



Food and Agriculture
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Indicators for sustainable bioeconomy: Towards building a monitoring and assessment framework

High-level Summary of the FAO Report “Indicators for Sustainable Bioeconomy: Towards Building a Monitoring and Assessment Framework” (forthcoming in 2025)

Prepared to inform discussions under the “Towards establishing global bioeconomy standards and metrics” pillar of the South African G20 Presidency's Global Initiative on Bioeconomy (GIB)

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Introduction

Despite growing recognition of the bioeconomy's importance, there is no globally agreed-upon framework for monitoring its development and impacts. This lack of international coordination hampers efforts to track global bioeconomy trends and assess progress toward shared objectives. If bioeconomy is to be recognized as delivering sustainable environmental, economic and social benefits, it is critical to develop systems that can monitor its performance and assess its sustainability.

Establishing robust monitoring and assessment frameworks grounded in transparent, measurable, and science-based indicators, is fundamental to advancing the bioeconomy. Such frameworks should enable policymakers, businesses, investors, researchers, development practitioners, and local communities to collectively ensure that biological resources are sourced and managed sustainably, in line with the conservation of biodiversity and the fair and equitable sharing of benefits.

Given the diverse socioeconomic, ecological, and institutional contexts shaping national and regional bioeconomies, a prescriptive "one-size-fits-all" set of indicators is neither feasible nor desirable. Instead, a harmonized framework aligned, for example, with overarching sustainability principles (e.g. SDGs, G20 High-Level Principles on Bioeconomy and the FAO Aspirational Principles and Criteria for Sustainable Bioeconomy) can help balance coherence with flexibility. This balance is essential for tracking progress toward shared goals like climate resilience and equitable resource use without stifling innovation or local relevance (FAO, 2024b).

Shifting away from an economy based on the use of non-renewable fossil resources to produce materials, energy and other products and services to a bioeconomy that is based on the production, utilization, conservation and regeneration of biological resources is not an inherently sustainable process. The demand for biomass is already high. Increasing this demand to create alternatives to fossil-based fuels and products will put additional environmental pressures on natural resources (land, water and biodiversity).

The higher demand for biomass to produce non-food commodities could also impact food production and may increase food prices, which could threaten food security and nutrition, especially in communities where food insecurity and malnutrition are prevalent. Also, economic gains derived from bioeconomy are not automatically shared equitably by men and women or reach vulnerable and impoverished groups in the agricultural communities where most of the world's biomass is produced. All these potential trade-offs must be managed carefully and in a manner that is consistent across different bioeconomies across the globe.

Any monitoring framework should also assess whether agrifood systems are utilizing natural resources efficiently. Furthermore, these frameworks must evaluate the bioeconomy's contributions to broader societal objectives, including rural development, social equity, gender equality, decent work, and the empowerment of women, youth, Indigenous Peoples, and marginalized groups, consistent with the principles of inclusivity and equitable participation (GIB, 2024). This is important not only for ensuring the effectiveness of individual bioeconomy initiatives, but also for generating a strong evidence base on the sustainability and overall performance of bioeconomy development, which can help strengthen political commitment and attract greater investment in sustainable bioeconomy activities at scale.

Any system to monitor the performance of bioeconomy and assess its sustainability must cover all three dimensions of sustainability: economic, social, and environmental. The monitoring and assessment system also needs to consider the governance mechanisms that are in place that can cut across these three dimensions to identify and maximize synergies and minimize the trade-offs between the three sustainability dimensions associated with bioeconomy development.

Robust monitoring and assessment systems are foundational to effective bioeconomy governance and serve three critical functions:

1. supporting evidence-based decision making;
2. identifying trade-offs and synergies across the three dimensions of sustainability; and
3. tracking progress toward national and global sustainability commitments.

Establishing a set of indicators for sustainable bioeconomy development is therefore not an easy task. Indicator selection is often more of a political issue than a purely technical task. Different stakeholders have different views on the sectors, services and products that should be included within the scope of bioeconomy, and on the strategic objectives that have the greatest priority for sustainable development.

Indicators are part of an overarching bioeconomy strategy

Selecting the indicators for a monitoring and assessment framework is a process that should be nested within an overarching bioeconomy strategy or plan. Many bioeconomy strategies are political in nature and coordinated through a governmental process (e.g. subnational, national or supranational bioeconomy strategies), while others may be formulated by non-state actors. They all represent a strategic vision document that sets out objectives to be achieved – and therefore monitored.

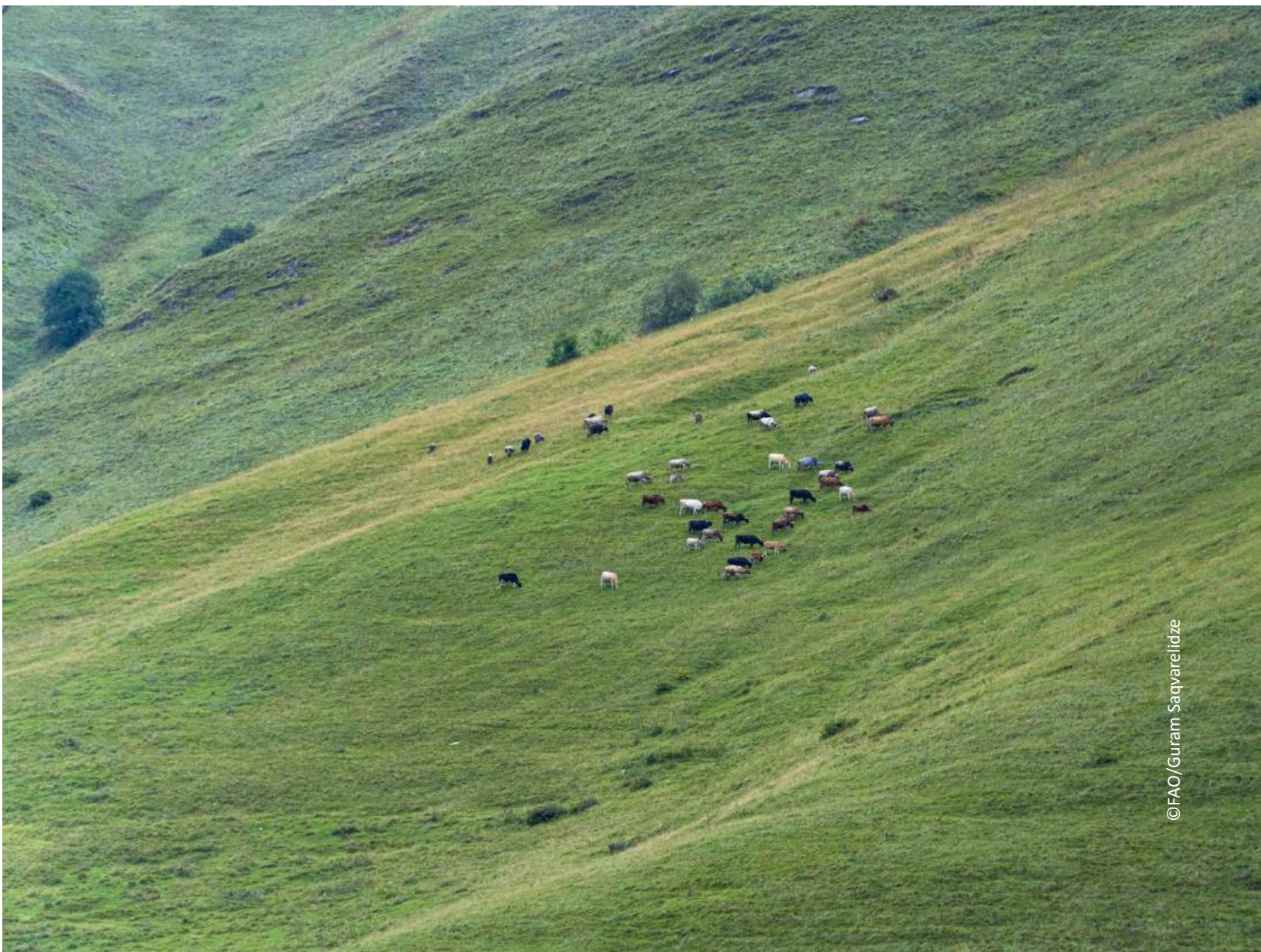
In 2024, FAO published *“The bioeconomy toolbox – A guide to support the development of sustainable bioeconomy strategies and policies”* (Gomez San Juan, 2024), which lays out a four-step approach for formulating and implementing a bioeconomy strategy. The four steps are:

- **Step 1.** Set up a governance mechanism and dedicated institution
This involves initiating a participatory process to identify key stakeholders who will work together to articulate an overall vision of bioeconomy, define its scope and sustainability objectives, and agree on a definition.
- **Step 2.** Devise the strategy
Activities in this step include mapping bioeconomy potential and gathering data, selecting the main elements of the strategy, and writing the final document.
- **Step 3.** Implement with an action plan
This step requires the preparation an action plan, the deployment of technologies and business models, and actions that can cover gaps in policy and investment.
- **Step 4.** Monitor progress and revise the strategy
During implementation, well-selected indicators help in monitoring progress and performance, as well as evaluating and assessing impact, sharing results and, if needed, revise the strategy. Once the indicators have been selected it is important to establish formal coordination mechanisms across relevant stakeholders to ensure the coherent implementation of the monitoring system and review mechanisms for the periodic assessment and updating of the indicator. This involves developing data-sharing and knowledge exchange between the public and private sector groups.

Stakeholders have developed various approaches to selecting indicators for monitoring and assessing bioeconomy. These approaches reflect differing priorities, data availability, and governance structures adapted to context specificities (FAO, 2024a). Given the diverse socioeconomic, ecological, and institutional contexts shaping national and regional bioeconomies, a prescriptive "one-size-fits-all" set of indicators is neither feasible nor desirable.

Instead, a harmonized framework with an adaptable menu of indicators can help balance coherence with flexibility. Such a framework should be aligned with overarching sustainability principles (e.g. SDGs, G20 High-Level Principles on Bioeconomy and the FAO Aspirational Principles and Criteria for Sustainable Bioeconomy).

By prioritizing harmonized frameworks over uniform indicator sets, policymakers can ensure comparability across regions while respecting unique bioeconomy pathways. This balance is essential for tracking progress toward shared goals like climate resilience and equitable resource use without stifling innovation or local relevance.



Database of sustainability indicators for bioeconomy

To make it easier for groups working together to select indicators for a monitoring and assessment framework for bioeconomy FAO has collaborated with the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) to develop a database on sustainability indicators for bioeconomy. This database can assist stakeholders to carry out step 4 in bioeconomy strategy development and implementation. It also serves to advance the broader normative, policy, technical and scientific work that FAO does to promote bioeconomy for sustainable food and agriculture, and reflects the Organization's commitment to helping its Members to follow up on recommendation 7 in the FAO position paper on bioeconomy:

“Establish globally accepted criteria for sustainable bioeconomy. Support the development of globally accepted sustainability criteria for bioeconomy that are underpinned by empirical data, closely aligned with the SDGs” (FAO, 2024b).

The database for sustainability indicators for bioeconomy consolidates existing sustainability indicators that are relevant to bioeconomy. It draws on reference frameworks found in 41 information sources, including international sustainability indicators (Annex 1). Only indicators with references that were less than 10 years old are included.



How to use the database

The database contains nearly 4,000 indicators selected from reference frameworks and information sources described in Annex 1. This large number highlights how challenging it can be for stakeholders to choose the right indicators to monitor bioeconomy performance and assess sustainability.

The database is designed to help stakeholders easily navigate and select a smaller, focused set of indicators for building their own bioeconomy monitoring and assessment framework. The following sections explain the different elements of the database structure, which users can navigate step-by-step to extract the most relevant indicators available for consideration and final selection. These are:

1. Levels
2. International sustainability frameworks
3. Strategic objectives
4. Key words
5. Tiers

1. Levels

Each indicator is associated with one of three levels at which bioeconomy can be developed:

- Territorial
Territorial indicators are used for monitoring and assessing bioeconomy development in a given geographical unit at any scale (local, subnational, national or regional).
- Product or value chain
Product and value chain indicators are used to monitor and assess the environmental, social, and economic impacts of specific bio-based products or services throughout their life cycle.
- Business or sector
These indicators are used when bioeconomy strategy focuses on businesses and sectors that may operate in several territories to produce one or several goods and/or services.

Stakeholders will have identified the level (or levels) of greatest priority to them in step 1 of the development of their bioeconomy strategy (Bracco *et al.*, 2019 and Bogdanski *et al.*, 2021) and can filter the database accordingly.

2. *International sustainability frameworks*

Each indicator is mapped to three international sustainability frameworks: the 17 Sustainable Development Goals and their targets, the 10 G20 High-Level Principles on Bioeconomy (GIB, 2024) and the FAO 10 Aspirational Principles and each of their 24 Criteria (FAO, 2021). This feature allows users to select indicators that are in line with any or all these three international sustainability frameworks.

3. *Strategic objectives*

The database also links each indicator with four types of strategic objectives (Gomez San Juan and Bogdanski, 2021). These objectives, which will have been identified step 2 of bioeconomy strategy development, cover the previously mentioned three dimensions of sustainability as well as good governance principles.

- **Environmental**
Objectives focus on replacing fossil-based resources with sustainable biological resources, addressing production challenges, and integrating climate and biodiversity goals.
- **Economic**
Objectives focus on adding value to biomass, developing new value chains, increasing producers' access to markets to reduce poverty and foster inclusive and equitable rural and urban development.
- **Social**
Objectives focus on safeguarding food and nutrition security, supporting vulnerable communities, promoting gender equality and encouraging the participation of young people.
- **Governance**
Objectives focus on developing effective and robust monitoring systems overseen by dedicated institutions and mechanisms to maximize synergies and minimize trade-offs.

Users can filter the database for the type(s) of strategic objectives that align with their bioeconomy strategy.

4. *Key words*

Each indicator is also associated with a pair of 'key words' that describe the main types of activities that the indicator is intended to address. These five pairs of key words can allow users to select with greater precision the indicators that are most suited to their overall bioeconomy strategy. The five pairs of key words are:

- **Produce/Add value**
Activities related to the production of raw biomass and derived biomaterials and bioproducts;

- **Optimize/Save**
Activities that lead to more efficient utilization of biomass along bioeconomy value chains;
- **Conserve/Preserve:**
Activities that preserve the natural environment and its related ecosystem services;
- **Secure/Protect:**
Activities that protect human rights, prevent discrimination, abuse or violence, enhance human health, ensure food, water and energy security, securing access to basic services, to land and other natural resources; and
- **Innovate/Integrate:**
Activities associated with scientific and technological and other types of innovations and the integration of modern science with local, traditional and Indigenous knowledge.

5. Tiers

It is important that the indicator is clearly understandable and based on a solid methodology. For this reason, each indicator is classified following the tier classification for global SDG indicators developed by the Inter-agency and Expert Group on SDG Indicators (IAEG-SDGs).

- Tier I indicators are conceptually clear and have available data. The database provides a link to this data source for user's easy reference.
- Tier II indicators have a clear methodology but currently lack sufficient data.
- Tier III denotes an indicator that still needs methodological development to produce an internationally established methodology or available standards. To support users in identifying more methodologically robust indicators, the database excludes indicators that were classified as Tier III during the preparatory analysis.

For example, stakeholders that do not have the means to gather primary data may wish to prioritize indicators which are classified as Tier I and have publicly available datasets. Periodic updates are foreseen to reclassify indicators as they may mature from a lower tier to a higher one.

For all indicators, there is a bibliographic reference and information on the sources of the data and its accessibility.

Illustrative examples

Table 1 provides an example set of bioeconomy sustainability indicators drawn from the database that could potentially be integrated into a monitoring and assessment framework. Table 2 indicates the level, sustainability objective and key words that the indicator is associated with and maps the indicator to the corresponding G20 High-Level Principle (HLPs) and FAO Aspirational Principles and Criteria (P&Cs). This is an example that could be useful for comparison in different countries and showing a similar indicator for each of the three levels. The overall strategic objectives are

Table 1. Global sustainability frameworks interlinked and examples of indicators across the three levels

Global sustainability frameworks				Examples of indicators by level		
G20 HLPs	FAO Criteria	Examples of SDG targets	Overall strategic objective	Territorial	Product or value chain	Business or sector
1	1.1; 3.1; 1.4	1.2; 1.a; 2.1; 2.2; 3.9; 17.15	Social	Food security and nutrition	Value of food imports in total merchandise exports	Allocation and tenure of land for new production
6	7.1; 7.2	9.5; 9.b; 17.6	Social	Intellectual property rights (IPRs) (patent, trademark, design) applications in bioeconomy subsectors (number of applications per 1k employees)	Monetary and non-monetary benefits received in accordance with applicable internationally agreed ABS instruments	Workers' participation rate in education and training in the previous 12 months
7	8.1; 9.2	2.b; 8.5; 12.a; 17.10	Social	Bioeconomy employment (percent of total employment)	Available certification or documentation about social sustainability	Labour productivity (value added / person employed)
2	1.3; 3.2; 6.2	2.3; 5.5	Economic	Net trade of biomass (percent of total domestic consumption)	Value added of biomass per person employed in bioeconomy	Bioeconomy SME birth & death rates
8	6.3	12.6; 17.19	Economic	Bioeconomy value added (percent of total GDP)	Cost efficiency ratio (output value/input value)	Turnover per sector of bioeconomy

3	2.2; 1.2; 9.1; 4.2; 5.1; 5.2	7.2; 12.1; 13.1; 13.2; 13.3	Environmental	Net GHG emissions (sources and sinks)	Carbon footprint (kgCO ₂ eq/kg)	GHG emission intensity (kgCO ₂ e/ value added)
4	2.1	2.5; 15.4; 15.6	Environmental	Domestic public funding on conservation and sustainable use of biodiversity and ecosystems	Biological carbon content (percent of product total carbon content)	Bio-based share of inputs and outputs, by category
5	2.3; 2.4	15.3; 15.5	Environmental	Area under sustainable management practices (percent of total agricultural vs. forest area)	Land footprint (m ² /kg)	Land productivity (value added/ ha)
9	10.1	17.7; 17.9; 17.16	Governance	Number of countries developing, adopting, or implementing policy instruments aimed at encouraging and enabling people to make sustainable consumption choices.	Share of certified sustainable products in the given market	Research into technical and organisational aspects of new bioeconomy initiatives
10	3.3; 4.1; 6.1	1.b; 11.a; 16.7	Governance	Existence of a territorial strategy for the development of a sustainable bioeconomy involving all relevant stakeholders	Verification of data of the incoming certified product	Sustainable procurement

The way forward

Despite progress in developing bioeconomy monitoring frameworks, several significant challenges in designing and implementing monitoring and assessment systems remain. The scarcity of data about biomass availability and uses presents a fundamental challenge. Many biological resources, including crop residues, organic waste, indigenous products consumed locally, and microorganisms used in industry, are not accounted for in national statistics or international trade data. This leads to incomplete assessments of bioeconomy activities and impacts. Furthermore, data collected by countries vary substantially since the definitions and assumptions considered differ in space (different administrative areas), time (different baselines and reporting periods), and sectorial boundaries (different classification systems for biological resources). This lack of standardization complicates cross-country comparisons and aggregation of data (FAO, 2024a and 2024b).

Differing institutional capacities among countries and regions is a major hurdle to bioeconomy advancement. Many countries lack technical expertise, infrastructure, and resources needed to implement comprehensive monitoring systems. This is particularly true for developing countries, which may have great potential for bioeconomy development but limited capacity to monitor it effectively (FAO, 2024a and 2024b).

The diverse nature of bioeconomy strategies across countries creates challenges for establishing standardized monitoring approaches. Differences in definitions, scope, objectives, and priority sectors make it difficult to develop universally applicable indicators. This diversity, while reflecting legitimate differences in national priorities, complicates efforts to create harmonized monitoring frameworks (FAO, 2024a).

Monitoring systems struggle to capture the complex interactions between economic, environmental, and social dimensions of bioeconomy. Trade-offs and synergies between these dimensions are often context-specific and difficult to quantify using standardized indicators. Additionally, the long-term impacts of bioeconomy development may not be immediately apparent, requiring monitoring systems that can track changes over extended timeframes (FAO, 2024b).

The FAO database of sustainability indicators addresses this last critical gap in monitoring the sustainability and development of bioeconomy. Given the rapidly expanding landscape of relevant frameworks and indicators, the database is not intended to be exhaustive; rather, it is conceived as a living document and regular updates are foreseen as new knowledge, methodologies, and stakeholder needs emerge.

The database serves as a practical tool for stakeholders, enabling them to select indicators that are both contextually appropriate and aligned with their bioeconomy strategies. By supporting the selection of relevant indicators, the database helps build a robust evidence base for sustainable bioeconomy development. This, in turn, facilitates the generation of comparable results across countries and regions, supporting informed decision-making and the development of coherent, effective bioeconomy policies.

References

Bogdanski, A., Giuntoli, J., Mubareka, S., Gomez San Juan, M., Robert, N. & Tani, A. 2021. *Guidance Note on Monitoring the Sustainability of the Bioeconomy at a Country or Macro-regional Level*. Environment and Natural Resources Management Working Papers – Bioeconomy, No. 90. Rome, FAO and EC-JRC. <https://openknowledge.fao.org/handle/20.500.14283/cb7437en>

Bracco, S., Tani, A., Calicioglu, O., Gomez San Juan, M. & Bogdanski, A. 2019a. *Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward*. Environment and Natural Resources Management Working Paper – Bioeconomy, No. 77. Rome, FAO. <https://openknowledge.fao.org/handle/20.500.14283/ca6048en>

GIB (G20 Initiative on Bioeconomy). 2024. *High-Level Principles on Bioeconomy*. <https://g20.gov.br/pt-br/trilhas/trilha-de-sherpas/bioeconomia/high-level-principles-on-bioeconomy.pdf/@download/file>

Gomez San Juan, M. & Bogdanski, A. 2021. *How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies*. Rome, FAO. <https://openknowledge.fao.org/handle/20.500.14283/cb5798en>

Gomez San Juan, M. 2024. *The bioeconomy toolbox – A guide to support the development of sustainable bioeconomy strategies and policies*. Environment and Natural Resources Management Working Paper, No. 99. Rome, FAO. <https://openknowledge.fao.org/handle/20.500.14283/cc8856en>

FAO. 2021. *Aspirational principles and criteria for a sustainable bioeconomy*. Rome. <https://openknowledge.fao.org/handle/20.500.14283/cb3706en>

FAO. 2024a. *Bioeconomy for food and agriculture: A global stocktaking study*. Rome. <https://doi.org/10.4060/cd2490en>

FAO. 2024b. *Bioeconomy for sustainable food and agriculture: a global opportunity. Position paper*. Rome. <https://openknowledge.fao.org/handle/20.500.14283/cd1976en>

UN. 2024. *SDG Indicators: Global indicator framework for Sustainable Development. Goals; Metadata repository; and Tier classification*. [online]. New York. [Cited 12 December 2024]. <https://unstats.un.org/sdgs/dataportal>

Annex 1. Reference frameworks and information sources used to select indicators for the database

Reference framework or information source	Source
Territorial level	
Database FAOSTAT – selected bioeconomy indicators	FAO (2025)
World Development Indicators	WB (2024)
Monitoring framework for the Kunming-Montreal Global Biodiversity Framework.	CBD (2022;2025)
UN SDG Global Indicator Framework, after the 2024 refinement	UN (2024) Bracco <i>et al.</i> (2019) Calicioglu and Bogdanski (2021)
Database EUROSTAT – selected bioeconomy indicators	EUROSTAT (2024) Giuntoli <i>et al.</i> (2020)
National or regional strategies: ○ National bioeconomy strategies in the G20 and OCDE ○ Argentina ○ Italy ○ Finland ○ Malaysia ○ European Commission ○ Namibia ○ Colombia and Antioquia	FAO (2024) Gardossi <i>et al.</i> (2023) Bracco <i>et al.</i> (2019) Giuntoli <i>et al.</i> (2020) Patani <i>et al.</i> (2024) Lier <i>et al.</i> , (2018) Namibia (2024) Alviar <i>et al.</i> (2021)
Indicator System for Assessing the Sustainability of the Bioeconomy	Egenolf and Bringezu (2019)
Social Progress Index (SPI) database (2024)	SPI (2024)
Other frameworks ○ The green economy progress (GEP) measurement framework (PAGE, 2017, 2018) ○ State-of-Play of National Consumption-Based Indicators (SERI, 2013) ○ Maritime Spatial Planning (MSP) for Blue Growth (European Commission, 2018) ○ Greening the Ocean Economy; A preliminary assessment of indicators for SDG 14 on “Oceans” (Mackie <i>et al.</i>, 2017; OECD, 2017; Recuero Virto, 2017). ○ Global Sustainable Land Use (IINAS/GLOBALANDS, 2015) ○ A good life for all within planetary boundaries (O’Neill <i>et al.</i>, 2018)	Extraction of bioeconomy-relevant indicators in Bracco <i>et al.</i> (2019)
Product or value chain level	
International Sustainability and Carbon Certification	ISCC (2022 ; 2023 ; 2024) Bracco <i>et al.</i> (2019)
Certification Bonsucro Chain of Custody Standard (Version 5.1, March 2019) and Bonsucro Production Standard (Version 5.2, July 2023)	Bonsucro (2019; 2023) Bracco <i>et al.</i> (2019)
Roundtable on Sustainable Palm Oil	RSPO (2018) updating Bracco <i>et al.</i> (2019) which included version of 2013

Roundtable on Sustainable Biomaterials	RSB, (2023) updating Bracco <i>et al.</i> (2019) which included versions of 2011 and 2016
Forest Stewardship Council (FSC) International Generic Indicators. Version 2.1	FSC (2023)
Life-cycle assessment indicators to monitor the sustainability of bio-based value chains	Lago-Oliveira <i>et al.</i> (2024)
Thünen Institute indicators and methodology : Monitoring the sustainability of the bioeconomy - Pilot in Uruguay	Pozo <i>et al.</i> (2023)
Other frameworks: ○ ASC-MSC Seaweed (Algae) Standard (Aquaculture Stewardship Council and Marine Stewardship Council, 2018) ○ Certification Blue Angel for recycled paper; biodegradable lubricants; wood materials for interiors; panel-shaped materials for construction; leather; unbleached filter papers; wallpapers; wood chips and pellets (Blue Angel, 2008, 2014a, 2014b, 2014c, 2014d, 2015, 2016, 2017a, 2017b) ○ Cradle to Cradle Products Innovation Institute, 2016: product standard version 3.1 ○ DIN Certco certification of biodegradability in soil, products made from compostable materials, biobased products, etc (2015a, 2015b, 2017) ○ EU Eco Label e.g. for soil improvers and mulch; printed paper; lubricants; wood, cork, bamboo-based floor coverings (European Commission, 2009, 2011a, 2011b, 2012a, 2012b, 2014, 2015, 2017b) ○ MSC Fisheries Standard (Marine Stewardship Council, 2019) ○ Sustainable Agriculture Standard (Rainforest Alliance, 2017) ○ RTRS Standard for Responsible Soy Production V3.1 (2010) ○ D2.2: Selection of environmental indicators and impact categories for the life cycle assessment of bio-based products (Star-ProBio, 2018) ○ Greening Global Supply Chains: From Blind Spots To Hotspots To Action. Impact Report (The Sustainability Consortium, 2016) ○ Guidelines for social life cycle assessment of products (UNEP Setac Life Cycle Initiative, 2009) ○ Vinçotte certification for bioproducts compostability, degradation in soil, in water and in seawater (Vinçotte, 2012a, 2012b, 2012c, 2013, 2015) ○ Summary report on the social, economic and environmental impacts of the bioeconomy - BioStep (Hasenheit <i>et al.</i>, 2016)	Extraction of bioeconomy-relevant indicators in Bracco <i>et al.</i> (2019)
Business or sectoral level	
GBEP Sustainability indicators for bioenergy applied to several countries	FAO (2011) Bracco <i>et al.</i> (2019)
Forest bioeconomy indicators	Wolfslehner <i>et al.</i> (2016) Bracco <i>et al.</i> (2019)
Sustainability indicators for the EU's biobased chemical sector & Bioproducts independent of any sector	Baldoni <i>et al.</i> (2021) Bracco <i>et al.</i> (2019)

The Global bioeconomy. Preliminary stocktake of G20 Strategies and Practices: a contribution to the Brazilian G20 Presidency's Global Initiative on Bioeconomy	NF and FGV (2024)
Analyzing major bio-based industries in Europe	Fernández Ocamica <i>et al.</i> (2024)
Updated (2015) pan-European set of indicators for sustainable forest management	Forest Europe (2020)
Consistent Cross-Sectoral Sustainability Criteria & Indicators; and D5.2: Benchmark and gap analysis of criteria and indicators (C&I)	S2Biom (2015) Bracco <i>et al.</i> (2019)
D1.2 Sustainability principles and criteria for biological resources and bio-based products (SUSTCERT4BIOBASED EU project)	WR-WFBR (2023)
Global Reporting Initiative for relevant sectors	GRI (2024a; 2024b)
Carbon Disclosure Project	CDP (2025)
The Taskforce on Nature-related Financial Disclosures	TNFD (2023; 2024)
International Financial Reporting Standards (IFRS)	IFRS (2023)
European Sustainability Reporting Standards	EC (2023)

References of Annex 1

Alviar, M., García-Suaza, A., Ramírez-Gómez, L. & Villegas-Velásquez, S. 2021. Measuring the Contribution of the Bioeconomy: The Case of Colombia and Antioquia. *Sustainability*, 13: 2353. <https://doi.org/10.3390/su13042353>

Baldoni, E., Philippidis, G., Spekrijse J., Gurriá, P., Lammens, T., Parisi C., Ronzon, T. et al. 2021. Getting your hands dirty: A data digging exercise to unearth the EU's bio-based chemical sector. *Renewable and Sustainable Energy Reviews*, 143: 110895. <https://doi.org/10.1016/j.rser.2021.110895>

Bonsucro. 2019. *Bonsucro Mass Balance Chain of Custody Standard including implementation guidance. Version 5.1.* <https://bonsucro.com/wp-content/uploads/2019/04/BONSUCRO-MASS-BALANCE-CHAIN-OF-CUSTODY-STANDARD-INCLUDING-IMPLEMENTATION-GUIDANCE.pdf>

Bonsucro. 2023. *Bonsucro Production Standard. Version 5.2.* https://bonsucro.com/wp-content/uploads/SCH_Bonsucro-Production-Standard-V5.2-July-2023-ENG.pdf

Bracco, S., Tani, A., Calicioglu, O., Gomez San Juan, M. & Bogdanski, A. 2019. *Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward.* Environment and Natural Resources Management Working Paper – Bioeconomy, No. 77. Rome, FAO. <https://openknowledge.fao.org/handle/20.500.14283/ca6048en>

Calicioglu, O. & Bogdanski, A. 2021. Linking the bioeconomy to the 2030 sustainable development agenda: Can SDG indicators be used to monitor progress towards a sustainable bioeconomy? *New Biotechnology*, 61: 40–49. <https://doi.org/10.1016/j.nbt.2020.10.010>

CBD (Convention on Biological Diversity). 2022. **Global targets for 2030.** Kunming-Montreal Global Biodiversity Framework. In: *CBD*. Montreal, Canada. [Cited 4 April 2025]. <https://www.cbd.int/gbf/targets>

CBD. 2025. *Framework Monitoring framework for the Kunming-Montreal Global Biodiversity.* 16/31 decision adopted by the Conference of the Parties to the Convention on Biological Diversity: Sixteenth meeting, second resumed session. 32 pp. <https://www.cbd.int/doc/decisions/cop-16/cop-16-dec-31-en.pdf>

CDP (Carbon Disclosure Project). 2025. Capital Markets Signatories. In: *CDP*. Brussels. [Cited 27 April 2025]. <https://www.cdp.net/en/capital-markets-signatories>

EC (European Commission). 2023. *Commission Delegated Regulation (EU) 2023/2772 of 31 July 2023 supplementing Directive 2013/34/EU of the European Parliament and of the Council as regards sustainability reporting standards.* Official Journal of the European Union. 284 pp. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302772

Egenolf, V. & Bringezu, S. 2019. Conceptualization of an Indicator System for Assessing the Sustainability of the Bioeconomy. *Sustainability*, 11(2): 443. <https://doi.org/10.3390/su11020443>

EUROSTAT. 2024. EUROSTAT: Database. In *European Union*. [Cited 15 November 2024]. <https://ec.europa.eu/eurostat/web/main/data/database>

- FAO (Food and Agriculture Organization of the United Nations).** 2011. *The Global Bioenergy Partnership Sustainability Indicators for Bioenergy*. First edition. Rome. <https://openknowledge.fao.org/server/api/core/bitstreams/9f46f095-3f13-4996-93e6-2637a1dece0d/content>
- FAO.** 2025. FAOSTAT: Food and agriculture data. In *FAO*. [online]. Rome. [Cited 7 January 2025]. <https://www.fao.org/faostat/en/#home>
- Fernández Ocamica, V., Bernardes Figueirêdo, M., Zapata, S. & Bartolomé, C.** 2024. Assessment of EU Bio-Based Economy Sectors Based on Environmental, Socioeconomic, and Technical Indicators. *Sustainability*, 16(5): 1971. <https://doi.org/10.3390/su16051971>
- Forest Europe.** 2020. *State of Europe's Forests 2020*. https://foresteurope.org/wp-content/uploads/2016/08/SoEF_2020.pdf
- FSC (Forest Stewardship Council).** 2023. *International Generic Indicators*. (FSC-STD-60-004 V2-1). Version 2.1. <https://connect.fsc.org/document-centre/documents/resource/262>
- Gardossi, L., Philp, J., Fava, F., Winickoff, D., D'Aprile, L., Dell'Anno, B., Ole Jørgen Marvik, OJ. et al.** 2023. Bioeconomy national strategies in the G20 and OECD countries: Sharing experiences and comparing existing policies. *European Federation of Biotechnology (EFB) Bioeconomy Journal*, 3: 100053. <https://doi.org/10.1016/j.bioeco.2023.100053>
- Giuntoli, J., Robert, N., Ronzon, T., Sanchez Lopez, J., Follador, M., Girardi, I., Barredo Cano, J. et al.** 2020. *Building a monitoring system for the EU bioeconomy*. EUR 30064 EN, Publications Office of the European Union, Luxembourg. <https://doi.org/10.2760/717782>
- GRI (Global Reporting Initiative).** 2024a. Universal Standards. In: *GRI*. Amsterdam, The Netherlands. [Cited 27 April 2025]. <https://www.globalreporting.org/standards/standards-development/universal-standards>
- GRI.** 2024b. Topic Standards. In: *GRI*. Amsterdam, The Netherlands. [Cited 27 April 2025]. <https://www.globalreporting.org/how-to-use-the-gri-standards/gri-standards-english-language/>
- ISCC (International Sustainability and Carbon Certification).** 2022. *ISCC EU 202-2. Agricultural Biomass: ISCC Principles 2-6. Version 1.1*. Valid from: 1st December 2022. https://www.iscc-system.org/wp-content/uploads/2022/08/202_2_Agricultural-Biomass_ISCC-Principles-2-6_v1.1_August_2.pdf
- ISCC.** 2023. *ISCC EU 202-4. Forest Biomass: ISCC Principles 2 – 6. Version 1*. Valid from: 01 March 2023. https://www.iscc-system.org/wp-content/uploads/2023/03/ISCC_EU_202-4_Forest-Biomass_-ISCC-Principle-2-6_Final.pdf
- ISCC.** 2024. *ISCC EU 202-1. Agricultural Biomass: ISCC Principle 1. Version 4.1*. Valid from: 01 January 2024 https://www.iscc-system.org/wp-content/uploads/2024/01/ISCC_EU_202-1_Agricultural-Biomass_ISCC-Principle-1_v4.1_January2024.pdf
- IFRS (International Financial Reporting Standards).** 2023. IFRS S2 Climate-related Disclosures. In: *IFRS*. London. [Cited 21 May 2025]. <https://www.ifrs.org/issued-standards/ifrs-sustainability-standards-navigator/ifrs-s2-climate-related-disclosures/#standard>

Lago-Oliveira, S., Arias, A., Rebolledo-Leiva, R., Feijoo, G., González-García, S., & Moreira, M.T. 2024. Monitoring the bioeconomy: Value chains under the framework of life cycle assessment indicators. *Cleaner and Circular Bioeconomy*, 7: 100072. <https://doi.org/10.1016/j.clcb.2024.100072>

Lier, M., Aarne, M., Kärkkäinen, L., Korhonen, K.T., Yli-Viikari, A. & Packalen, T. 2018. *Synthesis on bioeconomy monitoring systems in the EU Member States - indicators for monitoring the progress of bioeconomy*. Natural resources and bioeconomy studies 38/2018. Natural Resources Institute (LUKE), Helsinki. <https://jukuri.luke.fi/handle/10024/542249>

Namibia. 2024. *The Namibia Sustainable Bioeconomy Strategy 2024-2029*. By the Namibian Ministry of Higher Education, Technology and Innovation and the Namibian National Commission on Research, Science & Technology, with the technical and financial support of the Food and Agriculture Organization of the United Nations. https://www.n-big.org/wp-content/uploads/2024/06/NATIONAL-BIOECONOMY-STRATEGY-2024-FINAL_compressed-2.pdf

NF (Nature Finance) and GVF (Getúlio Vargas Foundation). 2024. *The Global Bioeconomy: Preliminary Stocktake of G20 Strategies and Practices: a contribution to the Brazilian G20 Presidency's Global Initiative on Bioeconomy*. https://www.naturefinance.net/wp-content/uploads/2024/05/ENG-TheGlobalBioeconomy_FINAL.pdf

Patani, S., Mubareka, S.B., Olsson, M., Girardi, J., Kilsedar, C., Zepharovich, E. & Camia, A. 2024. *EU Bioeconomy Monitoring System dashboards: extended with social indicators*. Joint Research Centre report, JRC136613. Publications Office of the European Union, Luxembourg. <https://doi.org/10.2760/827057>

Pozo, P., Gordillo, F., Polcaro, S., Gomez San Juan, M. & Schweinle, J. 2023. *Monitorear la sostenibilidad de la bioeconomía - Piloto en Uruguay/Monitoring the sustainability of the bioeconomy - Pilot in Uruguay*. Rome, FAO. <https://openknowledge.fao.org/handle/20.500.14283/cc7309b>

RSB (Roundtable on Sustainable Biomaterials). 2023. *RSB Principles & Criteria*. (RSB-STD-01-001). Version 4.0. Published 18 December 2023: <https://rsb.org/wp-content/uploads/2024/05/rsb-principles-criteria-std-01-001-v4-1.pdf>

RSPO (Roundtable on Sustainable Palm Oil). 2018. *Principles and Criteria for the Production of Sustainable Palm Oil*. Endorsed by the RSPO Board of Governors and adopted at the 15th Annual General Assembly by RSPO Members on 15 November 2018. Revised 01 February 2020 with updated Supply Chain Requirements for Mills. <https://rspo.org/resources/?id=6025>

S2Biom. 2015. *D5.4 Consistent Cross-Sectoral Sustainability Criteria & Indicators*. Final Report by Iriarte, L. and Fristch, U.R. March 2015. Sustainable Supply of non-food Biomass to support a “resource-efficient” Bioeconomy in Europe (S2Biom). Project co-funded by the European Union. https://www.s2biom.eu/images/Publications/D5.4_S2Biom_Cross-Sectoral_Sustainability_Indicators_Final.pdf

SASB (Sustainability Accounting Standards Board). n.d. Standards for the Financial Services Sector: Asset Management & Custody Activities; Commercial Banks; Consumer Finance; Insurance; Investment Banking & Brokerage; Mortgage Finance; Security and commodity

exchanges. In: SASB. San Francisco, California, USA. [Cited 27 April 2025]. <https://sasb.ifrs.org/standards/materiality-finder/find/>

SPI (Social Progress Imperative). 2024. *Social Progress Index*. Version 2024 – Results covering the period 2011-2023. Social Progress Imperative, Washington DC. <https://www.socialprogress.org/2024-social-progress-index/>

TNFD (The Taskforce on Nature-related Financial Disclosures). 2023. *Recommendations of the Taskforce on Nature-related Financial Disclosures*. 154 pp. <https://tnfd.global/wp-content/uploads/2023/08/Recommendations-of-the-Taskforce-on-Nature-related-Financial-Disclosures.pdf?v=1734112245>

TNFD. 2024. *Additional guidance for financial institutions*. 37 pp. https://tnfd.global/wp-content/uploads/2024/06/TNFD-Additional-guidance-for-financial-Institutions_v2.0.pdf

UN. 2024. *SDG Indicators: Global indicator framework for Sustainable Development. Goals; Metadata repository; and Tier classification*. [online]. New York. [Cited 12 December 2024]. <https://unstats.un.org/sdgs/dataportal>

Wolfslehner, B., Linser, S., Pölzl, H., Bastrup-Birk, A., Camia, A. & Marchetti, M. 2016. *Forest bioeconomy – a new scope for sustainability indicators*. From Science to Policy 4. European Forest Institute. https://efi.int/sites/default/files/files/publication-bank/2019/efi_fstp_4_2016.pdf

WB (World Bank Group). 2024. *World Development Indicators*. Databank. <https://databank.worldbank.org/reports.aspx?source=world-development-indicators>

WR-WFBR (Wageningen Research – Wageningen Food and Bio-based Research). 2023. *D1.2 Catalogue of sustainability certification schemes and labels*. Sustainability certification for bio-based systems (SUSTCERT4BIO-BASED). Project funded by the European Union. April 2023. https://sustcert4bio-based.eu/wp-content/uploads/2024/12/D1.2_Catalogue-of-sustainability-certification-schemes-and-labels_final_compressed-1.pdf

