Food and Agriculture Organization of the United Nations

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BIOECONOMY

Indicators for sustainable bioeconomy

Towards building a monitoring and assessment framework

G20 SOUTH AFRICA 2025

Indicators for sustainable bioeconomy

Towards building a monitoring and assessment framework

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G20 Presidency Foreword

The pressing challenges we face as inhabitants of Earth underscore the critical need to care more responsibly for our planet and all forms of life it sustains. While some issues can be tackled locally, others require a broader, international lens and coordinated global action to achieve meaningful impact.

Climate change, biodiversity loss, environmental degradation, and unsustainable patterns of development are among the most pressing challenges of our time, demanding urgent global attention. While these crises are profound, solutions do exist - and effective mitigation is both possible and necessary. Success will depend on actions that are swift, coordinated, and transformative, carrying wide-ranging implications for how economies are organized and sustained. The transition to sustainable bioeconomies represents an unparalleled opportunity: not only to addresses environmental risks but also to catalyze more inclusive, resilient, and equitable socio-economic development.

The vision for global bioeconomies, shaped under Brazil's leadership of the G20 in 2024, has been a critical first step. We must now move decisively from aspiration to implementation. As South Africa took forward this agenda in the G20 in 2025, its priorities—advancing equity and inclusion, amplifying Africa's voice in global decision-making, driving a just transition in the face of climate change, strengthening food security, and promoting sustainable development—underscore the pathways by which bioeconomy strategies can deliver for people and planet alike.

A cornerstone of this transition is the development of trade that supports sustainable bioeconomy goods and services. Such trade offers a powerful opportunity to drive socio-economic advancement, particularly across the biomass-rich tropical and developing regions of the world. To unlock this potential, robust metrics and measurement frameworks for sustainable bioeconomy will not only facilitate and incentivize trade, but also serve as vital tools to track bioeconomy progress at national and regional levels.

FAO has shown commendable leadership in compiling a globally relevant system of bioeconomy metrics and an accompanying database. These tools provide a critical foundation—but it is now our collective responsibility to put them to work, ensuring that they drive the transition to a more sustainable and equitable future.

Ben Durham

Chief Director: Bio Innovation

Department of Science, Technology and Innovation

Government of South Africa

FAO Foreword

Bioeconomy holds great promise for transforming how we live, produce, and share resources, with people and the planet at the heart of development. But this potential will not be fulfilled without clear metrics of what counts as sustainable bioeconomy and how it can be monitored and assessed.

The G20 High-Level Principles on Bioeconomy are our starting point. Principle 8 calls on us to adopt monitoring frameworks that are both tailored to local contexts and globally comparable. These monitoring frameworks need to be rooted in transparent, science-based, and measurable data. They must also empower all stakeholders – policymakers, businesses, investors, researchers, communities – to steward biological resources responsibly and ensure that their benefits are equitably shared.

This publication, *Indicators for Sustainable Bioeconomy: Towards Building a Monitoring and Assessment Framework*, and its accompanying database, are an important step toward filling this gap. The publication offers a wide and comprehensive range of indicators that users can draw from in ways that are in line with their own strategies and targets and connected to global ambitions such as the 2030 Agenda for Sustainable Development.

FAO will continue to support countries and partners to steer sustainable bioeconomy forward. Through shared knowledge, coordinated policies, joint investment, and, above all, clear metrics, we can build a bioeconomy that delivers on its promise: a future where prosperity thrives in harmony with nature.

Kaveh Zahedi

Director, Office of Climate Change Biodiversity and Environment

Food and Agriculture Organization of the United Nations

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The report was prepared within the framework of the FAO Programme Priority Area on Bioeconomy (PPA BE2), 'Bioeconomy for Sustainable Food and Agriculture', and aims 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). The authors would like to thank Ben Durham, Chief Director of Bio-innovation at South Africa's National Department of Science and Innovation and Chair of the G20 Initiative on Bioeconomy, for his valuable guidance.

This publication is the result of a collective effort. While it does not represent their official views, members of the Forests, Trees and Agroforestry Partnership (FTAP), along with focal points from the PPA BE2 and the FAO-led International Sustainable Bioeconomy Working Group, generously contributed their expertise through a participatory consultation process, ensuring that the publication builds on existing knowledge. FTAP consultations were organized on 7 May 2024 to provide initial feedback to the draft annotated outline and guidance on the workplan, and on 16 October 2024 to revise the advanced draft. FTAP members who participated in these online workshops were: Arlene Lopez Sampson and Roger Madrigal (Tropical Agricultural Research and Higher Education Center, CATIE), Bas Louman and Roderick Zagt (Tropenbos International), Diana Tuomasjukka (European Forest Institute, EFI), Dietman Stoian (CIFOR-ICRAF), Guillermo Pena Chipatecua (Alliance of Bioversity International and CIAT, ABC), Ivar Virgin (Stockholm Environment Institute, SEI), Marie-Gabrielle Piketty (French Agricultural Research and Higher Education Centre, CIRAD), Rita Milagres and Erich Schaitza (Brazilian Agricultural Research Cooperation, Embrapa), Yanxia Li (International Network for Bamboo and Rattan, INBAR). FAO experts from different divisions also engaged: Sven Walter and Natalia Cardoso (Forestry), Antonio Scognamillo (Agrifood Economics), Lingyan Li (Fisheries and Aquaculture), Alfonso Sanchez, Tiziana Pirelli and Constance Miller (OCB), Victor Prada and Matheus Cardim (Markets and Trade), Karel Callens (Agrifood Systems and Food Safety Division) and Maryam Rahmanian (Chief Scientist Office), Felipe Chamizo (Regional Office for Latin America and the Caribbean), Illias Animon (Regional Office for Asia and the Pacific), during a final, in-person workshop organised on 15 November 2024 in Rome, Italy. Additionally, the following partners provided comments during the workshop: Governments of Canada, Finland, Germany, Ireland, Italy, South Africa, and United Kingdom, the European Commission and its Joint Research Center, as well as the United Nations Economic Commission for Latin America and the Caribbean (ECLAC), United Nations Environment Programme (Monica Lopez Conlon and Llorenc Mila I Canals), University of Kassel and

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Abbreviations

CSRD	Corporate Sustainability Reporting Directive
ESG	Environmental, Social and Governance
ESRS	European Sustainability Reporting Standards
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
G20	Group of 20
GBF	Global Biodiversity Framework
GIB	G20 Initiative on Bioeconomy
GHG	greenhouse gases
GRI	Global Reporting Initiative
HLPs	G20 High-Level Principles on Bioeconomy
IFRS	International Financial Reporting Standards
ISSB	International Sustainability Standards Board
LCA	life cycle assessment
NBSAP	National Biodiversity Strategy and Action Plan (South Africa)
PPA BE2	Programme Priority Area on Bioeconomy for Sustainable Food and Agriculture
SASB	Sustainability Accounting Standards Board
SDGs	Sustainable Development Goals
TNFD	Taskforce on Nature-related Financial Disclosures
WR-WFBR	Wageningen Research – Wageningen Food and Bio-based Research

Recommendations for the Group of 20

The leadership of the Group of 20 (G20) is vital in shaping the global bioeconomy agenda. The G20 has played a pivotal role in advancing the bioeconomy by fostering research and innovation and strengthening coordination between science and policy. Notably, under Brazil's presidency, the G20 Initiative on Bioeconomy was established. South Africa is now building on this leadership. In line with Principle 8 of the G20 High-Level Principles on Bioeconomy, adopted in 2024, which calls for the promotion of evidence-based policy and decision-making through robust monitoring, reporting, and review mechanisms, the G20 is uniquely positioned to accelerate the development and adoption of harmonized monitoring and assessment frameworks for the bioeconomy.

By championing clear standards, advancing transparent data harmonization, and fostering inclusive, participatory approaches to indicator development, G20 members can ensure that bioeconomy progress is measured comprehensively. This will not only strengthen national bioeconomy strategies but also catalyze global progress towards sustainability, helping to ensure that bioeconomy development delivers concrete benefits for people, prosperity, and the planet.

FAO has developed this publication in support of discussions under the 'Towards establishing global bioeconomy standards and metrics' pillar of the South African G20 Presidency's Global Initiative on Bioeconomy (GIB) and, on this basis, highlights the following recommendations for the G20's consideration:

Establish science-based, harmonized monitoring frameworks. Develop transparent, comparable, and measurable bioeconomy monitoring frameworks utilizing the prioritization approach laid out in this publication and accompanying database. Invest in research to improve methodologies for assessing bioeconomy contributions to national economies, particularly addressing the current gap where official economic statistics rarely differentiate between bio-based and non-bio-based products.

Build institutional capacities and cross-sectoral coordination. Establish dedicated national bioeconomy monitoring functions within relevant ministries that are empowered to coordinate data collection and analysis across traditional sectoral boundaries. These institutional mechanisms should integrate bioeconomy indicators into national statistical systems and ensure compatibility with international reporting frameworks, including the Sustainable Development Goals (SDGs), climate action, and biodiversity conservation targets.

International organizations should enhance technical assistance to developing countries. This would include methodological guidance, training programmes, data collection support, and technology transfer to ensure equitable participation in bioeconomy monitoring. This assistance would acknowledge that many developing countries have significant bioeconomy potential but limited monitoring and assessment capacities.

Foster multi-stakeholder engagement and continuous framework refinement. Establish mechanisms for regular stakeholder engagement involving research institutions, the private sector, and civil society in developing and implementing bioeconomy monitoring frameworks that ensure accountability and drive sustainable practices. These mechanisms should enable the regular review and updating of indicators based on stakeholder feedback and emerging scientific understanding, ensuring the framework remains relevant and effective in addressing emerging challenges and opportunities in the sustainable bioeconomy.

Adopt phased implementation with adaptive management. Implement a phased approach that allows for the progressive development of monitoring capabilities. Initial phases could focus on establishing institutional frameworks and collecting data on core indicators where methodologies are well-established and data are readily available. Subsequent phases could incorporate more sophisticated indicators as methodological development progresses and national statistical capacities are strengthened. During all these phases, political commitment must be sustained to ensure adequate financial resources and continuous adaptation based on emerging scientific understanding and practical experience.

Encourage the adoption and evolution of the prioritization approach set out in this publication. To help standardize the ways that diverse stakeholders in different contexts build bioeconomy assessment and monitoring frameworks, promote the uptake of the prioritization approach proposed by FAO and partners hand in hand with its accompanying database. Facilitate adoption beyond G20 countries to work towards more harmonized international monitoring and assessment frameworks that support evidence-based decision-making for sustainable and equitable bioeconomy development globally. The prioritization approach and database represent a key first step towards such harmonization and will require regular updates and refinement to ensure continued relevance and effectiveness in addressing emerging challenges and opportunities in sustainable bioeconomy development.

Introduction

Despite growing recognition of the importance of bioeconomy, 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. There are also data gaps in terms of biomass availability and utilization, climate and pollution reduction benefits, global trade, and investment growth. If bioeconomy is to be recognized as delivering interlinked 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 bioeconomy sustainably. These frameworks should enable policymakers, businesses, investors, researchers, development practitioners, local communities and other stakeholder to collectively ensure that biological resources are sourced and managed sustainably in ways that conserve biodiversity and ensure that its benefits are shared fairly and equitably.

Given the diverse socioeconomic, ecological, and institutional factors that shape national and regional bioeconomies, a prescriptive 'one-size-fits-all' set of indicators is neither feasible nor desirable. Instead, a harmonized approach aligned with overarching sustainability principles (e.g. the SDGs, the 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 (e.g. building climate resilience and ensuring an equitable use of resources) without stifling innovation and undermining local relevance. Principle 8 of the G20 High-Level Principles on Bioeconomy advocates for context-specific criteria and methodologies that are in turn transparent and comparable (GIB, 2024).

The present publication introduces a comprehensive approach and a database designed to bridge these critical gaps. It enables stakeholders to select indicators tailored to their specific contexts and strategic goals. By supporting indicator selection through easily replicable steps, results across diverse contexts become more readily comparable. A stronger foundation for evidence-based decision-making can lead to improved international policy coherence and sustainable investments in inclusive and resilient bioeconomy value chains.

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

- supporting evidence-based decision-making;
- identifying trade-offs and synergies across and within the three dimensions (social, economic, and environmental) of sustainability; and
- tracking progress toward honouring national and global sustainability commitments.

THE SUSTAINABILITY OF BIOECONOMY MUST BE MONITORED

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 pressures on natural resources (land, water, and biodiversity).

Furthermore, the higher demand for biomass to produce non-food commodities could have an impact on food production and may increase food prices, which could threaten food security and nutrition, especially in the most vulnerable communities. Any monitoring framework should assess whether agrifood systems are using natural resources efficiently. Agrifood systems cover food production harvesting, processing, packaging, transport, distribution, trade, commercialization, preparation, consumption, and disposal; the entire journey of food from farm to table. These systems also include non-food products that support livelihoods. All the people, activities, investments and choices that play a part in making available food and agricultural products constitute the agrifood system (FAO *et al.*, 2025).

Also, economic gains derived from bioeconomy are not automatically shared equitably by men and women or reach vulnerable and impoverished groups in 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 around the world.

As stated in the G20 High-Level Principles on Bioeconomy, to be consistent with the principles of inclusivity and equitable participation, monitoring and assessment frameworks must also evaluate 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 (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 framework to monitor the performance of bioeconomy and assess its sustainability must cover all three dimensions of sustainability. It also needs to consider the governance mechanisms in place that can cut across these three dimensions to identify and maximize synergies and minimize the trade-offs associated with bioeconomy development.

STAKEHOLDERS NEED SUPPORT TO NAVIGATE THE MANY INDICATORS AVAILABLE

Establishing a set of indicators for sustainable bioeconomy development is not an easy task. Indicator selection is often more than a purely technical endeavour; it also requires strategic decision-making. 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.

Differing institutional capacities among countries, regions, sectors and stakeholders present a major hurdle to sustainable bioeconomy advancement. Many countries and stakeholders lack the technical expertise, infrastructure, and resources needed to implement comprehensive monitoring frameworks. This is particularly true for developing countries that may have great potential for bioeconomy development but limited capacity to monitor it effectively (Albinelli *et al.*, 2024). Additionally, stakeholders are struggling to identify and assess the financial effects of risks associated with their dependencies and impacts on nature (TNFD, 2025). Comparability is becoming increasingly important for environmental, social and governance (ESG) disclosures, as commercial entities start to develop their nature transition plans[1] to adapt the overall business strategy to align with the Kunming-Montreal Global Biodiversity Framework (GBF) .

The diverse nature of bioeconomy strategies across different contexts 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, which reflects legitimate differences in national or stakeholder priorities, complicates efforts to create harmonized monitoring frameworks (FAO, 2024a).

Monitoring frameworks struggle to capture the complex interactions across and within the social, economic and environmental dimensions of bioeconomy. Their synergies and trade-offs are often context-specific and difficult to quantify using standardized indicators. Additionally, the long-term impacts of bioeconomy development may not be immediately apparent. Monitoring frameworks are required that can track changes over extended timeframes that go beyond the time horizons of bioeconomy strategies (FAO, 2024b).

To help address this diversity and complexity, FAO and its partners have developed a comprehensive database, collating and categorizing indicators relevant for bioeconomy. By navigating the database using the prioritization approach set out in this publication, stakeholders can enhance comparability across contexts and at the same time respect the unique bioeconomy pathways that different groups have chosen in their respective bioeconomy strategies.

[1] As defined by the Taskforce on Nature-related Financial Disclosures (TNFD), "A nature transition plan is an aspect of an organisation's overall business strategy that lays out the organisation's goals, targets, actions, accountability mechanisms and intended resources to respond and contribute to the transition implied by the Global Biodiversity Framework where biodiversity loss is halted and reversed by 2030 to put nature on a path to recovery by 2050" (TNFD, n.d)

A HARMONIZED APPROACH TO DEVELOPING MONITORING FRAMEWORKS CAN GUARANTEE BOTH UNIQUE BIOECONOMY PATHWAYS AND COMPARABILITY ACROSS CONTEXTS

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 (e.g. they may be embedded in the nature transition plans of commercial entities). They all represent a strategic vision document that sets out objectives to be achieved. To determine whether these objectives have been reached, progress must be 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 four steps for formulating, implementing and monitoring a bioeconomy strategy, plan or initiative. 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. Data is used to define the boundaries of bioeconomy.

- **Step 2. Devise the strategy**

  Activities in this step include mapping bioeconomy potential and gathering information for designing and selecting the main elements and actions of the strategy and writing the final document.

- **Step 3. Implement with an action plan**

  This step requires the preparation of an action plan, the deployment of technologies and business models, and actions that can cover gaps in policy and investment. Data is used for setting up the required policies or investments to enable implementation.

- **Step 4. Monitor progress and revise the strategy**

  During implementation, carefully selected indicators help in monitoring progress and performance, assessing impacts, sharing results and, if needed, revising the strategy. Once the indicators have been selected it is important to establish formal coordination mechanisms with stakeholders to ensure the coherent implementation of the monitoring system and review mechanisms for the periodic assessment and updating of the indicators selected. This involves sharing data and exchanging knowledge between the public and private sector.

While advancing through these steps, different national, value chain or commercial stakeholders may pursue various approaches to selecting indicators for monitoring and assessing bioeconomy. These reflect differing priorities, data availability, and governance structures that are adapted to specific contexts (FAO, 2024a, 2024b). By harmonizing the approach to develop monitoring frameworks, in line with the guidance provided in this publication, stakeholders can both improve comparability across contexts while respecting unique bioeconomy pathways.

A prioritization approach towards building a bioeconomy monitoring and assessment framework

INTRODUCING THE SUSTAINABLE BIOECONOMY INDICATORS DATABASE

FAO has collaborated with the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) to develop a comprehensive database of sustainability indicators for bioeconomy. By providing an extensive menu of options, this database can assist stakeholders (including commercial entities developing nature transition plans) to carry out steps 1 to 4 in the development of a bioeconomy strategy and in the implementation and monitoring of these strategies. It also serves to advance the broader normative, policy, technical and scientific work that FAO does to promote bioeconomy for sustainable agrifood systems, 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, p.xi).

The development of the database is the result of several years of collaboration between FAO and its partners to consolidate a comprehensive range of sustainability indicators from a range of sources that cover all dimensions of sustainability. Of particular importance was the work done by Bracco *et al.* (2019), which made the first comprehensive compilation of sustainability indicators for bioeconomy. The database considerably expands the number of sources from which the sustainability indicators have been drawn. Only sources that are less than ten years old have been included in the database.

The sources for the indicators can be divided into three broad categories:

- sources for territorial indicators;
- sources for product and value chain indicators; and
- sources for business and sectoral indicators.

The selection of the sources for database was the first step in the development an approach for prioritizing indicators. All the indicators in the database can be identified and filtered by the sources from which they were drawn. Annex 1 describes each source in greater detail.

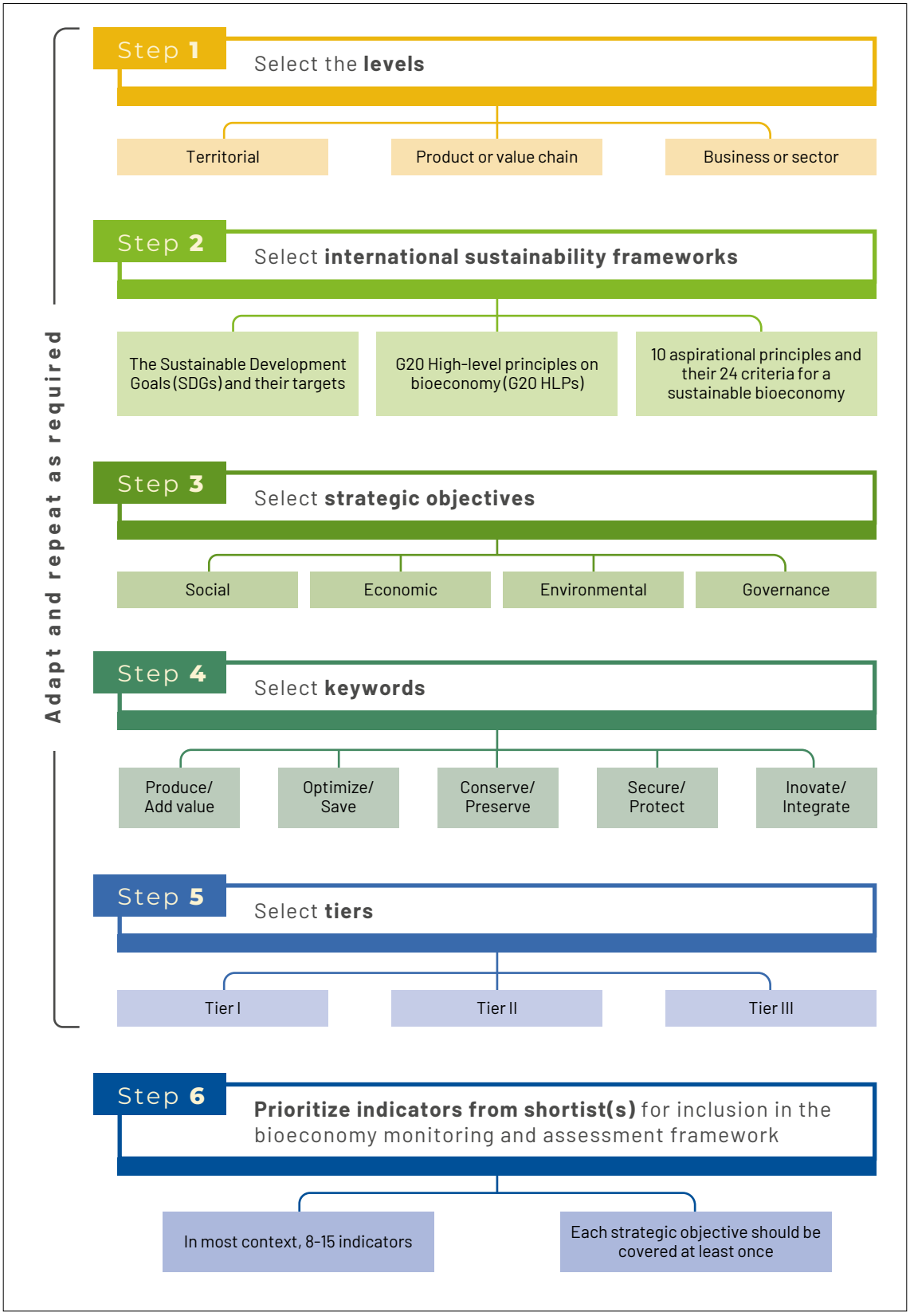
The original analysis underlying this publication assessed around 5 800 indicators drawn from 38 key references. This large number highlights how challenging it can be for stakeholders to choose the right indicators to monitor bioeconomy performance and assess sustainability. Of the indicators assessed, around 4 100 indicators were identified as relevant for bioeconomy. Duplicates were removed, and indicators not considered relevant for bioeconomy were excluded. Among the relevant indicators, around 3 000 are currently classified as Tier I or Tier II indicators (definitions of Tiers are provided below) and are clustered by topics as per the HLPs and FAO Aspirational Principles and criteria (e.g. criterion 2.3 on water, criterion 2.4 on soil). Around 1 200 have global, open access datasets available (e.g. FAOSTAT, World Bank and Eurostat) that can be used for measurement and comparison without requiring further data collection.

USING THE DATABASE

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. This section explains the FAO prioritization approach, whereby the different elements of the database's structure are used to extract the most appropriate indicators available for consideration and final selection. Figure 1 provides a graphic overview of the six steps involved, and the options within each step.

It should be noted that these six steps are presented in a sequential order, with steps 1-5 following a hierarchy from a broader to more granular degree of indicator categorization. However, the user can also shortlist indicators from the database by following steps 1-5 in their order of choice, including by omitting steps less relevant for their purpose. All indicators in the database have been fully categorized, facilitating comparison with other indicators even if a particular categorization was not used for shortlisting purposes.

Figure 1. **The FAO indicator prioritization approach in six steps**



Source: Author's own elaboration.

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Step 1. Levels

Each indicator is associated with one of three levels at which bioeconomy can be developed. The three levels reflect the overall approach that guided the selection of the sources for the indicators in the database:

- **Territorial indicators** can be used for monitoring and assessing bioeconomy development in a geographical unit at any scale (local, subnational, national or regional), and tracking the progress being made towards reaching global targets.
- **Product or value chain indicators**, including indicators present in standards, labels and certification schemes, can be 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 indicators**, including ESG indicators, can be used when developing bioeconomy businesses and sectors and report on their sustainability. They bridge the other two levels, as they may operate in several territories to produce several goods and/or services.

Stakeholders can filter for indicators according to the level (or levels) of greatest priority to them in accordance with their bioeconomy objectives (Bracco *et al.*, 2019; Bogdanski *et al.*, 2021).

Step 2. International sustainability frameworks

Each indicator is mapped to three international sustainability frameworks:

- the 17 SDGs and their targets, agreed on by all United Nations Members (UN, 2024);
- the 10 G20 High-Level Principles on Bioeconomy (G20 HLPs), agreed on by the G20 Members (GIB, 2024); and
- the FAO 10 Aspirational Principles and each of their 24 Criteria for a Sustainable Bioeconomy, agreed on by the FAO-led International Sustainable Bioeconomy Working Group and tailored to the work carried out under the FAO Programme Priority Area on Bioeconomy under the FAO Strategic Framework 2022-2031 (FAO, 2021).

This indicator categorization allows users to select indicators that are in line with any or all of these three international sustainability frameworks.

Step 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 in step 2 of bioeconomy strategy development, cover the previously mentioned three dimensions of sustainability as well as good governance principles:

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

Users can filter the database for the types of strategic objectives that align with their bioeconomy strategy. FAO recommends that a bioeconomy monitoring and assessment framework balances indicators across all strategic objectives, including at least one indicator per strategic objective.

Step 4. Key words

Each indicator is also associated with a pair of action-oriented 'key words' that describe the main types of activities that the indicator is intended to monitor or assess. They can also further differentiate indicators in terms of types of bioeconomy (e.g. focused on biodiversity or high technology) and

of implementing stakeholders (e.g. the communities fostering the resource, farmers, small and medium-sized enterprises, large-scale bio-based industries). 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**

  Indicators related to the production of raw biomass and derived biomaterials, bioproducts and services.

- **Optimize/Save**

  Indicators related to more efficient utilization of biomass along bioeconomy value chains.

- **Conserve/Preserve**

  Indicators related to preserving the natural environment and maintaining ecosystem services.

- **Secure/Protect**

  Indicators related to human rights, preventing discrimination, access and benefit sharing, enhancing human health, ensuring food, water and energy security, securing access to basic services, land and other natural resources.

- **Innovate/Integrate**

  Indicators associated with scientific and technological and other types of innovations, the integration of bioeconomy in legal frameworks, and the collaboration among stakeholders, including advanced sciences institutions and groups with traditional or indigenous knowledge.

This new classification by 'key words' was developed specifically for the purpose of this publication and database. In addition to supporting indicator prioritization, it can also facilitate comparison between diverse indicators across different bioeconomy monitoring and assessment frameworks on a more action-oriented basis.

Step 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.

- **Tier I** indicators are conceptually clear and have available data. The database provides a link to this dataset for user's 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.

Stakeholders who do not have the means to gather primary data may wish to prioritize indicators that are classified as Tier I and have publicly available datasets. As the database is conceived as a living resource, periodic updates are foreseen to reclassify indicators as they may advance 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.

Step 6. Final prioritization

Steps 1-5 can be replicated as often as needed, to shortlist different types of indicators according to as many categorizations the user may consider advisable.

As described above, selecting the indicators for a monitoring and assessment framework should be nested within an overarching bioeconomy strategy or plan. As foreseen in step 1 of bioeconomy strategy development, 'Set up a governance mechanism and dedicated institution' (Gomez San Juan, 2024), a participatory coordination mechanism or group should be in place to jointly undertake the final prioritization of indicators.

Each country or organization will have its own needs when selecting indicators for its monitoring and assessment framework. As noted in the introduction, there is no 'one-size-fits-all' set of sustainability indicators. However, the more indicators used, the more resources will be needed to gather the data. In most contexts, it is advisable to keep the number of indicators to a representative yet manageable number (between eight and 15).

To build a representative monitoring and assessment framework, the final set of indicators selected should cover each of the four overall strategic objectives (the social, economic and environmental dimensions of sustainability as well as good governance principles) at least once.

There is considerable flexibility within these parameters, and because each indicator is associated with three overarching sustainability frameworks (SDGs, G20 High-Level Principles on Bioeconomy and the FAO Aspirational Principles and Criteria for Sustainable Bioeconomy), the harmonization with overarching sustainability principles is assured for any set of indicators selected.

Illustrative examples

Table 1 provides illustrative examples of indicators that could be shortlisted from the database, with options for each of the three levels (territorial, product or value chain, business or sector – step 1) corresponding to each of the 10 G20 High-Level Principles (step 2). The table also indicates how the selected indicators map to the other two global sustainability frameworks (step 2) alongside strategic objectives (step 3).

The table purposely features similar indicators for each level to demonstrate how a bioeconomy monitoring and assessment framework pitched at any level could identify an appropriate indicator that nevertheless could be considered comparable to another indicator targeted at a different level. For example, a province setting up its monitoring framework would take the territorial level as its entry point to assess net greenhouse gas (GHG) emissions from sources and sinks within its territorial boundaries. Meanwhile, a monitoring framework developed for a specific bioeconomy product could consider the carbon footprint along the product's value chain. Finally, a business may see fit to assess the GHG emission intensity of a service it provides over value added within its sustainability reporting. Each of these example indicators is mapped to the overarching environmental strategic objective and more specifically, G20 High Level Principle 3:

> *Advance **mitigation and adaptation efforts against global climate change**, in line with applicable multilateral climate agreements.*

To follow through another example, this time on the social side, corresponding to G20 High Level Principle 7:

> *Benefit from **robust and coherent policy frameworks** that foster trade for bioeconomy products and services, market conditions, sustainable business models, decent jobs, local value creation and private sector and civil society participation.*

A province may wish to track employment within its bioeconomy as a percentage of overall employment within its territory. A given bioeconomy value chain could prioritize demonstrating its social sustainability by qualifying for a recognized certification scheme. A business may wish to assess labour productivity as a function of value added by person employed to ensure local value creation while keeping cost efficiency in mind.

Table 1. **Examples of similar indicators by level, sorted by G20 High-Level Principle on Bioeconomy**

Global sustainability frameworks			Strategic objectives	Indicators by level		
G20 HLPs	Examples of SDG targets	FAO Principles and criteria		Territorial	Product or value chain	Business or sector
1	1.2; 1.a; 2.1; 2.2; 3.9; 17.15	1.1; 3.1; 1.4	Social	Food security and nutrition (in its four dimensions)	Value of food imports in total merchandise exports	Operations shall assess risks to food security in the region
2	2.3; 5.5	1.3; 3.2; 6.2	Economic	Net trade of biomass (percent of total domestic consumption)	Value added of biomass per person employed in bioeconomy	Bioeconomy small and medium enterprise birth and death rates
3	7.2; 12.1; 13.1; 13.2; 13.3	1.2; 2.2; 4.2; 5.1; 5.2; 9.1;	Environmental	Net GHG emissions (sources and sinks)	Carbon footprint ($kgCO_2eq/kg$)	GHG emission intensity ($kgCO_2e$/ value added)
4	2.5; 15.4; 15.6	2.1	Environmental	Domestic public funding on conservation and sustainable use of biodiversity and ecosystems	% of biomass produced on land that is/was highly biodiverse	Bio-based share of inputs and outputs, by category
5	15.3; 15.5	2.3; 2.4	Environmental	Area under sustainable management practices (percent of total agricultural vs. forest area)	Land footprint (m^2/kg)	Land productivity (value added/ha)
6	9.5; 9.b; 17.6	7.1; 7.2	Social	Intellectual property rights (patent, trademark, design) applications in bioeconomy subsectors (number of applications per 1 000 employees)	Monetary and non- monetary benefits received in accordance with applicable internationally agreed access and benefit sharing instruments	Worker participation rate in education and training in the previous 12 months
7	2.b; 8.5; 12.a; 17.10	8.1; 9.2	Social	Bioeconomy employment (percent of total employment)	Available certification or documentation about social sustainability	Labour productivity (value added/person employed)
8	12.6; 17.19	6.3	Economic	Bioeconomy value added (percent of total GDP)	Cost efficiency ratio (output value/input value)	Turnover per sector of bioeconomy
9	17.7; 17.9; 17.16	10.1	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 organizational aspects of new bioeconomy initiatives
10	1.b; 11.a; 16.7	3.3; 4.1; 6.1	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

Source: Author's own elaboration.

CASE STUDY: APPLYING THE PRIORITIZATION APPROACH TO BUILD A BIOECONOMY MONITORING AND ASSESSMENT FRAMEWORK IN SOUTH AFRICA

Hypothetical scenario

User

For the purpose of this illustrative case study, the hypothetical user of the database is a technical focal point for bioeconomy in the Department of Science and Technology of South Africa. Their role is to facilitate a working group, comprised of representatives from other government departments and key non-state stakeholder groups, that has been tasked to track progress in the implementation of South Africa's National Bioeconomy Strategy (DST, 2013). To do so, the working group will need to establish a monitoring and assessment framework. To get started, the group wishes to review of existing, relevant indicators.

Context

South Africa's National Bioeconomy Strategy articulates objectives across a range of sectors within the bioeconomy, to be achieved through 27 actions across three main sectors: agriculture, health, and the industrial and environmental sector. These actions focus widely on promoting innovation and technology and capacity development. For this case study, the working group will focus on:

- **Agriculture sector**: The aim is to strengthen innovation in biosciences to ensure food security, enhance nutrition and improve health, and enable job creation through the expansion and intensification of sustainable agricultural production and processing. Actions include establishing an innovation hub for agriculture, expanding agro-processing enterprises and promoting bio-inputs for soil and water quality conservation and waste reduction.
- **Industrial and environmental sector:** The aim is to prioritize and support research, development and innovation in biological processing. Actions include developing biomanufacturing capacities and integrated biorefineries.

Additionally, South Africa's National Biodiversity Economy Strategy (DFFE, 2016) can be seen as a 'sister' strategy to the National Bioeconomy Strategy, bridging the Bioeconomy Strategy and the National Biodiversity Strategy and Action Plan (NBSAP). South Africa's NBSAP also explicitly mentions bioeconomy: "Among the NBSAP's flagship projects, the 'Foundational Biodiversity Information Programme' aims to fund the generation and dissemination of crucial biodiversity data to address the bioeconomy" (DFFE, 2015).

Prioritizing indicators based on national context

In this context, the user wishes to generate a shortlist of existing indicators for discussion in their working group that could help monitor progress towards the objectives and actions the National Bioeconomy Strategy while also emphasizing biodiversity aspects to ensure the link with the National Biodiversity Economy Strategy and the flagship 'Foundational Biodiversity Information Programme' highlighted in the NBSAP.

Step 1 Levels

As South Africa's National Bioeconomy Strategy covers the entire country, the user starts by selecting 'Territorial' level indicators.

Step 2 International sustainability frameworks

As South Africa is a member of the UN, FAO, and the G20, the user is interested in all three of the international sustainable development frameworks. The user wants the monitoring and assessment framework to feature at least one indicator for each of the 10 G20 HLPs but are also interested in how these speak to the more granular FAO Aspirational Principles and Criteria and the SDGs. Table 2 shows this prioritization exercise.

The user decides that the best way to begin shortlisting indicators is to prioritize 10 of the FAO criteria, which are the most granular of the international sustainability frameworks. They select these to correspond well to the overarching objectives of the National Bioeconomy Strategy, while also ensuring that each of the 10 G20 HLPs is represented.

Table 2. **FAO Principles and Criteria selected to respond to national priorities**

G20 HLPs	FAO Principles and Criteria	Strategic objectives
1	Criterion 1.1 Food security and nutrition are supported	Social
2	Criterion 3.2 Inclusive economic growth is strengthened	Economic
3	Criterion 4.2 Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened	Environmental
4	Criterion 2.1 Biodiversity conservation is ensured	Environmental
5	Criterion 2.4 The degradation of land, soil, forests and marine environments is prevented, stopped or reversed	Environmental
6	Criterion 7.2 Knowledge generation and innovation are promoted	Social
7	Criterion 8.1 Local economies are not constrained but rather expanded through the trade of raw and processed biomass, and related technologies	Economic
8	Criterion 6.3 Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented	Economic
9	Criterion 10.1 Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate	Governance
10	Criterion 6.1 Policies, regulations and institutional structures relevant to bioeconomy sectors are adequately harmonized	Governance

Source: Author's own elaboration.

Step 3 Strategic objectives

Having carefully selected FAO criteria that correspond to each of the 10 G20 principles, the user finds that all four strategic objectives (environmental, social, economic and governance) have been covered at least once (Table 2), as recommended by the FAO prioritization approach towards building a bioeconomy monitoring and assessment framework.

Step 4 Key words

The user decides to maintain all five key word pairs for the purpose of shortlisting indicators. As these key words are a new concept only recently introduced by FAO, the user prefers to reflect on how best to use this categorization with their colleagues and partners as part of the final prioritization process.

Step 5 Tiers

Ideally, the user would like to prioritize Tier I indicators for which data is already gathered at the global level to capitalize on existing efforts. This would include many SDG indicators and FAOSTAT and World Bank indicators. However, because of South Africa's strong emphasis on the bioeconomy-biodiversity link, the user feels that it would also be worth considering GBF indicators, even though these are currently only classified as Tier III, without established methodologies or datasets behind them yet. The user knows that in future, the Convention on Biological Diversity will coordinate global data gathering efforts for GBF indicators and that South Africa would already like to begin taking steps in this direction.

This means that the user does not wish to exclude indicators exclusively by tier, but rather prioritizes the indicator by the sources mentioned. The user therefore shortlists Tier I indicators from the SDG, FAOSTAT and World Bank open access databases and Tier III indicators from the GBF.

Step 6 Final prioritization

Based on the choices the user made in steps 1-5, around 500 indicators result (slightly more than 10 per cent of the indicators available in the database). The user brings this list to their working group, which considers them one G20 HLP at a time. The working group quickly excludes some while taking longer to discuss the advantages and disadvantages of others based on their varying needs and priorities. It also discusses possible baselines and targets for the indicators under consideration.

A possible final selection of 10 indicators to be included in a monitoring and assessment framework that covers all 10 G20 HLPs and all four strategic objectives is shown in Table 3.

Table 3. **A possible prioritization of 10 indicators covering selected national priorities**

G20 HLP	FAO Principles and criteria	SDG target	Strategic objective	Indicator	Tier	Source
1	1.1	2.1	Social	Percentage of the population unable to afford a healthy diet	I	FAOSTAT
2	3.2	2.4	Economic	Proportion of agricultural land area that has achieved an acceptable or desirable level of net farm income	I	FAOSTAT
3	4.2	14.2	Environmental	Number of countries using ecosystem-based approaches to managing marine areas	I	SDG
4	2.1	15.2	Environmental	Increase in secondary natural forest cover	III	GBF
5	2.4	15.3	Environmental	Proportion of land that is degraded over total land area	I	SDG
6	7.2	9.5	Social	Firms that spend on research and development (% of firms)	I	World Bank
7	8.1	2.b	Economic	Forestry Production and Trade - Export Quantity	I	FAOSTAT
8	6.3	13.1	Economic	Droughts, floods, extreme temperatures (% of population, average 1990-2009)	I	World Bank
9	10.1	2.a	Governance	Government Expenditure - Research and development on agriculture, forestry, fishing (General Government)	I	FAOSTAT
10	6.1	17.14	Governance	Value of subsidies and other incentives harmful to biodiversity, that are redirected, repurposed or eliminated	III	GBF

Source: Author's own elaboration.

The way forward

Despite progress in developing and implementing bioeconomy monitoring and assessment frameworks, several significant challenges remain. The scarcity of data on the availability of biomass and its uses presents a fundamental challenge. For example, many biological resources (e.g. crop residues, organic waste, indigenous products consumed locally, or microorganisms used in industry) are not accounted for in national statistics or international trade data. This leads to incomplete assessments of bioeconomy activities and their impacts.

Many countries, particularly in developing contexts, lack the technical expertise, infrastructure, and resources needed to capture the complex interactions between the social, economic and environmental dimensions of bioeconomy, which should be equally represented in monitoring frameworks, together with good governance. This is also true for the commercial entities that are starting to identify and assess their dependencies and impacts on the environment but lack definitions and standardized approaches.

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 and bio-based sectors). This diversity, which reflects legitimate differences in national or stakeholder priorities, complicates efforts to create harmonized monitoring frameworks. In particular, current national and global statistics lack the appropriate sectoral classification to capture the share of bioeconomy. This lack of standardization complicates cross-country comparisons and the aggregation of data at various levels.

The database of sustainability indicators for bioeconomy accompanying this publication is intended to address these critical gaps and support countries and organizations in selecting indicators for their monitoring and assessment systems that can generate comparable results across countries and regions. For instance, sustainable bioeconomy monitoring should speak to ongoing efforts to report on Agenda 2030 and other sustainability frameworks. This publication and its accompanying database therefore propose a practical approach for prioritizing indicators that are both contextually appropriate and aligned with bioeconomy strategies, plans and targets.


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In this way, the publication and database will contribute to building a robust evidence base for sustainable bioeconomy development that can lead to more informed decision-making, improved coordination across sectors and ministries, and the development of coherent, effective bioeconomy policies, value chains and investments. At the international level, more harmonized bioeconomy monitoring frameworks can improve cooperation and build a coherent global picture, including on sustainable trade. The publication and database also serve to initiate broader discussions, for example on the linkages between nature-related ESG disclosures and bioeconomy for commercial entities that can lead to growth in bioeconomy investment.

Given the rapidly expanding landscape of sustainability frameworks and indicators, the database makes no claim to be exhaustive. It represents an important step towards greater harmonization but is conceived as a living resource. Regular updates are foreseen as new methodologies, standards, guidelines, and stakeholder needs emerge.

Annex 1

Sources of sustainable bioeconomy indicators for the database

FAO has collaborated with the Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF) to build a database of sustainability indicators for bioeconomy. This compilation is the result of several years of collaboration between FAO and its partners to consolidate a comprehensive range of sustainability indicators from a range of sources that cover all dimensions of sustainability. Of particular importance was the work done by Bracco *et al.* (2019), who made the first comprehensive compilation of sustainability indicators for bioeconomy. The database updates and expands the number of sources from which the sustainability indicators have been drawn. Only sources that are less than ten years old have been included in the database.

The sources for the indicators can be divided into three broad categories:

- sources for territorial indicators;
- sources for product and value chain indicators; and
- sources for business and sectoral indicators.

The selection of the sources for database was the first step in the development an approach for prioritizing indicators. All the indicators in the database can be identified and filtered by the sources from which they were drawn.

Sources for territorial indicators

Sustainable bioeconomy initiatives often focus on developing bioeconomy within a given geographical area, territory or jurisdiction. Territorial indicators are part of a framework to monitor and assess the contribution of bioeconomy to the sustainable development of the territory and allow for cross-territorial comparisons. Territorial issues that are generally covered by a bioeconomy monitoring and assessment system include:

- territorial governance;
- the relative size of bioeconomy in the total economy;
- the conservation of local natural resources and their sustainable management;
- the relative importance of biomass trade in the development of the territory; and
- the resilience of the territory and the extent to which local populations within the territory have secure access to land, natural resources and basic goods and services.

International monitoring frameworks and databases

Seven international sources contributed relevant indicators to the database:

- FAOSTAT (FAO, 2025).
- World Development Indicators (WB, 2024).
- Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development, after the 2024 refinement (UN, 2024) and previous (Bracco *et al.*, 2019; Calicioglu and Bogdanski, 2021).
- EUROSTAT (EUROSTAT, 2024) and previous (Giuntoli *et al.*, 2020).
- Monitoring framework for the Kunming-Montreal Global Biodiversity Framework (CBD, 2022, 2025).
- AITi Global Social Progress Index (SPI, 2025).
- Indicator System for Assessing the Sustainability of the Bioeconomy (Egenolf and Bringezu, 2019).
- FAOSTAT, World Development Indicators, the SDG Global Indicator Framework and Eurostat have open access databases than can be consulted for each of the selected indicators.

National, sub-national and regional bioeconomy programmes, strategies and monitoring frameworks

Bioeconomy programmes, strategies and monitoring frameworks are also important sources for territorial indicators. Seven sources that include strategy-related indictors are added in the database. Bracco *et al*. (2019) compiled indicators from four national bioeconomy strategies that had been formulated before 2019 (Argentina, Finland, Italy and Malaysia) and drew on lessons from Lier *et al*. (2018), who focused on the European Union. Since then, other countries have developed national strategies and indicator frameworks. Indicators from these strategies have been captured in FAO (2024b), Namibia (2024), Alviar *et al*. (2021), Gardossi *et al*. (2023), Giuntoli *et al*. (2020), and Patani *et al*. (2024). The database therefore includes examples of indicators from national strategies, as well as regional strategies and monitoring frameworks, the European Union (EU) Bioeconomy Monitoring System, and sub-national monitoring and assessment frameworks, Antioquia, Colombia.

Other territorial level sources

The database also includes indicators that Bracco *et al*. (2019) extracted from:

- The Green Economy Progress measurement framework from the United Nations Partnership for Action on Green Economy.
- National Consumption-Based Indicators of the Sustainable Europe Research Institute.
- Maritime Spatial Planning (MSP) for Blue Growth by the European Commission.
- Assessments of indicators for SDG 14 on 'Oceans' by the Organisation for Economic Co-operation and Development (OECD) and partners.
- Global Sustainable Land Use by the International Institute for Sustainability Analysis and Strategy (IINAS) and the Global Land Use and Sustainability (GLOBALANDS) project.
- *A good life for all within planetary boundaries*, a study conducted by the University of Leeds, United Kingdom, and the Mercator Research Institute on Global Commons and Climate Change, Germany.

Sources for product and value chain indicators

Many bioeconomy initiatives focus on developing specific bio-based products and the value chains in which these products are embedded. Standards, certification and labelling schemes, which are voluntary tools used by producers, manufacturers, retailers and service providers to demonstrate sustainability, have proven to be valuable sources of sustainability indicators for monitoring bioeconomy development initiatives that target products and value chains. Life cycle assessment (LCA) methodologies, which can be an effective approach for assessing the economic, social and environmental impacts of a product along the whole value chain, are also important sources of indicators. Principle 8 of the G20 High-Level Principles on Bioeconomy explicitly mentions the need for comparable criteria to assess the sustainability of value chains (GIB, 2024).

Standards Map database

The Standards Map is the world's largest database for sustainability standards. Developed by The United Nations International Trade Center, the Standards Map provides information on over 350 voluntary sustainability standards from over 190 countries and sorts them according to criteria related to different dimensions of sustainability. The Standards Map covers a range of economic sectors, many of which are closely associated with bioeconomy. The SUSTCERT4BIO-BASED European project screened the Standards Map database and produced a short list of 11 sustainability certification schemes and labels that are among the most relevant for bio-based industries (WR-WFBR, 2023). NatureFinance and the Getúlio Vargas Foundation also reviewed the Standard Map database to create a short list 12 sustainability certification standards that are the most used for biomaterials, bio-based products and bioenergy, (NF and GVF, 2024). Five standards figured on both short lists, and these were included as sources of indicators for the database of sustainability indicators for bioeconomy:

- International Sustainability and Carbon Certification (ISCC, 2022, 2023, 2024).
- Certification Bonsucro Chain of Custody Standard V5.1 and Bonsucro Production Standard V5.2 (Bonsucro, 2019, 2023).
- Roundtable on Sustainable Palm Oil Principles and Criteria (RSPO, 2018), updating Bracco *et al.* (2019) which included the version of 2013.
- Roundtable on Sustainable Biomaterials Principles and Criteria (RSB, 2023) updating Bracco *et al.* (2019) which included versions of 2011 and 2016.
- Forest Stewardship Council International Generic Indicators. Version 2.1 (FSC, 2023).

Other standards, certification and labelling schemes

The database also incorporates indicators from the standards and certification schemes that were selected by Bracco *et al.* (2019). These nine sources are:

- Seaweed Standard of the Aquaculture Stewardship Council and Marine Stewardship Council.
- 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 (2008-2017).
- DIN Certco certification of biodegradability in soil, products made from compostable materials and biobased products (2015 and 2017).

- EU Eco Label (e.g. for soil improvers and mulch; printed paper; lubricants; wood, cork, bamboo-based floor coverings) from 2009 to 2017.
- Fisheries Standard of the Marine Stewardship Council.
- Rainforest Alliance Sustainable Agriculture Standard.
- The Round Table on Responsible Soy Standard V3.1.
- Vinçotte certification for bioproducts compostability, degradation in soil, in water and seawater from 2012 to year 2015.
- The BioStep project report on the social, economic and environmental impacts of the bioeconomy.

Material flows and life cycle assessments

The main objectives of a monitoring and assessment system for a bio-based product are to assess the impacts of a product along its entire life cycle and track material flows. Using established methodologies for the assessment and comparison of products, such as LCA, could provide a solid starting point. Six sources that have applied these approaches or material flow analyses to assess the sustainability of bio-based products and value chains have been specifically used to select indicators for the database:

- LCA indicators to monitor the sustainability of bio-based value chains (Lago-Olveira *et al.*, 2024). While traditional LCA focuses on environmental impacts (covering broad areas of protection around human health, ecosystem quality, and service value of natural resources), life cycle sustainability assessment encompasses also social aspects across the life cycle as well as life cycle costing.
- Thünen Institute indicators and methodology: Monitoring the sustainability of the bioeconomy - Pilot in Uruguay (Pozo *et al.*, 2023) for material flows, their sustainability and economic significance.

Other standards, certification and labelling schemes

The database also incorporates indicators from the standards and certification schemes that were selected by Bracco *et al.* (2019), including:

- Guidelines for social LCA of products by the United Nations Environment Programme and the Society of Environmental Toxicology and Chemistry Life Cycle Initiative.
- EU project Star-ProBio Deliverable 2.2: Selection of environmental indicators and impact categories for the LCA of bio-based products.
- Standards of the Cradle to Cradle Products Innovation Institute.
- The Sustainability Consortium impact reports of greening global supply chains.

Sources for business and sectoral indicators

The database has also drawn on sources for indicators that can be used for monitoring and assessing the development of businesses that may operate in one or several bioeconomy sectors (Gomez San Juan, Bogdanski and Dubois, 2019; Lier *et al.*, 2018). Bioeconomy sectors can be divided into three main groups:

- **Primary production sectors**

  This group includes the agriculture, forestry and fisheries and aquaculture sector, which produce food and non-food biomass.

- **Secondary sectors (bioindustries)**

  This includes the food and agroindustry sector; forest industry (e.g. pulp and paper, bio-based furniture and bio-based construction); bio-based textiles, chemicals, and materials; the health and pharmaceutical industry; and bioenergy.

- **Tertiary sectors**

  This incudes services such as waste management, recreation (e.g. parks, sustainable ecotourism), and the conservation of biological diversity.

It should be noted that there are different approaches for classifying the sectors that bioeconomy comprises. For example, the current EU bioeconomy monitoring system focuses on biotechnology and bio-based processes, yet explicitly excludes the health biotechnology and pharmaceutical sector, or the services related to wastewater.

Business indicators, including ESG indicators, can be used to report on sustainability. Additional indicators can be found in impact investment and bioeconomy-specific funds.

Sectoral sources

The eight sources from which indicators have been selected for the database of sustainability indicators for bioeconomy are:

- Global Bioenergy Partnership Sustainability indicators for bioenergy applied to several countries (FAO, 2011; Bracco *et al.*, 2019).
- Forest bioeconomy indicators (Wolfslehner *et al.*, 2016; Bracco *et al.*, 2019).
- Sustainability indicators for the EU's biobased chemical sector and Bioproducts independent of any sector (Bracco *et al.*, 2019; Baldoni *et al.*, 2021).
- The Global bioeconomy. Preliminary stocktake of G20 Strategies and Practices: a contribution to the Brazilian G20 Presidency's Global Initiative on Bioeconomy (NF and GVF, 2024).
- Analysing major bio-based industries in Europe (Fernández Ocamica *et al.*, 2024)
- Updated pan-European set of indicators for sustainable forest management (Forest Europe, 2020).
- Consistent cross-sectoral sustainability criteria and indicators; and D5.2: Benchmark and gap analysis of criteria and indicators (S2Biom, 2015; Bracco *et al.*, 2019).
- Deliverable 1.2 of the EU project SUSTCERT4BIOBASED on *Sustainability principles and criteria for biological resources and bio-based products* (WR-WFBR, 2023).

Sustainability disclosure frameworks and standards

Sustainability disclosure frameworks and standards aim to enhance transparency, accountability and support decision-making in the ESG reporting of commercial entities, particularly financial institutions. For this reason, they represent an emerging and increasingly important source for sustainability indicators for bioeconomy. The preparation of this publication marked the first time that ESG indicators had been explicitly assessed from a bioeconomy perspective. More detailed descriptions are therefore provided for each source of ESG indicators.

Financial institutions can stimulate sustainability in all sectors of bioeconomy. For example, for primary production sectors, financial institutions provide loans for sustainable investments, blended-finance schemes and insurance policies. For biobased industries, these institutions are well positioned to underwrite project finance for biorefineries, biobased industries and circularity practices initiatives by offering green bonds, sustainability-linked loans or venture-capital funds tailored to emerging technologies. Financial institutions can also offer services (e.g. trade finance, technical assistance grants, and working capital lines of credit) that can strengthen bioeconomy valuechain traceability and transparency and encourage suppliers to make investments in sustainability that have positive effect across many industries.

The six sustainability disclosure frameworks and standards listed below, which form the core architecture of global ESG disclosures, have been used as sources for sustainability indicators in the database. These disclosure frameworks and standards are used by investors, regulators, supply chain partners and other stakeholders to help them understand, manage, and report on their ESG performance in a credible and structured way. Data availability and accessibility as well as technical capacity on environmental issues remain significant constraints to making effective ESG disclosures, and this would encompass bioeconomy. As this is a highly dynamic field, this work serves as a starting point and should be expanded over time. This would include broadening the current focus on financial institutions to include corporations.

- **Sustainability Accounting Standards Board (SASB)**

  SASB is a framework that develops sustainability disclosure standards for financial reporting. SASB has developed the Materiality[2] Map and disclosure standards for 77 industries in 11 sectors. The Materiality Map identifies the most likely sustainability issues by sector and helps organizations focus on the most relevant ESG issues for their industry (SASB, 2023). For the Financial sector, SASB Standards provide specific guidance on the ESG topics of relevance to seven industries in this sector (SASB, 2023), in terms of how they could affect a company's financial performance (e.g. revenue, costs, assets, liabilities, or cost of capital). In August 2022, the International Sustainability Standards Board (ISSB) of the International Financial Reporting Standards (IFRS) Foundation assumed responsibility for the SASB Standards.

- **International Financial Reporting Standards (IFRS) S-1 and S-2**

  IFRS Standard 1 and 2 (S-1 and S-2) are disclosure standards that provide companies with a consistent framework to disclose risks related to sustainability and climate as well as opportunities that could impact their financial performance. Both standards are structured around four pillars: governance, strategy, risk management, and metrics and targets.

  IFRS S1 requires entities to disclose any sustainability-related risks and opportunities that are reasonably likely to influence their cash flows, ability to secure financing, or cost of capital (collectively referred to as 'sustainability-related risks and opportunities that could reasonably be expected to affect the entity's prospects')(IFRS, 2023a). IFRS S-2 standard on climate-related

[2] 'Materiality' is the principle commercial entities apply to understand which ESG issues to prioritize in their organization's strategy, budget allocation, risk and opportunity identification. In 2019, the EU published guidance on 'double materiality' specifically in relation to climate change, combining the traditional principle of financial materiality (the financial impact of a climate event on the company) with social and environmental materiality (the social and environmental impacts the company's activities may have)(EC, 2019).

disclosures requires companies to report on both physical and transition risks, GHG emissions (Scopes 1, 2, and 3), carbon offsets, internal carbon pricing, and scenario analysis for climate resilience (IFRS, 2023b). As of January 2024, as per indication of the Financial Stability Board created under the G20, the ISSB's IFRS S-2 fully incorporates the recommendations of the former Task Force for Climate Related Financial Disclosures (TCFD, 2023).

- **Taskforce on Nature-related Financial Disclosures (TNFD)**

  TNFD is a global, market-led, science-based and government-supported initiative to help companies and financial institutions incorporate nature issues into their decision making (TNFD, 2023, 2024). TNFD emerged in response to growing recognition that biodiversity loss and ecosystem degradation pose significant financial risks and opportunities. However, unlike climate change, biodiversity loss and ecosystem degradation were not being adequately captured in corporate and financial decision-making. TNFD is now a cornerstone for understanding interactions between nature and corporate responsibility. It is also structured around the same four pillars as IFRS S-1 and S-2 (which were first introduced by TCFD): governance, strategy, risk management, and metrics and targets.

  TNFD Recommendations help investors, boards, and executives assess nature-related risks and opportunities in financial terms, enabling them to make better decisions on capital allocation and risk management (TNFD, 2023). There have been 116 TNFD reports published to date, with the largest number (34 percent) of the reports coming from the SASB Financials sector.

  TNFD reporting is not yet mandatory, but momentum is building for it in jurisdictions where sustainability regulations are under development. In 2024, at the time of the sixteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP 16), 502 organizations were registered as 'TNFD Adopters', including 129 financial institutions, one-quarter of which are considered 'global systemically important banks' by the Financial Stability Board and the Basel Committee on Banking Supervision. These are the banks of significant economic weight based on their size, interconnectedness, complexity, substitutability, and cross-jurisdictional activity. These financial institutions represent a total of USD 17.7 trillion in assets under management.

- **Global Reporting Initiative (GRI)**

  GRI focuses on the impacts that organizations have on the economy, people and the environment. Its work enables organizations to be transparent and take responsibility over these impacts. GRI standards are applicable to both public and private organizations of any size. All GRI standards are classified into three series (GRI, n.d.):

  - Universal Standards, which are the foundation of all reporting through GRI, incorporate reporting on human rights and environmental due diligence. They are in line with intergovernmental expectations and apply to all organizations.
  - Sector Standards, which enable more consistent reporting for 40 selected sectors and are based on the highest sector-specific impacts.
  - Topic Standards list disclosures relevant to a particular topic (e.g. biodiversity). Following the adoption of the GBF, GRI developed its biodiversity Topic Standard (GRI 101), which will become effective in 2026 and supersede the GRI 304 on biodiversity from 2016.

- **CDP (former Carbon Disclosure Project)**

  CDP is a non-profit organization that runs the world's most widely used global disclosure system. Currently operating in more than 90 countries, CDP helps entities measure and manage their environmental impacts by collecting data primarily on climate change, water security, and deforestation through a single corporate level annual questionnaire.

  Each year, financial institutions partner with CDP to request environmental data from companies. They use this information on climate, deforestation, and water to guide investment decisions, manage risks, and identify opportunities. In 2025, over 640 capital markets signatories asked thousands of companies to disclose through CDP, which contributed to building the world's largest environmental database (CDP, 2025). Almost two-thirds of companies are now disclosing nature-related information on matters other than climate. All corporate disclosers now have the option to disclose information on biodiversity and plastics.

- **European Sustainability Reporting Standards (ESRS)**

  The Corporate Sustainability Reporting Directive (CSRD) is key EU regulation on ESG reporting requirements for entities operating in the EU (EC, 2023). Entities that are subject to the CSRD must prepare disclosure reports according to European Sustainability Reporting Standards (ESRS). The standards, which are currently in draft form, have been developed by EFRAG (previously known as the European Financial Reporting Advisory Group). There are three categories of ESRS: i) cross-cutting standards; ii) topical standards (ESG standards); and iii) sector-specific standards.

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Despite significant progress in developing monitoring and assessment frameworks for sustainable bioeconomy, important challenges persist. There is no globally agreed-upon definition or 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. Comprehensive data on biomass availability and utilization remain limited. Measuring the complex interlinkages between the social, economic and environmental dimensions of bioeconomy continues to prove difficult. The diversity of national and regional strategies further complicates efforts to harmonize monitoring and assessment of bioeconomies on a global scale.

This publication introduces a prioritization approach and comprehensive database designed to bridge these critical gaps. By assessing and categorizing bioeconomy-relevant indicators drawn from a range of sources across three broad categories (territories, products and value chains, and business and sectoral indicators) this resource enables policymakers, businesses, development practitioners, researchers and other stakeholders to select indicators tailored to their specific contexts and strategic goals. It also ensures the indicators are in alignment with three key international sustainability frameworks: the Sustainable Development Goals, the G20 High-Level Principles on Bioeconomy, and the FAO Aspirational Principles and Criteria for Sustainable Bioeconomy.

Expanding on the 2019 FAO report, *Indicators to Monitor and Evaluate the Sustainability of Bioeconomy*, this comprehensive update incorporates new sources, most notably the latest environmental, social, and governance (ESG) disclosure frameworks. It thereby broadens its potential application from governments and other development stakeholders also to commercial entities. By supporting indicator selection through easily replicable steps, results across contexts become more readily comparable. A more robust foundation for evidence-based decision-making can lead to improved policy coherence and sustained investment in inclusive, resilient, and sustainable bioeconomy development.

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