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Methods to define indicators on research and innovation in the bioeconomy

EU Bioeconomy Monitoring System update

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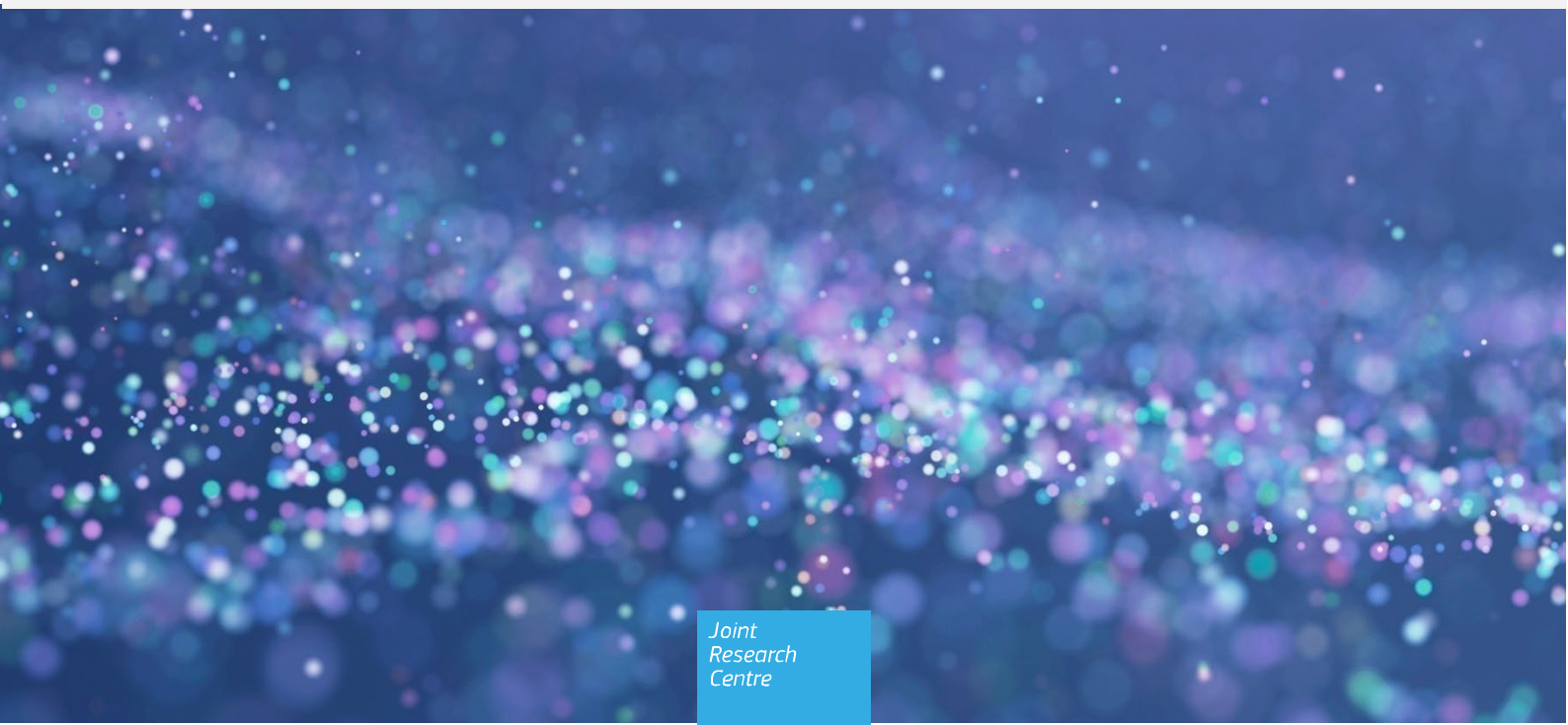

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Contents

Abstract

The innovation in the bioeconomy sectors is a key enabler for transitioning towards a carbon-neutral economy and complying with the objectives of the EU's Bioeconomy Strategy. Consequently, the EU-Bioeconomy Monitoring System places significant emphasis on indicators of research and innovation activities in the bioeconomy sectors, and some placeholders within this field were foreseen in its current structure.

In order to retrieve relevant data on bioeconomy innovation and make methodological choices, the Joint Research Centre (JRC) contracted recognized experts in the field. The experts assessed the feasibility of implementing the planned indicators and proposed complementary ones.

This report presents the results of the experts' analysis of the evaluation of the indicators foreseen in the EU-Bioeconomy Monitoring System, and offers an operational description of the methodologies to retrieve, transform, and display data for research and innovation in the bioeconomy sectors. The final list of proposed indicators is as follows:

— Private Sector investment in research and development

— EU Public Sector investment in research and development

— Public Sector investment in research and development (member states)

— Number of students/graduates in fields relevant to the bioeconomy

— Number of research outputs in the field of bioeconomy

— Total number of patents for the bioeconomy

— EC-Sponsored Pilot Plants opened in a given year (number/investment)

The report concludes that some indicators, such as private sector investment in research and development, number of students/graduates in bioeconomy-related fields, and research outputs in the bioeconomy field, are almost readily implementable. However, other indicators, such as public sector investment in research and development, market volume in bioeconomy relevant areas, and total number of patents for the bioeconomy, may require a moderate or resource-intensive investment for implementation.

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Executive summary

The present report was committed under an Administrative Arrangement between the DGs RTD and JRC [DG RTD N° 013 KCB; JRC Reference N ° 35895 NFP] for the "improvement of the current system of strategic intelligence [that] is needed to analyse the knowledge on, and monitor the progress of, the EU bioeconomy as provided for in the HORIZON 2020 Work Programme 2018-2020, part 9. Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy, Other Actions, Bioeconomy Knowledge Centre (Commission Decision C(2020)6320 of 17 September 2020)".

Policy context

This report contributes to the aim of providing a holistic view of the research and innovation activities of the EU Bioeconomy within the European Union Bioeconomy Monitoring Systems (EU-BMS hereinafter, see Kilsedar et al., 2021a, 2021b), by proposing replicable methodologies for the inclusion of new indicators in the aforementioned monitoring system, related to the research and innovation activities in the bioeconomy sectors

The expert consultation organized by the JRC through a series of workshops during the conceptualization phase of the European Union Bioeconomy Monitoring System (EU-BMS hereinafter) has revealed a great interest towards indicators of bioeconomy innovation, with innovation being viewed as a key enabler for the transition towards a carbon-neutral economy. Consequently, the EU-BMS foresees some indicators related to research and innovation in the bioeconomy.

Main findings

To retrieve relevant data on bioeconomy innovation and of the complexity of methodological choices to be made (see Annex 1), the JRC contracted two recognized experts in the field:

- Dr. Sven Wydra, quoted above, is the coordinator of the Business Unit "Bioeconomy & Life Sciences" at Fraunhofer ISI. He is a specialist of Bioeconomy and Economics of innovation.
- Dr. Henning Alexander Kroll is the coordinator of Business Unit "Innovation Trends and Science Studies" at Fraunhofer ISI. He is a specialist of Industrial innovation policy, Innovation systems and regulatory framework for innovation.

The experts first assessed the feasibility of implementing the indicators that were already foreseen in the EU BMS, and proposed complementary indicators (Section 1). In a second step, they provided the JRC with an operational description of the methodologies to retrieve, transforming and display data for research and innovation in the bioeconomy sectors (Section 2).

After analysing the research and innovation indicators foreseen in the EU-Bioeconomy Monitoring System, the experts identified those for which publicly available information exists, as well as those that do not have sufficient information to be estimated and updated regularly. For the dimensions represented by the latter, alternative indicators that can be estimated were proposed.

Conclusions and future JRC work

From the assessment performed by bioeconomy R&I experts, we conclude that the methodology for data retrieval and transformation:

1) Is <u>almost readily implementable</u> in the case of the indicators:
   - Private Sector investment in research and development (R&D, see Section 2.1)
   - Number of students / graduates in fields relevant to the bioeconomy (Section 2.4).
   - Number of research outputs in the field of bioeconomy based on Elsevier Scopus data (Section 2.5).
2) <u>Requires a moderate investment</u> for a sound implementation of the indicators:

- EU Public Sector investment in bioeconomy R&D and EC-Sponsored bioeconomy Pilot Plants opened in a given year (number / investment).
- Total number of patents for the bio-economy.

3) Is judged rather resource-intensive and/or might not be implementable with current resources for indicators:
   - Public Sector investment in research and development (R&D) (Member States)
   - Market volume in bioeconomy relevant areas

The table below summarizes these indicators together with the key output and data transformation needed, which has been elaborated in more detail for each indicator in section 2.

Conceptual dimension	Indicator	Consideration in the EU-BMS	Description
Monetary investment (private)	Private Sector investment in research and development (R&D)	Placeholder (No division between public or private financing)	R&D investments on 2-digit NACE sectors (Eurostat data) to be by weighted with estimates of bio-based shares per NACE sector
Monetary investment (public, EU)	EU Public Sector investment in research and development (R&D)	Placeholder (No division between public or private financing)	Various sub-indicators (e.g. number of projects, total EU funding) based on EU-funded projects available in E-CORDA, by attribution of projects to the bioeconomy
Monetary investment (public, member states)	Public Sector investment in research and development (R&D) (member states)	Placeholder (No division between public or private financing)	Country by country data for public R&D investment in the bioeconomy to be provided by national research councils of all Member States
Human capital	Number of students / graduates in fields relevant to the bioeconomy	Proposed by experts	Number of students enrolled and graduates in tertiary education identifiable by using Eurostat data and attributing ISCED Fields of education and training can be used to the bioeconomy
Academic results	Number of research outputs in the field of bioeconomy	Placeholder	The number of bioeconomy publications can be queried e.g. from Elsevier Scopus Database and various more detailed-indicators (e.g. share of bioeconomy) can be derived
Inventive	total number of patents for the bio-economy	Placeholder	The number of bioeconomy patents can be directly queried from existing (and free) data sources (PATSTAT / Espacenet) and various more detailed-indicators (e.g. share of bioeconomy) can be derived
Innovation	EC-Sponsored Pilot Plants opened in a given year (number / investment)	Placeholder	Relevant projects with pilot plant activities to be identified in E-CORDA, and related information about size or related investment to be extracted
Jobs[1]	Persons employed per bioeconomy sectors	Implemented in the EU-BMS	See Bioeconomy Monitoring System
Growth	Turnover in bioeconomy per sector	Implemented in the EU-BMS	See Bioeconomy Monitoring System
Climate change mitigation	All indicators related to Climate Change	Implemented in the EU-BMS	See Bioeconomy Monitoring System

Note: The term 'placeholder' refers to those indicators that are foreseen in the EU-BMS, but still not populated with data.

[1] Information on the options of gearing future official statistics towards covering the bio-economy better: Adding bio-based products and materials to statistical classifications (cbs.nl)

1 Introduction

The present report was committed under an Administrative Arrangement between the DGs RTD and JRC [DG RTD N° 013 KCB; JRC Reference N ° 35895 NFP] for the "improvement of the current system of strategic intelligence [that] is needed to analyse the knowledge on, and monitor the progress of, the EU bioeconomy as provided for in the HORIZON 2020 Work Programme 2018-2020, part 9. Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy, Other Actions, Bioeconomy Knowledge Centre (Commission Decision C(2020)6320 of 17 September 2020)".

The EU's Bioeconomy Strategy remarks the role of the bioeconomy in the modernization and strengthening of the European industrial base. To fulfil this purpose, the bioeconomy has to be research and innovation driven, so as to provide solutions to substitute fossil-based production and energies with bio-based alternatives. The expert consultation organized by the JRC through a series of workshops during the conceptualization phase of the European Union Bioeconomy Monitoring System[2] (EU-BMS hereinafter, see Kilsedar et al., 2021a, 2021b) has indeed revealed a great interest towards indicators of bioeconomy innovation, with innovation being viewed as a key enabler for the transition towards a carbon-neutral economy.

This report contributes to the aim of providing a holistic view of the sustainability of the EU Bioeconomy within the European Union Bioeconomy Monitoring Systems (EU-BMS hereinafter, see Kilsedar et al., 2021a, 2021b), by proposing replicable methodologies for the inclusion of new indicators in the aforementioned monitoring system, related to the research and innovation activities in the bioeconomy sectors

The EU-BMS is structured around a classification comprising, by increasing order of aggregation: indicators / Key components / Normative criteria / Objectives (Giuntoli et al. 2020). The present task aims at proposing methodologies for retrieving, transforming and displaying data for indicators on research and innovation, which relates to the fifth objective of the EU' "Strengthening European competitiveness and creating jobs". Some indicators classified under the key component "Market mechanisms" are also related with innovation outputs. The full list of innovation-related indicators to be potentially included in the EU-BMS, pointed out by internal and external consultations, are shown in Table 1.

Many of the indicators listed at Table 1 remain non-informed by public data providers. In view of the difficulty to retrieve relevant data on bioeconomy innovation and of the complexity of methodological choices to be made (see Annex 1), the JRC contracted two recognised experts in the field, namely:

- Dr. Sven Wydra is the coordinator of the Business Unit "Bioeconomy & Life Sciences" at Fraunhofer ISI. He is a specialist of Bioeconomy and Economics of innovation.
- Dr. Henning Alexander Kroll is the coordinator of Business Unit "Innovation Trends and Science Studies" at Fraunhofer ISI. He is a specialist of Industrial innovation policy, Innovation systems and regulatory framework for innovation.

The present report summarizes their work step-by-step: They first assessed the list of innovation indicators foreseen for the EU Bioeconomy Monitoring System and proposed complementary indicators to the the identified data need of the EU Bioeconomy Monitoring System (sections 1.1 and 1.2). In a second step, they have provided the JRC with an operational description of the methodologies to implement at the time of integrating the proposed indicators within the EU-BMS framework and dashboard (section 2). Their final report was delivered in July 2022.

[2] https://knowledge4policy.ec.europa.eu/visualisation/eu-bioeconomy-monitoring-system-dashboards_en

Table 1. Normative criteria, objectives and indicators identified under the Headline "R&I"

Normative criterion - Key component	Identified indicators	
Existing knowledge is adequately valued and proven sound technologies are fostered - Existing knowledge on Bioeconomy technologies	5.4.a.1	Adoption of new Bioeconomy technology by primary producers for both production and transformation levels
	5.4.a.2	Rolling-out of pilot projects
	5.4.a.3	Investment in TRL8-9 bio-based products
Knowledge generation and innovation are promoted - Knowledge generation/ (high level) education	5.5.a.1	% persons employed with 3º education in Bioeconomy sectors
	5.5.a.2	Changes in University curricula (number)
	5.5.a.3	Investment in higher education related to Bioeconomy
Knowledge generation and innovation are promoted - Research and innovation	5.5.b.1	Number of patents by Bioeconomy sectors
	5.5.b.2	Investment in research and innovation (1000 euro)
	5.5.b.3	Open innovation
	5.5.b.4	New non-food products produced from primary sources
	5.5.b.5	Number of research outputs in the field of Bioeconomy
Demand and supply-side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced - Market mechanisms (e.g. prices, consumer awareness)	5.6.a.1	Market or consumers acceptance
	5.6.a.2	Number of labelled or certified bio-based products

Source: Own elaboration based on the EU-Bioeconomy Monitoring System

1.1 Assessment of the EU-BMS list of indicators

The first step of the experts study was to assess if the indicators foreseen for the EU-BMS indicators (see Kilsedar et al., 2021a, and Kilsedar et al., 2021b) under the Normative Criteria pertaining to the theme of research and innovation were plausible within reasonable human and economic resources, and if they indeed suited monitoring needs (e.g. available time series, reproducibility).

The result of their assessment is presented at Table 2. Rows highlighted in green indicate the indicators that can be informed with data and for which more information is reported Section 2. Table 2 also provides the justification on the reason(s) why the other indicators cannot be informed with data or are too resource intensive.

Table 2. Experts' assessment on foreseen R&I indicators in the EU-BMS (Kilsedar et al. 2020)

Normative criteria - Key component	Identified indicators		Interpretation / Suggestion	Availability	Reason for Exclusion Further Consideration
Existing knowledge is adequately valued and proven sound technologies are fostered **- Existing knowledge on bioeconomy technologies**	5.4.a.1	Adoption of new bioeconomy technology in the primary sector		not available/ no basis for estimation	There are no reliable statistics on the diffusion or uptake of biotechnology-relevant technologies in the primary (or for that matter also the secondary) sector; Such statistics would require broad-based firm surveys which - other than e.g. with a view to IT technologies - are not currently being conducted.
	5.4.a.2	Rolling-out of pilot projects			
	5.4.a.3	Private and/or Public Investment in TRL8-9 bio-based products		not available/ no basis for estimation	There is no official statistic on TRL8-9 bio-based products list or available statistics of capacities without high fees and copyright issues. Investment sum for high-volume bio-based products seems possible, but would have to rely extensively on document reviews of public announcements - hence very resource-intensive to update. Also in public funding statistics there is no methodologically valid way to identify projects related to TRL8-9 bio-based products. In addition, activities at TRL8-9 are not commonly funded, as they usually cannot be publicly supported given competitiveness regulations.
Knowledge generation and innovation are promoted **- Knowledge generation/ (high level) education**	5.5.a.1	% persons employed with 3º education in bioeconomy sectors		not available/ no basis for estimation	European Labour Force Survey differentiates sector only at NACE 1-digit level while at least 2-digit level would be needed to delineate the bioeconomy in a meaningful way. Greater disaggregation might be possible in close collaboration with Eurostat (inter-service request), but take time and effort, and would probably still yield limited options with regard to national level figures for smaller countries (secrecy issues).
	5.5.a.2	Changes in University curricula (number)	Study courses explicitly dedicated to bioeconomy or closely related topics	not available/ no basis for estimation	There is no central repository of European study programmes and curricula, it could probably be established manually for a number of key universities. However, this exercise would be very resource-intensive.

	5.5.a.3	Investment in higher education related to bioeconomy		not available/ no basis for estimation	In most Member States, investment into higher education is at least to a substantial degree distributed as block grants to institutions (universities). There is no information regarding the internal distribution of these investments. Additionally, the term "investment in higher education" is quite broad, as it could potentially cover many aspects (e.g. personal costs, investment in equipment or training). The sum of expenditure in these concepts (or others) would result in an unclear indicator.
Knowledge generation and innovation are promoted **- Research and innovation**	5.5.b.1	Number of patents by Bioeconomy sectors			
	5.5.b.2	Investment in research and innovation (1000 euro)			
	5.5.b.3	Open innovation	Extent of collaboration within the private sector	not available/ no basis for estimation	As all Member States are market economies, collaborations between firms are not recorded in any public register. Co-Patents are not a relevant proxy as they mostly capture collaboration within the same corporate, among its subsidiaries. Number of collaborations that are supported in the context of European Funding.
	5.5.b.4	New non-food products produced from primary sources		not available/ no basis for estimation	The "number" of new products is only to a limited extent a valid indicator conceptually, as a simple count of products does not provide a relevant indication about the degree of change in the market. Additionally, it would be necessary to delimit the concept of “new product”. On the one hand, one new product could potentially cover both simple incremental changes as much as a breakthrough innovation. Moreover, many specialty products like biolubricants, biosurfactants etc. are offered in different varieties, therefore making unclear how to count them.
	5.5.b.5	Number of research outputs in the field of Bioeconomy			

Demand and supply-side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced **- Market mechanisms (e.g. prices, consumer awareness)**	5.6.a.1	Market or consumers acceptance	Acceptance meaning "awareness"	Proxied though press and online coverage of themes	There are some alternatives to approach this indicator, but with high level of uncertainty regarding reliability. The expert's assessment would be that press- or online coverage of certain issues should rather not be part of a classic monitoring, as it would be first difficult to have a meaningful comparable indicator on a country level. Further, it would have to be elaborated, how awareness is measured (every reference measured as count, or certain content / statement required for counting). Possible data sources are Google Trends, LexisNexis, PressAPI. Basic competence would be required for querying search portals required (key words related to the bioeconomy, such as bio-based products, bioeconomy, bio-based materials, bio-based plastics, biofuels, bioenergy).
	5.6.a.2	Number of labelled or certified bio-based products		not available/ no basis for estimation	The "number" of new products is only to a limited extent a valid indicator conceptually as a simple count of products does not provide a relevant indication as to the degree of change in the market (even if it could be established with sufficient precision). One newly certified product could indicate a tiny, meaningless incremental change as much as a breakthrough innovation. Concerning data availability there are different certification schemes related to bio-based products in the EU and not such initiative as the USDA Certified Biobased Product Scheme in the U.S. (partly related to the BioPrefered Programme). There is no regular updated database that would enable to count new labelled or certified products per year (the most comprehensive, but not updated database comes from the projects OpenBio/InnProBIo. https://www.biobasedconsultancy.com/).
Economic development is fostered - Value of raw and processed biomass, value added in bioeconomy sectors	5.1.b.2	Value added in the bioeconomy sectors			
Inclusive economic growth is strengthened - Employment in bioeconomy	5.2.a.1	Employment in the bioeconomy sectors			

Source: Own Elaboration from external experts' report

1.2 Proposal for indicators on Research and Innovation in the bioeconomy sectors

In the next step, the experts proposed data sources and methodologies for those indicators in Table 2 that can be informed with data as well as proposed additional indicators. Therefore they proposed an indicator system based on a general logic commonly used in innovation studies which, at least for purposes of measurement, conceives the innovation chain[3] as a sequence of investments/input which leads to interim results (or throughputs) which triggers results (or outputs) which in turn develops an impact on socio-economic development (or outcome). In reality, relationships between the different stages of the innovation process are much more complex, recursive, part self-referential and in any case subject to a number of separate, external influences that the presented indicator system will not capture. Accordingly, it would be both conceptually and methodologically misguided to construct the relation between the presented stages as cause-effect relationships. Rather, the presented structure can serve to determine at which stages of the innovation process relevant developments have already taken place and at which they remain absent. Table 3 provides a more specific vision on the described logic.

Table 3. Description of the main innovation dimensions.

Approach	Advantages
Input	Related to monetary and human capital investments as well as policy support. In essence, the measurement of "inputs" allows to establish to what extent relevant activities are at all taking place.
Throughput	Related to interim results in academia (publications) and practice (patents). In essence, the measurement of "throughputs" allows to establish to what extent a basis for solutions with transformative potential has been developed.
Output	Related to the extent to which solutions with transformative potential have actually been developed and made available on the market/to society.
Outcome	Related to the extent of transformative changes within the sector as well as the transformation's contribution to broader societal goals like growth and change.

Note: For the Objective / Key components "Knowledge generation and innovation are promoted - Knowledge generation/ (high level) education" and "Demand and supply-side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced" no indicator in the initial list can be collected.

Source: Own elaboration by authors

The selection of indicators presented is limited to those indicators that can either be obtained from official statistics directly or which can be calculated based on such publicly available indicators without further specific expert knowledge. Additionally, it has been avoided to propose indicators that would require the acquisition or licensing of additional data sources, with the exception of bibliometric statistics (which some European Commission services already have licensed). However, it has been set as a requirement that future analysts would have the capacity of performing keyword searches that in principle do not extend beyond those every trained researcher perform during literature reviews. As a result of the indicator assessment, a few EU-BMS indicators already populated with data are considered useful to inform outcome stage of the innovation process (e.g., jobs, turnover). Table 4 describes the selected indicators along with some methodological considerations.

[3] While the OECD Oslo Manual for Innovation Indicators does not explicitly sets up a framework for structuring indicators, the presented logic is very much in line with those guidelines and conceptual outlines; OECD, Oslo Manual: guidelines for Collecting, Reporting and Using Data on Innovation, 2018.

Table 4. List of Indicators, structured based on the general conceptual framework outlined above

Conceptual dimension	Indicator	Availability	Reference within the EU-BMS framework	Description Methodological considerations Competencies for data collection and processing required (in brackets)
INPUT				
Monetary investment (private)	Private Sector investment in research and development (R&D)	Available	5.5.b.2 (here divided in public and private)	R&D investments on 2-digit NACE sectors are available in Eurostat, so that bioeconomy can be delineated by weighting with estimates of bio-based shares per NACE sector. Output-based weighting would be most adequate as for R&D activities the size of a sector's own activity in a certain activity is relevant and less the input (e.g. bio-based energy).[4]
Monetary investment (public, EU)	EU Public Sector investment in research and development (R&D	Available	5.5.b.2 (here divided in public and private)	EU-funded projects can be queried from E-CORDA, via reference to societal challenges (HE: Destinations) most of projects directly attributable, with some keywords to search in other topic and areas to be completed. Only basic competence in querying E-CORDA required.
Monetary investment (public, member states)	Public Sector investment in research and development (R&D) (member states)	can be produced without specific technical competence	5.5.b.2 (here divided in public and private)	The national research councils of all Member States could be contacted to request the amount of money allocated to bioeconomy-relevant fields. To facilitate the answers, the request can be associated to non-medical "life sciences".
Human capital	Number of students / graduates in fields relevant to the bioeconomy	Estimation possible	5.5.a	In the Eurostat statistics on Students enrolled [EDUC_UOE_ENRT03] and graduates (educ_uoe_grad02) in tertiary education differentiated by ISCED Fields of education and training (ISCED-F 2013) would allow to estimate bioeconomy related students.[5]

[4] It has still to be noted that this assumption of proportionality of bio-based output shares for R&D activities – meaning that if the chemical sector's output contains to 10% bio-based products, 10% of its R&D are attributed to bioeconomy – may still be a less accurate approach then e.g. using this assumption for turnover or employment, because the current R&D activities relate to new products and processes in the feature and partly to transform the sectors, and hence may differ to current activities of a sector still relying more on traditional products and processes.

[5] An identification of Fields of education and training for the German classification system has been done by Wydra (2020) and may be useable as a starting point to delineate the bioeconomy for ISCED fields.

Table 4. List of Indicators, structured based on the general conceptual framework outlined above (continuation)

Conceptual dimension	Indicator	Availability	Reference within the EU-BMS framework	Description Methodological considerations Competencies for data collection and processing required (in brackets)
THROUGHPUT				
Academic results	Number of research outputs in the field of bioeconomy	can be produced without specific technical competence	5.5.b.5	The number of bioeconomy publications can be queried from existing data sources (SCOPUS/ Web of Science/ Dimensions). The downside is the cost required for access to such databases, which may be substantive.
Inventive	total number of patents for the bio-economy	can be produced without specific technical competence	5.5.b.1	The number of bioeconomy patents, delimited according to a selection of IPC codes (see Annex 2) can be directly query from existing and freely accessible data sources (PATSTAT / Espacenet). An approximation via sectors is also possible but could result in figures that are rough estimates and – not uncommonly - misleading, hence, should be ideally avoided.
OUTPUT				
Innovation	EC-Sponsored Pilot Plants opened in a given year (number / investment)	Available	5.4.a.2	In analogue to indicator "Monetary investment (public, EU) relevant projects with pilot plant activities to be identified in E-CORDA dataset, and related information about size or related investment to extract/research manually (potentially available from BBI/CBE).
Adoption and scaling	Market volume in innovative bioeconomy segments	indirectly available		There are no official statistics on the development of markets of relevance for the market economy. Alternatively, regular reports by a number of market research agencies can be accessed to compile relevant information on specific or innovative bio-based products (e.g. biofuels, biosurfactants, among others)[6]. If such indicator would be used, coherence / overlap with existing turnover indicators (see below) has to be checked. Cost of such reports: 3,000-5,000 Euro; moreover it has to be checked to which extent results can be distributed regarding copyright issues.

[6] Some examples that aim to cover many bio-based markets are: Biobased Products Market Report | Global Forecast To 2028 (industrygrowthinsights.com); https://www.cognitivemarketresearch.com/chemical-%26-materials/biobased-products-market-report; Biobased Products Market Size, Trends, Industry Demand, SWOT Analysis, Segments and Regional Analysis 2021-2029 (chemreportstore.com);

Table 4. List of Indicators, structured based on the general conceptual framework outlined above (cont.)

Conceptual dimension	Indicator	Availability	Reference within the EU-BMS framework	Description Methodological considerations Competencies for data collection and processing required (in brackets)
OUTCOME				
Jobs[7]	Persons employed per bioeconomy sectors	Already included in EU Bioeconomy Monitoring System	5.2.a.1	See Bioeconomy Monitoring System
Growth	Turnover in bioeconomy per sector		5.1.b.1	See Bioeconomy Monitoring System
Climate change mitigation	All indicators related to Climate Change		All 4.1.a indicators	See Bioeconomy Monitoring System

[7] Interesting and informative (on the options of gearing future official statistics towards covering the bio-economy better): Adding bio-based products and materials to statistical classifications (cbs.nl)

2 Detailed methodology for proposed indicators

2.1 Private Sector investment in research and development (R&D)

Private R&D investments are reported for 2-digit NACE sectors in Eurostat. The experts propose to delineate the bioeconomy by weighting with estimates of bio-based shares per NACE sector.

A number of suitable weights that estimate R&D intensity in bioeconomy-relevant sectors has been used by JRC in earlier publications[8]. The experts recommend the output-based weighting which they consider most adequate for the estimation of private R&D investment in the bioeconomy because the size of a sector's own activity is highly relevant for R&D compared to the (mostly physical) input derived weights from other sectors.

Regarding the delineation of the bioeconomy, the experts suggest to consider the biomass producing and processing industries (NACE A to F) and the R&D expenditures of M721 (Research and experimental development on natural sciences and engineering). Indeed, R&D expenditures of dedicated R&D firms like labs or providers of engineering services add to the R&D expenditures in the core sectors.

The experts propose to compute the share of the R&D expenditures (NACE M721) as the gross value added ratio of M7211 on M721, where M721 comprises the two 4-digit sub sectors M7211 and M7219 (Other research and experimental development on natural sciences). Using the latest available data (2018), that share would be equivalent to 14.3%[9] and could be used in subsequent years, for which a 4-digit disaggregation is not yet available.

Box 1. Technical information to estimate indicator 'Private Sector investment in research and development (R&D)'

Indicator: Private R&D expenditures in the bioeconomy.
Data source: Eurostat, BERD by NACE Rev. 2 activity (rd_e_berdindr2).
Filter: Bioeconomy relevant sectors according to the output-based approach for industry,[10] but also M721 (Research and experimental development on natural sciences and engineering).
Data Transformation: sectors that cannot be fully attributed to the bioeconomy have to be weighted with estimates of bio-based shares per NACE sector as used for value and employment estimates. Partly additional weights have to be applied, as Eurostat R&D data is partly not available on the same digit level (see M721 as above).

[8] Most recent Ronzon, T., Iost, S., & Philippidis, G. (2022). Has the European Union entered a bioeconomy transition? Combining an output-based approach with a shift-share analysis. Environment, Development and Sustainability, 24(6), 8195-8217.

[9] This percentage was calculate by taking Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) (Online code: SBS_NA_1A_SE_R2) and dividing value added at factor cost in NACE sector 7211 (4300 million € for 2018) by the value in NACE sector 721 (30000 million € for 2018).

[10] Most recent Ronzon, T., Iost, S., & Philippidis, G. (2022). Has the European Union entered a bioeconomy transition? Combining an output-based approach with a shift-share analysis. Environment, Development and Sustainability, 24(6), 8195-8217.

2.2 EU Public Sector investment in research and development (R&D)

Public sector investments are reported to statistical authorities but it is in many cases difficult to differentiate to what extent a specific university building, or a public research institutes maintenance effort or a specific professor's wage can be assigned to bioeconomy related activities. The core challenge thus is that largest investments in R&D are often multi-purpose and not easily attributable.

However, in the case of individual, competitively awarded research projects, it is easy to determine whether they pertain to bioeconomy-related efforts or not based on proposal summaries or more information when available. The European Commission's E-CORDA database is the only source of harmonized and structured information on research funding for all Member States among which bioeconomy related efforts can be identified. The database is free of charge and can be obtained from DG RTD on request, at least those - here fully sufficient - parts that do not contain personal information. The identification of relevant projects can be made by searching project summaries with the terms 'bioeconomy', 'biotechnology' or any other range of potentially relevant technologies or domain activities.[11] Considering the vast number of projects in H2020 or Horizon Europe, this process has to be performed by a suitable database tool, e.g., Oracle SQL, MS Access, R, and to a degree even MS Excel.

The money spent from the Framework Programmes can only be spent once. Consequently, the money invested in bioeconomy-relevant projects can be added up with no risk of double counting. Moreover, the full E-CORDA database permits differentiating the information by Member State as funding is reported by recipient and not by project. Differentiating by region may be trickier, as the legal seat of a research organization does not necessarily correspond to the exact location where research is performed (in particular for large ones like Fraunhofer, CNR, CNRS).

Box 2. Technical information to estimate indicator 'EU Public Sector investment in research and development (R&D)'

Relevant indicators to be queried:

- Number of bioeconomy projects
- Overall spending on bioeconomy projects
- Overall EC contribution to bioeconomy projects
- Overall partner contribution to bioeconomy projects
- Share of bioeconomy projects in overall H2020/Horizon spending

Data Source: E-CORDA Database. The complete E-CORDA database can be obtained in Excel or .csv on request from the responsible units in DG RTD, there is no data portal directly fit for purpose (CORDIS and OpenAIRE do not really provide suitable search functionalities). It is helpful to request it without personal contact information so that GDPR issues are avoided.

Filters: Generic Keyword Search Strategy as per Annex 2.

Data Transformation: None.

[11] Cf. Annex 2 on existing definitions and search strategies for the bioeconomy.

2.3 Public Sector investment in research and development (R&D) (Member States)

As for EU spending, it is in many cases difficult to differentiate to what extent a public monetary investment made by a Member State can be assigned to bioeconomy related activities. International classifications such as NABS 2007 capture some socio-economic objectives but does not delineate bioeconomy explicitly[12]. The German classification for national public spending ("Leistungsplansystematik des Bundes") is an exception as it includes a section for Bioeconomy for the R&D spending, in terms of institutional funding for research institutes as well as project-based funding (i.e., excluding institutional funding for universities is not included).

Alternatively, a survey could be conducted to the national research councils of all Member States, asking how much money they have allocated to relevant fields. For that purpose, a comparable scheme of which kind of activities are attributed to the bioeconomy has to be developed. Such a collection may also be included in potential future surveys on bioeconomy policy developments in different countries, such as has been earlier conducted, e.g. by a joint effort of JRC, BBI JU and IEA Bioenergy[13].

Consequently, the estimation of this indicator is rather resource intensive. It is also a priori not clear, for which and how many of the Member States sufficient data to estimate Government budget allocations for R&D (GBARD) is available.

Box 3. Technical information to estimate indicator 'Public Sector investment in research and development (R&D) by Member State'

Indicator: Public Sector investment in research and development (R&D) for the bioeconomy (member states)
Data source: Survey to research councils related to GBARD (GBA_NABSFIN07)
Filter: Bioeconomy-related GBARD based on individual information by Member States
Data Transformation: Either weighting of GBARD by using individual estimates of the member states or direct values provided by the member states.

[12] E.g., the NABS 2007 distinguishes between agriculture, energy, etc. (see GBA_NABSFIN07 from Eurostat).

[13] Lusser, M., Sanchez Lopez, J., Landa, L., Avraamides, M., Motola, V., Zika, E., & Mallorquin, P. (2018). Joint survey on bioeconomy policy developments in different countries. European Commission: Brussels, Belgium.

2.4 Number of students / graduates in fields relevant to the bioeconomy

The numbers of students and graduates can be used to estimate the availability and importance of highly qualified staff in the bioeconomy. Time dynamics informs on the capacity to meet with increasing knowledge-intensive resource needs for the bioeconomy.

No official statistics report bioeconomy as a separate field. Instead, the Eurostat statistics on Students enrolled (educ_uoe_enrt03) or graduates (educ_uoe_grad02) in tertiary education differentiated by ISCED Fields of education and training (ISCED-F 2013) may serve as a basis for estimations for the bioeconomy.

As with NACE-based statistics, some education fields can only be partly attributed to the bioeconomy, e.g. chemistry. In the absence of suitable weighting method - such as the bio-based shares for NACE – tow options are possible: (i) adopt a narrow delineation of education fields that can be fully attributed to the bioeconomy, or (ii) adopt a wider definition that probably goes beyond the actual workforce that will be available for bioeconomy activities, but could indicate a potential. The experts propose the narrow delineation. In particular are excluded those manufacturing and process industry-related education fields that are mostly relevant for non-bioeconomy fields, e.g. Chemical engineering and processes (F0711) or materials (F0722) related education. The experts propose to include environment-related education fields (F052) in spite of its broad coverage (bioeconomy and non bioeconomy domains of education) as environmental issues are of decisive importance for the bioeconomy and for the EU monitoring framework.

Box 4. Technical information to estimate indicator 'Number of students / graduates in fields relevant to the bioeconomy'

Relevant indicators are:

— Number of Students enrolled in tertiary education in bioeconomy-related fields.

— Number of Graduates in bioeconomy-related fields.

Data source: Eurostat Data Tables educ_uoe_enrt03 and educ_uoe_grad02.

Filter: ISCED F051 Biological and related sciences, F052 Environment, F0712 Environmental protection, F0721 Food processing, F08 Agriculture, forestry, fisheries and veterinary.

Data Transformation: None.

2.5 Number of research outputs in the field of bioeconomy

Information on research outputs is collected in harmonized, centralized databases, e.g. Elsevier Scopus, Clarivate Web of Science and Dimensions. The aforementioned databases slightly differ in both geographic and disciplinary coverage, but they all meet the quality standards required for monitoring needs. Elsevier Scopus is however a natural choice as it is of free access for European Commission staff.

Online search interfaces are easy to browse and self-explanatory for even inexperienced users to e.g. determine the number of publications of a certain type from country x in year y that contain a relevant keyword in title or abstract (e.g. "bioeconomy", "biotechnology" and others indicated in Annex 2). A focus can also be put on pre-defined disciplines. Deeper insights can be search in full databases on on-site servers,e.g. Elsevier Scopus.

Box 5. Technical information to estimate indicator 'Number of research outputs in the field of bioeconomy'

Possible, relevant indicators in the domain of research outputs include:

- Number of bioeconomy publications.
- Share of bioeconomy publications in all publications.
- Number of authors with bioeconomy publications (possible only with on-site database).
- Number of international bioeconomy co-publications (possible only with on-site database).
- Citations of bioeconomy publications (possible only with on-site database).

Data source: Elsevier Scopus database

Filter: Filter by ASJC Classes using SUBJTERMS(), or by Generic Keyword Search Strategy (see Annex 2). It is advisable to exclude conference proceedings and focus on articles, reviews letters and notes.

The allocation of publication by country will be made according to authors' affiliation.

Data Transformation:

- Number of bioeconomy publications: no data transformation. Considering that all co-authors of a same publication have full knowledge of the paper, a same publication will be counted as many times as co-authors (instead of sharing a same publication across the co-authors' countries of affiliation).
- Share of bioeconomy publications in all publications: division of total publications by bioeconomy publications.
- Number of authors with bioeconomy publications: that indicator requires database query knowledge impossible to explain in a sentence. However, everyone who has ever queried a database will be able to execute instruction above.
- Number of international bioeconomy co-publications: same as previous.
- Citations of bioeconomy publications: same as previous.

2.6 Total number of patents for the bioeconomy

All information on patent applications and grants is collected by the patent authorities in harmonized, centralized databases, among which EPO PATSTAT is the most relevant for the purposes here considered. These databases contain comprehensive information on every single patent application, including a title and an abstract on which keyword searches can be performed, as well as classification according to diverse thematic classification schemes, including most prominently IPC and CPC.

Patents can have different countries of origin (invention) and countries of destination (target market). Therefore, the analytical process requires specific choices and at least basic knowledge of intellectual property rights, including the different ways of obtaining such rights (direct application, PCT transfer, etc.). The experts suggest to analytically deploy an already existing approach, i.e. to focus exclusively on EP applications, or triadic patents or transnational applications. Many published studies and Eurostat secondary data tables still use the EP approach. However, the transnational approach is academically advisable and also used in headline studies like DG GROW's Advanced Technologies for Industry[14].

The field of economic activity (sector) is of no direct relevance from a legal perspective and therefore not listed in patent databases. The experts advise against subsequent annotation for two main reasons. First, such annotations are complex, can only be performed by experts in indicator studies and prone to fuzziness based on vague NACE allocations at firm level, e.g. for holdings. These issues would only worsen with probabilistic assignments. Second, and more importantly, sector annotation misses the point in substance. IPC and CPC classes - if need be complemented by keyword searches - are completely sufficient and very accurate to delineate which part of the observed inventive activity pertains to the bioeconomy. As this information is available at the micro level, there is no need to work through further proxies that would only construe detours and blur the picture.

All patent databases come in a format that requires at least basic experience in working with databases, e.g. basic competences in SQL based queries. Available templates can also be used for established approaches to measurement such as triadic or transnational patents. The experts suggest to invest a few days in SQL searches, as online interfaces for patent searches like Espacenet are more difficult to operate accurately for a person without in-depth, field specific knowledge on intellectual property rights.

Regarding the delineation of the bioeconomy, patent IPCs related the bioeconomy are listed in Annex 2. They cover the production of biomass (e.g. breeding techniques) and use of biological resources, but not machines (e.g. tractors) and apparatus for processing biological resources.

Box 6. Technical information to estimate indicator 'Number of patents for the bioeconomy'

Relevant indicators are:

— Total number of patents for the bioeconomy.

— Share of bioeconomy patents in all patents.

Data source: EPO Patstat.

Filter: Filter by IPC Class Search Strategy as per Annex 2.

Data Transformation: Not required, Query total number of patent applications by inventor country or inventor country group (e.g. EU-27).

[14] https://ati.ec.europa.eu/

2.7 EC-Sponsored Pilot Plants opened in a given year (number / investment)

Unfortunately, the private sector does not report any structured information on pilot plants to the statistical authorities. What can be identified, however, are pilot plants that have received public funding, especially, if this funding originated from European sources.

The European Commission's E-CORDA provides a harmonized and structured source of information on research funding for all Member States among which bioeconomy related efforts - as well as those involving pilot plants - can be identified. The database is free of charge and can be obtained from DG RTD on request, at least those - here fully sufficient - parts that do not contain personal information. As outlined above, all project items in the E-CORDA database contain project summaries, which can be searched for the terms 'bioeconomy', 'biotechnology' or any other range of potentially relevant technologies or domain activities to identify projects that include effort in the domain of the bioeconomy. In parallel, these same texts could be searched for keywords like 'pilot plant', 'demonstrator' or other synonyms of a similar nature in order to narrow the search further to those with respective activities in focus.

E-CORDA information can also be extended through inquiries at the Bio-based Industries Joint Undertaking (BBI JU) or newly Circular Bio-based Europe Joint Undertaking (CBE JU) as well as at responsible Member State authorities.

Box 7. Technical information to estimate indicator 'EC-Sponsored Pilot Plants opened in a given year (number /investment)'

Data source: E-CORDA

Filter: Filter by Generic Keyword Search Strategy as per Annex 2, in addition by keywords 'pilot plant*', 'demonstrator*'

Data Transformation: Not required.

2.8 Market volume in bioeconomy relevant areas

The market volume of bio-based products in innovative fields is a key output indicator to measure market adoption. The EU Bioeconomy Monitoring System informs on the turnover generated in bioeconomy sectors but the sectorial breakdown is not fine enough to reveal dynamic developments in innovative segments. A complementary source are regular reports from market research agencies. In addition to distinguishing innovative sectors, those reports usually contain a forward-looking perspective and could provide outlook data. However, the drawbacks for using market studies are unclearness in definition and sources, inconsistencies in data and boundaries over time, often over-optimistic views, etc.

The access cost varies depending on the supplier of market statistics, the access to a single market study vs. the access to a database or regular reports (e.g. for Lux research, Frost & Sullivan) for a certain time period. Single market study vary roughly EUR 3,000-5,000. Copyright issues have to be clarified before any use in the EU-BMS.

Potential approach could be an extension of earlier JRC commissioned studies[15] that contain information beyond the chemical sector and may contain an approach that could be potentially in-house updated by the EC. Moreover, data from private market studies could serve the validation of JRC's existing efforts. Other researchers' approaches can also inspire adjustment.

Box 8. Technical information to estimate indicator 'Market volume in bioeconomy relevant areas'

Relevant indicators:

- Market volume in innovative bioeconomy relevant segments
- Market forecast in innovative bioeconomy relevant segments

Data source: cf. examples are stated in the table above and again provided below.

- Biobased Products Market Report | Global Forecast To 2028 (industrygrowthinsights.com); https://www.cognitivemarketresearch.com/chemical-%26-materials/biobased-products-market-report;
- Biobased Products Market Size, Trends, Industry Demand, SWOT Analysis, Segments and Regional Analysis 2021-2029 (chemreportstore.com);
- Ceresana Market Reports: Bio-Economy https://www.ceresana.com/en/market-studies/bio-economy/
- Filter: Not required. To potentially prioritize segments to be covered potentially a qualitative assessment by experts to choose "innovative segments" may be needed.

Data Transformation: Not required

[15] Such as:
- Spekreijse, J., Lammens, T., Parisi, C., Ronzon, T., & Vis, M. (2019). Insights into the European market for bio-based chemicals. Publications Office of the European Union, Luxembourg.
- Innovative sectors monitored in the Biomonitor project (http://biomonitor.eu/).
- Fraunhofer ISI collected and synthesizes market information for 12 innovative fields of the bioeconomy for the National bioeconomy Monitoring for Germany (Symobio 2.0). A segment is classified as „innovative", if an internal expert either assess that currently significant R&D activities are conducted and/or a significant impact for a certain market is expected. See Wydra, Sven; Reyhani, M.N., Hüsing, Bärbel; Schwarz, Alexander (2023): Exploring Innovative Technology Fields for a Circular Bio-Based Economy. Karlsruhe: Fraunhofer-Institute für System- und Innovationsforschung ISI, https://symobio.de/wp-content/uploads/2023/10/230818_Symobio_D1_5_1_final_references_all.pdf

3 Conclusions

The EU's Bioeconomy Strategy recognizes the relevant role of the bioeconomy in the modernization and the strengthening of the EU industrial base, which must be driven by knowledge and innovation. The expert consultation conducted within the frame of the EU-BMS confirmed the interest of stakeholders in the monitoring of innovation indicators in the bioeconomy, which is viewed as a key enabler of the green transition. Consequently, the EU-BMS foresees some indicators related to research and innovation in the bioeconomy.

From the assessment performed by bioeconomy R&I experts, we conclude that the methodology for data retrieval and transformation is almost readily implementable in the case of three indicators. Those are based on Eurostat or Elsevier Scopus data:

- Private Sector investment in research and development (R&D), see Section 2.1
- Number of students / graduates in fields relevant to the bioeconomy, see Section 2.4.
- Number of research outputs in the field of bioeconomy based on Elsevier Scopus data.

Three other indicators require moderate investment for a sound implementation of the proposed methodology:

- EU Public Sector investment in bioeconomy R&D and EC-Sponsored bioeconomy Pilot Plants opened in a given year (number / investment):
- Total number of patents for the bio-economy.

Finally, the methodology for the remaining two indicators is judged rather resource-intensive and might not be implementable in the limits of the resources available for the EU-BMS implementation:

- Public Sector investment in research and development (R&D) (Member States): the implementation of the respective methodology requires surveying the national research councils of all EU MS.
- Market volume in bioeconomy relevant areas: the implementation of the respective methodology cannot be automatized. It requires an individual analysis of market reports that cost around EUR 3,000-5,000. Moreover the availability harmonized data across markets, EU Member States and years is not guaranteed.

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Annexes

Annex 1. Tacking stock of the literature

Recommendations to be considered

The scientific literature also offers proposals of data frameworks to overcome the existing lack of evidence on bioeconomy innovation. Wydra (2020) claims that "to understand the evolution of innovation in the bioeconomy, measurement has to provide an assessment about the general innovation development in the bioeconomy, but it should be able to provide insights on structural patterns inside the bioeconomy complex as well". With this aim, he proposes a framework that informs on each step of the innovation[16] process (i.e., Input, Throughput, Output, Outcome and Transversal-human resources, see

Figure). This structure resonates with many wished indicators of the EU-BMS (see some examples at

[16] "An innovation is a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)" (OECD 2018 in Wydra 2020).

Table A.1).

Jander et al. (2020) observe that the scope of the bioeconomy is not consensual across stakeholders and prevents harmonized indicators. Therefore, they advocate "efforts towards a common list of keywords and patent codes based on current classifications" while on the long term they consider "appropriate to further develop codes and classifications that enable the identification of bio-based innovations". Focusing on the German bioeconomy, they compile data on patent and publication indicators which represent the early stages of the innovation process. As a workaround to fill existing data gaps on outcome and impact indicators, they recommend "conducting an explicit survey regarding the bioeconomy or through adding another item in the European Community Innovation Survey (CIS) asking whether responding firms are active in the bioeconomy or not or by adding questions similar to those concerning environmental innovation, which is a topic in the CIS every few years".

Figure A.1. Potential innovation indicators along the innovation process (Source: Wydra, 2020)

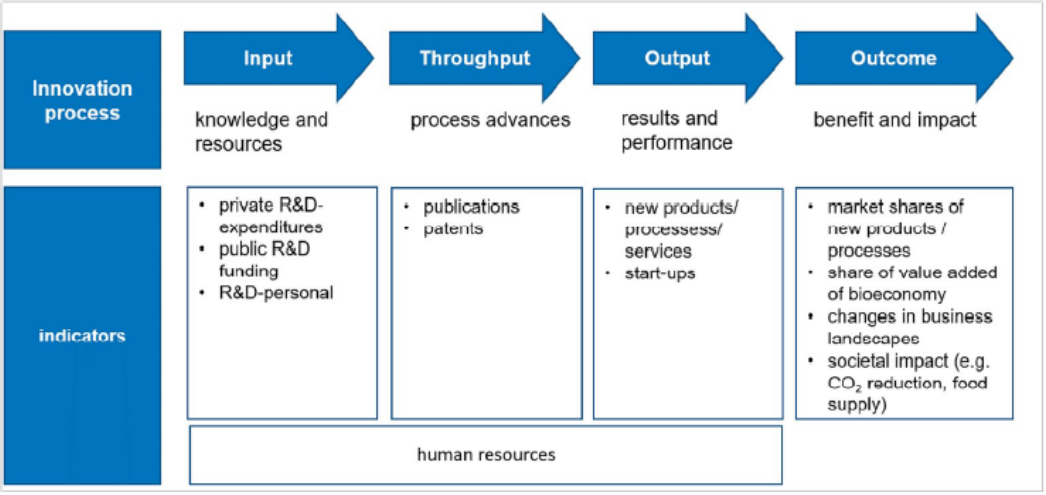

Table A.1. Possible match between the frameworks for monitoring innovation of the Bioeconomy from Wydra (2020) and the EU-BMS

Step of the innovation process	Example of corresponding indicator
Input	EU-BMS 5.4.a.3, 5.5.b.2 Eurostat data on BERD, R&D personal and researchers JRC data on public support
Throughput	EU-BMS 5.5.b.5, 5.5.b.1
Output	EU-BMS 5.6.a.2
Outcome	EU-BMS 5.1.a.2
Transversal	EU-BMS 5.5.a

Methodological controversies to be considered

Different attempts have been made in the literature to determine product/sectorial bio-based shares that are then applied to classical statistics in order to disentangle their Bioeconomy part (e.g. number of patents in a given set of economic sectors). However, the utilization of such coefficients on innovation indicators is a matter of debate:

- "While one approach might be the use of bio-based shares, this may be inappropriate for R&D estimations, as many innovations concern products or processes in high-value added segments, where the amount and price feedstock plays a minor role. An alternative would be the respective bio-based share in patents per sector" (Wydra, 2020).
- "There is uncertainty about whether the bio-based share is truly the same for all indicators. (…) there are not yet any lists for codes or keywords for the Bioeconomy for patents and publications that are widely accepted" (Jander et al. 2020).
- "Before the data could be relocated, however, it had to be weighted, since it cannot be assumed that a patent has the same "price" in terms of R&D input in each of the fields, e.g. a patent in the fields of pharmaceuticals can be assumed to consume larger amounts of R&D expenditures than a patent in the field of other consumer goods" (Frietsch et al., 2017).

The confusion over the relevant use of bio-based shares partly lies on the fact that the term "bio-based share" is indifferently used for coefficients that reflect the proportion of biomass used by a sector of activity (Kuosmanen et al. 2020), the proportion of biomass embedded in final products (Ronzon et al. 2022), more complex modelling of upstream and downstream Bioeconomy activities (Cingiz et al. 2021) or of fields of technology (Frietsch et al. 2017). It also partly lies in the fact that there is no common agreement on what a Bioeconomy process / product / sector is (see for example the different lists of Bioeconomy IPC classes drawn by Wydra (2020), supplement tables).

Annex 2. Existing Definitions for the Bioeconomy

GENERIC search strategy in case keywords should be used

Agricul*, agro*, plant* crop*, cellulos*, fung*, wood,*, pulp*, forest*, Aqua*, Fish*, biowaste,

Biophy*, Biotech*, Bioeng*, Cell Biolog*, Molecular Biolog*, Microbiolog*, Food*, bio-based*, fibre, Biochem*, bio-energy, bio-fuel, biolub', bio-surfactants

as well as

Environmental Eng*, Process Chem*, Chemical Eng*, Genet*,

but those latter ones ONLY, if the text also contains Bio* ('AND' coupling)

to exclude pure medical biotechnology related fields such as the development of new drugs (while biotechnological production should be still included=, matches should be excluded if they include

drug delivery, medical treatment,

This generic research strategy has been developed the experts and a review of two recent research articles, which have to our knowledge the most comprehensive approach to delineate bioeconomy in existing data sources.[17]

There is a continuous discussion in the field whether each specific data source needs a specific, adapted search strategy with own terms, tailored to the nature of the texts to be searched (e.g. technical or scientific)

It is our expert opinion, that - at least for the data sources and for the level of aggregation in question here - it is more useful to have one generic strategy for all sources as this ascertains fundamental compatibility.

In general, it is easier to subsequently interpret the results of one stringent approach, even if those may differ by data source, than to continuously have to remember which exact approach was used for the particular analysis right now. In the end, using too many different search strategies tends to create more problems than it solves.

PUBLICATIONS

per Elsevier ASJC - All Science Journal Classification

'1101','1102','1301','1303','1304','1305','1307','1312','1502','1503','2204','2402','2502'

PATENTS

A01C21/00	Methods of fertilising
A01G31/00	Soilless cultivation, e.g. hydroponics
A01K67/00	Rearing or breeding animals, not otherwise provided for; New breeds of animals

[17] D'Amato, D., Korhonen, J., & Toppinen, A. (2019). Circular, green, and bio economy: how do companies in land-use intensive sectors align with sustainability concepts?. Ecological economics, 158, 116-133; Duquenne, M., Prost, H., Schöpfel, J., & Dumeignil, F. (2020). Open Bioeconomy—A Bibliometric Study on the Accessibility of Articles in the Field of Bioeconomy. Publications, 8(4), 55.

A01H	NEW PLANTS OR PROCESSES FOR OBTAINING THEM; PLANT REPRODUCTION BY TISSUE CULTURE TECHNIQUES **[5]**
A01N63/00	Biocides, pest repellants or attractants, or plant growth regulators containing microorganisms, viruses, microbial fungi, animals or substances produced by, or obtained from, microorganisms, viruses, microbial fungi or animals, e.g. enzymes or fermentates
A01N 65/00	Biocides, pest repellants or attractants, or plant growth regulators containing material from algae, lichens, bryophyta, multi-cellular fungi or plants, or extracts thereof
A21D08/24	treating dough with microorganisms or enzymes
A23J03/20	Proteins from microorganisms or unicellular algae
A61K36/00	Medicinal preparations of undetermined constitution containing material from algae, lichens, fungi or plants, or derivatives thereof, e.g. traditional herbal medicines
C02F3	Biological treatment of water, waste water, or sewage
C02F11/02	Treatment of sludge; Devices therefor; Treatment of sludge; Devices therefor
C05F11/08	Organic fertilisers containing added bacterial cultures, mycelia or the like
C05F11/10	Fertilisers containing plant vitamins or hormones
C07G	Organic chemistry, COMPOUNDS OF UNKNOWN CONSTITUTION; including Lignin, glycosides, antibiotics, vitamins, hormones
C07H	SUGARS; DERIVATIVES THEREOF; NUCLEOSIDES; NUCLEOTIDES; NUCLEIC ACIDS
C07J	Steroids
C07K	Peptides
C08B	POLYSACCHARIDES; DERIVATIVES THEREOF
C08F253/00	Makromolekulare Verbindungen, die durch Polymerisieren von Monomeren auf natürliche Kautschuke oder deren Derivate erhalten werden
C08H	DERIVATIVES OF NATURAL MACROMOLECULAR COMPOUNDS
C08L1/00	Compositions of cellulose, modified cellulose or cellulose derivatives
C08L3/00	Compositions of starch, amylose or amylopectin or of their derivatives or degradation products
C08L5/00	Compositions of polysaccharides or of their derivatives not provided for in groups
C08L7/00	Compositions of natural rubber
C08L89/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of proteins; Compositions of derivatives thereof
C08L91/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of oils, fats or waxes; Compositions of derivatives thereof
C08L93/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of natural resins; Compositions of derivatives thereof
C08L97/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of lignin-containing materials

C08L99/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of natural macromolecular compounds or of derivatives thereof not provided for in groups
C08L101/00	Compositions of natural macromolecular compounds or of derivatives thereof: Compositions of unspecified macromolecular compounds
C09D11/04	Printing inks based on proteins
C09D11/08	Printing inks based on natural resins
C09D101	Coating compositions based on cellulose, modified cellulose, or cellulose derivatives
C09D103	Coating compositions based on starch, amylose or amylopectin or on their derivatives or degradation products
C09D105	Coating compositions based on polysaccharides or on their derivatives, not provided for in groups C09D101/00 or C09D103/00
C09D107	Coating compositions based on natural rubber
C09D189	Coating compositions based on proteins; Coating compositions based on derivatives thereof
C09D193	Coating compositions based on natural resins; Coating compositions based on derivatives thereof
C09D197	Coating compositions based on lignin-containing materials
C09D199	Coating compositions based on natural macromolecular compounds or on derivatives thereof, not provided for in groups C09D101/00 - C09D107/00 or C09D189/00 - C09D197/00
C09J101	Adhesives based on cellulose, modified cellulose, or cellulose derivatives
C09J103	Adhesives based on starch, amylose or amylopectin or on their derivatives or degradation products
C09J105	Adhesives based on polysaccharides or on their derivatives
C09J107	Adhesives based on natural rubber
C09J189	Adhesives based on proteins; Adhesives based on derivatives thereof
C09J193	Adhesives based on natural resins; Adhesives based on derivatives thereof
C09J197	Adhesives based on lignin-containing materials
C09J199	Adhesives based on natural macromolecular compounds or on derivatives thereof, not provided for in groups
C11	ANIMAL OR VEGETABLE OILS, FATS, FATTY SUBSTANCES OR WAXES; FATTY ACIDS THEREFROM; DETERGENTS; CANDLES
C12C	BEER; PREPARATION OF BEER BY FERMENTATION; PREPARATION OF MALT FOR MAKING BEER; PREPARATION OF HOPS FOR MAKING BEER
C12C	RECOVERY OF BY-PRODUCTS OF FERMENTED SOLUTIONS; DENATURED ALCOHOL; PREPARATION THEREOF
C12G	WINE; PREPARATION THEREOF; ALCOHOLIC BEVERAGES
C12H	PASTEURISATION, STERILISATION, PRESERVATION, PURIFICATION, CLARIFICATION OR AGEING OF ALCOHOLIC BEVERAGES; METHODS FOR ALTERING THE ALCOHOL CONTENT OF FERMENTED SOLUTIONS OR ALCOHOLIC BEVERAGES
C12J	VINEGAR; PREPARATION OR PURIFICATION THEREOF

C12M	APPARATUS FOR ENZYMOLOGY OR MICROBIOLOGY; APPARATUS FOR CULTURING MICROORGANISMS FOR PRODUCING BIOMASS, FOR GROWING CELLS OR FOR OBTAINING FERMENTATION OR METABOLIC PRODUCTS, i.e. BIOREACTORS OR FERMENTERS
C12N	MICROORGANISMS OR ENZYMES; COMPOSITIONS THEREOF; PROPAGATING, PRESERVING, OR MAINTAINING MICROORGANISMS; MUTATION OR GENETIC ENGINEERING; CULTURE MEDIA
C12P	FERMENTATION OR ENZYME-USING PROCESSES TO SYNTHESISE A DESIRED CHEMICAL COMPOUND OR COMPOSITION OR TO SEPARATE OPTICAL ISOMERS FROM A RACEMIC MIXTURE
C13B	PRODUCTION OF SUCROSE; APPARATUS SPECIALLY ADAPTED THEREFOR
C13K	SACCHARIDES OBTAINED FROM NATURAL SOURCES OR BY HYDROLYSIS OF NATURALLY OCCURRING DISACCHARIDES, OLIGOSACCHARIDES OR POLYSACCHARIDES
C14C1/065	Enzymatic unhairing (Chemical treatment prior to tanning)
C14C3/10	Vegetable tanning
C22B3/18	Extraction of metal compounds from ores or concentrates by wet processes with the aid of microorganisms or enzymes, e.g. bacteria or algae
D01B	MECHANICAL TREATMENT OF NATURAL FIBROUS OR FILAMENTARY MATERIAL TO OBTAIN FIBRES OF FILAMENTS, e.g. FOR SPINNING
D01C1/04	CHEMICAL TREATMENT OF NATURAL FILAMENTARY OR FIBROUS MATERIAL TO OBTAIN FILAMENTS OR FIBRES FOR SPINNING; CARBONISING RAGS TO RECOVER ANIMAL FIBRES: Bacteriological retting
D21B	PAPER-MAKING; PRODUCTION OF CELLULOSE: FIBROUS RAW MATERIALS OR THEIR MECHANICAL TREATMENT
D21C	PAPER-MAKING; PRODUCTION OF CELLULOSE: FIBROUS RAW MATERIALS OR THEIR MECHANICAL TREATMENT
D21H11/00	Pulp or paper, comprising cellulose or lignocellulose fibres of natural origin only
G01N33/02	Investigating or analysing food
G01N33/447	Investigating or analysing materials by specific methods not covered by groups; Leather
G01N33/46	Investigating or analysing wood
G11B7/2539	Recording or reproducing by optical means [...] made from biodegradable polymers, e.g. cellulose
H01M8/16	Biochemical fuel cells, i.e. cells in which microorganisms function as catalysts
Y02P20/145	CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS; Technologies relating to chemical industry; the feedstock being materials of biological origin
Y02P30/20	CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS; Technologies relating to oil refining and petrochemical industry; using bio-feedstock
Y02E50/10	Biofuels, e.g. bio-diesel
Y02W30/40	Technologies for solid waste management: Bio-organic fraction processing; Production of fertilisers from the organic fraction of waste or refuse

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