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GUIDANCE NOTE ON MONITORING THE SUSTAINABILITY OF THE BIOECONOMY AT A COUNTRY OR MACRO-REGIONAL LEVEL

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
and EUROPEAN COMMISSION, JOINT RESEARCH CENTRE
Rome, 2021



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FOREWORD

FAO's commitment to promoting a sustainable bioeconomy has been demonstrated in recent years through its Towards Sustainable Bioeconomy Guidelines project, supported by the Government of the Federal Republic of Germany. One of the main objectives of this project has been to develop guidelines for policymakers and practitioners on how to monitor sustainability in the bioeconomy, an objective shared by the International Bioeconomy Forum (IBF).

The publication of the present guidance note contributes to the above objective. The guidance note was developed jointly by FAO and the European Commission's Joint Research Centre (JRC), under the mandate of the IBF members. The ten steps outlined to help policymakers monitor the sustainability of the bioeconomy in their country or region are easy to follow and can be adapted according to context. They are also closely aligned with two other valuable publications on sustainable bioeconomy that FAO has recently published: *Aspirational Principles and Criteria for a Sustainable Bioeconomy*, developed under the auspices of the International Sustainable Bioeconomy Working Group (ISBWG); and *How to mainstream sustainability and circularity into the bioeconomy? A compendium of bioeconomy good practices and policies*.

As we move forward in the Decade of Action to Achieve the Sustainable Development Goals, there is increased urgency on all stakeholders to strive for more sustainable ways of producing and consuming, including through embracing the possibilities of a more bio-based economy. However, an economic model that is built on biological resources does not necessarily

guarantee sustainability, unless the model is underpinned by enabling good policies, practices and technologies tailored to the social, environmental and economic contexts. Moreover, where trade-offs exist between different sustainability objectives, it is important to understand what the implications are of choosing one option over another. Without effective monitoring it is difficult to gauge these implications, hence the importance of clear guidelines to ensure that sustainability and circularity, as well as transparency and fairness, are embedded in bioeconomy development.

Furthermore, embracing new, improved ways of doing things is particularly important as we seek to build back better and "greener" from COVID-19, which has exposed many environmental and social inequalities around the globe.

With the adoption of a new FAO Strategic Framework 2022–31 in June 2021, FAO demonstrated its unwavering support for the 2030 Agenda through the transformation to more efficient, inclusive, resilient and sustainable agri-food systems for better production, better nutrition, a better environment, and a better life, leaving no one behind. Bioeconomy for Sustainable Food and Agriculture will be one of the Organization's programme priority areas for the next decade. Within the sustainable bioeconomy, there are huge opportunities for bio-based technological, organizational and social innovations to help us both mitigate and become more resilient to climate change, biodiversity loss, environmental degradation and other global challenges, while increasing food security and social equity.



Eduardo Mansur

Director, Office of Climate Change, Biodiversity and Environment
Food and Agriculture Organization of the United Nations (FAO)

FOREWORD

Bioeconomy is credited as being one of the key pillars for the Green Transition in the European Union (EU), yet it is not a new concept. The world has changed since the days where economies were indeed principally “bio-based” and fully depended on the primary production systems that sustained our lives. Population growth followed by increased consumption of natural resources and subsequently increasing pressures on the biosphere, including climate change, are leading us to push the planet beyond several of its biophysical boundaries. Thus, the very systems that are necessary to support the conditions that have allowed modern human civilization to flourish, are rapidly degrading.

The bioeconomy offers an opportunity to realign the economy with the biosphere. A sustainable bioeconomy can contribute to remove the shackles of fossil sources in favour of renewable biological sources, to consider and reduce our emissions along the full supply chain and to modernize industries and create new jobs. A sustainable bioeconomy also encourages an overall decrease in consumption through its underlying principles of resource efficiency: cascading use of biological resources, waste prevention and recycling. A new bioeconomy forces us to re-think our traditional concepts of economic growth while acknowledging the need to innovate in order to operate within ecological boundaries.

Despite its transformative power, the deployment of the bioeconomy is not without uncertainty and hazards. Bioeconomy, encapsulated as a concept, has made us acutely aware of our impact on the planet and forces us to re-think and rearrange how our societies and economies operate. How can we govern this shift without a complete view of the trends and broad-ranging impacts of bioeconomy sectors on environment, economy, and society? How can we understand the complex and potentially numerous impacts of a complete shift in the way our primary production systems are managed? When navigating new waters where so much is at stake, reflexive governance is critical.

Monitoring systems are flexible tools that are critical to provide useful knowledge to steer such complex socio-ecological systems. This Guidance Note builds on our experience in developing a monitoring system for the EU bioeconomy. It highlights the importance of understanding the impacts of bioeconomy through a holistic lens and encourages and guides countries and regions to set up their own monitoring systems to assess the impacts of the multi-faceted bioeconomy. In this way countries and regions may produce the reflexive governance tools needed to ensure that their bioeconomies are truly a key pillar to green transition.

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ABBREVIATIONS AND ACRONYMS

CAP	EU Common Agricultural Policy
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRLs	Forest reference levels
GFFA	Global Forum for Food and Agriculture
GHG	Greenhouse gas
IBF	International Bioeconomy Forum
ISBWG	International Sustainable Bioeconomy Working Group
JRC	European Commission's Joint Research Centre
LCA	Life cycle analysis
LULUCF	Land use, land use change and forestry
MRIO	Multiregional input-output
P&Cs	Principles and Criteria
SDGs	Sustainable Development Goals

INTRODUCTION

1.1 BACKGROUND

In October 2016, the European Commission launched the International Bioeconomy Forum (IBF), a flexible multilateral informal platform, where European and global research and innovation partners gather to discuss and act on common challenges; share ideas, knowledge and experiences on policies, strategies and actions; and foster collaboration and joint activities that promote innovation in key sectors of the bioeconomy. The IBF, which provides a forum for regular, strategic international cooperation, focuses on building policy coherence and aims at exploiting synergies among countries, regions and sectors. During the Vancouver IBF workshop in May 2019, the Food and Agriculture Organization of the United Nations (FAO) and the

European Commission's Joint Research Centre (JRC) were given a joint mandate to develop a guidance note on monitoring the sustainability of the bioeconomy.

FAO is a specialized agency of the United Nations that leads international efforts to defeat hunger. With 194 Member States, FAO works in over 130 countries to raise levels of nutrition, improve agricultural productivity, better the lives of rural populations and contribute to the growth of the world's economy. FAO received a mandate to coordinate international work on 'food first' sustainable bioeconomy from 62 government ministers at the Global Forum for Food and Agriculture (GFFA) meeting in Berlin in 2015. After receiving this mandate, FAO has received support from the Government of Germany to assist countries in the development of bioeconomy strategies and programmes. In particular, the project, Towards Sustainable Bioeconomy Guidelines, includes work on monitoring the sustainability of the bioeconomy.

The JRC, the European Commission's science and knowledge service, provides the European Union (EU) and national authorities with independent scientific support. In collaboration with several other European Commission Services, Member States and stakeholders, the JRC is leading the development of an EU-wide, internationally coherent monitoring system to track economic, social and environmental progress towards a circular and sustainable bioeconomy. The EU Bioeconomy Monitoring System (EC, 2021) is publicly available through the European Commission's Knowledge Centre for Bioeconomy.

1.2 OBJECTIVE AND CONTEXT

This document provides guidance to policymakers on how to monitor the sustainability of the bioeconomy in their country or within a macro-region, such as the EU. It can also be applied to monitor the sustainable implementation of bioeconomy strategies at sub-national level. In any geographical context, the bioeconomy encompasses the primary production sectors (crop and livestock production, forestry, fisheries and aquaculture) and the ecosystems that supply the primary materials and services to these sectors. It also comprises secondary production sectors, such as food manufacturing and processing industries; and tertiary (service) sectors, such as research and innovation, the retail sector, the food service industry, and waste management. The exact composition of the bioeconomy depends on the context of each country or macro-region.

This guidance note describes a series of general steps for designing and implementing a monitoring system to assess the sustainability of the bioeconomy in a country or macro-region. This note builds on lessons learned from existing experiences of national and macro-regional bioeconomy monitoring systems as described in

the FAO report *Indicators to monitor and evaluate the sustainability of bioeconomy, overview and a proposed way forward* (Bracco et al., 2019) and the JRC report, *Building a monitoring system for the EU Bioeconomy* (Giuntoli et al., 2020).

1.3 RATIONALE

Monitoring systems allow decision makers to assess the performance and progress towards specific strategic objectives that reflect an overall vision. The bioeconomy consists of complex social, economic, and environmental systems. Most direct and indirect impacts are unpredictable, and trade-offs are unavoidable. A reliable, holistic, and timely monitoring system is an essential component for the adaptive governance of these complex systems.

The bioeconomy takes different forms within various geographical contexts. These forms will depend on the current economic, social and environmental conditions, available opportunities, and the priorities set by each country. Consequently, monitoring systems will need to reflect the specific strategic objectives that underpin the national or macro-regional bioeconomy strategies.

Nonetheless, some key principles and criteria that provide important elements of a normative definition of a “sustainable” bioeconomy should be taken up by all national and macro-regional bioeconomy frameworks to ensure coherence. This was proposed by the FAO-led International Sustainable Bioeconomy Working Group (ISBWG), which then developed a set of *Aspirational Principles and Criteria for a Sustainable Bioeconomy* (FAO, 2021). These principles and criteria allow for mutual learning on issues to be considered when implementing bioeconomy technologies, practices or policies and for the monitoring of progress towards sustainability. The aspirational principles and criteria also remind countries of their global responsibility to respect existing multilateral environmental agreements.

Regardless of national or macro-regional priorities, the bioeconomy is a part of the broader economy and has an impact on the well-being of society and the environment. The normative definition of the monitoring framework assures that the framework is able to assess progress towards sustainability and circularity that covers the range of economic, social and environmental dimensions.

An internationally coherent monitoring system would help:

- ▶ ensure that monitoring of the bioeconomy addresses all dimensions of sustainability, and highlights and facilitates the management of potential synergies and trade-offs in ways that are in line with the 2030 Agenda and the Sustainable Development Goals (SDGs) and other multilateral environmental agreements, including the Paris Agreement on Climate Change;

- ▶ foster mutual learning between countries and macro-regions on innovative solutions to economic, social and environmental challenges, and enable the sharing of good practices and policies (Gomez San Juan and Bogdanski, 2021);
- ▶ evaluate the transboundary effects of sustainable consumption and production of food, feed, bioproducts and bioenergy in a transparent way (OECD and EC-JRC, 2021); and
- ▶ create some common shared elements of a normative definition and understanding of what a sustainable bioeconomy should look like.

This guidance note provides a step-by-step guide on how to set up a monitoring system for the bioeconomy at a country or macro-region level, and outlines why it is important to develop a robust monitoring system before moving towards implementation.

THE GUIDANCE NOTE

A full bioeconomy monitoring system helps to assess the performance and progress of the bioeconomy in a given country or macro-region. This guidance note describes a series of general steps that should be followed to establish an effective and robust system to monitor a sustainable bioeconomy. These steps can be grouped in three stages that establish three types of framework:

- 1 a conceptual framework, where all the elements of the monitoring system are defined;
- 2 an implementation framework, where the conceptual framework is populated with indicators and data collection methodologies are selected; and
- 3 an assessment and communication framework, where the trends are assessed and communicated.

A **conceptual framework** is essential to the success of the monitoring efforts. It lays the foundation for the effective collection, organization, interpretation and communication of complex information. A conceptual framework will:

- ▶ build a concrete vision of a sustainable and circular bioeconomy that can be easily shared, discussed, and interpreted among different stakeholders;
- ▶ ensure that the holistic nature of bioeconomy is captured;
- ▶ enable a disaggregation of the various aspects of the bioeconomy, which are often interlinked, and highlight the trade-offs and synergies that have been identified through the selected indicators; and
- ▶ reveal common aspects of the bioeconomy across different stakeholders and economic sectors.

The **implementation framework** will:

- ▶ provide selection criteria for indicators;
- ▶ ensure that the selected set of indicators is balanced across all dimensions of sustainability;
- ▶ highlight gaps in data availability; and
- ▶ enable the definition of reference values.

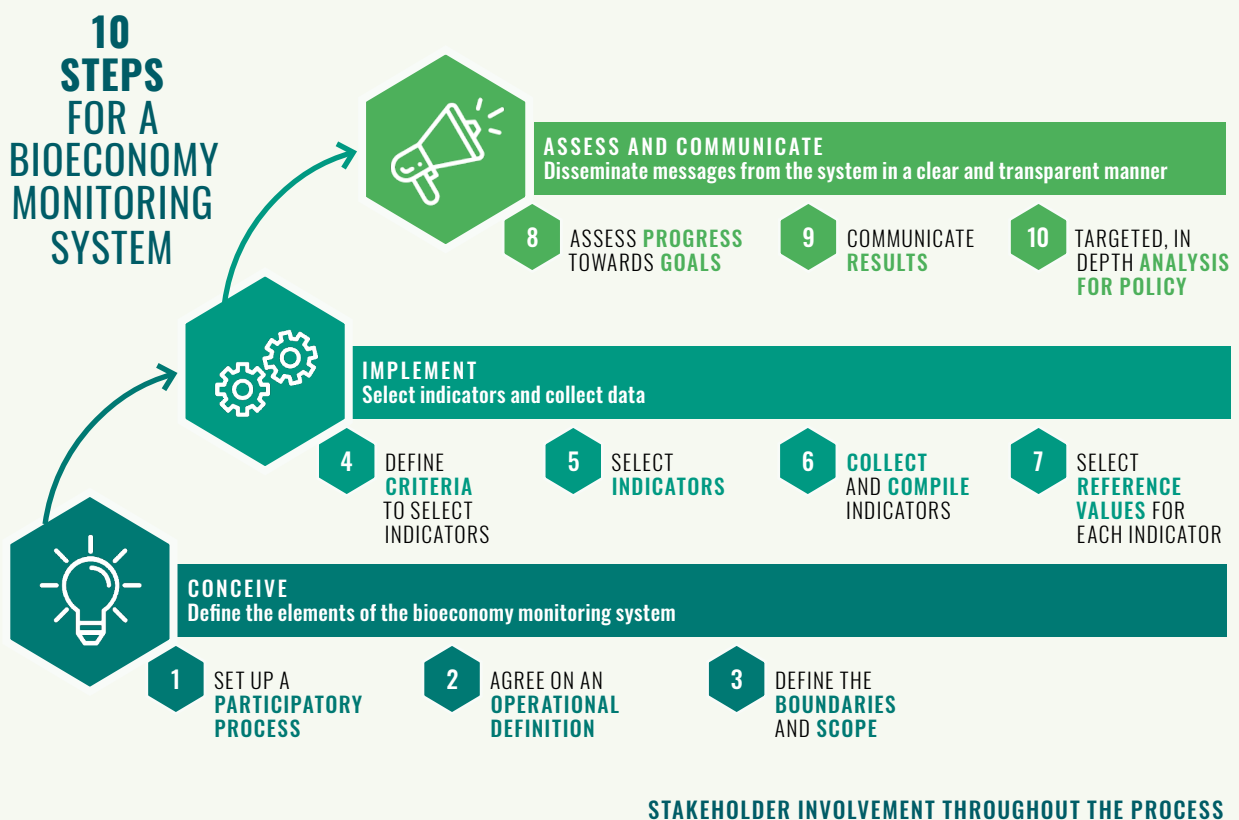
The **assessment and communication framework** will:

- ▶ assess progress towards reaching the strategic objectives and sustainability goals of the bioeconomy;
- ▶ help to communicate the results in an effective and transparent manner; and
- ▶ provide in-depth, ad hoc policy-relevant assessments based on the indicators.

Stakeholder involvement is critical in all steps of the process.

FIGURE 1.

GENERAL STEPS TOWARDS AN EFFECTIVE AND ROBUST MONITORING SYSTEM FOR A SUSTAINABLE AND CIRCULAR BIOECONOMY



Source: Authors' elaboration.

PART I

CONCEPTUAL STAGE:

Define the elements of a bioeconomy monitoring system

A key issue in monitoring progress towards a sustainable and circular bioeconomy is defining what a 'sustainable' and 'circular' bioeconomy should look like from an operational perspective. This normative task is essential to capture the holistic nature of sustainability. It will minimize gaps in the monitoring system and ensure that as many as possible direct and indirect impacts of the bioeconomy are properly captured, so that they can be managed.

There are three main elements that can help assess and mitigate gaps in monitoring systems. The first is to embrace a participatory approach that involves a representative group of committed stakeholders. The second is to define and adopt a sound set of principles and criteria to ensure the indicators cover all the different dimensions of sustainability. The third is to define the scope of the monitoring effort. Guidance on how to effectively implement these three elements is provided below.

Step 1: Set up an inclusive, consensus-oriented and transparent participatory process

Implementing good governance principles is an integral part of sustainable bioeconomy development. This includes participatory decision-making, inclusiveness, consensus building and transparency throughout the process. This applies both to the bioeconomy and its monitoring, assessment and communication.

The motivation for developing a bioeconomy monitoring system varies depending on the

context, as different stakeholders may be interested in different aspects and information (Robert *et al.*, 2020). The primary target group of the final system and the active proponents of a monitoring framework are usually policymakers. However, other stakeholders have to be included in the participatory process to develop a monitoring system. Involving different stakeholders ensures that the system meets expectations, addresses concerns, highlights opportunities of relevance to each group and, finally, broadens the expertise pool involved in delivering a comprehensive and quality system.

- ▶ **Policymakers** will use the results of the monitoring to assess the performance and progress of the bioeconomy, and make suggestions for further improvements.
- ▶ **Private sector** stakeholders may be particularly interested in the sustainability performance of specific aspects of the bioeconomy related to food, feed, materials and energy.
- ▶ **Consumers** may want to be informed about their consumption choices, and hold the government and the private sector accountable for management decisions.
- ▶ **Stakeholders from academia** may be interested in accessing the monitoring framework and its underlying data to compile their own analyses.
- ▶ **All stakeholders** will be able to contribute their expertise and experiences.

Stakeholder participation is critical, but inclusiveness, consensus building and transparency are also important aspects for building and implementing a monitoring system.

- ▶ **Inclusion** of a wide range of stakeholders allows for a variety of perspectives and values to be considered during the design of the monitoring system and reflected later in the choice of priorities for assessing risks and hotspots, and evaluating trade-offs.

- ▶ **Consensus** on the indicators selected for the conceptual framework guarantees that the indicators are well accepted, and their meaning is well understood and shared by all stakeholders, which will facilitate the adoption of the system.
- ▶ **Transparency** ensures that information is available, accessible and comprehensible to all stakeholders involved in the participatory process.

A multistakeholder platform that includes representatives from the public and private sectors, as well as from civil society can be created to accompany and participate along the whole process: from setting a workable definition of what constitutes the bioeconomy based on a shared vision of the bioeconomy strategy, to the establishment of the conceptual framework, to potential cooperation on data collection.

Participatory and inclusive approaches can be challenging, and reaching any form of consensus

among many stakeholders with divergent views can be a complicated task. In a participatory process, a major challenge is to balance wide and representative participation with an effective decision-making process that can determine the structure and content of the monitoring system. Considering that there is a need to deliver a full-fledged system, and that participation of different stakeholders is a time-consuming endeavour, a solution may be to establish different levels of participation. In practice, this would translate into the involvement of some stakeholders throughout the entire process in a step-by-step process, while the views of other categories of stakeholders are collected at different stages where appropriate.

The strengths and weaknesses of the monitoring system will become evident once it is operational. It is therefore important to plan for periodic reviews of the system with the appropriate stakeholders.

■ BOX 1. MULTISTAKEHOLDER APPROACH

Promote the development of participatory, inclusive, consensus-oriented and transparent processes, and the creation of a multistakeholder working group for developing and monitoring a sustainable bioeconomy.

- Identify and map all categories of stakeholder.
- Develop multistakeholder platforms.
- Foresee a mechanism to periodically reassess the monitoring system.

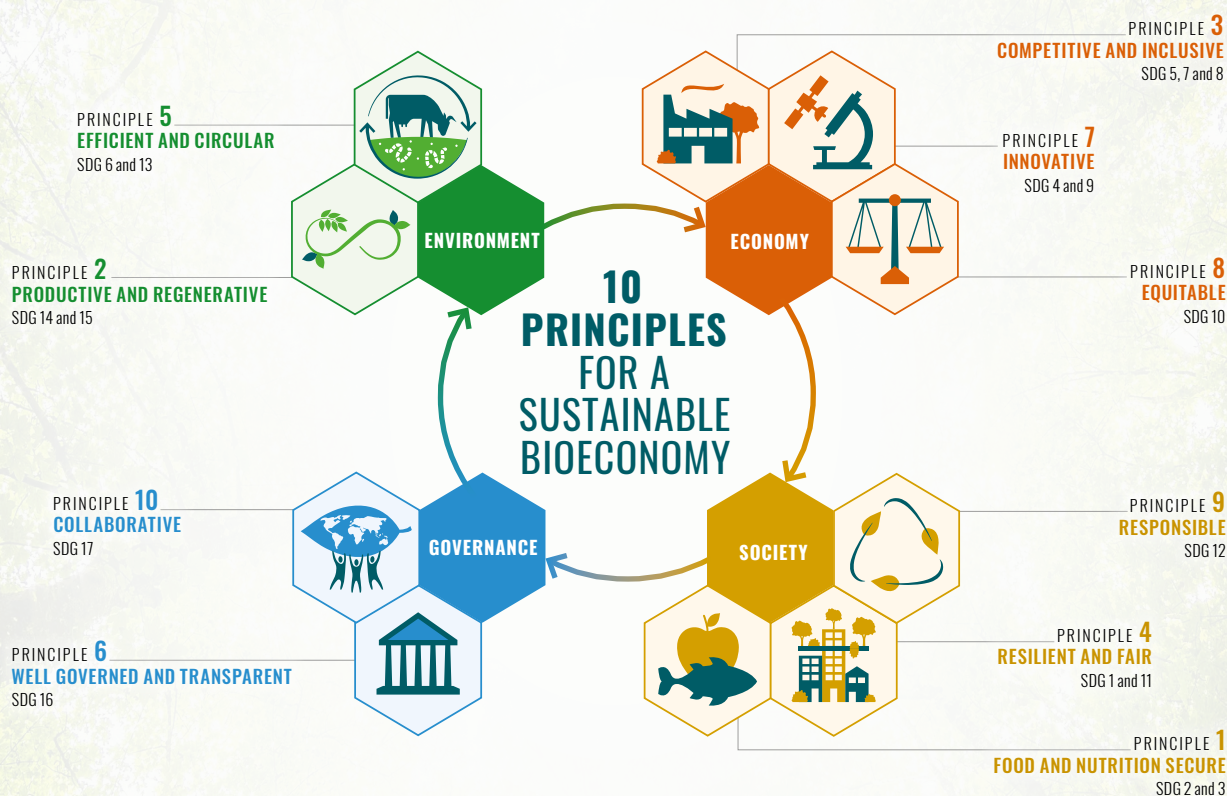
Step 2: Formulate and agree on an operational definition of 'sustainable' and 'circular' bioeconomy

In most cases, the mandate for a monitoring system will be defined within the national or macro-regional bioeconomy strategies. Consequently, the goal of the system will be to track the progress towards the specific objectives established in the strategy documents. However, for the purpose of this guidance note, the overarching goal of the monitoring system is to assess the progress of the bioeconomy towards achieving environmental, social, and economic sustainability, which includes resource-use efficiency and circularity.

The SDGs represent a global agreement on what sustainable development should look like, and through this normative exercise the international community has agreed on and spelled out what is good, right and desirable progress. Following the same principles, the ISBWG has carried out a similar normative exercise for the concept of bioeconomy. The result is a list of ten aspirational principles and 24 criteria (henceforth referred to as the P&Cs) that were agreed upon by the ISBWG in 2016 and represent the cornerstones of a sustainable bioeconomy (See **Figure 2** and **Annex 1**). Defining normative criteria facilitates the establishment of a clear link between the proposed indicators and their broader meaning. It also allows for a clear qualification of the directionality of

FIGURE 2.

TEN ASPIRATIONAL PRINCIPLES FOR A SUSTAINABLE AND CIRCULAR BIOECONOMY (FAO, 2021)



Source: FAO (2021).

trends of the indicators, which serves to qualify “positive” and “negative” progress towards the underlying objective.

Three examples of operationalization of the P&Cs can be found in Gomez San Juan, Bogdanski and Dubois (2019), Bracco *et al.* (2019) and Giuntoli *et al.* (2020). Bracco *et al.* (2019) further disaggregated the list of P&Cs into “impact categories” and conducted a literature review of existing indicators for each category. Giuntoli *et al.* (2020) rearranged the list of P&Cs to create a conceptual framework to articulate a concrete vision for a sustainable and circular bioeconomy in the European Union (EU).

The P&Cs are composed of 24 criteria that cover economic, environmental and social dimensions of sustainability, as well as principles related to governance, which underpin all three of these dimensions.

The P&Cs provide countries with a blueprint for what should be monitored to achieve a holistic view of the bioeconomy. The aspirational list should be seen as a source of inspiration that will evolve over time.

At a minimum, progress should be monitored across all the ten principles (Figure 2 and Annex 1), and as many criteria as are pertinent to the national context should be covered. While the P&Cs are general and aspirational, the specific meaning, interpretation, and indicators chosen to monitor the progress towards the P&Cs will change depending on national or macro-regional policy goals and circumstances.

Since many aspects of sustainability are interlinked, it is necessary to pay particular attention to the unintentional negative impacts that the fulfillment of one criterion may have, or the synergies that it may share with other

criteria. This is why it is necessary to consult with a wide range of stakeholders (see Step 1). A well formulated and inclusive monitoring framework

will facilitate a dialogue about trade-offs and synergies, and allow for an informed discussion among involved stakeholders.

■ BOX 2. CONTEXT SPECIFIC

Tailor the conceptual monitoring system to the national and macro-regional needs and context without losing the system perspective.

- Formulate a workable definition of a sustainable bioeconomy within the national or macro-regional context by adapting the list of ten aspirational principles and 24 criteria developed by the ISBGW.
- Identify the impact boundaries.

Step 3: Define the boundaries and scope of the monitoring system

The third step in the conceptual phase involves defining a clear scope with well-defined boundaries for the monitoring system. The scope of the monitoring will likely be closely aligned with the scope and boundaries of the bioeconomy as defined in the national or macro-regional strategy and related regulations and rules.

An important step for the success of monitoring efforts is the precise definition of the sectoral composition of the bioeconomy that is subject to monitoring. The geographic scope also needs to be defined (i.e. whether the monitoring will focus on the macro-regional, national or sub-national level). Most of the indicators in the literature describe national performance, but there are also examples of sub-national frameworks, for example the approach used by the BioEconomy Regional Strategy Toolkit project (BERST, 2016), and methodologies for specific products.

At a technical workshop conducted by the ISWGB before the Global Bioeconomy Summit in Berlin in 2018, experts introduced two different levels of focus for monitoring systems: a territorial level and a product level. The two levels can be used alternatively depending on the scope of the monitoring, or they can be used as complementary tools to provide a more complete picture of the bioeconomy. For example, Giuntoli *et al.* (2020) followed a complementary

approach using some product-based life cycle analysis (LCA) indicators within a wider territorial approach in their conceptual framework. The added value of the product-based monitoring derives from its assessment of the environmental impact of trade of bio-based commodities in the place of origin, and the environmental impact of bio-based products consumed in the EU (based on the indicators proposed by Sala and Castellani, 2019). Other frameworks, for example Schweinle *et al.* (2020) and Iost *et al.* (2020), propose similar product-based indicators.

The two monitoring levels have different characteristics, different data requirements, and mainly differ in their capacity to establish an explicit causal link with the bioeconomy. For instance, the United Nations framework for global monitoring of the SDGs explicitly recommends the use of simple, single variable indicators. In many cases, basic statistical and measured data can be given a precise interpretation and be used directly as indicators, functioning as proxies for more complex processes and trends, even though causally distant from the element that is intended to be indicated (the indicandum). An effective conceptual framework supports the proper organization and interpretation of these proxies.

On the other hand, product-based indicators allow a closer level of control over the datasets that are used. They can filter out many confounding drivers, and eventually obtain results that are attributable to the specific product or sector under investigation. The two

main approaches found in the literature are product-based LCA and the use of multiregional input-output (MRIO) databases (see e.g. Sala and Castellani, 2019; Schweinle *et al.*, 2020). While LCA approaches for sustainability are being developed to include social and economic dimensions, both the classic LCA and MRIO approaches are currently more developed and applied to assess environmental flows and impacts. Therefore, care must be taken to interpret these indicators correctly to avoid the shifting of the burden from one dimension of sustainability to another.

Finally, product-based indicators can be used for different purposes within monitoring frameworks. For instance, Sala and Castellani

(2019) present the Consumer Footprint indicator, which uses product-based LCA to evaluate the environmental impact of EU consumption based on a representative basket of products. On the other hand, Schweinle *et al.* (2020) selected indicators to evaluate some environmental, social, and economic effects of a bio-based material flow.

A different scope could be the use of product-based indicators to produce labelling information or benchmarking of similar products to inform consumers and producers. An example of this approach is the EU Product Environmental Footprint methodology (Zampori and Pant, 2019).

■ BOX 3. SETTING THE BOUNDARIES

Define a clear scope with clearly defined boundaries for the monitoring system.

- Define the exact sectoral composition of the bioeconomy.
- Define the geographic scope.
- Decide whether or not to monitor at the territorial level, the product level or both.

PART II IMPLEMENTATION STAGE: Select indicators and collect data

After the conceptual framework has been established, the next stage involves the development of an implementation framework. In this stage, the conceptual framework is populated with relevant indicators. These indicators need to be identified, screened, and selected through a multistakeholder approach (Step 1) to report progress on the sustainability of the bioeconomy.

Step 4: Define criteria to select indicators

The first step in developing the implementation framework is to define the parameters that will be used to rank and select available indicators.

Several examples of selection criteria can be found in the literature. For instance, Eurostat has proposed a scoreboard for the selection of indicators within the SDG framework with parameters focusing mostly on the statistical quality of the indicators, e.g. timeliness, data availability, frequency of dissemination, geographical coverage (Eurostat, 2016). FAO has established the links between the Sustainable Bioeconomy Principles and Criteria and the SDG indicators (Çalicioğlu and Bogdanski, 2021).

Based on the experience with existing frameworks, it is recommended to rank and select indicators partly or entirely on the following parameters.

Meaningful: The indicator contributes clear information to the achievement of the normative criterion of the framework. The meaning of the indicator is clear in terms of the chain of cause and effect. The directionality and its relationship with the normative criterion are clear and accepted.

Established: The indicator is policy-relevant and already used in other policy monitoring frameworks. The indicator is used in other international statistical sets, which guarantees that the indicator is achievable and measurable. This allows for the development of a time series based on well-established data sources. The selected indicators are methodologically well founded, and documentation on the indicators includes information on the uncertainty and quality of the data.

Timely: The indicator should be based on data that have been recently published and reflect recent conditions.

Frequency: The indicator should be based on routinely and frequently collected data,

for instance data collected to meet reporting obligations under international agreements. The underlying data for the indicator should also be frequently disseminated.

Geographical coverage: Global, macro-international regions, macro-regions, national level, sub-national level.

Comparable across countries and/or products or sectors: Where possible, the indicator should be defined in the same way across countries and products or sectors. This parameter applies when several indicators can be used for the same purpose. Internationally comparable indicators are preferable as they allow for setting benchmarks for the performance of bioeconomies, and facilitate the exchange of ideas.

Comparable over time: There should be no variations over time in the methodology used to generate the data series.

Transparent and accessible: The data should be openly available and clearly documented.

■ BOX 4. DEFINING CRITERIA TO SELECT INDICATORS

Define relevant parameters that will be used to rank and select available indicators.

- Select the approach to take.
- Prepare a methodology to rank indicators accordingly.

Step 5: Select indicators to reflect the operational definition of bioeconomy

An indicator is a measure based on verifiable data that conveys information about more than itself. Indicators are purpose-dependent, meaning that the interpretation given to the data depends on the context in which the indicator and data are used. Different types of indicators are needed to answer different types of questions, or the same indicator can be used to assess different questions.

As established before, each country or macro-region should identify the best potential indicator(s) for each criterion within the conceptual framework through a multistakeholder approach and based on the opinion of experts, and then select the indicators

that comply with the selection criteria (step 4), such as information and data that are available and regularly updated, comparable over time, etc.

This step should lead to the selection of a balanced set of indicators covering all aspects of a sustainable bioeconomy. Many indicators may already be available, as has been shown by the recent literature review by Bracco *et al.* (2019). Although the indicators will depend on the monitoring goals and will be the result of stakeholder consultation, the final set of indicators will also depend on data availability and on the possibility to expand data collection. At the territorial level, several indicators may already have been collected by each country or macro-region. These indicators can then be re-interpreted according to the bioeconomy monitoring priorities using the conceptual framework defined in Step 2 as a basis.

For instance, indicators that are defined (or in the process of being defined) to measure progress towards the SDGs are also often sufficiently representative for several bioeconomy criteria with minimal or no alterations (Bracco *et al.*, 2019), so that countries may use them as a helpful starting point. Nonetheless, not all criteria may be covered by existing SDG indicators, and the exploration of other sources of information and data is encouraged to cover all dimensions of sustainability. For detailed links between the P&Cs and SDGs, refer to Giuntoli *et al.* (2020), and Calicioglu and Bogdanski (2021). When the scope of the monitoring is focused on the product or value chain, the selected indicators can be adapted for each bio-based product, based on the relevant product value chain and its hotspots. The data for these indicators may already be available, for instance if the bio-based product is certified or labelled. Again, it is important to ensure that results are displayed in a way that can be easily understood by all consumers and users.

Many indicators are quantitative, e.g. kg yield/ha, the amount of financial investments in bio-based industries, or greenhouse gas (GHG) emissions/kg of product. However, qualitative indicators also provide important information and may be used in a monitoring system. For instance, some indicators require the reporting of a good practice as a proxy, as done in the EU common agricultural policy (CAP) monitoring system (see Step 8). In some cases, the Boolean “yes/no” indicator can be used. In the case of Boolean indicators, it is possible to attach numerical value to the indicator for additional quantitative analysis: “yes” can be attributed a score of 1 or 100 percent, while “no” can be attributed a zero score. In other cases, some indicators may not be directly measurable. For example, soil degradation can be measured

by a direct indicator (e.g. soil organic carbon content) that shows soil quality, or by a proxy indicator, such as the number of hectares under conservation agriculture that reports on the implementation of conservation agriculture as a good practice for preserving soil quality. Similarly, avoided GHG emissions from livestock can be measured through direct indicators or estimated using indicators of size of the herd. For a comprehensive introduction to indicator typologies, including basic indicators, process indicators or system-level indicators, see Bracco *et al.* (2019).

To give a general overview of the status of the bioeconomy using a limited number of indicators, aggregated or representative indicators can be used. The complexity of an indicator and its objectivity depends on its level of aggregation. Robert *et al.* (2020) present a pyramid of information with different categories of indicators. At the foundation of the pyramid are the underlying statistical data that can be measured. On this foundation, there are three tiers of indicators that differ in complexity, and are consequently subject to greater interpretation. In some cases, it is appropriate to use basic indicators, whereas in other cases it is appropriate to use processed or system-level indicators. Processed indicators are the result of a transformation of basic indicators so that they provide a harmonized view on a particular aspect of the bioeconomy. The processing can consist in the harmonization of basic indicators to enable comparison between sectors. System-level indicators are indicators that require a higher level of value judgment in their compilation because of the higher level of complexity of the questions the indicators are addressing. In some cases, but not always, the system-level indicators make use of basic or processed indicators.

BOX 5. SELECTION OF INDICATORS

Select indicators in a collaborative and participatory process.

- Consider both quantitative and qualitative indicators.
- Consider what needs to be measured and monitored first, then assess whether or not an indicator exists for this or an indirect proxy must be sought.
- Allow different levels of aggregation of indicators in the monitoring system.
- Leverage open science data policy for data access.

Step 6: Collect and compile indicators

To quantify the indicators, the most immediate option is to make use of existing and internationally recognized indicators to limit the reporting burden. For example, data on economic information can be retrieved from national or international accounts, or from international databases (e.g. statistics from the United Nations). For instance, data on the status of forests are partly reported to the Global Forest Resource Assessment, which is coordinated by FAO.

Other indicators are aspirational, and data are currently not available. This is often the case for environmental and social statistics, although some national, regional and international initiatives have been undertaken in this area. For example, the environmental accounts of the EU provide information on environmental protection that covers activities related to preventing, reducing and eliminating pollution and any other environmental degradation, and improving resource management and the preservation of natural resources.

Another challenge is that existing reporting systems are not necessarily adapted to the bioeconomy, but are geared for reporting on the economy as a whole. However, economy-wide indicators at the most basic level may be applicable to the bioeconomy. For instance, processed indicators can be the result of a transformation of basic indicators, and these

transformations can range from changes in the measurement unit to the aggregation of sectoral statistics into “bioeconomy-wide” datasets (Ronzon *et al.*, 2020). System-level indicators, though requiring a more subjective value judgment, can be obtained based on consolidated techniques (e.g. product-based LCAs).

When there are data gaps at the territorial level, data may be aggregated at the product or value chain level, or vice versa (i.e. data at territorial level can be disaggregated if there are gaps at product or value chain level). For instance, footprint-type indicators can be calculated to provide aggregated, synthetic information within the framework (O’Brien *et al.*, 2015; 2017). A social LCA for a product depends heavily on the geographical location of the production plant. Therefore, if case-specific data for a more precise assessment of the socio-economic impact of a bioproduct are lacking, the impact can be assessed more generally using data at the territorial level (e.g. working conditions, labour rights and child labour at the national level).

It is possible that certain P&Cs in the conceptual framework cannot be covered by any available dataset or indicator. However, it is recommended that all sections of the frameworks be filled with indicators, even if that means using a proxy (e.g. a qualitative or good practice indicator) or selecting a placeholder. This will guarantee that gaps in any dimension of sustainability are not ignored and can be addressed in the future.

■ BOX 6. QUANTIFICATION OF INDICATORS - AVOID REINVENTING THE WHEEL

Take into consideration existing methodologies, indicators and data.

- Review existing literature on sustainable development monitoring and sustainability assessments.
 - Where possible, use indicators from frameworks that stakeholders are already reporting on, such as SDGs, standards, certificates and labels.
 - Select a proxy or placeholder when no suitable indicators are found for one or more of the sustainability dimensions defined in the conceptual framework and work towards filling the gap.
-

Step 7: Select reference values for each indicator

The P&Cs provide a normative definition of what a sustainable bioeconomy should achieve, and thus already define the assessment of positive and negative progress for each section of the framework. However, the P&Cs do not include any specific quantitative target or sustainability threshold. This is left to the needs and circumstances of each country. Targets may be clearly expressed in the bioeconomy strategy or related policies of a country, but in many cases, these targets remain qualitative. Stakeholder groups can be called upon to reach commonly agreed targets on quantitative objectives.

Targets, and subsequently the measurement of progress, can be defined in a relative or absolute way. In other words, a target can simply define a desired trend with respect to a fixed reference value (e.g. reduction of GHG emissions compared to 1990), which is considered positive, or define a specific numerical target to be achieved (e.g. a 55 percent reduction of GHG emissions compared to 1990). In turn, the numerical target can represent an aspirational or normative one (usually employed for social targets), or a firm biophysical threshold, such as in the case of the

planetary boundaries. Another possible, but more complicated alternative, is to determine targets compared to an alternative counterfactual (i.e. comparing the value of an indicator to the value that indicator would have in a business-as-usual scenario without the current intervention). An example is the forest reference levels (FRLs) that are defined for the land use, land use change and forestry (LULUCF) regulation of the EU.

The directionality of each indicator should be evaluated against the P&Cs within the conceptual framework. The identification of a clear directionality is a clear sign of relevance of the indicator for the specific criterion. Confusion or disagreement about directionality should be interpreted as a sign of insufficient relevance or unclear link between the indicator and the indicandum. If the conceptual framework is properly designed, it should be fairly simple to isolate the different aspects of the system that have been analysed and assign a directionality to each indicator. For instance, increased harvest from forests might appear as a positive indicator in economic terms, and as a negative indicator in environmental terms. Different indicators should be used to capture these aspects in different sections of the framework.

■ BOX 7. REFERENCES FOR INDICATORS

Take targets into consideration.

- Targets can be numerical or a desired trend.
 - If they are numerical, clearly state the numerical reference values.
 - Ensure that the indicator is appropriately placed in the conceptual framework by verifying its directionality with respect to the targets.
-

PART III

ASSESSMENT AND COMMUNICATION STAGE

Once the conceptual framework is populated with meaningful, established, high-quality indicators that cover all dimensions of sustainability, and the indicators have been quantified and relevant reference values have been set, it is the responsibility of policymakers to assess the results of the monitoring and communicate them to the public in a transparent manner.

Step 8: Assess progress towards bioeconomy objectives and sustainability goals

This step provides the final information on progress that has been made towards reaching the bioeconomy strategy objectives and sustainability goals and is based on the quantification of the indicators in Step 6 and the careful selection of reference values in Step 7.

Careful consideration should be given to whether aggregating indicators may be more effective than presenting a dashboard of the whole set of indicators. One of the main goals of a monitoring system for the bioeconomy is to identify potential trade-offs and synergies that might not be evident when looking at a single sector or dimension of sustainability.

Identifying the synergies and trade-offs is particularly important not only to monitor the sustainability of the bioeconomy, but also to establish cross-sectoral integration and collaboration that is required to fully capitalize on these synergies and minimize the trade-offs as much as possible.

BOX 8. TRADE-OFF ANALYSIS

Some examples of potential trade-offs that might influence the sustainability of the bioeconomy and limit its boundaries include:

- Poverty vs biodiversity.
- Agricultural productivity vs climate change action.
- Agricultural productivity vs employment.
- Nutrient recovery from wastewater vs human health and soil quality.
- Land use vs ecosystem services.

Step 9: Communicate the results effectively and transparently

The results should be presented in a sound and simple way, ideally through interactive web-based dashboards. This is essential for communicating the results effectively to policymakers and other interested stakeholders to support an informed decision-making process, and to the general public to increase consumer awareness and the market uptake of the more sustainable bio-based products.

For instance, spider diagrams and/or interactive graphics can be an effective way of showing progress in a subset of the analysed indicators. Grouping indicators into the three sustainability dimensions (environmental, social and economic) may make it easier to communicate the results. Alternative ways of aggregating the indicators could be considered, for instance by grouping them into headline indicators that answer some overarching questions (e.g. “Does the bioeconomy contribute to climate change mitigation?”).

Transparency regarding the data and methods that are used is also an important issue to be considered for the communication of the results. All data used to create the indicators in the system should be made available to the public. The data should be accompanied by a technical description of each indicator that clearly details the data quality and sources, and the ways the data were transformed. Additionally, value choices will be made along the whole process of defining the monitoring system, from the definition of the framework, to the selection of indicators and their targets, to the definition of indices and communication

tools. Even though multiple viewpoints will be considered through the participatory process, it is important that value choices are transparently reported and explained when defining the system and disseminating the results.

Finally, a feedback loop that feeds into Step 1 is required to evaluate whether the monitoring system is functional and useful for a variety of stakeholders, and to update it as the policy priorities change or the scientific understanding improves. However, the core of the system should be allowed to remain unchanged to guarantee the comparability of trends over time.

■ BOX 9. TRANSPARENT AND EFFECTIVE COMMUNICATION

Enable an informed and transparent decision-making process and increase consumer awareness.

- Identify and use innovative and effective methodologies for communicating results and showing progress.
 - Provide information to citizens in a clear and understandable way by encouraging concerted action from all stakeholders.
 - Provide analysis and insights to inform policy.
-

Step 10: Strengthen the science to policy interface through analysis and reporting

The output of the monitoring system does not necessarily tell a complete story unless additional analysis is undertaken, and it certainly does not represent a political position. The strength of a good monitoring system is in its objective reporting. It is often the case, however, that specific questions need to be answered. Frequently these will be policy questions related to the effectiveness or impacts

of the implementation of the bioeconomy. In these cases, ad hoc analysis can be made using the data available in the monitoring system. Different data will be used to answer different questions. However if the system has been developed in a transparent and participatory manner, covers all dimensions of sustainability, and represents the indicators that are necessary to assess the region or country's bioeconomy, many different questions can be answered from the same data pool, which will ensure transparency and continuity.

■ BOX 10. ANALYSIS AND REPORTING

Strengthen the interface between science and policy through ad hoc expert analysis.

- Analyse specific policy-relevant questions using the appropriate data in the monitoring.
 - Periodically select themes for in-depth analysis using the monitoring system, which will also highlight the strengths and weaknesses that may be taken up during the review process of the system.
-

CONCLUSIONS

The bioeconomy can make important contributions to solving global challenges, like health and nutrition of a growing global population; sustainable provision of food, energy, water and raw materials; as well as soil, climate and environmental protection and restoration, thereby contributing to the Sustainable Development Goals of the United Nations.

This guidance note suggests how to monitor the sustainability of the bioeconomy at different scales. It describes a series of general steps for designing and implementing a monitoring system to assess the sustainability of the bioeconomy in a country or macro-region.

This note builds on lessons learned from existing experiences of national and macro-regional bioeconomy monitoring systems.

Various governments around the world have already implemented or are in the process of implementing their own bioeconomy strategies and monitoring systems. Learning with and from each other is essential for regular, strategic international cooperation, building policy coherence and exploiting synergies between countries and regions to support the development of a sustainable, global bioeconomy (IBF, 2021).

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ANNEX 1

ASPIRATIONAL PRINCIPLES AND CRITERIA FOR SUSTAINABLE BIOECONOMY

The description of each one of the *Aspirational Principles and Criteria for Sustainable Bioeconomy* can be found in FAO (2021). **Annex 1** provides a summary of the background, purpose, scope and intended users based on FAO (2021) and provides an overview of the P&Cs at the end.

BACKGROUND AND RATIONALE

Although bioeconomy addresses global, multidimensional challenges, it does not guarantee sustainability *per se*. At the Global Forum for Food and Agriculture in January 2015, 62 ministers of agriculture agreed on the importance of seizing opportunities to implement bioeconomy in a sustainable and circular manner. They recommended that the Food and Agriculture Organization of the United Nations (FAO) coordinate international work on sustainable and circular bioeconomy.

Through the International Sustainable Bioeconomy Working Group (ISBWG), a multistakeholder group established in 2016,

FAO provides international support to increase national capacities to develop strategies and policies for sustainability in the bioeconomy. The mechanism adopted by the ISBWG represents a sound approach for achieving Sustainable Development Goal (SDG) 17, particularly target 17.9 on enhancing international support for implementing national plans. The ISBWG facilitates international dialogue and serves as a platform for sharing knowledge and experiences on sustainable and circular bioeconomy innovations, technologies, practices and policies. It also acts as an advisory body for FAO in the Organization's technical work on sustainable and circular bioeconomy. Other networks related to bioeconomy also exist. The FAO-led ISBWG is unique in that it advocates for the shift to more sustainable agri-food systems through a sustainable and circular bioeconomy.

OVERVIEW OF THE PRINCIPLES AND CRITERIA

PRINCIPLE 1



SUSTAINABLE BIOECONOMY DEVELOPMENT SHOULD SUPPORT FOOD SECURITY AND NUTRITION AT ALL LEVELS

Criterion 1.1

Food security and nutrition are supported

Criterion 1.2

Sustainable intensification of biomass production is promoted

Criterion 1.3

Adequate land rights and rights to other natural resources are guaranteed

Criterion 1.4

Food safety, disease prevention and human health are ensured

PRINCIPLE 2



SUSTAINABLE BIOECONOMY SHOULD ENSURE THAT NATURAL RESOURCES ARE CONSERVED, PROTECTED AND ENHANCED

Criterion 2.1

Biodiversity conservation is ensured

Criterion 2.2

Climate change mitigation and adaptation are pursued

Criterion 2.3

Water quality and quantity are maintained, and, as much as possible, enhanced

Criterion 2.4

The degradation of land, soil, forests and marine environments is prevented, stopped or reversed

PRINCIPLE 3



SUSTAINABLE BIOECONOMY SHOULD SUPPORT COMPETITIVE AND INCLUSIVE ECONOMIC GROWTH

Criterion 3.1

Economic development is fostered

Criterion 3.2

Inclusive economic growth is strengthened

Criterion 3.3

Resilience of the rural and urban economy is enhanced

PRINCIPLE 4



SUSTAINABLE BIOECONOMY SHOULD MAKE COMMUNITIES HEALTHIER, MORE SUSTAINABLE, AND HARNESS SOCIAL AND ECOSYSTEM RESILIENCE

Criterion 4.1

The sustainability of urban centres is enhanced

Criterion 4.2

Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened

PRINCIPLE 5



SUSTAINABLE BIOECONOMY SHOULD RELY ON IMPROVED EFFICIENCY IN THE USE OF RESOURCES AND BIOMASS

Criterion 5.1

Resource use efficiency, waste prevention and waste reuse along the whole bioeconomy value chain are improved

Criterion 5.2

Food loss and waste is minimized and, when unavoidable, its biomass is reused or recycled

PRINCIPLE 6



RESPONSIBLE AND EFFECTIVE GOVERNANCE MECHANISMS SHOULD UNDERPIN SUSTAINABLE BIOECONOMY

Criterion 6.1

Policies, regulations and institutional structures relevant to bioeconomy sectors are adequately harmonized

Criterion 6.2

Inclusive consultation processes and engagement of all relevant sectors of society are adequate and based on transparent sharing of information

Criterion 6.3

Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented

PRINCIPLE 7



SUSTAINABLE BIOECONOMY SHOULD MAKE GOOD USE OF EXISTING RELEVANT KNOWLEDGE AND PROVEN SOUND TECHNOLOGIES AND GOOD PRACTICES AND, WHERE APPROPRIATE, PROMOTE RESEARCH AND INNOVATIONS

Criterion 7.1

Existing knowledge is adequately valued and proven sound technologies are fostered

Criterion 7.2

Knowledge generation and innovation are promoted

PRINCIPLE 8



SUSTAINABLE BIOECONOMY SHOULD USE AND PROMOTE SUSTAINABLE TRADE AND MARKET PRACTICES

Criterion 8.1

Local economies are not constrained but rather expanded through the trade of raw and processed biomass, and related technologies

PRINCIPLE 9



SUSTAINABLE BIOECONOMY SHOULD ADDRESS SOCIETAL NEEDS AND ENCOURAGE SUSTAINABLE CONSUMPTION

Criterion 9.1

Consumption patterns of bioeconomy goods match sustainable supply levels of biomass

Criterion 9.2

Demand-side and supply-side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced

PRINCIPLE 10



SUSTAINABLE BIOECONOMY SHOULD PROMOTE COOPERATION, COLLABORATION AND SHARING BETWEEN INTERESTED AND CONCERNED STAKEHOLDERS IN ALL RELEVANT DOMAINS AND AT ALL RELEVANT LEVELS

Criterion 10.1

Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate



PURPOSE

Given the challenges and opportunities that are involved in making the transition to a sustainable and circular bioeconomy, in 2016 the ISBWG agreed on a set of *Aspirational Principles and Criteria for Sustainable Bioeconomy* (hereafter referred to simply as the Principles and Criteria). The Principles and Criteria cover the different dimensions of sustainability and provide a reference list of issues that should be addressed to develop bioeconomy in a sustainable and circular way at international, national and local levels. The Principles and Criteria also provide an overview of the role that these different dimensions of sustainability play in the development and implementation of bioeconomy, and are complementary as they encompass the social, economic, environmental and governance aspects of sustainability. The Principles and Criteria aim to ensure that bioeconomy, when implemented correctly, can benefit individual communities and the global environment in ways that are in line with the SDGs.

Bioeconomy strategies, which are inherently multisectoral, face greater challenges than sustainable development strategies that target a single sector, as the implementation of sustainable and circular bioeconomy involves making trade-offs among different sustainability objectives, on the one hand, and sectors, on the other. The dialogue among international partners fostered through the ISBWG creates a greater understanding of the potential synergies and trade-offs associated with the implementation of sustainable bioeconomy, and the opportunities for sustainability and circularity.

SCOPE

The Principles and Criteria create a common ground for discussions on sustainability and circularity in the bioeconomy. They can be applied by policymakers and other stakeholders in the development of national and regional

bioeconomy strategies. They emphasize aspects that need to be considered when making a shift to a sustainable and circular bioeconomy. The Principles and Criteria can also be used in monitoring frameworks for measuring the sustainability of the bioeconomy or to monitor the progress being made in making this shift. If sustainability is considered in the design phase of strategy development and in assessments of its implementation, future risks, hidden costs and trade-offs can be avoided right from the outset, which can eliminate the need to implement corrective measures later.

The Principles and Criteria are non-binding, and they should be interpreted in ways that take into account the local social, economic, environmental and governance context.

INTENDED USERS

The Principles and Criteria target national and international stakeholders who are involved in, benefit from, and are affected by the development of strategies, programmes and action plans for promoting a sustainable and circular bioeconomy. These stakeholders include countries, intergovernmental and regional organizations, financing institutions, research organizations, business enterprises (including farmers and bioproduct manufacturers), civil society organizations, consumer organizations, and other decision makers who want to carry out bioeconomy projects or activities in a sustainable way.

Building on the Principles and Criteria, the FAO Project on Sustainable and Circular Bioeconomy provides guidance documents and country support to policymakers and other stakeholders in developing and implementing sustainable and circular bioeconomy strategies, policies and programmes (FAO, 2021).



This guidance note describes a series of general steps to establish an effective and robust system to monitor the sustainability of the bioeconomy in a given country or macro-region. This note builds on lessons learned from existing experiences of national and macro-regional bioeconomy monitoring systems. Learning with and from each other is essential for regular, strategic international cooperation, building policy coherence. The steps outlined in the note can be grouped into three stages under three types of framework: (i) conceptual, (ii) implementation, and (iii) assessment and communication.

The steps are easy to follow and adaptable based on social, economic and environmental context, since they are based on the *Aspirational Principles and Criteria for a Sustainable Bioeconomy*, developed under the auspices of the International Sustainable Bioeconomy Working Group.

This note was jointly developed by the Food and Agriculture Organization of the United Nations (FAO) and the European Commission's Joint Research Centre (JRC), under the mandate of the International Bioeconomy Forum.

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