, synthetic sugars (C5 and C6), corn (HFS), dextrose and ligno-cellulosic sugars).

[3] Note: the question was designed to allow respondents to specify the types of 'other sugar', but not to allocate use to specific years.

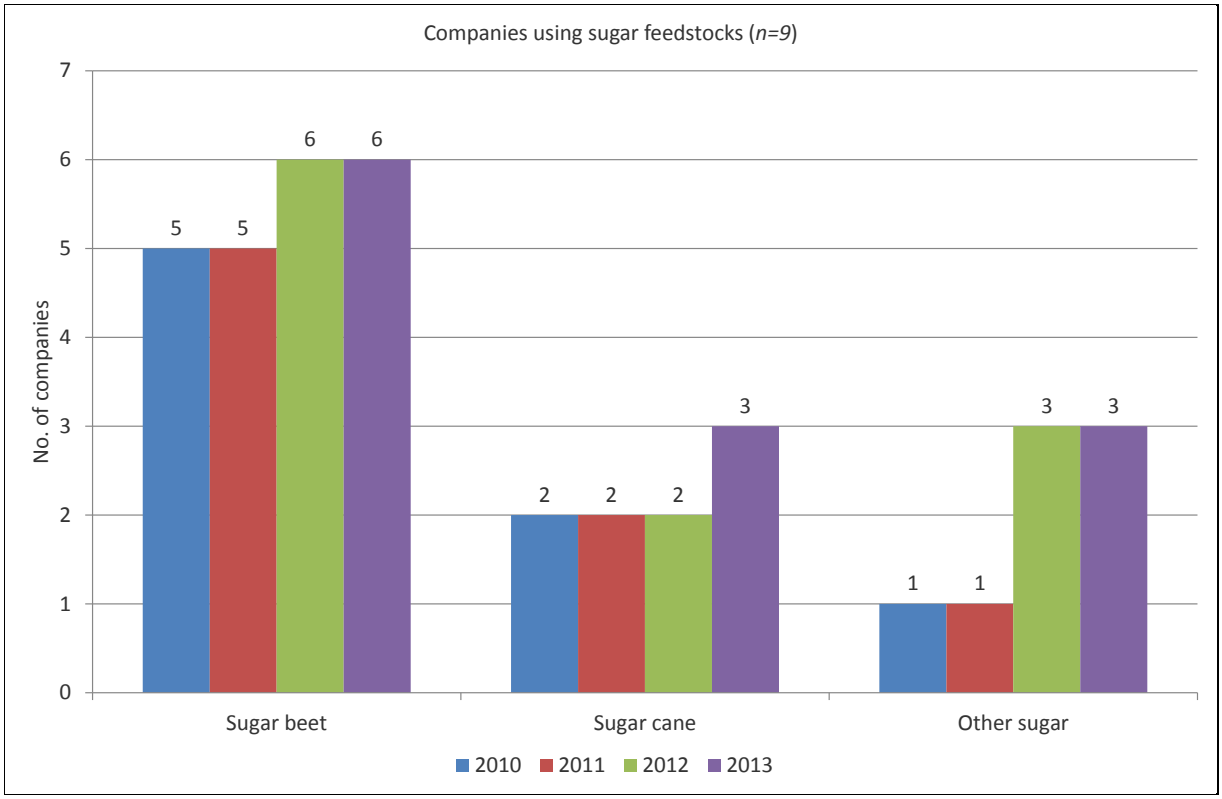


Figure A58: Number of companies using sugar feedstocks

Source: EU bio-based industries survey.

Q51. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Starch

Figure A59 illustrates the number of companies using starch feedstocks for bio-based products in the EU over the period from 2010 to 2013. 15 companies state that they use various forms of starch, of which maize (10 companies), wheat (7 companies), potato (3 companies), cassava (1 company) and other starch (1 company, which specified rice starch feedstock).

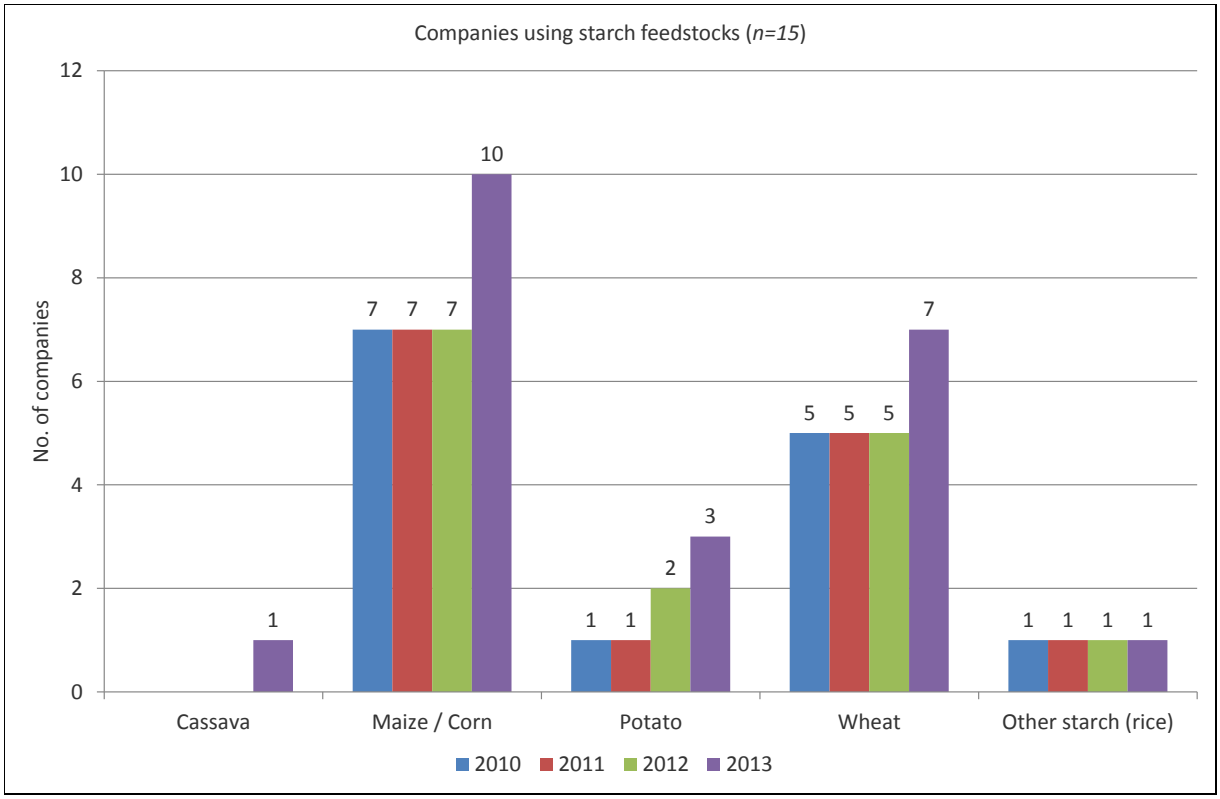


Figure A59: Number of companies using starch feedstocks

Source: EU bio-based industries survey.

Q52. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Vegetable oils

Figure A60 illustrates the number of companies using vegetable oil feedstocks for bio-based products in the EU over the period from 2010 to 2013. 19 companies state that they use various forms of starch, of which rapeseed oil (11 companies), palm oil (10 companies), coconut oil (8 companies), soybean oil (7 companies) and linseed oil (3 companies). 12 companies indicate that they use other vegetable oils[4] (e.g. palm kernel oil, castor oil, sunflower oil and microalgae oil).

[4] Note: the question was designed to allow respondents to specify the types of 'other vegetable oils', but not to allocate use to specific years.

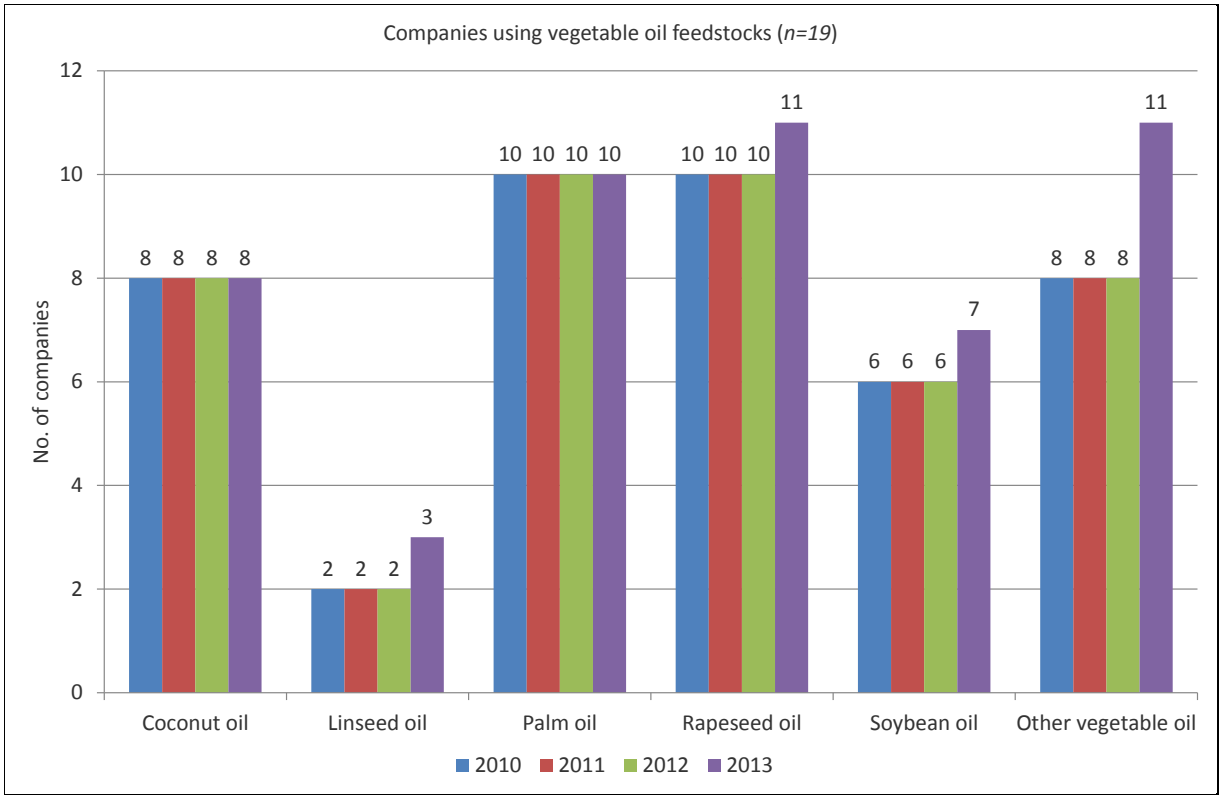


Figure A60: Number of companies using vegetable oil feedstocks

Source: EU bio-based industries survey.

Q53. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Residues

Figure A61 illustrates the number of companies using residue feedstocks for bio-based products in the EU over the period from 2010 to 2013. 19 companies state that they use various residues, of which animal fats (10 companies) and agricultural residues (7 companies). 5 companies indicate that they use other residues[5] (e.g. bagasse, bran and beet pulp, cellulose residues; soy protein and tallow).

[5] Note: the question was designed to allow respondents to specify the types of 'other residues', but not to allocate use to specific years.

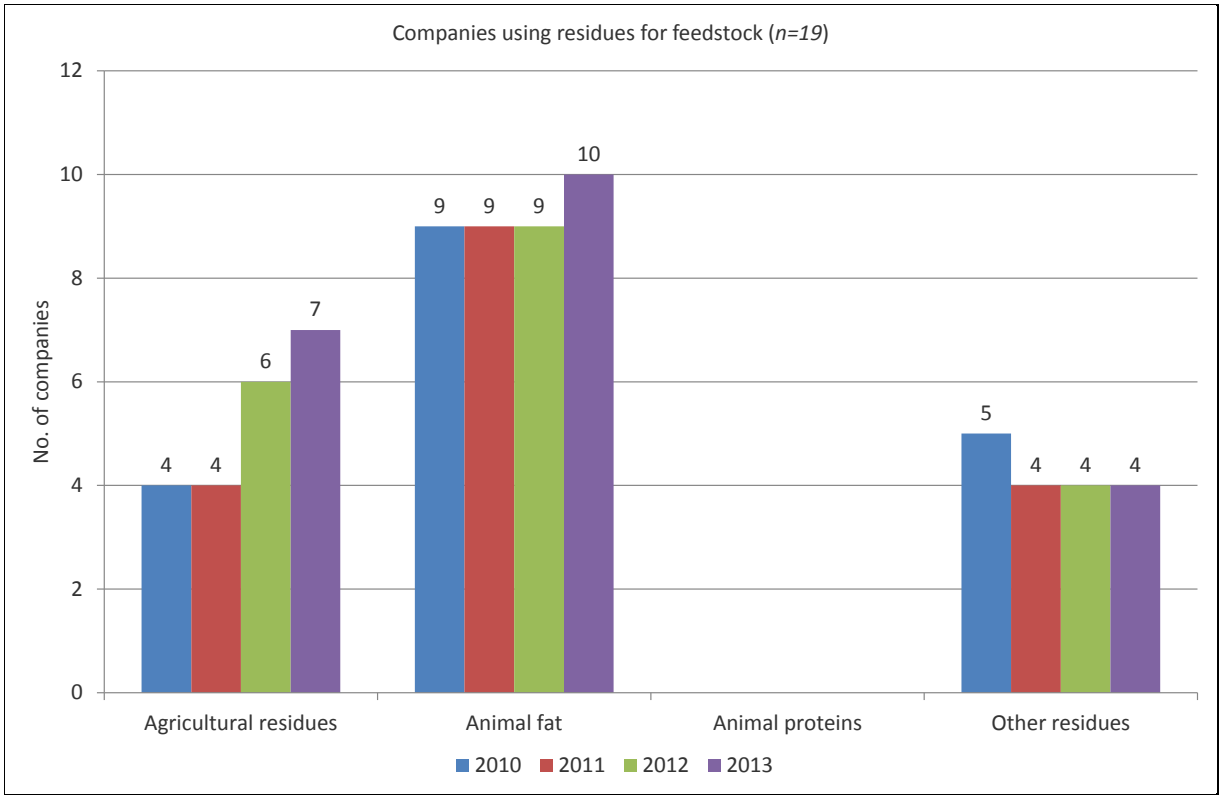


Figure A61: Number of companies using residue feedstocks

Source: EU bio-based industries survey.

Q54. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Alcohols

Figure A62 illustrates the number of companies using alcohol feedstocks for bio-based products in the EU over the period from 2010 to 2013. 14 companies state that they use various alcohols, of which glycerol (9 companies) and bio-ethanol (7 companies). 4 companies indicate that they use other alcohols[6] (e.g. amylic alcohol, octyl alcohol, decyl alcohol and fatty alcohols C8-C22).

[6] Note: the question was designed to allow respondents to specify the types of 'other alcohols', but not to allocate use to specific years.

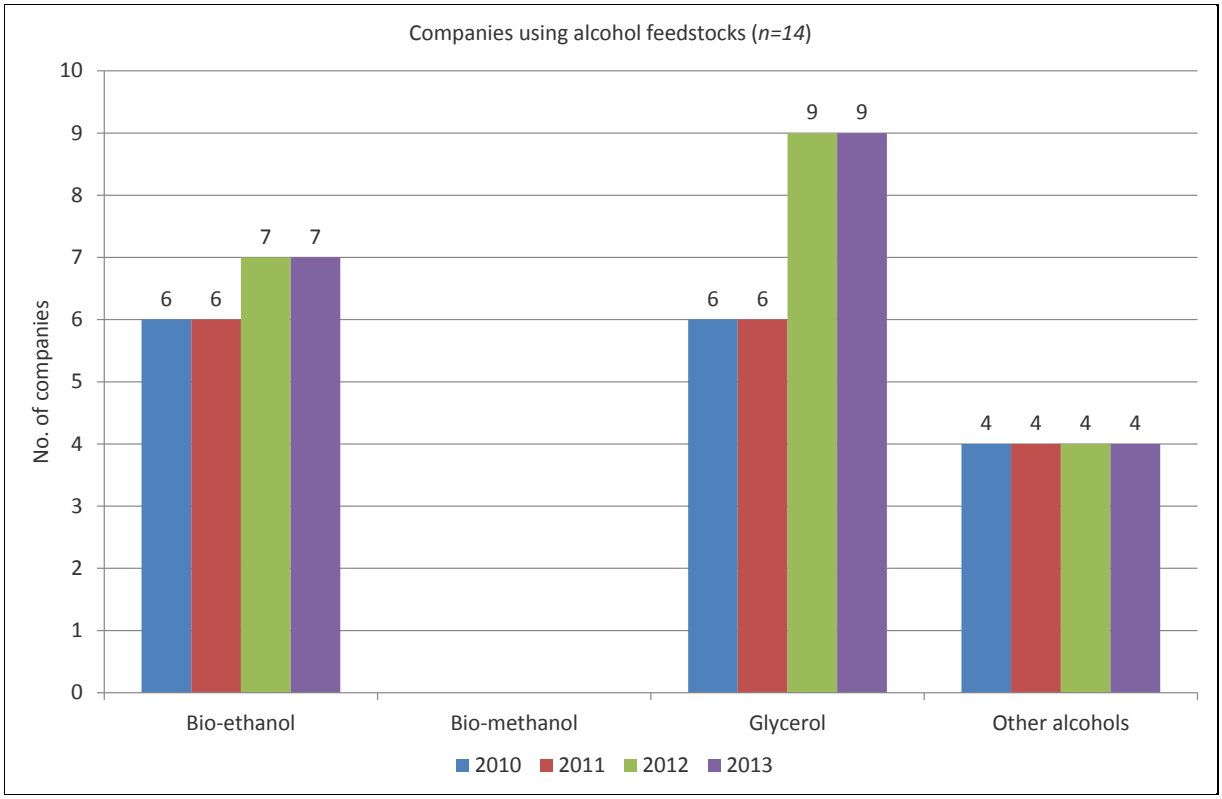


Figure A62: Number of companies using alcohol feedstocks

Source: EU bio-based industries survey.

Q55. What type(s) of feedstock does your company use to produce bio-based products in the EU? - Other

Figure A63 illustrates the number of companies using other feedstocks for bio-based products in the EU over the period from 2010 to 2013. 7 companies state that they use other feedstocks[7], including lignocellulose, brown liquor from sulphite pulping, sebatic acid, fatty acids C8-C24, shells and sugar based lactides.

[7] Note: the question was designed to allow respondents to specify the types of 'other feedstocks', but not to allocate use to specific years.

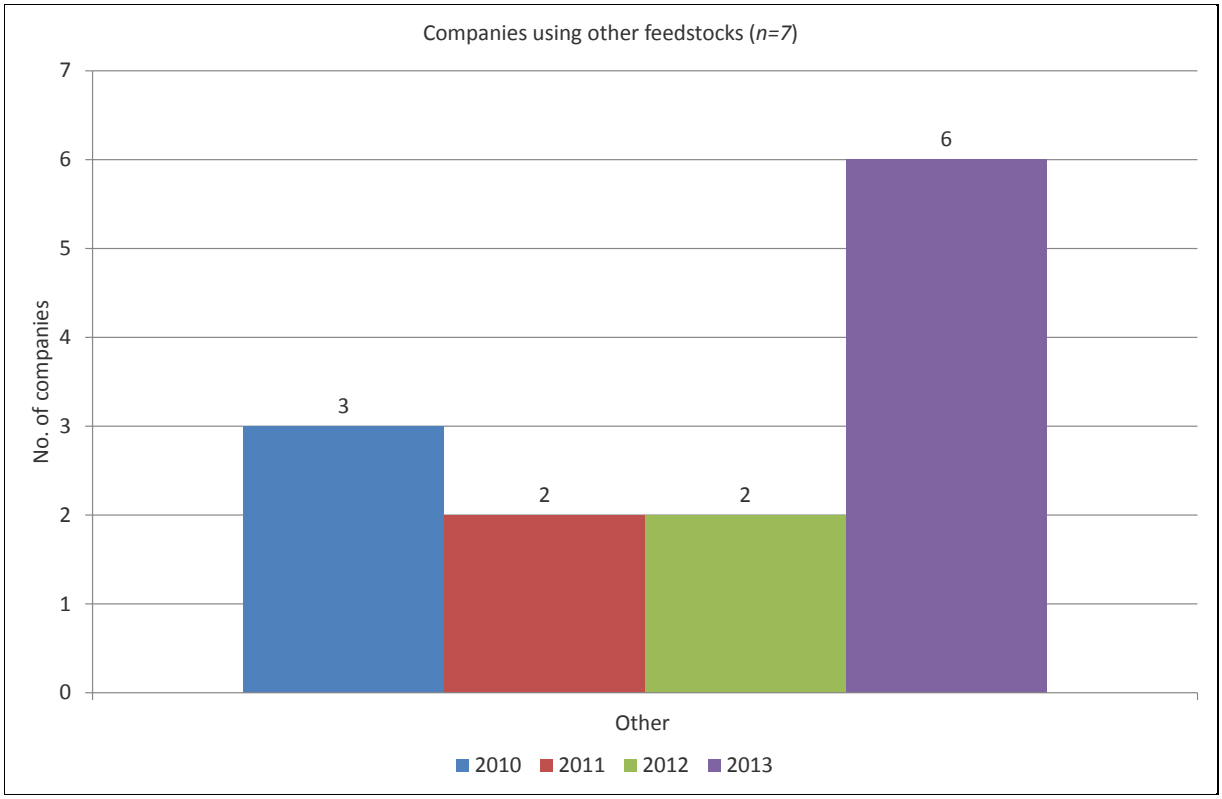


Figure A63: Number of companies using other feedstocks not previously captured

Source: EU bio-based industries survey.

Q56. What share (%) of bio-based feedstock is sourced from within the EU (i.e. feedstock of EU origin)?

Figure A63 presents the average share of bio-based feedstock sourced from within the EU over the period from 2010 to 2013. As can be seen, the share increased from 71% in 2010 to 72% in 2011, before declining to 67% in 2013.

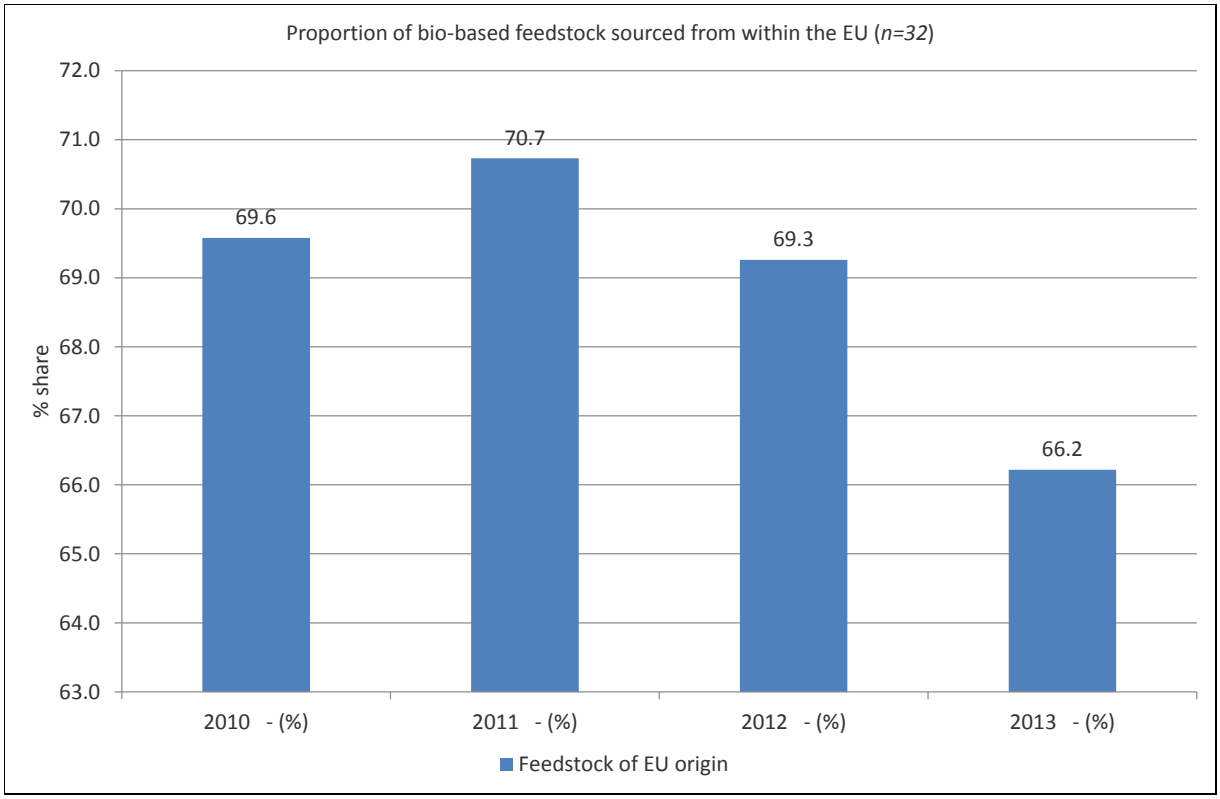


Figure A64: Proportion of bio-based feedstock sourced from within the EU

Source: EU bio-based industries survey.

Q57. What is the share (%) of bio-based feedstock in total feedstock use for producing bio-based products in the EU?

Figure A65 presents the average share of bio-based feedstock in total feedstock use for producing bio-based products in the EU over the period from 2010 to 2013. The share has increased steadily from 64% in 2010 to 68% in 2013.

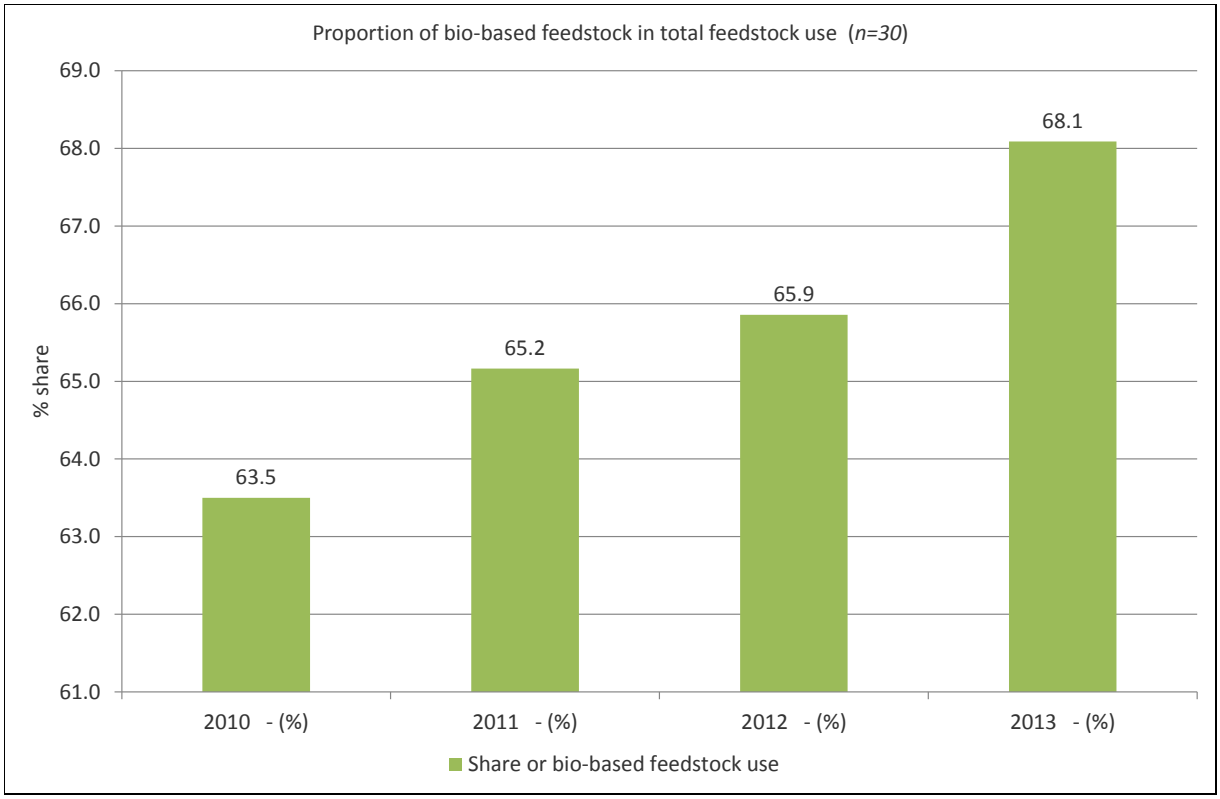


Figure A65: Proportion of bio-based feedstock in total feedstock use

Source: EU bio-based industries survey.

Q58. How is the contribution of bio-based feedstock to total feedstock use likely to change by 2020?

36 companies indicated their expectation for how the contribution of bio-based feedstock to total feedstock use likely to change by 2020 (Figure A66):

- 9 companies expect the contribution to increase >100%;
- 16 companies expect the contribution to increase <100%;
- 11 companies expect no change in contribution;
- no companies expect the contribution to decrease;
- no companies expect the contribution to decrease to zero.

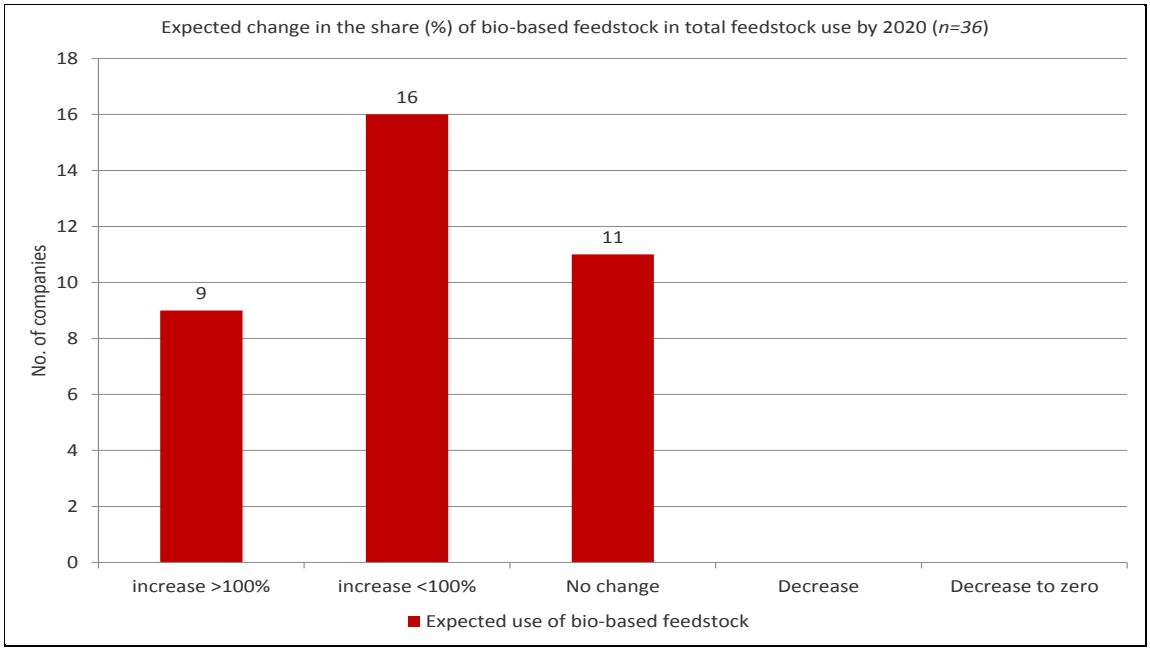


Figure A66: Expected change in the share (%) of bio-based feedstock in total feedstock use by 2020

Source: EU bio-based industries survey.

12. Sales turnover

Q59. What was your company's total sales turnover of bio-based products worldwide (in Euros)?

In total, 24 companies responded to the question providing data on total sales turnover of bio-based products worldwide between 2010 and 2013. The total sales turnover for bio-based products for all companies is presented in Table A10. Table A11 presents an analysis of average sales turnover of bio-based products worldwide.

Table A10: Total sales turnover of bio-based products (Million euros)

2010	2011	2012	2013
2,636.5	2,819.4	2,858.4	6,812.4
n = 19	n = 19	n = 20	n = 24

Table A11: Average sales turnover of bio-based products by size category (Million euros)

	2010	2011	2012	2013
>€50m	286.6	306.1	309.4	612.3
€10-50m	26.5	20.8	23.3	23.7
€2-10m	3.0	2.4	3.5	5.0
<€2m	1.2	0.0	0.0	0.0

Source: EU bio-based industries survey.

Q61. What was your company's total sales turnover in the EU (i.e. fossil-based and bio-based products) (in Euros)?

27 companies responded to the question providing data on total sales turnover (fossil and bio-based products) in the EU between 2010 and 2013. The total sales turnover for bio-based products for all companies is presented in Table A12. Table A13 present an analysis of average sales turnover in the EU.

Table A12: Total sales turnover in the EU (Million euros)

2010	2011	2012	2013
27,329	31,051	60,343	63,290
n = 19	n = 20	n = 22	n = 27

Table A13: Average sales turnover in the EU by size category (Million euros)

	2010	2011	2012	2013
>€50m	2,484	2,588	4,642	3,956
€10-50m	35.0	35.0	35.0	35.0
€2-10m	2.7	2.6	3.1	3.7
<€2m	0.8	0.3	0.4	0.4

Source: EU bio-based industries survey.

Q62. What was your company's total sales turnover of bio-based products in the EU (in Euros)?

23 companies responded to the question providing data on total sales turnover of bio-based products sold in the EU between 2010 and 2013. The total sales turnover for bio-based products for all companies is presented in Table A14.

Table A15 presents an analysis of average sales turnover of bio-based products in the EU.

Table A14: Total sales turnover for bio-based products in the EU (Million euros)

2010	2011	2012	2013
846	1,052	1,040	1,378
n = 17	n = 18	n = 19	n = 23

Table A15: Average sales turnover of bio-based products in the EU by size category (Million euros)

	2010	2011	2012	2013
>€50m	141.0	150.3	148.5	153.1
€10-50m	23.5	19.0	20.7	22.3
€2-10m	3.0	0.0	0.0	2.0
<€2m	0.6	0.9	1.0	0.4

Source: EU bio-based industries survey.

Q60. How is total sales turnover of bio-based products worldwide expected to change by 2020?

34 companies indicated their expectation for how sales turnover of bio-based products worldwide expected to change by 2020 (see Figure A67):

- 19 companies expect sales worldwide to increase >100%;
- 12 companies expect sales worldwide to increase <100%;
- 3 companies expect no change in sales worldwide;
- no companies expect sales worldwide to decrease;
- no companies expect sales worldwide to decrease to zero.

Q63. How is total sales turnover of bio-based products in the EU expected to change by 2020?

33 companies indicated their expectation for how sales turnover of bio-based products in the EU is expected to change by 2020 (Figure A67):

- 17 companies expect sales in the EU to increase >100%;
- 14 companies expect sales in the EU to increase <100%;
- 2 companies expect no change in sales in the EU;
- no companies expects sales in the EU to decrease;
- no companies expect sales in the EU to decrease to zero.

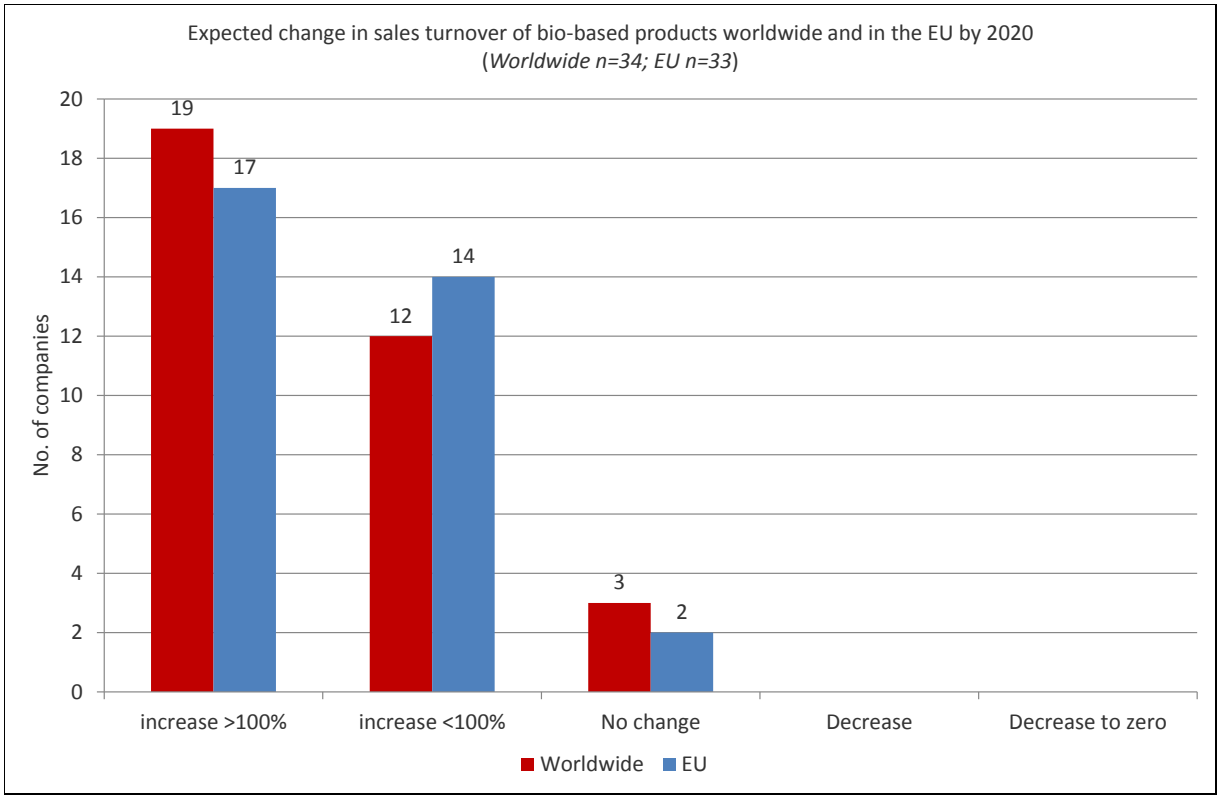


Figure A67: Expected change in sales turnover of bio-based products worldwide and in the EU by 2020

Source: EU bio-based industries survey.

13. Costs

Q64-67. What was the approximate contribution (%) of each of the following categories to production costs for bio-based products produced in the EU?

The average contribution (%) of various cost categories to production costs for bio-based products produced in the EU are broken down as follows:

- Feedstock: 46%
- Labour: 12%
- Utilities: 9%
- Other OPEX: 7%
- R&D: 4%
- CAPEX: 7%
- Other (balance): 15%

14. Public funding

Q68. Has your company received public funding since 2010?

Yes: 25 (55.6%)

No: 20 (44.4%)

Answered question: 45

Q69. What was the total value (in Euros) of public funding received?

17 companies provided data on the value of public financing received over the period from 2010 to 2013. Table A16 presents average and total values for the companies which provided information.

Table A16: Average and total value of public financing received over the period from 2010 to 2013

	Average	Total	No of Respondents
2010 - (in Euros)	1,883,417	22,601,000	12
2011 - (in Euros)	2,069,735	24,836,819	12
2012 - (in Euros)	1,848,334	25,876,674	14
2013 - (in Euros)	2,892,776	46,284,418	16

Source: EU bio-based industries survey.

Q70. What was the name(s) of the programme from which public funding was received?

20 companies provided information on the various sources of national and EU public funding, e.g.:

- Bandi MIUR-MISE; Bandi Regionali; BioCore (FP7)
- Câmara Municipal; Ciência Viva
- EOS-LT; EU FP7; EuroBioRef (FP7), ERA-NET IB; Energy
- FEDER; Finnish Ministry; FR (AII -now BPI); Fundo Florestal Permanente
- Instituto do Emprego e Formação Profissional; Italian Industria 2015; IWT
- KBBE
- Marie Curie; MKB Innovatie Programma
- National and transnational funding schemes; NMP
- Poli d'Innovazione; People; PON
- QREN - Quadro de Referência de Estratégia Nacional
- RDA (NL)
- Structural funds
- TEKES; Term Pilot facilities; Topsector ENergie
- Ultrafibre
- Valorization of non-food feedstock in valuable chemicals; Vinnova Skogskemi
- WBSO

Q71. Did this derive from an 'EU Framework Programme'?

Table A17 provides information on whether the source of public funding received over the period from 2010 to 2013 included funding from an 'EU Framework Programme'.

Table A17: Companies that received funding from an 'EU Framework Programme'

Answer Options	Yes	No	Don't know
2010	5	9	1
2011	6	9	1
2012	5	10	1
2013	9	8	1

Annex IV: Detailed analysis of products indicated in the survey responses

The survey collected information from 50 companies on the types of products produced (Figure A68). As reported in the figure, the bio-based products indicated by most respondents are organic acids, polymers (obtained from bio-based monomers) and surfactants. If we compare the products currently produced with the ones expected to be produced in 2020, there is a general growing trend in terms of number of products, but not concerning all products.

Based on the survey responses, 27 companies currently produce or expect to produce bio-based polymers by 2020, 26 companies currently produce or expect to produce organic acids by 2020, 19 companies currently produce or expect to produce bio-based alcohols by 2020, and 14 companies currently produce or expect to produce bio-based composites by 2020. Within the bio-based polymers, 25 companies indicated that they currently produce or expect to produce bio-polymers from monomers by 2020, and 12 companies indicated that they current produce or expect to produce bio-based polymers from natural polymers by 2020. 37 companies currently produce or expect to produce other bio-based products by 2020, including surfactants (14), paints and coatings (11), lubricants (9), binders (7), plasticisers (6), and solvents (4).

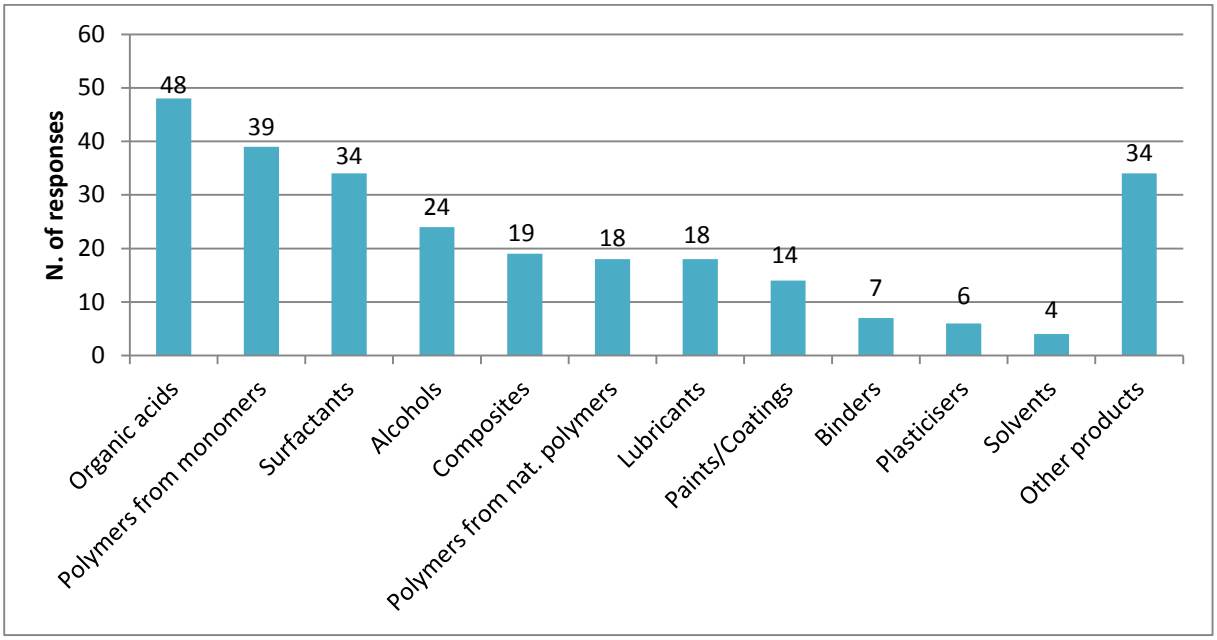


Figure A68: Number of companies that currently produce and/or expect to produce bio-based products by 2020

Source: EU bio-based industries survey.

Note: 50 respondents.

If we count both the currently produced and the expected bio-based products, 284 products have been indicated in total by the 50 respondents (i.e. between 5 and 6 per company in average). While some companies only indicated 1-2 products, others indicated up to 20 products, and often belonging to different product categories. This variety makes the overall data analysis very complex, since most indicators have been asked for the whole bio-based sector within the company, and not specifically per product.

The most frequently indicated products are illustrated in Bio-based products most frequently indicated by the survey respondents.

69, which presents the number of companies that currently produce or expect to produce the product by 2020. This includes a range of speciality (or functional)

chemicals, oleochemicals, polymers, and chemical building blocks. Many of these are established products, such as fatty acids and fatty acid esters, paint additives, polymeric surfactants, starch polymers, and wood –plastic composites. However, a number of these products currently have few producers, but more companies report that they expect to begin production by 2020. For PBS and HMF, no current producers were identified but four companies indicated they expect to produce by 2020. For FDCA and PHAs, two companies indicated that they currently produce these products, and five companies indicated that they expect to produce these products in 2020. In addition, three companies expect to begin production of levulinic acid, n-butanol and propylene glycol by 2020.

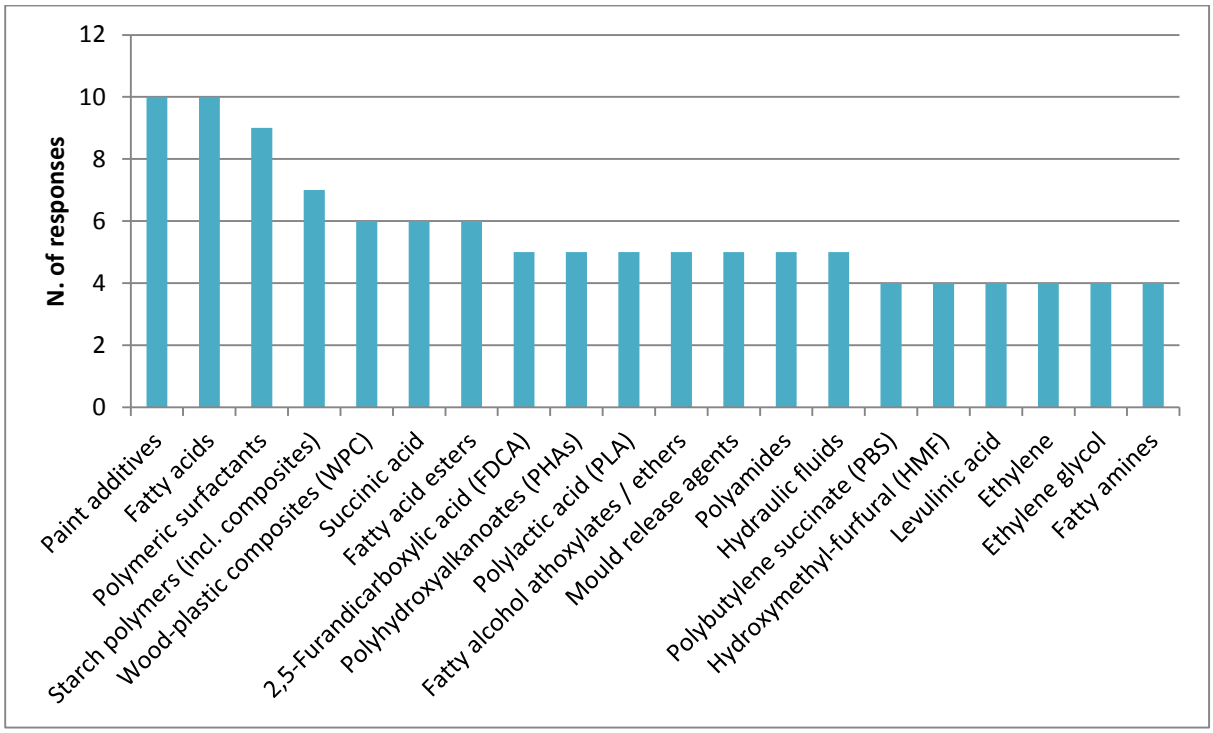


Figure A69: Bio-based products most frequently indicated by the survey respondents.

Source: EU bio-based industries survey.

For each product category, the tables below show the distribution of responses between what is currently produced and what is expected for 2020.

Organic acids

According to Table A18, succinic acid, FDCA and levulinic acid are promising bio-based organic acids, for the current and future (2020) market. Other products indicated as promising 2020 candidates are adipic acid and furfural. The use and production process of these products is described in Box 1. The future potential of these products is confirmed also by the fact that the companies indicating them also show a growing trend in total annual output of bio-based products in the EU and are expecting the share of bio-based product output sold in the EU to increase by 2020 (according to their answers to the survey). The table also shows products that are currently produced but for which no growing trends was detected for 2020 in terms of new companies entering the market.

Many new bio-based products were indicated outside the list provided in the questionnaire. In particular, a long list of fatty acids was indicated by, in total, 11 respondents as products not described in the initial list. Certain companies have indicated that they will start the production of certain (unspecified) fatty acids only by 2020.

Table A18: Responses distribution about the production of bio-based organic acids.

Organic acids	Total companies indicating the product as current or expected	New companies entering the market in 2020
Succinic acid	6	**2**
2,5-Furandicarboxylic acid (FDCA)	5	**3**
Levulinic acid	4	**3**
Lactic acid	3	1
Acetic acid	3	1
Sebacic acid	3	0
Adipic acid	2	**2**
Furfural	2	**2**
Formic acid	2	1
Lauric acid	2	0
Acrylic acid	1	1
Terephthalic acid	1	1
Methacrylic acid	1	1
Methyl methacrylate	1	0
Other (outside the intial list)	14	**3**
• Fatty acids and derivates, including partly hydrogenated fatty acids and fatty acids from rapeseed, soybean, palm, shea and tallow. In particular: hexanoic acid, heptanoic acid, caprylic acid, pelargonic acid, decanoic acid, C11 fatty acids, undecenoic acid, palmitic acid, stearic acid and fractionated stearic acids, oleic acid and more C16 – 18, both saturated and unsaturated • Azelaic acid		

Source: EU bio-based industries survey.

Alcohols

According to Table A19, all bio-based alcohols initially proposed in the survey list are showing a growing trend towards 2020 in terms of new players entering the field and planning to start producing them by 2020. According to the collected data, the most promising bio-based alcohols for the current and future (2020) market are n-butanol, propylene glycol, 1,3-propanediol (PDO) and 1,4-butanediol (BDO), which are described in Box 2.

Outside the list provided in the questionnaire, several bio-based fatty acid alcohols were indicated by the respondents. Two companies indicated that they will start fatty alcohols production only by 2020.

Table A19: Responses distribution about the production of bio-based alcohols

Bio-based alcohols	Total companies indicating the product as current or expected	New companies entering the market in 2020
n-butanol	3	3
Propylene glycol	3	3
1,3-Propanediol (PDO)	3	2
1,4-Butanediol (BDO)	2	2
Isobutanol	2	1
Furfuryl alcohol	1	1
Methanol	1	1
Other	8	2
• Fatty Alcohols: 2-octanol, Heptanol, Oleyl Alcohol, Cetyl Oleyl Alcohol, Decanol, Dododecanol, Tetradecanol, Hexadecanol		

Source: EU bio-based industries survey.

BOX2 – Promising Bio-based Alcohols

n-butanol

n-butanol is an important chemical building block, particularly for the manufacture of butyl acetate, and therefore has uses as solvent in paints and coatings for wood products, but also appearing as food flavouring. Most industrial initiatives in the field of n-butanol are aimed at the biofuels market due to better properties of n-butanol compared to ethanol.

The production of n-butanol has historically taken place via acetone, through the acetone (ABE) or isopropanol (IBE), butanol and ethanol fermentation. However, it became more economically convenient to produce n-butanol chemically via fossil propylene. Currently, many companies are active to re-introduce the ABE or IBE process commercially again, particularly in China.

Propylene glycol

45% of propylene glycol produced is used as chemical feedstock for the production of unsaturated polyester resins. It is used as a humectant (E1520), solvent, preservative in food and for tobacco products, as well as in electronic cigarettes. Propylene glycol is also used as a solvent in many pharmaceuticals.

Industrially, propylene glycol is produced from propylene oxide. Bio-based propylene glycol is currently obtained from starch and sugars (like sorbitol and dextrose) or from glycerol.

1,3-Propanediol (PDO)

1,3-propanediol is the promising bulk chemical which has attracted worldwide attention due to its enormous applications in polymers (such as polytrimethylene terephthalate - PTT), cosmetics, foods, adhesives, lubricants, laminates, solvents, antifreeze and medicines.

The majority of commercial synthesis of 1,3-propanediol are through the hydration of acrolein and through the hydroformylation of ethylene oxide to afford 3-hydroxypropionaldehyde. Its microbial production is based on glucose or on glycerol, which promises to be a good substrate being a major by-product of the biodiesel industries.

1,4-Butanediol (BDO)

BDO is used industrially as a solvent and serves as a raw material for a range of important chemicals including polymers polybutylene terephthalate (PBT), polybutylene succinate (PBS) and tetrahydrofuran (THF). BDO also acts as precursor to a number of specialty chemicals used as solvents or as raw materials in pharmaceuticals and agrochemicals.

1,4-butanediol (BDO) is a bulk product that is currently being produced in large volumes from petrochemical raw materials in various ways (e.g. from petrochemical maleic anhydride). Various large companies and consortiums are working on the development and upscaling of bio-based BDO production. Different bio-based routes have been developed: from glucose, xylose, sucrose and biomass-derived mixed sugar streams Alternatively, BDO can be obtained from 4-hydroxybutyrate or from succinic acid.

Polymers

Polymers are classified in two main groups: polymers derived from natural polymers (like starch and cellulose) and polymers obtained from bio-based monomers (like e.g. organic acids and alcohols). According to survey respondents, among natural polymers the most promising are starch polymers, indicated by seven companies, of which three are planning to enter the market by 2020 (Table A20).

The list of polymers obtainable from bio-based monomers is very long (Table A20), the most promising being PHAs (which include several different polymers), PLA and PBS. They are described in more details in Box 3. Respondents also indicated additional

polymers that are outside the initial list, like polyesters, polyethers and their derivatives, among others. Some companies indicated that they produce or are planning to produce polymers that are not indicated in the provided list (both derived from natural polymers and from monomers), but they did not specify the name of the products.

Table A20: Responses distribution about the production of bio-based polymers

Bio-based polymers (derived from	Total companies indicating the product as current or expected	New companies entering the market in 2020
Starch polymers, inc. composites	7	3
Cellulose ether	2	1
Cellulose ester, inc. cellulose acetates	1	0
Microfibrillated cellulose	1	0
Other (unspecified)	5	4
Bio-based polymers (derived from monomers)	**Total companies indicating the product as current or expected**	**New companies entering the market in 2020**
Polyhydroyalkanoates (PHAs), inc. PHB	5	3
Polylactic acid (PLA)	5	2
Polybutylene succinate (PBS)	4	4
Polyamides	4	0
Polyesters	3	0
Polyethylene furanoate (PEF)	2	1
Polyurethane (PUR)	1	1
Polybutyrate (PBAT)	1	1
Polyethylene (PE)	1	1
Polyvinyl chloride (PVC)	1	1
Polypropylene (PP)	1	1
Polyethylene terephthalate (PET)	1	1
Polybutylene terephthalate (PBT)	1	0
Polyvinyl acetate (PVA)	1	0
Polystyrene (PS)	1	0
Polymethyl methacrylate (PMMA)	1	0
Schizophyllan	1	0
Co-polyols (capa-lactide)	1	0
Polycarbonates (PC)	0	0
• Formulated polyesters • Polyester resins • Polyether block amide (PEBAX) • Polyester-polyols • TPC-ET: (thermo-plastic polyester elastomer) • PTT (polytrimethyleneterephtalate) • Polyesters		

Source: EU bio-based industries survey.

BOX3 – Promising Bio-based Polymers

Starch polymers, inc. composites

Plasticised starch is essentially starch that has been modified by the addition of plasticisers (or other plasticising additives) to enable processing. Thermoplastic starch is plasticised starch that has been processed (using heat/pressure) to completely destroy the crystalline structure of starch, to form an amorphous thermoplastic starch – this typically involves an irreversible order-disorder transition called gelatinisation.

Polyhydroyalkanoates (PHAs), inc. PHB

Polyhydroxyalkanoates or PHAs are a class of linear polyesters produced in nature by the direct bacterial fermentation of sugar or lipids. These plastics are biodegradable (suitable for home composting) and can either be thermoplastic or elastomeric materials. More than 150 different monomers can be combined within this family to give materials with extremely different properties. PHAs are increasingly used for blending, for instance to increase the impact resistance of PLA. Polyhydroxybutirate (PHB) and polyhydroxyvalerate (PHVB) are common types of PHAs seen in nature.

Polylactic acid (PLA)

Polylactic acid, or polylactide, is a thermoplastic polyester. It is suitable for packaging materials, insulation foam, car parts, fibres (textile and non-woven), and as a feedstock for 3D printers.

PLA is a fully bio-based plastic, derived from corn starch (in the US), tapioca roots, chips or starch (in Asia) or sugarcane (in the rest of the world). Production occurs via fermentation of sugars to lactic acid, then dehydratation to form lactide, which can then be polymerized to make PLA, either cast, injection molded or spun. PLA is biodegradable/compostable under certain circumstances.

Polybutylene succinate (PBS)

PBS is a relatively new thermoplastic polyester. The material is biodegradable and used for blending with starch polymers to improve properties. PBS is most commonly manufactured via the esterification of succinic acid and butane-1,4-diol. PBS has previously been of fossil origin, but developments to produce it from bio-based succinic acid and bio-based BDO are on their way. PBS has a properties profile similar to that of polypropylene (PP), thus the potential application area is enormous. It could be processed into films, bags or boxes (for food and cosmetic packaging). Other applications could be found as disposable products such as tableware, agricultural mulching films or delayed release materials for pesticide and fertilizer, drug encapsulation systems, medical implants, fishing nets, and other sectors.

Composites

Bio-based composites, especially natural fibres plastic composites, have been indicated by several companies in the survey, in particular plastic composites with wood (WPC) and other unspecified natural fibres, which are planned to be produced by two and six companies respectively by 2020 (Table A21 and Box 4). Four respondents indicated that they are producing bio-based composites beyond the list provided, but they did not specify which ones.

Table A21: Responses distribution about the production of bio-based composites

Bio-based composites	Total companies indicating the product as current or expected	New companies entering the market in 2020
Other natural fibre reinforced plastics	8	6
Wood-plastic composites (WPC)	6	2
Cork reinforced plastics	1	0
Other (unspecified)	4	0

Source: EU bio-based industries survey.

BOX4 – Bio-based composites

Natural fibre reinforced plastics

Natural fibre plastic composites (NFPCs) are a potential environmentally friendly and cost-effective alternative to synthetic fibre reinforced composites. NFPC may contain non cellulose-based fibre fillers such as pulp fibres, peanut hulls, bamboo, straw and digestate.

Wood-plastic composites (WPC)

Wood-plastic composites (WPC) are composite materials made of wood/fibre/wood flour and virgin or recycled thermoplastic(s) including HDPE, LDPE, PVC, PP, ABS, PS and PLA. Polyethylene based WPCs are by far the most common.

The main known use of WPC is as building materials, in particular in outdoor deck floors , railings, fences, park benches, window and door frames, among many other possibilities.

Surfactants

Several surfactant products were indicated by the survey respondents (Table A22). In particular polymeric surfactants, fatty alcohol ethoxylates/esthers and esther quats were indicated by at least four different companies. Polymeric surfactants and glycolipids are also considered as promising since two companies have indicated that they plan to enter the market by 2020. These products are described in Box 5.

Several bio-based surfactants have been indicated by respondents outside the list provided. They include Fatty acid ethoxilates and esters, Fatty ester ethoxilates, Alkylquats, Sodium alkoxylates and Metallic salts.

Table A22: Responses distribution about the production of bio-based surfactants

Bio-based products - surfactants	Total companies indicating the product as current or expected	New companies entering the market in 2020
Polymeric surfactants	9	**2**
Fatty alcohol ethoxylates/ethers	5	0
Ester quats	4	0
Alkyl polyglucosides	3	1
Fatty alcohol ether sulfates	3	0
Fatty alcohol sulfates	3	0
Glycolipids, inc. sophorolipids	2	**2**
Amphoteric surfactants (inc. betaines)	2	0
Metallic soaps	2	0
Amphoacetates	1	0
Lipopeptides and digopeptites	0	0
Other	5	0
• Fatty acid ethoxilates • Alkylquats • Sodium alkoxylates • Fatty alcohol esters • Fatty ester ethoxilates • Metallic salts of fatty acids and fatty esters		

Source: EU bio-based industries survey.

BOX5 – Promising bio-based surfactants

Polymeric surfactants

Polymeric surfactants refer to macromolecules containing both hydrophilic and hydrophobic parts. This definition also includes amphiphilic polymers, micellar polymers, hydrophobically modified water-soluble polymers, associative polymers, and related terms. Certain proteins (e.g. casein in milk) and polysaccharides like emulsan and chitosan are also examples of polymeric surfactants.

It is usually very difficult to isolate polymeric surfactants from natural sources, and their structures and compositions can vary depending on the source; therefore, most of the systems studied and reported in the literature are synthetic.

They are demonstrating actual and potential applications in several fields including (mini)emulsion polymerizations, coatings, biotechnology, nanotechnology, medicine, pharmacology, cosmetics, agriculture, water purification, electronic, optoelectronic, and enhanced oil recovery (http://pubs.acs.org/doi/pdf/10.1021/cr500129h).

Fatty alcohol ethoxylates/ethers

Ethoxylation is the process by which ethylene oxide is added to a fatty acid alcohol to create detergent properties in a surfactant. Alcohol ethoxylates (AE) and alcohol ethoxysulfunates (AES) are surfactants found in products such as laundry detergents, surface cleaners, cosmetics and for use in agriculture, textiles and paint. In industrial ethoxylation, alcohol is heat & pressure treated with ethylene oxide, using potassium hydroxide (KOH) as a catalyst. Traditionally the alcohols were obtained by hydrogentation of fatty acids, but currently most are "oxo alcohols", obtained via hydroformylation.

Alkyl ether sulfates result from the sulfation of an ethoxylated fatty alcohol. AES found in consumer products generally are linear alcohols. A common example is sodium lauryl ether sulfate (SLES), an anionic detergent and surfactant found in many personal care products (soaps, shampoos, toothpaste, etc.), as well as industrial detergents.

Ester quats

Esterquats, which are quaternary ammonium compounds having two long (C16-C18) fatty acid chains with 2 weak ester linkages, represent a new generation of fabric softening agents, having replaced the dialkyldimethylammonium salts. This new generation of fabric softening agents combines a good environmental profile with the structural features required for an effective fabric conditioner. https://www.jstage.jst.go.jp/article/jos/56/6/56_6_269/_article

Glycolipids, inc. sophorolipids

The major and most widely used biosurfactants in cosmetics and personal care products are glycolipids because of their physic-chemical properties, biological activities, biocompatibility and biodegradability, and are used as multifunctional ingredients in the formulation of cosmetics. Potential glycolipid biosurfactants employed in the cosmetics industry are sophorolipids, rhamnolipids and mannosylerythritol lipids. A sophorolipid is a surface-active glycolipid compound that can be synthesized by certain yeast species. http://onlinelibrary.wiley.com/doi/10.1111/j.1468-2494.2009.00493.x/epdf

Other oleochemicals (Solvents, Binders, Plasticizers and Paints&Coatings)

Among the oleochemicals described in this section, the products indicated most often by respondents are paint additives (ten companies indicated them), and certain types of lubricants: Mould release agents, Hydraulic fluids and Chain & bearing lubricants (all described in Box 6). However, not many new companies are entering the market by 2020, according to the responses obtained: only two companies will start producing paint additives and one company will start producing the plasticizers furanoate esters by 2020. Some respondents also indicated that they produce oleochemical products outside the list provided, but they did not specify the exact products.

Table 23: Responses distribution about the production of bio-based Solvents, Binders, Plasticizers and Paints&Coatings

	Total companies indicating the product as current or expected	New companies entering the market in 2020
Bio-based solvents		
Methyl levulinate	1	0
Other (unspecified)	3	0
Bio-based binders		
Adhesives (inc. lignin-based)	2	0
Colloid binders	1	0
Pentaerytrithol	1	0
Modified starches	1	0
Sugar-based binders	1	0
Others (unspecified)	2	0
Bio-based plasticisers		
Furanoate esters	1	1
Phthalate esters	1	0
Epoxidized Soya bean oil	1	0
Isosorbide diester	1	0
Other (unspecified)	1	0
Bio-based paints/coatings		
Paint additives	10	2
Resins / Alkyd resins	2	0
Printing colours	1	1
Hybrid polymer coatings (mixtures of natural and synthetic polymers)	1	0
Rheology additives	1	0
Other (unspecified)	1	0
Bio-based lubricants		
Mould release agents	5	0
Hydraulic fluids	5	0
Chain & bearing lubricants	4	0
Additives / Raw materials for lubricants	2	0
Metal working fluids	1	0
Metalic stearates	1	0

Source: EU bio-based industries survey.

BOX6 – Promising bio-based oleochemicals

Paint additives:

Paint can have a wide variety of additives, usually added in small amounts, yet providing a significant effect on the product. Examples include additives to modify surface tension, improve flow properties, finished appearance, wet edge, pigment stability, antifreeze properties, plus control foaming and skinning. Other types of additives include catalysts, thickeners, stabilizers, emulsifiers, texturizers, adhesion promoters, UV stabilizers, flatteners (de-glossing agents), biocides to fight bacterial growth.

Mould release agents

Some release agents, also known as de-moulding agent, form oil, parting agent or form releaser, are substances used in moulding and casting that aid in the separation of a mould from the material being moulded and reduce imperfections in the moulded surface. This lubricant category do not to cover rubber release agents, which are silicone based.

Hydraulic fluids

Hydraulic fluids can contain a wide range of chemical compounds, including: oils, butanol, esters (e.g. phthalates, like DEHP, and adipates, like bis(2-ethylhexyl)adipate), polyalkylene glycols (PAG), organiphosphate (e.g. tributylphosphate), silicones, alkylated aromatic hydrocarbons, polyalphaolefins (PAO) (e.g. polyisobutenes), corrosion inhibitors (incl. acid scavengers), anti-erosion additives, etc.

Chain & bearing lubricants

Typically lubricants contain 90% base oil (most often petroleum fractions, called mineral oils) and less than 10% additives. Vegetable oils or synthetic liquids such as hydrogenated polyolefins, esters, silicones, fluorocarbons and many others are sometimes used as base oils. Additives deliver reduced friction and wear, increased viscosity, improved viscosity index, resistance to corrosion and oxidation, aging or contamination, etc.

Other bio-based products

The bio-based products that are not included in the previous categories constitute a heterogeneous group (Table A24), in which the ones that are indicated by most companies are fatty acid esters, ethylene glycol, Hydroxymethyl-furfural (HMF) and ethylene. Of those, a promising future bio-based product is HMF, which is not currently produced by any of the respondents, but four companies are planning to start its production by 2020. Also, three companies will start the production of ethylene glycol and two of ethylene by 2020. Among the products indicated by respondets beyond the list provided are agents for oilfield and dishwashing applications, Carbon Nanotubes and additives for Polyvinyl chloride (PVC).

Table A24: Responses distribution about the production of other bio-based products

Other bio-based products	Total companies indicating the product as current or expected	New companies entering the market in 2020
Fatty acid esters (inc. FAGE and cosmetics)	6	1
Ethylene glycol	5	**3**
Hydroxymethyl-furfural (HMF)	4	**4**
Ethylene	4	**2**
Fatty amines	4	0
Isosorbide	2	0
Isoprene	1	1
Farnesene	1	1
Para-xylene	1	1
Limonene	1	1
Epichlorohydrin	1	0
Chelating agents	1	0
Other polymer additives (curing agents)	1	0
Lignosulphonates	1	0
Acetaldehyde	1	0
Ethyl acetate	1	0
Fatty acid amide	1	0
Acetone	0	0
Other	4	0
• Agents for oilfield and dishwashing applications • Carbon Nanotubes produced from ethanol • Other polymer additives (additives for PVC)		

Source: EU bio-based industries survey.

BOX7 – Other promising bio-based products

Fatty acid esters

Fatty acid esters (FAEs) are a type of ester that results from the combination of a fatty acid with an alcohol. The alcohol can be for example methanol, giving rise to fatty acid methyl esters or FAME, used to produce detergents and biodiesel, or ethanol, giving rise to fatty acid ethyl esters (FAEE).When the alcohol component is glycerol, the fatty acid esters produced can be monoglycerides, diglycerides, or triglycerides. Biodiesels are typically fatty acid esters produced by the transesterification of vegetable fats and oils which results in the replacement of the glycerol component with a different alcohol. Fatty acid glycerol formal esters (FAGE) are obtained from oils (vegetable, animal or waste oils) and glycerol and can be used as a blending component in diesel fuels.

Hydroxymethyl-furfural (HMF)

HMF is a very important building block for a wide range of applications, including polymers, fine chemicals and fuels. HMF can be converted to a range of furan derivatives, like FDCA. HMF can be converted to 2,5-dimethylfuran (DMF), which is a liquid biofuel with a greater energy content bioethanol. Among others, HMF can also be converted to gamma-valerolactone (GVL) for the perfume and flavor industries and 2,5-bis(hydroxymethyl)furan for the manufacture of polyurethane foams and polyesters.

HMF is produced from carbohydrates such as fructose, glucose, sucrose, cellulose and inulin. The most common route is dehydration of fructose or other hexoses. Different solvent systems have been researched to obtain an efficient HMF production but significant challenges still remain in transferring it to an industrial scale.

Ethylene

Ethylene is produced in the petrochemical industry by steam cracking, with worldwide production of 127 million tonnes. It widely used in chemical industry, for polymerisation (into polyethylene) a major use, as well as oxidation to ethylene dioxide, halogenation (e.g. to ethylene dichloride for PVC), alkylation to ethylbenzene (precursor to styrene), and hydration to ethanol. Ethylene is also as important natural plant hormone, used in agriculture to force the ripening of fruits.

Ethylene glycol

Ethylene glycol is produced from ethylene (ethane), via the intermediate ethylene oxide. Ethylene glycol is primarily used as raw material in the manufacture of polyester fibers and fabric industry, and polyethylene terephthalate resins (PET) used in bottling. A small percent is also used in other applications such as antifreeze formulations and other products.

Fatty amines

Fatty amines are oleochemical compounds in which an amine is attached to a hydrocarbon chain of eight or more carbon atoms in length, more commonly C12-C18 hydrocarbons derived from fatty acids. Commercially important fatty amines include coco amine, oleylamine, tallow amine, and soya amine. Some applications of these compounds are in fabric softeners, flotation agents, corrosion inhibitors, dispersants and emulsifiers. They are the basis for a variety of cosmetic formulations.

Fatty amines are commonly prepared from fatty acids that can derive from vegetable oils. The overall reaction is sometimes referred to as the Nitrile Process and begins with a reaction between the fatty acid and ammonia at high temperature and in the presence of a metal oxide catalyst.

BOX1 – Promising Bio-based Organic Acids

Succinic Acid

Succinic acid and its derivatives are most widely used as food or pharmaceutical ingredients. Succinic acid also has a wide range of industrial applications, still limited by its price, like the manufacture of the biodegradable polymer polybutylene succinate (PBS). Succinic acid could also be used as replacement for maleic anhydride and precursor for 1,4 butanediol (BDO), tertahydrofuran (THF) and γ-butyrolactone (GBL).

Succinic acid is conventionally produced from butane or benzene. Bio-based succinic acid can be produced by fermenting carbohydrate or glycerol using engineered bacteria or yeast.

2,5-Furandicarboxylic acid - FDCA

FDCA is showing a big potential as a replacement of several petroleum based platform chemicals, e.g. terephthalic acid, adipic acid and other important di-acids by polymerization. FDCA has also strong potential to be used in the production of solvents, especially novel solvents.

FDCA is a furan that can be synthesized from the oxidation of 2,5-disubstituted furans or the catalytic conversion of various furan derivatives. A bio-based route is the oxidative dehydration of glucose by using either oxygen or electrochemistry. FDCA can also be produced by the oxidation of 5-hydroxymethylfurfural (HMF), an intermediate in the production of levulinic acid from hexose sugars.

Levulinic Acid

Presently, levulinic acid finds applications in pharmaceuticals, pesticides, cosmetics, food additives, cigarettes and minor use in nylons, synthetic rubbers and plastics. It has been identified as critical building block to act as precursor to chemicals including fuel additives, pesticides and certain biofuels.

Levulinic acid is usually obtained by the hydrolysis of sucrose to glucose, isomerisation to fructose, then dehydration of fructose to hydroxynethylfurfural (HMF), followed by hydrolysis resulting in levulinic acid with formic acid as a by-product.

Adipic Acid

The great majority of adipic acid is used as monomer for the production of nylon by a polycondensation reaction forming 6,6-nylon. Other major applications also involve the production of Polyurethane and its esters. Other uses of adipic acid can be found in the field of medicine, for drug delivery, and of food ingredients.

Several fossil-based processes for the production of adipic acid are known, including biosynthesis of adipic acid from cyclohexanol and cyclohexane-based processes among others. One process described in 2006 that involves a biomass substrate is the biosynthesis of cis,cis-muconic acid by fermentation of glucose, followed by catalytic hydrogenation to adipic acid. Since then several companies have claimed different processes for adipic acid from raw renewable materials.

Furfural

Furfural is an important chemical solvent and chemical building block. Hydrogentation of furfural provides furfuryl aolcohol (FA), which is a useful chemical intermediate and which may be further hydrogenated to tretrahydrofurfuryl alcohol (THFA). It is also used to make other furan chemicals, such as furoic acid (via oxidation) and furan (via decarboxylation).

Furan is a colourless oily liquid derived from a variety of agricultural byproducts, including corncobs, oat, wheat bran and sawdust.

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LF-NA-27736-EN-N

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Publications Office

doi:10.2791/806858

ISBN 978-92-79-54969-4