Food and Agriculture Organization of the United Nations

BIOECONOMY

ENVIRONMENT AND NATURAL RESOURCES MANAGEMENT

The bioeconomy toolbox

A guide to support the development of sustainable bioeconomy strategies and policies

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Foreword

A bioeconomy approach holds enormous potential to help countries confront the major challenges facing them today. Managing biological resources in a smarter way will help increase food security, tackle poverty, fight climate change and biodiversity loss, and eliminate waste and pollution.

The Food and Agriculture Organization (FAO) is at the forefront of international work on sustainable and circular bioeconomy. Bioeconomy for Sustainable Food and Agriculture is a programme priority area in FAO's Strategic Framework 2022-2031, which steers its efforts to transform agrifood systems and promote a food secure world for all.

FAO leads the International Sustainable Bioeconomy Working Group (ISBWG) and actively engages in global discussions as a member of the International Advisory Council on Global Bioeconomy (IACGB) and the International Bioeconomy Forum, among other international fora. It supports countries in building their bioeconomy capacities and promotes bio-innovations.

A growing number of countries are now developing bioeconomy or bioeconomy-related strategies, focusing on areas such as bioscience and biotechnology. Through the "Towards Sustainable Bioeconomy Guidelines" project, with the assistance of the German Ministry for Food and Agriculture, FAO has helped guide these efforts.

This publication, *'The Bioeconomy toolbox: A guide to support the development of sustainable bioeconomy strategies and policies'*, incorporates the experiences and insights of experts at the leading edge of bioeconomy research and action – from FAO, its country and regional partners and its advisory bodies. It is designed to support policymakers in formulating and implementing bioeconomy strategies, so they address the many challenges facing their nations more effectively.

FAO is committed to harnessing the potential of the bioeconomy to drive a transformation toward more sustainable agrifood systems worldwide. I sincerely hope this toolbox will serve as encouragement for Members and other partners to accelerate the transition.

Kaveh Zahedi

Director, Office of Climate Change, Biodiversity and Environment,
Food and Agriculture Organization of the United Nations.

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Abbreviations

ASEAN	Association of Southeast Asian Nations
BEFS	Bioenergy Assessment Toolkit
BIC	Bio-based Industries Consortium
BMBF	Federal Ministry of Education and Research
BMEL	German Ministry for Food and Agriculture
BMWG	Bioeconomy Multisectoral Working Group Namibia
CBD	Convention on Biological Diversity
EASTECO	East African Science and Technology Commission
EC	European Commission
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCF	Green Climate Fund
GDP	gross domestic product
GEF	Global Environmental Facility
GIT-BS	Inter-institutional working group (Uruguay)
IACGB	International Advisory Council on Global Bioeconomy
IDB	Inter-American Development Bank
IICA	Inter-American Institute for Cooperation on Agriculture
ISBWG	International Sustainable Bioeconomy Working Group
ISIC	International Standard Industrial Classification
KPI	key performance indicator
LCA	life-cycle assessment
MGAP	Ministry of Livestock, Agriculture and Fisheries (Uruguay)
NCRST	National Commission on Research, ScienBce and Technology

NDCs	nationally determined contributions (NDCs)
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Co-operation and Development
RDI	research, development, and innovation
SDGs	Sustainable Development Goals
SWOT	strengths, weaknesses, opportunities, threats
TEEB	The Economics of Ecosystems and Biodiversity
TSC	The Sustainability Consortium
UNDESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Convention for Climate Change

Executive summary

FAO supports counties and regions in developing and implementing sustainable bioeconomy strategies. FAO has identified fifteen common objectives driving the development of bioeconomy strategies and initiatives. They range from substituting fossil-based products, conserving and regenerating biological resources, fostering innovations in agrifood systems, revitalizing rural areas, or enhancing equitable economic growth.

The bioeconomy is situated at the intersection of many sectors, so sustainable bioeconomy strategies will necessarily be cross-sectoral and involve many different stakeholders. The different objectives laid out in bioeconomy strategies will be determined by the specific social, economic, and environmental conditions in the target area. When these objectives are translated into concrete proposals, trade-offs and synergies become apparent. These trade-offs occur both within and between economic sectors, and within and between different dimensions of sustainability. Without a dedicated and holistic bioeconomy strategy, trade-offs cannot be made in a transparent manner, ensuring that no one is left behind.

Developing a sustainable bioeconomy strategy is a complex undertaking. This toolbox is designed to support policymakers involved in the formulation and implementation of bioeconomy strategies. In this toolbox, the process of developing a sustainable bioeconomy strategy is divided into four steps, with each step subdivided into three substeps:

Step 1. Set up a governance mechanism and dedicated institution. Substeps include to initiate a participatory process, create a vision and sustainability objectives, and agree on a definition.

Step 2. Devise the strategy. Substeps include to map the bioeconomy potential and data, select the main elements of the strategy, and write the final document.

Step 3. Implement with an action plan. Substeps include to build an action plan, deploy technologies and business models, and cover gaps in policy and investment.

Step 4. Monitor progress and revise the strategy. Substeps include to build a monitoring framework, evaluate progress and impact, and share results and revise the strategy.

Case studies from Namibia, Uruguay, Malaysia, and Germany, as well as examples of bioeconomy strategic documents from other countries, illustrate the process. A list of resources is provided to support policymakers in developing, implementing and monitoring their bioeconomy strategy.

Chapter 1. Introduction

THE RATIONALE FOR A TRANSITION TO A SUSTAINABLE BIOECONOMY

A shift to a sustainable bioeconomy offers an opportunity to realign the economy so that it respects the limits of the biosphere. Unsustainable production and consumption patterns based on fossil fuels and other non-renewable resources are rapidly depleting the world's natural resources including agrifood systems[1]. The planetary ecosystem is being pushed beyond its biophysical boundaries and socio-economic thresholds (Fanning, 2022), biodiversity is being lost, and global warming is increasing. This shift could help reverse decades of environmental degradation and reduce the accumulation of greenhouse gases in the atmosphere. Developing a sustainable bioeconomy also offers options for reducing hunger and malnutrition, boosting rural livelihoods, and stimulating innovation in the sound use of biological resources.

A transition to a sustainable bioeconomy can also be a means to socio-economic growth. According to Chui *et al.* (2020), over the next ten to twenty years, bioeconomy innovations in the fields of agriculture, food, human health, consumer products, chemicals and energy could have direct economic impact of between USD 2 trillion and USD 4 trillion globally per year. Bioeconomy can bring an opportunity to improve equity in economic growth and include the valuable knowledge of vulnerable people, such as indigenous communities and smallholder farmers. The World Business Council for Sustainable Development (WBCSD, 2020) estimates the total global market for food, feed, bio-based products, and bioenergy is expected to grow from USD 10.3 trillion in 2018 to USD 12.8 trillion in 2030, representing a 1.8 percent annual growth rate. The required biomass to fuel this growth is projected to increase from 23.4 billion tonnes in 2018 to 26.7 billion tonnes in 2030.

It should not be surprising that making a transition to a sustainable bioeconomy ranks high on the political agenda of many countries and regions (IACGB, 2024). The G20 countries have adopted the concept of the bioeconomy (Gardossi *et al.,* 2023). The G20 Environment and Climate Sustainability Working Group discussed three areas for consensus building: a global partnership, comprehensive bioeconomy metrics framework, and standards for international trade that supports developing countries that have the highest potential (G20 ECSWG, 2023). And the G20 Bioeconomy Initiative was formed in 2024 (GIB, 2024).

1 **Agrifood systems** encompass both agricultural and food systems and focus on both food and non-food agricultural products. Agrifood systems cover the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal. They comprise crop and livestock production, forestry, fisheries and aquaculture, as well as the broader economic, societal and natural environments in which these diverse systems are embedded (FAO, 2023).

FAO (2024) has identified, as of December 2023, around one-third of the world's countries (60–70) have formulated bioeconomy-related policies, of which 21 countries had developed a dedicated and holistic bioeconomy strategy and around 17 more are under development. Some countries may have a national law that mandates a bioeconomy strategy. In some cases, a supranational regional may have been formulated that requires a national strategy or a set of local strategies to implement it.

Many more countries have integrated the bioeconomy into other national policies and sustainable development strategies to meet the targets of the Paris Agreement on climate change, national reports on progress being made to achieve to the Sustainable Development Goals (SDGs), national food systems pathways, and national biodiversity strategies and action plan. For example, bioeconomy figures in 22 countries have identified bioeconomy as a means to address long-term emission reduction objectives, in their Long-term Low Emissions Development Strategies (LT-LEDS). that The most recurrent bioeconomy elements include the emphasis on sustainable resource utilization, integration of circular economy principles, promotion of renewable energy production from bio-based resources, investment in research and innovation, incorporation into climate change mitigation and adaptation strategies, and recognition of its role in economic development and job creation. often figures in long-term low emissions development strategies, nationally determined contributions (NDCs).

In general, putting in place a holistic and dedicated bioeconomy strategy is seen as a way of creating opportunities for coordinating all bioeconomy efforts and initiatives across sectors and institutions. The bioeconomy strategies tare necessarily cross-sectoral and they pave the way to make trade-offs in a transparent manner, ensuring that no one is left behind. Bioeconomy is always a framework that includes all actors in all sectors that have a stake in the management of biological resource and the production, utilization, conservation, and regeneration of biomass (see Box 1).

BOX 1. Overview of the main sectors included in bioeconomy strategies

The International Standard Industrial Classification of All Economic Activities (ISIC) developed by the Statistics Division of the Department of Economic and Social Affairs of the United Nations (UNDESA) has classified macro-categories of economic activities and the associated sectors (UN, 2008). Many of the sectors included in ISIC fall are connected to the bioeconomy. The sectors that are most often analysed and included in the bioeconomy strategies that FAO has reviewed are included in Figure 1 and below:

Primary production sectors

This includes agriculture, forestry and fisheries and aquaculture and centres on the production of food and non-food biomass. These are considered bioeconomy sectors for three main reasons:

- they provide biomass;
- many bio-based products are produced for use in the sector itself, e.g. compostable mulching film, biofertilizers, biopesticides; and
- they are the first sectors affected by environmental degradation, undermining their capacity to provide good quality and consistent quantity of biomass, food, and ecosystem services.

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Secondary sectors (bioindustries)

This concerns all the sectors involved in biomass processing including:

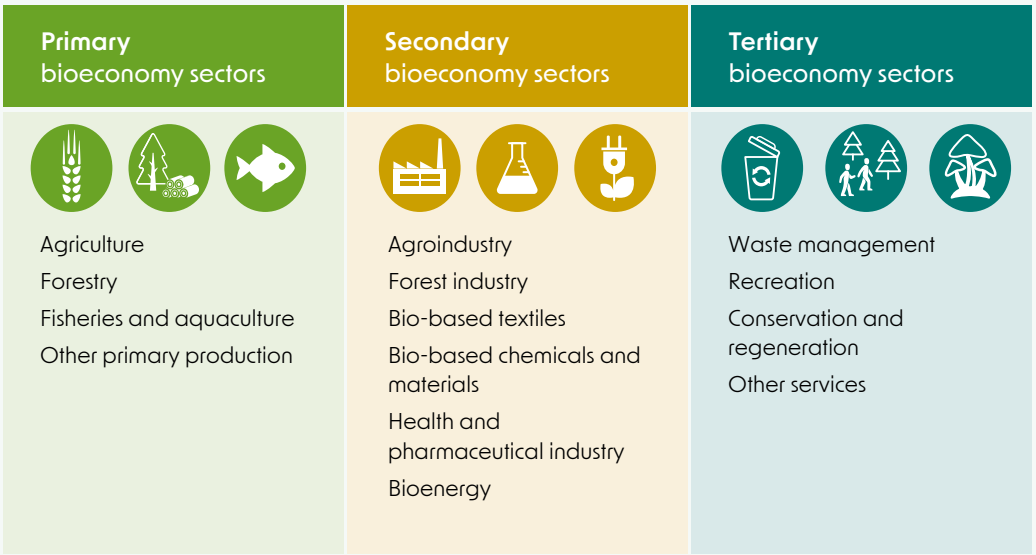
- food and agroindustry and the forest industry (e.g. pulp and paper, bio-based furniture and bio-based construction);
- bio-based textiles, chemicals, and materials:
- health and pharmaceutical industry; and
- bioenergy.

Along with the biomass that is processed, other inputs used in these industries may also be of biological origin (e.g. enzymes and bacteria for chemical reactions through fermentation, or plant extracts for tanning of textiles).

Tertiary sectors

These sectors cover services including waste management and recreation (e.g. parks, forests, sustainable ecotourism, wildlife conservation). In recent years, the tertiary sectors have increased their share in the global bioeconomy. There has been an emergence of second-generation feedstock obtained from waste, which can increase efficiency in the use of feedstocks. As a result, waste management and materials recovery have become a critical component in the development of a bioeconomy. The tertiary sectors also include the conservation, regeneration and restoration of biological resources, biodiversity, and ecosystem services. Some countries also include other activities such as food services, training and education on the bioeconomy, research and data collection, and biosecurity monitoring.

FIGURE 1. Sectors included in a bioeconomy



Source: Author's elaboration based on **UN (United Nations). 2008.** *International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4.* Statistical Papers Series M. New York, United States of America.

Source: Author's elaboration based on **UN (United Nations).** 2008. *International Standard Industrial Classification of All Economic Activities (ISIC), Revision 4.* Statistical Papers Series M. New York, United States of America.

By adopting a range of measures dedicated to developing a sustainable bioeconomy, governments create favourable conditions for investment in pioneering technologies and practices. These innovations can spur the development of new value chains and stimulate consumer demand for products sustainably made from and with biological resources.

Many strategies emphasize the role of science, technology, and innovation in the development of a bioeconomy with different types of actions (see Box 2).

BOX 2. What is meant by science, technology, and innovation in the bioeconomy?

Looking at the bioeconomy definition, scientific research, technological applications, bio-innovations, and traditional and new knowledge are at the center (Gomez San Juan and Bogdanski, 2021). In summary, bioeconomy science, technology and innovation include:

- Bioeconomy science

  Biological and life sciences, bioengineering, bio-based systems design, agricultural economics and other related sciences.

- Bioeconomy technology

  Biological, digital and engineering solutions that are scientifically validated, and designed with consumers, will contribute to efficient and sustainable use of biological resources, equitable value-added production, and reduced pollution.

- Bioeconomy innovation

  Technological, social, policy, institutional, and financial innovations; bio-based innovations (e.g. microbiome applications, plastic alternatives, and alternative sources of protein, inter alia) to promote interdisciplinary and cross- sectoral knowledge exchange for increased productivity, address One Health issues and ensure natural ecosystems are sustainably managed.

For successful bioeconomy development, there are three areas of action that are central for science, technology and innovation:

- Building the evidence base, on which decisions are made concerning the application of bioinnovations. Focus needs to be placed on supporting the implementation and uptake of transformative practices and the transfer of bioeconomy knowledge and technology from other regions. For example, linking research, development, and innovation to industries and markets, and connecting agrifood actors to support participation in global research programmes in breakthrough areas (e.g. novel foods, nature- and climate-friendly urban agriculture and the built environment, and sustainable aquaculture) and bringing transformative technologies and products to consumers in an inclusive manner.
- Expanding knowledge and awareness on the benefits and risks of commonly available sustainable bioinnovations. For instance, FAO (2024) shows that about one-third of the actions in bioeconomy strategies are closely linked to enhancing technology and innovation, especially in the secondary sector (54%), which includes bio-based industries. Additionally, 16% of the measures focus on the primary sector like agriculture and forestry, with 22% being cross-sectoral, showcasing the bioeconomy's integrative approach.

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- Providing support to the most sustainable bioeconomy innovations so that they move 'from the lab to the market' and attract investment. For example, public–private partnerships on bioeconomy for food security and nutrition, rural development, sustainable agriculture, and the efficient use and sustainable management of natural resources can be promoted to deploy good practices and technologies.

Source: Author's elaboration based on **Gomez San Juan, M. & Bogdanski, A.** 2021. How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies. Rome, FAO. https://www.fao.org/documents/card/en/c/cb5798en

BIOECONOMY STRATEGIES AND THEIR SUSTAINABILITY OBJECTIVES

The objectives laid out in bioeconomy strategies are determined by the specific social, economic, and environmental conditions in the area targeted by the strategy. As noted, the strategies also aim to narrow sectoral approaches to development to a broader more systematic approach to sustainability that integrates a range of sectors. The bioeconomy strategies currently in place also aim at promoting bio-based innovation. They always highlight the need to make a transition to a new type of economy which relies more in nature, and in ways that contribute to achieving the SDGs. Realizing this system-wide transformation will involve the coordinated actions at the local and global levels and demand broad participation from representatives from all economic sectors and social groups (Dietz *et al.*, 2023).

The 2021 FAO publication, *How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies* identifies the fifteen most common objectives in bioeconomy strategies and links these objectives with the *Aspirational Principles and Criteria for a Sustainable Bioeconomy* and SDGs, at target level. For more details on this publication and other FAO bioeconomy documents, see the Chapter 4.

In most cases, these objectives include to promote a shift from fossil fuels and non-renewable resources to bio-based feedstocks and biomass that can be produced sustainably. Other common objectives are improving food security; reducing pollution and waste; creating opportunities for decent employment; improving economic competitiveness while at the same time reducing competition for biological resources by valorizing and using these resources more efficiently; supporting rural and territorial development; strengthening inclusivity and equity; and accelerating innovation as well as data collection and analysis.

When the strategic sustainability objectives are translated into concrete proposals, trade-offs and synergies often become apparent. These trade-offs occur both within and between economic sectors, and within and between the different dimensions of sustainability. For example, the right balance may need to be struck between enhancing agricultural production and processing and implementing action on climate change; between increasing agricultural efficiency and promoting rural employment; between the recovering and using nutrients from waste and wastewater and safeguarding human health and soil quality; and between making changes in land use and maintaining ecosystem services. Social and economic trade-offs may also need to be made to ensure consumer acceptance for the introduction into local markets of innovative bio-based products as substitutes for more familiar fossil-based resources or environmentally damaging products.

A bioeconomy strategy will need to identify the potential trade-offs and synergies involved in reaching the strategic objectives. And just as the objectives will be context specific, so too will be the range of available options for mitigating trade-offs and maximizing synergies. The multi-sectoral nature of the bioeconomy makes it necessary to consider the relationships between technical, ecological, economic, and social factors when looking for suitable sustainable options.

Developing a bioeconomy strategy is a complex undertaking. Compounding this complexity is the fact that bioeconomy terminology and definitions may vary between countries.

In the 2020 Global Bioeconomy Summit Communiqué prepared by the International Advisory Council on Global Bioeconomy (IACGB, 2020a) **the bioeconomy is defined as**:

> the production, utilization, conservation, and regeneration of biological resources, including related knowledge, science, technology, and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy.

This is the definition that was adopted in the FAO Strategic Framework 2022-31 (FAO, 2021a).

Similarly, there is no universally recognized definition of **what is meant by a bioeconomy strategy**. In general, strategies are programmatic documents that outline the building blocks and strategic directions for developing a bioeconomy in a given territory, country or region. Despite naming and legal distinctions between bioeconomy strategies worldwide, these documents reflect the respective countries' commitment to develop a bioeconomy, domestically and internationally. For the purposes of this study, a "bioeconomy strategy" is defined as "*a programmatic document that outlines the building blocks and strategic directions for deploying a bioeconomy in a country*." In its fourth Global Bioeconomy Policy Report, the International Advisory Council on Global Bioeconomy (IACGB, 2020b) identify four defining elements of a strategy:

1. long-term consequences;
2. a significant relationship to a central purpose;
3. a defined acting subject; and
4. a concern with choices and prioritization.

Moreover, common structures in bioeconomy strategies include a vision and mission, a list of objectives, targets and actions, and an action plan with a stakeholder map and identified financial resources, as well as indicators to monitor its progress.

One of the key elements of implementing the strategies is the identification of financial resources, in particular for deploying technologies that are sustainable and support social, economic and environmental aspects at the same time. Box 3 provides examples of different financial instruments and explains the importance that these instruments should be chosen to suit the objectives of the bioeconomy strategy.

BOX 3. Examples of financial instruments in bioeconomy strategies

A study conducted by European Investment Bank (2017) finds that bio-based industries have difficulties in accessing private capital. The main barriers for access are investors' lack of understanding around the dynamics of bio-based industries and the difficulties that private equity faces in assessing risk associated with innovative projects. Also, in Latin America, public funds are the main financing source for bioeconomy development (Rodríguez and Aramendis, 2019). According to these authors, access of bio-based enterprises to venture capital should be encouraged so that innovative projects can compete on equal terms with traditional, fossil-based activities.

- Public–private partnerships

  Collaborative mechanisms between public sector and private investors and between different private actors can particularly help in the initial stages of development of the innovative business models. Instruments that target private sector initiatives usually consist of funds, typically in the form of grants or loans, that prioritize eligible projects according to the objective of public policy. The aim is usually to promote investment in infrastructure and soft, intangible skills development (e.g. research and development, entrepreneurship and business incubation, innovation promotion).

- Public procurement

  Public purchasing requirements for bio-based products are part of purchasing requests, agreements, contracts, specifications and other procurement vehicles of public agencies. Normally there is a catalogue (such as the one described in substep 3.2).

- International financing

  Global funds, such as the Green Climate Fund (GCF) and the Global Environmental Facility (GEF), can support climate and environmental goals of national bioeconomy strategies. Activities funded by GCF are related to climate change mitigation and adaptation. The GEF has a broader focus and provides funding for initiatives that protect biodiversity, promote climate action, or support sustainable resources management.

Source: Author's elaboration based on **EIB (European Investment Bank).** 2017. *Access-to-Finance conditions for Investments in BioBased Industries and the Blue Economy*. Prepared for: DG Research and Innovation European Commission. By: Innovation Finance Advisory European Investment Bank Advisory Services. Luxembourg. https://www.eib.org/en/publications/access-to-finance-conditions-for-financing-the-bioeconomy and **Rodriguez, A. G. & Aramendis, R.H.** 2019. *El financiamiento de la bioeconomía en América Latina Identificación de fuentes nacionales, regionales y de cooperación internacional.* Serie Recursos Naturales y Desarrollo, N° 193 (LC/TS.2019/82), Santiago, Comisión Económica para América Latina y el Caribe (CEPAL). https://repositorio.cepal.org/server/api/core/bitstreams/7b2687e5-9a49-49e2-a60d-310239a57678/content

A TOOLBOX FOR BIOECONOMY STAKEHOLDERS AND POLICYMAKERS

The objective of the FAO Bioeconomy Toolbox is to guide stakeholders in making decision in the development of their bioeconomy. The target audience of this toolbox is not only those who may have already developed a bioeconomy strategy; but also those who are in the process of developing one and those who may be considering initiating the process.

Chapter 2 outlines the four main steps and their substeps to guide policymakers in developing a shared vision and definition of bioeconomy for their country or region in consultation with a broad range of stakeholders, as well as setting objectives, targets and monitoring frameworks. It also includes guidance on how to ensure implementation on-the-ground.

Chapter 3 provides case studies from three countries where the FAO project, *Towards Sustainable Bioeconomy Guidelines* has given technical and policy support in the development of bioeconomy strategies (Namibia, Uruguay, Malaysia) as well as a case study from Germany, the resource partner that has supported the project. This chapter also includes examples of bioeconomy strategy documents from other countries.

Chapter 4 provides a set of resources that can be consulted and used in the development of the bioeconomy strategy.

Chapter 5 offers a conclusion and proposes some next steps. The ultimate goal of this toolbox is to encourage international commitments to scale up efforts to achieve sustainable bioeconomy. It is a call for action to develop, implement and monitor sustainable bioeconomy strategies. Currently there is no repository for bioeconomy strategies worldwide nor a common method for accountability for bioeconomy strategies. Even though bioeconomy strategies will necessarily be context specific, there remains a need for common structure that can allow for a coordinated mechanism to analyse the effectiveness and the bioeconomy strategies.

THE METHODOLOGY

The Bioeconomy Toolbox was partly developed based on the experiences gained by the FAO bioeconomy team in its collaboration with partner countries in the FAO *Towards Sustainable Bioeconomy Guidelines* project. As noted, the project has worked in three countries, Malaysia, Namibia, and Uruguay. Valuable insights have also been gained on bioeconomy strategy development through the Organization's collaboration with other countries and regions that are members of the International Sustainable Bioeconomy Working Group (ISBWG).

The Project has produced several resources that have been crucial in the preparation of the Toolbox, notably the 2016 publication, *How sustainability is addressed in official bioeconomy strategies at international, national and regional levels. An overview*, and a review of bioeconomy strategies worldwide that has been made available through an online *Dashboard on bioeconomy strategies and related actions for sustainable development*. These resources, along with others, are listed in Chapter 4.

Two other documents have provided useful insights in the preparation for the Toolbox:

- *Bioeconomy: Exploring the potential of emerging biotechnologies for driving sustainable economic growth.* A methodological guidance for the design of sub-national or local bioeconomy strategies and the assessment of local resources and capacities (IDB, 2023).
- *Deploying the Bioeconomy in the EU: A framework approach for bioeconomy strategy development. 10 policy recommendations for building national bioeconomies toward a fair and just climate neutral Europe.* A set of recommendations for translating regional strategies into national ones and to implement action on-the-ground (EC, 2021).

Both publications (further explained in Annex 1) target policymakers and outline step-by-step approaches for developing bioeconomy strategies and attracting investment by identifying potential new value chains and business models. The IDB guidance document focuses on stakeholder engagement and bioeconomy hubs for co-designing bioeconomy strategies for subnational territories. The EC framework approach, on the other hand, focuses on translating supra-national or regional strategies into national strategies by promoting good governance and building transformative coalitions.

Some of the steps and substeps laid out in this toolbox overlap with the steps described in these two sources. A summary of the steps used in these two documents is provided in Annex 1. However, the present toolbox, which seeks to offer guidance to decision-makers at all levels of government and provide insights gained from experiences from countries from different regions, has been prepared to address areas that these documents do not cover.

This toolbox offers resources, networks and tools that can support the development and implementation of sustainable bioeconomy strategies. Some of these resources, networks and tools have been developed by FAO, while others by its partners, such as research and academic institutions, countries, regions, private sector entities, etc.

Chapter 2. The four-step approach to developing a bioeconomy strategy

In this toolbox, the approach for formulating and implementing a bioeconomy strategy is divided into four steps, with each step divided into three substeps; from the establishment of a governing body, and the formulation of a holistic bioeconomy strategy document, to the implementation of the planned interventions through an action plan that includes policies and practices, and the monitoring, evaluation and revision of these. In each step, FAO publications on how to mainstream sustainability into the process are presented.

Step 1. Set up a governance mechanism and dedicated institution

- Substep 1.1. Initiate a participatory process
- Substep 1.2. Create a vision and sustainability objectives
- Substep 1.3. Agree on a definition

Step 2. Devise the strategy

- Substep 2.1. Map the bioeconomy potential and data
- Substep 2.2. Select the main elements of the strategy
- Substep 2.3. Write the final document

Step 3. Implement with an action plan

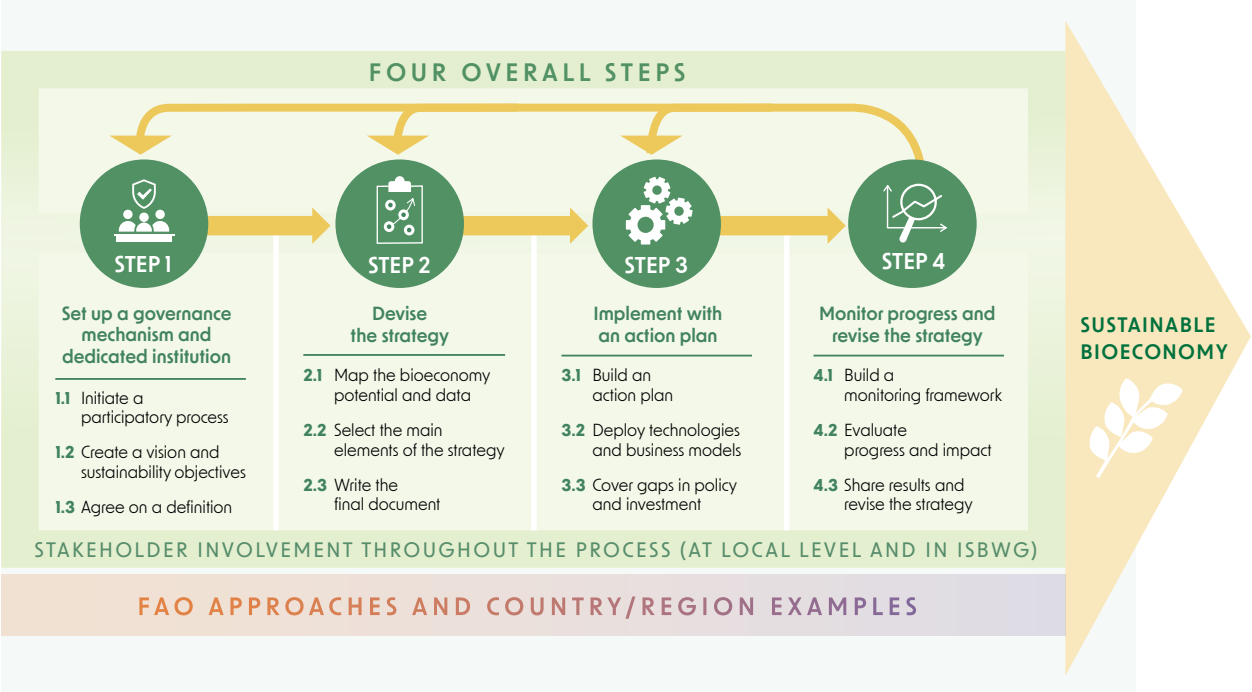
- Substep 3.1. Build an action plan
- Substep 3.2. Deploy technologies and business models
- Substep 3.3. Cover gaps in policy and investment

Step 4. Monitor progress and revise the strategy

- Substep 4.1. Build a monitoring framework
- Substep 4.2. Evaluate progress and impact
- Substep 4.3. Share results and revise the strategy

This process guides policymakers and other stakeholders in the development of local, national and regional sustainable bioeconomy strategies and the main tools and FAO approach at each step. The process is visualized in Figure 2 and in Appendix 1.

FIGURE 2. FAO's step-wise approach for the development of sustainable bioeconomy strategies



Source: Author's own elaboration.

STEP 1. SET UP A GOVERNANCE MECHANISM AND DEDICATED INSTITUTION

Establishing a participatory and collaborative governance mechanism is a critical element of any effective bioeconomy strategy. Governance, which influences decision-making and the coordination of policies, is the process through which diverse interests are accommodated and cooperative action is taken. A good governance process, along with bioeconomy-dedicated institutions within governments that determine the rules, norms and organizational structures, will shape better the bioeconomy strategy.

As noted in the introduction, bioeconomy strategies are intended to transform the entire economic system in a given area so that is more sustainable and equitable. There are many knowledge gaps and uncertainties about how exactly this transition will be achieved, especially as this transition will be shaped by the particular social and economic factors within a given context. Navigating this transition will necessarily involve making trade-offs. In a transition towards a sustainable bioeconomy some activities, processes or materials may lose social or economic value or are substituted by new ones. These changes will likely negatively affect some stakeholders.

This is why good governance is crucial. Proper governance will help ensure that opportunities and trade-offs, especially those that have not been foreseen, are adequately assessed, and accounted for. A good governance mechanism contributes to the formation of effective multistakeholder governing bodies that can lay solid foundations for formulating an equitable bioeconomy strategy. The aim is to design and implement harmonized and integrated policies and programmes, across different sections of society and different sectors of the bioeconomy. Good governance mechanisms ensure that the ground rules for making the shift to a bioeconomy are based on sound, just principles that have been agreed by all stakeholders contribute to promoting ownership and ensure that no one is left behind.

The United Nations (2009) has identified eight characteristics of good governance in decision-making: participation; rule of law; transparency; responsiveness; consensus oriented; equity and inclusiveness; effectiveness and efficiency; and accountability. The governance mechanism established during the process of formulating bioeconomy strategy should reflect all these characteristics.

The importance of good governance is not unique to bioeconomy. Countries may be able to draw on existing inclusive processes and governance mechanisms in the wider sustainable development context when looking at developing a bioeconomy strategy. Good governance can also help to achieve longer-term political commitments that may extend beyond the timeframe of the bioeconomy strategy.

A summary of this step, substeps and required inputs is presented in Figure 3.

SUBSTEP 1.1. INITIATE A PARTICIPATORY PROCESS

The first step in setting up an overarching inclusive and accountable governing body is to initiate a participatory process that can clearly define the commitment and level of engagement required from different segments of the government and non-government stakeholders. This process will determine who leads the process; what form the final strategy document will take; and how the strategy will be implemented.

The process can start with the formation of a core *interministerial group* with members from different ministries and policy-making agencies. This will often involve one or two ministries taking a lead role. This core group should then be expanded to form a wider *multistakeholder group* whose members are drawn from outside of the government. This group will include representatives from the private sector, civil society organizations, think-tanks, non-governmental organizations, producer organizations, academia, and financial institutions. In particular, experts in land and water tenure, and other types of access to natural resources should be included to ensure that bioeconomy strategy promotes access of local communities to natural resources and safeguards their rights to use these resources sustainably.

The group established through this the participatory process should reflect a diversity of perspectives and expertise. This diversity is essential to ensure the transition to a bioeconomy supports the realization of the complete range of national sustainability goals (e.g. decent and green employment, inclusive economic growth, carbon neutrality, biodiversity conservation).

It is also important to create spaces for building collective bioeconomy awareness and leadership in co-designing and implementing a bioeconomy strategy. This can involve the establishment of formal platforms for engaging stakeholders. Also, bioeconomy councils, panels and fora can ensure ongoing engagement in implementing, monitoring, and evaluating bioeconomy strategies and action plans. Other structures that can support long-term bioeconomy development are territorial or subnational hubs that share a large ecosystem and its biological resources and services. There are different factors that make a group become part of the strategy, such as stakeholders who have some authority over the system or resources (e.g. government), stakeholders that produce or use the products and services (e.g. professional associations or consumers) and stakeholders who become involved over time (e.g. youth).

The country or region may embed the governance mechanism within an institutional body dedicated to the bioeconomy. This is often required because the transition to a sustainable bioeconomy may not fall neatly under the responsibility of a single government department. A key challenge is to build into this mechanism collective leadership capacity that supports innovation, coordination, and communication (Johnson *et al.*, 2022). Regional (supra-national) strategies and related governing bodies can guide the development of national bioeconomy strategies, action plans, and roadmaps and ensure high-level political commitment.

A dedicated bioeconomy institution that ensures the application of good governance principles can bring stability and long-term commitment to bioeconomy development that outlives electoral cycles. The participatory process serves to build a dedicated long-lasting wider multistakeholder group with a clear mission. It is important to build a participatory process with a clear structure and engagement modalities, as the stakeholders should set a common

bioeconomy vision for the country or region, agree on sustainability objectives and a clear definition of bioeconomy, which are the next substeps that need to be taken.

A thorough stakeholder analysis should be carried out to select the most appropriate stakeholders for the wider multistakeholder group and ensure that the expertise within this group is well balanced. Stakeholder mapping includes the identification of stakeholders and their roles in addressing an identified problem, the analysis of their functions within a system, and the selection of which role each should have (Lelea *et al.*, 2014). The priorities of selected stakeholders will articulate the group's mission and frame its terms of reference. The role of an individual within the core stakeholder group may change over time. The stakeholder mapping and analysis should be considered as an iterative process and may need to be repeated as the strategy evolves. There are several approaches to stakeholder mapping and building networks. For instance, net maps and venn diagrams represent existing linkages between stakeholders and the level of cooperation using circles that intersect and relationship flows. Another example is the power–interest matrix that maps stakeholders based on questions, such as how interested the stakeholder is in the achievement of a bioeconomy objective (Lelea *et al.*, 2014).

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- The FAO *Towards Sustainable Bioeconomy Guidelines* project has led multistakeholder processes in the field work conducted in Uruguay and Namibia . Chapter 3 offers a summary of this work in pilot countries.

SUBSTEP 1.2. CREATE A VISION AND SUSTAINABILITY OBJECTIVES

The socioeconomic context and the institutional structure of the country or region will determine the composition of the bioeconomy governing body or institution, and will also influence the strategic objectives of the bioeconomy strategy.

In this substep, the context-specific sustainability objectives are clearly outlined. These objectives will be achieved through the eventual implementation of the bioeconomy strategy, since actions will be designed around them. This substep includes an analysis of the synergies and trade-offs among the different potential objectives and takes into consideration specific local conditions and proposes appropriate initiatives.

Often, objectives may reflect commitments that have been made by national governments in multilateral environmental agreements. Also, specific aspects of sustainability (e.g. food security or the competition and synergies among biomass end-use sectors) are covered by fewer strategy documents than broader topics such as climate action or economic growth (Dubois and Gomez San Juan, 2016). Other objectives of some strategies may be driven from by groups from outside the government and be spearheaded by industry. The objectives set in this substep are often long-term goals that are later broken down into targets when selecting the main elements of the strategy (substep 2.2).

Potential trade-offs and synergies which bioeconomy aims to address are manifold and context-specific, including agricultural production vs. climate change action, agricultural productivity vs. employment, nutrient recovery from waste and wastewater vs. human health and soil quality, and land use vs. ecosystem services. Socioeconomic trade-offs also occur in the substitution of

fossil-based or polluting products with bio-based ones, such as economies of scale vs. social acceptance. Most bioeconomy strategies are based on the need to reduce these tradeoffs and balance a reduced dependence on fossil resources with inclusive economic growth, climate and biodiversity action, and enhance the role of new and traditional knowledge, science, technology and innovation.

The governance mechanism should outline concrete action areas that address the problems or challenges identified within each sector of the bioeconomy and set a path to achieving bioeconomy objectives. The problem statement and strategy objectives form what is often called 'the vision' of the strategy. Ultimately, a shared vision of what a future bioeconomy could look like in the country or region should be co-created by governmental and non-governmental experts. Gathering gather expert opinion is needed to formulate different visions and find consensus towards a common articulation of the final text.

Examples of methods for creating a shared vision are argument mapping and the visioning exercise. They encourage contributions when there is a large group of stakeholders and can help to visually represent the logical structure of an argument to increase clarity and improve communication (FAO, 2013).

Ex ante assessments and modelling analysis tools can help in projecting the best outcomes under different pathways and allow for selecting the most appropriate objectives of the strategy. These tools can be used not only when creating an overarching vision and defining the objectives of the bioeconomy strategy but during other steps that require *ex ante* assessment models to predict and make the best choices. Chapter 4 and Annex 2 provide *ex ante* assessment tools and modeling tools from FAO and partners with links that can be used to assess the transition to a bioeconomy. There are three principal types of modelling tools: economic models, environmental models, and integrated assessment models (Angenendt *et al.*, 2018):

- Economic models can be general equilibrium models (which allow for the assessment of direct and indirect effects of the behaviour and interactions of suppliers and consumers for all economic sectors); partial equilibrium models (which focus only on one sector of the economy, making them less relevant for the bioeconomy); input–output models (which are simplified representations of the economic system and linkages between activities showing effects of interrelated activities in the aggregated GDP); and agent-based models (which focus on the behaviour of certain type of actors of the economy, e.g. households or producers, and assess the impact of their decisions in the aggregated system).
- Environmental models range in their scope. Examples of environmental models include earth-systems models (which capture the impacts of human activities and different land-use systems in environmental variables, particularly climate change), biophysical models (which simulate the behaviour of biological, animal, geological or chemical systems, and can go from farm to global level), and spatial land-allocation models (which study the process of occupation, substitution or transformation of land use).
- In between economic and environmental models are integrated assessment models. The purpose of integrated assessment models is to replicate interlinkages between productive activities by sector, biophysical and environmental systems and simulate impacts in all of them simultaneously. This type of model captures synergies and trade-offs among systems and activities over a long term. Usually, integrated assessment models combine multisectoral

analysis with analysis of the three dimensions of sustainability at once, which makes them particularly useful for bioeconomy. There are other tools such as bottom-up analysis that are based on linear programming methods and help answer questions of optimization of single technologies (e.g. determination of the optimal volume of input to be processed in a biorefinery). Also, footprint analyses use a standardized procedure to quantify the amount of a certain resource used by different activities or users, at different scales.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- The *Aspirational Principles and Criteria for a Sustainable Bioeconomy*, provide a crucial checklist of issues to consider when developing a vision for a sustainable bioeconomy.
- Another publication prepared by the project, *How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies*, identifies fifteen of the most common strategic objectives, mapping them against the principles and criteria and SDG targets.

SUBSTEP 1.3. AGREE ON A DEFINITION

An operational definition of bioeconomy must be agreed upon to support the objectives set up by the core interministerial group and/or the wider multistakeholder group. The definition can also help define from an early stage some of the boundaries that will help in Step 2, when key sectors and focus areas are selected.

The definition is often used as the basis for a mission statement that articulates a long-term commitment and can be included in national strategies, for example to achieve carbon neutrality or low-emission development. That is why the strategy objectives are selected in the previous substep.

The definition that was proposed by the International Advisory Council on Global Bioeconomy at the 2020 Global Bioeconomy Summit and adopted by FAO was given in the previous chapter.

The discussions on a bioeconomy definition will need to consider:

- the purpose of developing a bioeconomy strategy;
- the main target group or beneficiaries of the strategy; and
- the level of commitment by different mapped stakeholders (e.g. the main ministries, industrial coalitions, research institutions and other actors that will be involved in the implementation of the action plan Step 3.

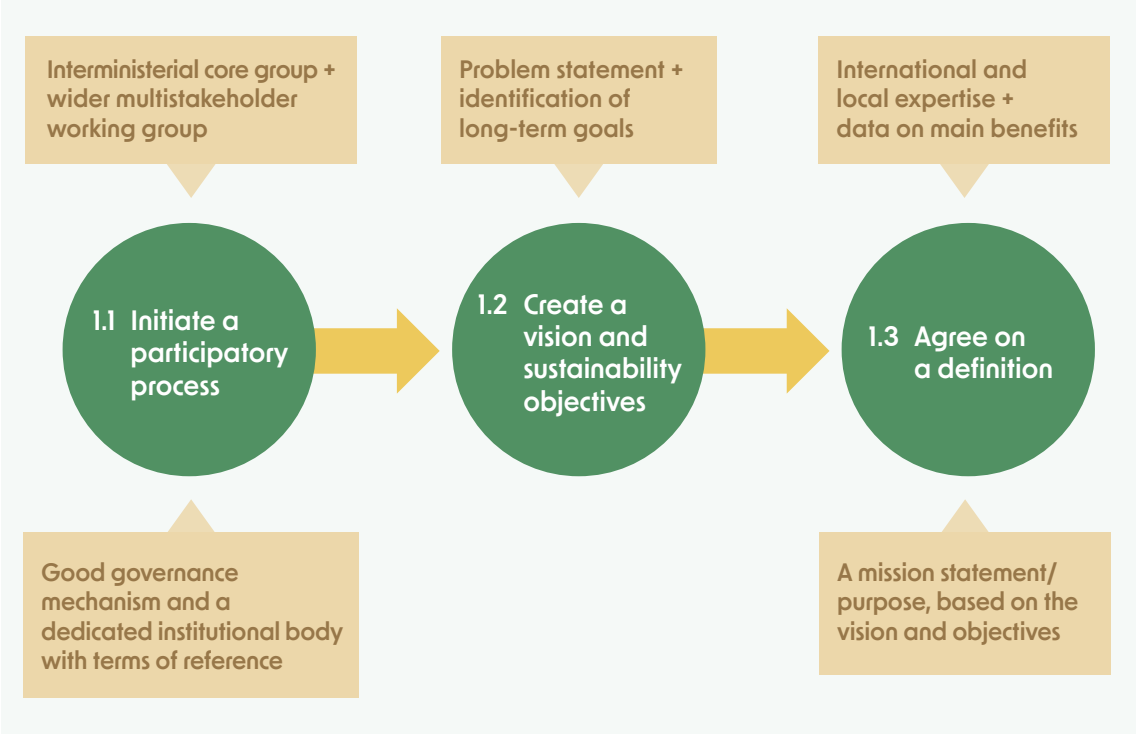
Examples of methods that can be used in the process of drafting a definition are the needs-fears mapping and brainstorming (FAO, 2013). They are used to gather evidence and background information on the most pressing local and global issues and challenges can help define the bioeconomy for a particular context. The process should also be informed by data and literature reviews.

International experts and consultations can support and provide feedback and inputs in this step and in the other steps in the development of the bioeconomy strategy (Lang, 2022).

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- Several FAO publications try to explain bioeconomy principles and key concepts. The 2019 FAO publication, *Towards sustainable bioeconomy. Lessons learned from case studies,* includes a glossary of the main terms for framing the definition of the bioeconomy. Also, *Bioeconomy for a sustainable future* gives a brief overview of what sectors and activities are included in the bioeconomy, also in Box 1 of this publication.
- The publication *How to mainstream sustainability and circularity into the bioeconomy? A compendium of bioeconomy good practices and policies* outlines all the sectors and respective economic activities present in the GBS definition of bioeconomy, from research, to industry, services, policymaking and communications.
- Finally, the *FAO-led International Sustainable Bioeconomy Working Group (ISBWG)* supports defining the knowledge base to come up with a bioeconomy definition and fosters exchange on the process of bioeconomy deployment, including the initial purpose of developing a strategy.

FIGURE 3. Description of substeps under Step 1: Set up a governance mechanism and dedicated institution



Source: Author's own elaboration.

STEP 2. DEVISE THE STRATEGY

After defining the strategic objectives and analysing potential trade-offs, the next step is to identify and map the sectors, thematic areas and targets that will contribute to meeting the objectives and minimizing the trade-offs. The bioeconomy strategy should build a comprehensive and holistic framework that cuts across sectors. It is essential that the process of formulating the strategy document should consider the full variety of economic activities covered in the bioeconomy.

The process of devising the strategy will generate a range of potential options for developing the bioeconomy in the targeted geographical area. Evidence from the FAO database on bioeconomy strategies shows that different tools are used for mapping the bioeconomy potential and gathering data to inform evidence-based selection of sectors, targets, and priority thematic areas. The formulation of the strategy document, which should adhere to participatory processes to facilitate decision-making and strategic thinking, involves *ex ante* assessments that model or estimate the outcomes of the different options. This process will serve to articulate the concept of the bioeconomy in the target area, assess the current state of the bioeconomy and define the level of ambition of the strategy.

The most common methods for involving stakeholders and carrying out broad consultations in the formulation of the bioeconomy strategy are:

- guided discussion with policymakers and steering groups in charge of writing the document, which will make use of decision support tools (e.g. brainstorming and argument mapping):
- focus groups and thematic surveys to obtain feedback from a wider group of experts from civil society, the private sector, academia, international organizations, financing institutions, such as foresight analysis on bioeconomy innovations[2]; and
- workshops, conferences or fora to validate the final document.

A summary of this step, substeps and required inputs is presented in Figure 4.

SUBSTEP 2.1. MAP THE BIOECONOMY POTENTIAL AND DATA

Mapping and baseline assessments provide the foundation for mapping the future potential of the bioeconomy. The objective of this substep is to take into account the main sustainability objectives defined beforehand and identify the potential of the biomass value addition and local capacities to build bioeconomy value chains and value webs. Defining the criteria for mapping the policies based on strategic bioeconomy objectives is an action that is often overlooked, but it is one of the most important aspects that will define the rest of the strategy document. It is also aimed at identifying the potential of the biomass value addition and local capacities to build bioeconomy value chains and value webs (Virgin *et al.*, 2022).

Information needed for this step includes sustainable consumption and production data, such as biomass production, supply, uses and flows, determined using different indicators: 1) raw biomass

2 For more information, consult *Global Visions for the Bioeconomy – An International Delphi-Study*, available at https://gbs2020.net/wp-content/uploads/2021/10/GBS2015_02_Delphi-Study.pdf

dry matter equivalents that allow for comparison of domestic production and trade of biomass in different sectors; 2) biomass directly consumed and traded and bio- based waste used through biomass flows; 3) cascade uses for different products (agriculture, forestry and fishery products); and 4) share of bio-based inputs used for each sector with input–output analysis (Avitabile *et al.*, 2023 and Ronzon *et al.*, 2023).

Also, mapping and assessing existing policies is crucial for the design of the strategy. Three important characteristics of public policies support the implementation of the bioeconomy by multiple actors and in different sectors: policy coordination (achieving consistency and sharing information), policy coherence (harmonizing policy goals, instruments and beneficiaries) and policy integration (involving all stakeholders in the decision-making process, centralizing the design of the policy together to contribute to cross-sectoral objectives) (Cejudo and Michel, 2017). Market potential and sustainability analyses consists of determining if the commercialization of a bio-based good is feasible from both the supply and demand side, e.g. size of the market, segmentation, growth rate, demand trends, state of technology in the country, production cost, socioeconomic and environmental analysis of biomass production and consumption, policy framework and trade opportunities.

Some actions that can be taken to carry out mapping and baseline studies include:

- identifying the area (local, national, regional, etc.) If the system boundaries are well defined, bioeconomy strategies can be developed at any geographic scale. They can cover supra-national regions in which different countries share waterways (e.g. the Danube region), marine areas (e.g. the Baltic Sea), or biomes (e.g. the Amazon), national territories, or subnational and municipal territories;
- assessing existing biomass streams and other biological resources, their bioeconomy potential, and the biophysical boundaries to define 'sustainable' thresholds for biomass production and the use of biological resources. In-depth interviews with stakeholders play a key role in these assessments, along with a review of statistics;
- assessing the maturity level and the type of bioeconomy already existing in the area; the state of industrial, human and technological capacities; and the innovators who can having significant impact in transforming value chains;
- measuring the bio-based economic sectors and mapping their markets and products (e.g. their contribution to the total gross domestic product using bio-based trade tracking tools) and seeking out ongoing bioeconomy programmes, projects and initiatives and lead innovators (e.g. universities receiving public funding on bioeconomy projects that can identify local stakeholders and capture emerging ideas) that can serve as lighthouse projects to motivate others and establish a more robust enabling environment;
- assessing, by sector, the main industries in targeted geographical area, the employment they provide (amount and type), the land they use, their turnover and added value (EC, 2020);
- identifying value chains and value webs with the most potential for the targeted area, and new products and processing methods that could support the strategic objectives proposed for the bioeconomy strategy while still respecting local environmental boundaries; and

- carrying out a stocktaking and gap analysis of the existing policies that support or hinder and the development of the bioeconomy, identify the existing enabling mechanisms and resources and the capacities of implementing institutions, and analyse gaps in existing policies and identify initiatives that support bioeconomy implementation.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- FAO publication *How to mainstream sustainability and circularity into the bioeconomy? A compendium of bioeconomy good practices and policies*, provides guidance for policy mapping in a range of sectors and provides a survey template for selecting preferred actions.
- Databases, such as the *FAO Corporate Statistical Database (FAOSTAT),* can be used in to create scenarios and can support the mapping of bioeconomy products potential.

SUBSTEP 2.2. SELECT THE MAIN ELEMENTS OF THE STRATEGY

Based on the results of the baseline assessments, actions will then need to be taken regarding each of the objectives defined in Step 1. These actions will include:

- refining the outcomes of the strategic objectives;
- setting measurable targets and corresponding benchmarks, which will help to monitor progress and revise the strategy (Step 4);
- selecting the main sectors of intervention; and
- establishing boundaries for the main sectors of intervention, including value chains and value webs, and prioritizing the key thematic components or action areas.

These actions will contribute to the implementation of a bioeconomy action plan (Step 3). Option assessment tools can be used to identify issues that need to be addressed when selecting the main sectors of intervention and delineating their boundaries.

To compile a list of potential obstacles or national and regional challenges and value chain level and clarify the purpose of the strategy, stakeholders should collect background information by using:

- qualitative tools
  (literature reviews; expert interviews; wider stakeholder consultations)
- quantitative tools
  (survey data, statistical reports, environmental, social, and economic indicators)
- visual tools
  (maps that visualize the findings of data collected with geographical information systems)

Other actions that will need to be undertaken are:

- comparing the potential impacts of different options, which will involve scenario and modelling analysis, and outlining concrete action areas that address the problems and challenges that have been identified in relation to the proposed objectives;

- assessing past and future trends with extrapolative or forecasting tools, or statistical methods (e.g. time-series analyses);
- building consensus or 'consolidation', in which agreement is sought between the various policy formulators and other stakeholders and beneficiaries, involving multistakeholder consultations and the weighing up of several factors; and
- assessing potential solutions and identify the most suitable pathways to reach the vision and the objectives.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- Several FAO publications analise how sustainability goals are included in bioeconomy efforts around the world (e.g. *How sustainability is addressed in official bioeconomy strategies at international, national and regional levels*; *Sustainable and circular bioeconomy in the biodiversity agenda: Opportunities to conserve and restore biodiversity in agrifood systems through bioeconomy practices*; and *Sustainable and circular bioeconomy in the climate agenda: Opportunities to transform agrifood systems*) can be consulted to see how different elements of the bioeconomy strategies can relate to other sustainability issues at an international level.
- The *FAO Dashboard on bioeconomy strategies and related actions for sustainable development* also displays information on the different actions that are included in bioeconomy strategies at national, subnational and regional levels, mapping them against climate, biodiversity and food security criteria taken from international sources.

SUBSTEP 2.3. WRITE THE FINAL DOCUMENT

In Step 1, a stakeholder map and information were prepared to identify the main stakeholders who need to be consulted and when. In step 2, the multistakeholder group should be involved in each one of the three substeps to discuss the findings and actual writing of the document. International experts and consultations (e.g. with the ISBWG) can also support this work and provide feedback.

Depending on the type of document, including its legal form, either the group formed at the beginning validates the final document, or the strategy will have further endorsement by other government bodies, often by the cabinet of the head of government.

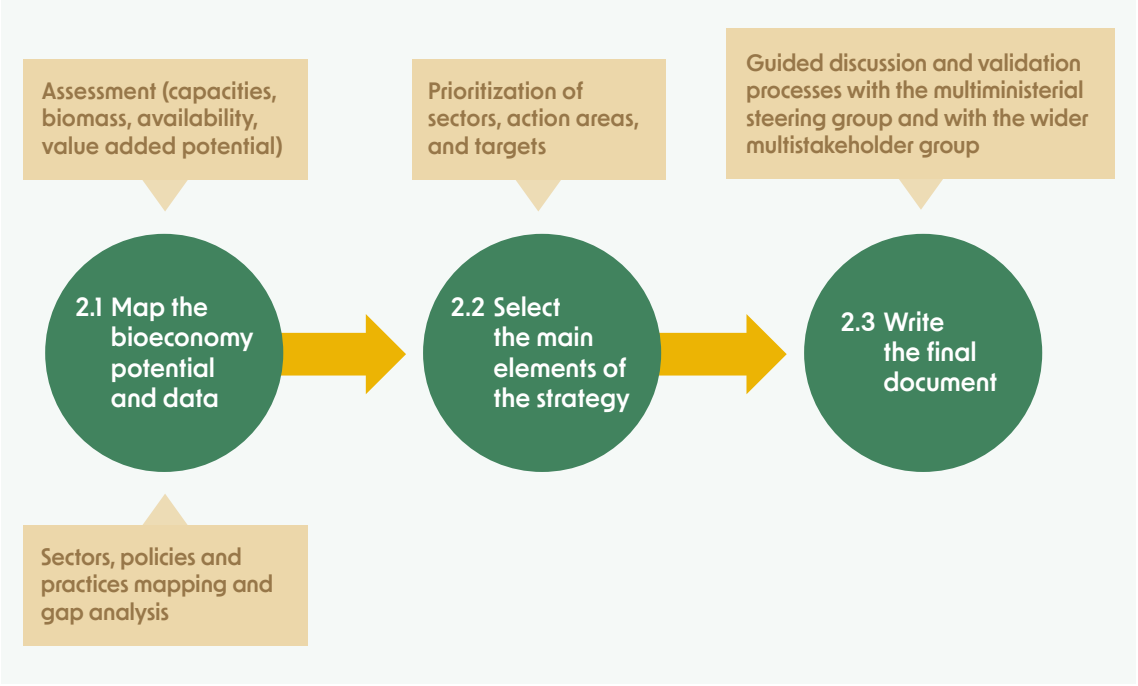
Flow charts that put together causal and logic information are useful to include in the final document. It is also advisable to include in the final document a logical framework matrix or logframe that provides a structure that helps consolidate stakeholder views into established assumptions, goals (or impacts), purpose (or outcomes), results (or outputs), and activities of a proposed strategy into a final document. It should also include the assumptions, the means of verification and other characteristics (FAO, 2013).

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- As with many steps in the strategy development process, international organizations such as the *FAO-led International Sustainable Bioeconomy Working Group (ISBWG)*, can provide support in making the final strategy document in a coherent way (see the international organizations, networks and consortia section in Chapter 4).

- *FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area* also has a network of experts that participate in international fora and platforms on bioeconomy and bioeconomy-related topics, capacitating different stakeholders.

FIGURE 4. Description of substeps under Step 2: Devise the strategy



Source: Author's own elaboration.

STEP 3. IMPLEMENT THE STRATEGY WITH AN ACTION PLAN

The implementation of the bioeconomy strategy will require the formulation of an action plan that will describe the measures to be taken at both the policy level and at the practical and technological level. The action plan will also indicate who is responsible for implementing the proposed measures and estimate the financial resources needed.

Policy instruments are the tools governments use to implement the actions to achieve their strategic objectives. Through policies (e.g. standards and regulations, or taxes and subsidies) governments seek to influence the behaviour of individuals and businesses. To be effective, policies should be tailored to the context in which they are applied. For instance, most of the policy instruments for the development of the bioeconomy are intended to promote bioinnovations; they are not explicitly designed to promote sustainability. Even if bioeconomy strategies and action plans claim to have a specific focus on sustainability in their overarching objectives, research suggests that the actions proposed in the strategies and their associated policy instruments mostly target the development and market uptake of bioinnovations, rather than specific sustainability actions. There is an assumption that bioinnovations in themselves will contribute to achieving sustainable development objectives.

The enabling environment catalyses action by creating conditions whereby policies can connect with the investment community, the private sector and other practitioners, farmers, innovation developers. etc. Evidence from the FAO dashboard on bioeconomy strategies and related actions for sustainable development (FAO bioeconomy dashboard) shows that some enabling factors are common to all existing dedicated strategies. If sustainability criteria are laid out already in the design of enabling environment mechanisms (e.g. conditions for investment and financial support), monitoring the performance will be easier and less expensive than impact monitoring.

Sometimes policy instruments outlined in bioeconomy strategies do not directly address sustainability. They may do so indirectly through additional requirements as part of current policies. For instance, granting a loan to an investor for a bioeconomy project does not lead automatically to a responsible action. However, if the loan is conditional on compliance with a range of environmental and social safeguards, it may turn into a 'green' policy instrument. Other policy instruments can directly impact the sustainability performance of bioeconomy. For example, certification schemes and labels can directly tell consumers whether a product has been produced according to specific environmental and social criteria.

To implement the strategy, scientific research should be carried out in parallel to provide continuous feedback on the most beneficial technologies and practices for the environmental and socio-economic context, and those that bring most opportunities for the bioeconomy transition. In addition, policies that create incentives and reduce barriers are critical for incentivising new bio-based sustainable products.

More and more countries are bringing the concepts of bioeconomy and circular economy together. For biological resources this means that stakeholders should 'cascade' the use of biomass. In this cascading use, the biomass should be processed in such a way that priority is given to the most valuable components, with the biomass considered both for its economic value and its social value (Gomez San Juan, Bogdanski and Dubois, 2019).

There are two core factors that support the effective implementation of the bioeconomy to achieve sustainability objectives:

- a policy, legal and regulatory environment that takes into account the interests of local communities and producers under current climate change and other local environmental and socioeconomic conditions and encourages the active participation of all actors; and
- the efficient use of biological resources in sustainable bio-based industries at all levels, with activities that aim to add value, reduce waste and address pollution to achieve sustainable consumption and production.

Most strategies do not venture into the development and implementation of specific bioinnovations. Instead, they outline a plan for a series of policies to build a national or regional bioeconomy framework with priority sectors, targets, and areas of action. In some rare cases where the formulation of the bioeconomy strategy is led by the private sector, specific plans for developing and deploying bioinnovations may be included.

A summary of this step, substeps and required inputs is presented in Figure 5.

SUBSTEP 3.1. BUILD AN ACTION PLAN

Bioeconomy strategy action plans are normally developed by the governance mechanism formed by a core interministerial group and/or a wider multistakeholder group.

The action plan is often part of the same document as the strategy but it can also be presented as separate documents. The structure of the action plan may follow the strategy document. In the action plan, it is good practice to have an annual or time-bound workplan that outlines roles and responsibilities and describes concrete projects and activities.

Dubois and Gomez San Juan (2016) identified that the three most common types of action plans are either a stand-alone document, or they are included in the strategy in the form of a list of actors and financing resources or in the form of measures within each action and within each objective.

In most action plans, activities and related policies are grouped under different sections. Examples include:

- research and innovation on specific bioinnovations;
- market creation and access for these innovations, and
- regulations and standards for supporting commercialization and stimulating demand for bioproducts.

Grouping activities and policies into sections can help to identify where a new policy or financing mechanism may need to be developed to address bottlenecks and pitfalls (substep 3.2). Action plans should also include activities related to monitoring and evaluation (Step 4). An example of an action related to monitoring and evaluation could be providing support to research institutions that can enable them to initiate or strengthen programmes to improve the national statistical system. Also, anticipating potential opportunities, as well as bottlenecks and pitfalls, can help to understand the potential needs and gaps.

When developing an action plan, it is an important to prioritize the actions within each objective and target. By evaluating the potential effectiveness of each action, the actions are prioritized according to the extent that they directly address the strategic objectives. The prioritization process could include a SWOT (strengths, weaknesses, opportunities, threats) analysis that can reveal when a particular objective is achievable and realistic (IDB, 2023). A robustness check of the SWOT matrix can be conducted through interviews with experts. To complement the SWOT analysis, the 'force field analysis' is another approach that can be used to gather expert opinions and forces for and against the desired change (FAO, 2013). For more details on force field analysis see Chapter 4.

A comprehensive list of financial resources that have been allocated for each action area is sometimes included in action plans. Another potential component of the action plan is an assessment of the financial support for the bioeconomy-related initiatives. The national budget can provide useful information on the sources of funding for the different initiatives and their sustainability over time. International cooperation funds can also provide financial resources. Substep 3.3. includes these and other important actions to consider in the planning phase already.

Lastly, action plans should clearly identify the actors responsible to the plan's implementation and the complete range of stakeholders and outlines their responsibilities for carrying out the priority actions in the plan. If the action plan extends over for several years, the plan should indicate the years in which concrete results will be delivered and intermediate milestones.

To select the stakeholder than will be responsible for the implementation of the strategy, the 'Rights, Responsibilities, Revenues and Relationships' (4R) framework can be used to analyse multistakeholders relations and identify potential issues and problems regarding power imbalances (Dubois, 1998; FAO, 2013). In parallel, a survey can be carried out to map good practices that already exist in the country (Gomez San Juan and Bogdanski, 2021). This survey will complement the policy map done when mapping the bioeconomy potential (substep 2.1).

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- Two FAO publications offer a compendium of lessons learned and good practices, which can provide insights on building an action plan: *How to mainstream sustainability and circularity into the bioeconomy? A compendium of bioeconomy good practices and policies*, and *How sustainability is addressed in official bioeconomy strategies at international, national and regional levels. An overview.*

SUBSTEP 3.2. DEPLOY TECHNOLOGIES AND BUSINESS MODELS

To prioritize the initiatives proposed in the action plan, a review should be undertaken of value chains or value webs.

Unlike value chains, which are linear and relate to the vertical or horizontal integration of different commercial products, value webs are territorial network that includes actors in all sectors of the economy (Gomez San Juan, Bogdanski and Dubois, 2019). The concept of a value web very useful for the bioeconomy. There are regions (e.g. West Africa where the focus is on biomass and Latin America where the focus is on research) that are already using it in their discussions and strategic documents on bioeconomy.

In the analysis of value chains, it is important to identify 'hot spots' for sustainability. Also, the prioritization of initiatives in the strategy and action involves the identification of specific challenges (e.g. gender issues, pollution hot spots, conflicts with Indigenous rights). As it is the case for all the steps in the development of the bioeconomy strategy, international experts and consultations can offer support and provide feedback and inputs for identifying sustainability hot spots.

Different types of analysis can be used to compare potential impacts of different options and to conduct risk assessments. Examples are cost–benefit analyses and related multi-criteria analysis (e.g. social cost-benefit analysis, economic cost–benefit analysis, cost–effectiveness analysis, cost–utility analysis and risk–benefit analysis). Cost–benefit analyses. They compare the costs and benefits of several interventions versus the current scenario, allowing comparison and the selection of the most appropriate pathway. The timeframe for social policies is usually long term (30 to 50 years) and is often determined by the useful life of investments in infrastructure required. Initial investment, costs and benefits are incurred in different years along the timeframe, so they need to be expressed in current monetary units. There are at last three summary indicators that can be obtained through the cost–benefit analyses: social net present value, social internal rate of return and social benefit/cost ratio. Other indicators can also be used, for example to encompass cost and benefits associated with gender equality or environmental co-benefits.

Also, life cycle assessments (LCA) are undertaken to determine the environmental impacts of bioproducts compared to current practices (e.g. a fossil-based material that is substituted for a bio-based one). The LCA evaluates the potential environmental impact from 'cradle to grave', i.e. from raw material provision and processing, to energy use and manufacturing, distribution, use, end-of-life treatment and final disposal; or from "cradle to cradle", when there is no disposal but it circulates back into the system (Gomez San Juan, Dubois and Bogdanski, 2019). For example, at product level, LCA tools enable comparison of life-cycle performances of subcomponents of bioeconomy outputs at different stages of the value chain – raw biomass production, bioproducts manufacturing, end of life (ISO, 2006).

Another analysis that should be carried out in this step is on the technology readiness level (TRL). Technologies can be at different stages of development. Some may already be readily available commercially. Others may still be at the research and development stage, or they may be fully developed but are not yet available at competitive prices. The TRL analysis provides information on the technologies that are still in a laboratory or demonstrations phase, and technologies that have reached the market. Based on the TRL analysis, a catalogue of technologies for different industries can be developed. Other catalogues can be also created. These catalogues could include a portfolio of bio-based industries that convert biomass into valuable components that can be used in everyday products (biorefineries) or a list of bio-based products that are already available in the market. The catalogues should be adapted to the local context as some technological options can deliver more benefits when applied under certain conditions than others. It is common that bioeconomy strategies include ongoing projects already under way in the country.

Green technology foresight exercises can contribute to identifying hidden costs of innovations in advance and can potentially avoid or mitigate unintended environmental effects of technological developments. In the RDI sector, green technology foresight exercises are often used to identify emerging research questions and anticipate future innovation challenges that can support the implementation of the bioeconomy (Ronzon *et al.*, 2017).

Bioeconomy technologies, bio-based products, new value chains and new business models can be introduced in the economic system and throughout the whole innovation chain. Actions in this area, would range from basic research to the development of innovative solutions and their market deployment; and cover the entire bio-based ecosystem from biomass sourcing to industrial processing, production, and consumption. Assessments should be made on the feasibility of using bio-based materials as a substitute for fossil-based materials and materials that are not environmentally friendly.

Also, market potential analyses serve to determine if the commercialization of a bio-based good is feasible from both the supply and demand sides. Key issues to determine in a potential market assessment are size of the market, segmentation, growth rate, demand trends, state of technology in the country, production cost, socioeconomic and environmental analysis of biomass production and consumption, policy framework and trade opportunities.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- The FAO publication, *Towards sustainable bioeconomy. Lessons learned from case studies*, can provide guidance on deploying new technologies and business models.
- *FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area.*

SUBSTEP 3.3. COVER GAPS IN POLICY AND INVESTMENT

In this substep, a broad range of instruments and mechanisms are harnessed to strengthen institutions and support policy, investments, and decision making (e.g. trade-offs) in bioeconomy research and innovation. Important policy aspects include:

- cross-sectoral collaboration for a strong and resilient bioindustry;
- incentives for scaling up RDI and support for commercialization;
- support for increasing the demand for bioproducts with public procurement policies and certification standards and labels; and
- the promotion of good governance through fostering policy dialogue and adapting policies using robust monitoring and evaluation frameworks.

Bioeconomy strategies and action plans usually build on existing laws and regulations. Several reports and sources have mapped policy efforts in countries worldwide and provided a comprehensive list of categories of instruments for improving the enabling environment for bioeconomy development (Dubois and Gomez San Juan, 2016; Gomez San Juan and Bogdanski, 2021; IACGB, 2020b; IACGB, 2024; and Bouwma *et al.*, 2015). Instruments and the actions that need to be taken into consideration to ensure that gaps are covered in the implementation of the bioeconomy strategy include:

<u>Legislative and regulatory instruments</u>

- Develop new supportive policy or adjust existing ones to create the enabling environment for the identified solutions (e.g. regulations on waste can be a barrier to scaling up with resource use efficiency).
- Deploy long-term bioeconomy priorities in sectoral policies.

- Develop linkages and pathways between bioeconomy policy, funding, strategic research, innovation and investment agendas, and rural and regional development.
- Develop a mix of policies and funding instruments to enable multi-actor approaches that operate within ecological boundaries and support the breakthrough of technological innovation in the creation of a sustainable bioeconomy.

Economic and fiscal instruments

- Map financial mechanisms and resources and create new ones to cover the missing sectors. A comprehensive list of the amount of financial resources that are allocated for each action area is sometimes included in action plans. Also, when doing the policy mapping in substep 3.1, it is important to assess the financial support for the bioeconomy-related initiatives. In this regard, the national budget can provide insightful information on the sources of funding of the different initiatives and their sustainability over time.
- Integrate bioeconomy into existing mechanisms (e.g. subsidies). Provide fiscal incentives, subsidies, and other forms of support through individual policies to mainstream the bioeconomy in the implementation of national instruments.
- Foster collaboration and co-creation between ministries. Combine funding instruments to promote not only RDI but also use funds targeted for rural and regional recovery and just transition funds to support innovation and collaboration among bioeconomy actors.
- Invest in research and bio-based knowledge services (e.g. curation of enzyme databases, biorepositories, microbiome support systems, research and technology centres, clusters, pilot biorefineries) as the shortest and most cost-effective route for strengthening the development of the bioeconomy.
- Use economic and fiscal instruments in the bioeconomy framework to influence the supply and demand (e.g. support tangible policy targets, invest in new technologies, stimulate the commercialization of bio-based products). An essential instrument in this category is public procurement. Another instrument is carbon emissions reductions credits or awards.
- Seek diverse sources for financing public policies. These can be of public or private origin and have a national or multilateral scope (or combination of both). International cooperation funds can also provide relevant resources. Since these sources are spread out and serve different purposes, the instruments should consider how the requirements of each instrument (particularly eligible activities and safeguards) match the needs (see Box 3).

Collaborative agreements and co-operative instruments

- Establish bioeconomy-friendly framework conditions (e.g. sound intellectual property management and equitable access and benefit sharing mechanisms; payment for ecosystem services; harmonization of standards).
- Establish collaborative bioeconomy partnerships for co-investment, and develop public-private partnerships, accelerator platforms and other supportive structures. Stakeholders often create consortia that share an agenda.
- Support international cooperation (bilateral and multilateral) on strategies to strengthen cross-border collaboration.
- Promote research and innovation that is linked not only to a specific area of innovation or technology (e.g. food and agriculture, pharmaceuticals) but to multidisciplinary research.

Industry, commercialization, and trade-enabling instruments

- Promote new markets and link them to available trade support measures.
- Provide support for demonstration projects and flagship biorefineries and for developing multi-actor approaches for the bioeconomy.
- Develop policies that promote voluntary certification schemes, labels, and standards. This will support the commercialization of food, feed, bio-based products, and bioenergy, and increase consumer awareness about bio-based products. These policies provide incentives to reduce the price of bio-based products. This can make them more accessible for consumers, support the transfer of bio-based technologies, and build trade infrastructure for bio-based products and sustainable, fair trade.
- Develop policies, including public procurement guidelines, that stimulate the demand for food, feed, bio-based products, and bioenergy, and provide an incentive structure for consumers.
- Develop policies that support the production of food, feed, bio-based products, and bioenergy; promote biomass production from waste, agriculture, forestry, aquaculture, cell culture and microorganisms; and encourage the use of bio-based products, materials, and energy. Concrete examples of these kinds of policies include:
  - → access to capital for investments;
  - → tax incentives for companies;
  - → incentives and grants for a sustainable production of biomass and income diversification for rural communities;
  - → supportive laws and regulations;
  - → the creation of markets for bio-based products and bioenergy; and
  - → collaboration channels, platforms, and infrastructure for producers (e.g. biorefineries and bio-based clusters) to create a balance between the demand and supply of biomass and intermediary products.

Knowledge and information sharing instruments

- Create favourable conditions for the formation of networks, communities of practices, interactive workshops, living labs, social experimentations, and similar instruments. These types of endeavors build cooperation and trust among stakeholders.
- Ensure transparency and accountability through public reporting and continuous dialogue, and the setting up of information platforms to increase public awareness on bioeconomy and its development in the country.

Service and infrastructure instruments

- Create the environment for companies and clusters to develop their own plans to facilitate strategic bioeconomy development and enable them to align their mandates and sectoral objectives with the targets laid out in the bioeconomy strategy.
- Develop a national bioeconomy research infrastructure (e.g. research centres, technology centres and regional clusters) to stimulate bioeconomy development. Research

infrastructure can bolster capacities by combining regional resources with technological expertise in a broader range of areas (e.g. microbial production, enzyme technology, green chemistry, and advanced physical and chemical processing).

- Support the formation of clusters. Bioeconomy infrastructure projects often rely on clusters to provide services. Clustering and the integration of sectors, industries and levels can reduce competition for biomass. Clustering involves the sharing of infrastructure, knowledge, and risk. This can help biomass producers or collectors become more organized and can facilitate the cascading use of industrial by-products obtained by different industrial sectors in the same area.

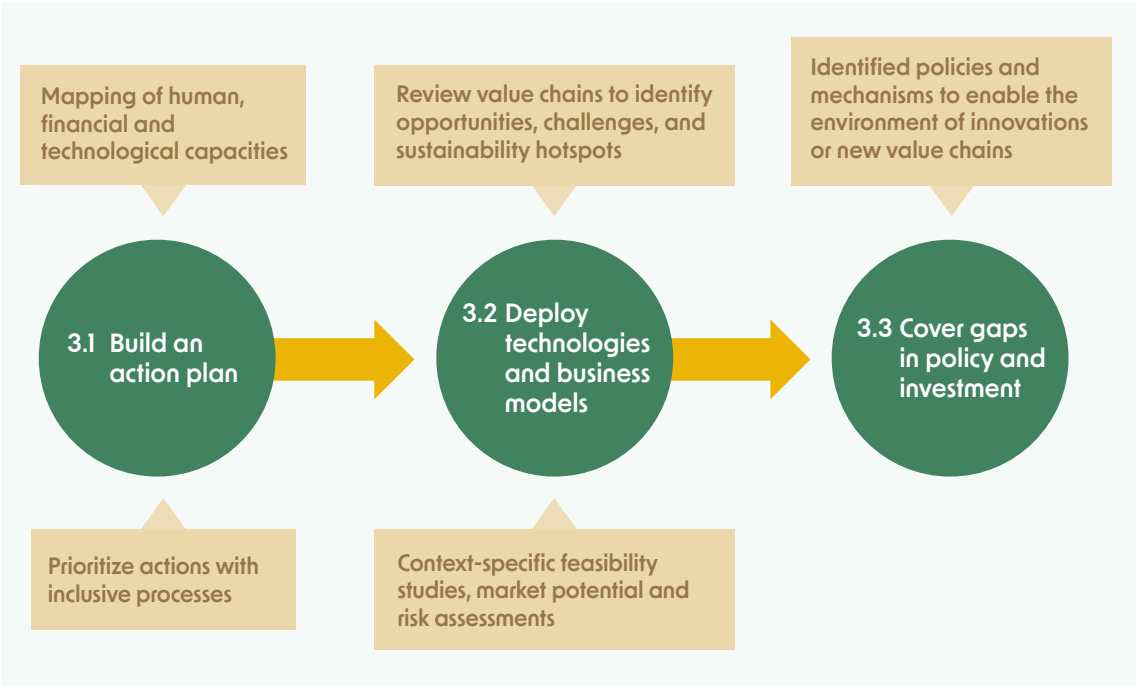
Education, capacity building, and communication instruments

- Ensure outreach and communication is embedded in the action plan. For instance, certifications, standards, and labels can also serve to provide consumers with product-related information. Other examples are courses and other educational offerings, social education, information campaigns, direct dialogues, and internet platforms.
- Support capacity building in bioeconomy project. It includes ensuring knowledge sharing and the transfer of the best technologies are activities carried out before starting implementation. This could include, for example, undertaking bioeconomy research and innovation to design practices and technologies that foster the development and market uptake of new technologies and at the same time protect natural resources.
- Using public–private partnerships in bioeconomy research and innovation to broaden pre-competitive collaboration. For example, knowledge of non-proprietary biorefinery platform technologies is already being shared in the public domain for stimulating entrepreneurship and supporting rural and regional development.
- Incorporating education, training and skills development in the bioeconomy strategies and action plans. The requires understanding the skills and professions (e.g. carbon managers or biosystems engineers) that will be needed to enable a transition towards greater sustainability. On-field training will also be needed for biomass producers and workers to adapt their skills to new or improved bio-based value chains and value webs.
- Stimulating the exchange of knowledge in farm advisory services to encourage primary producers, rural entrepreneurs, and industry to seize the opportunities that the bioeconomy offers and engage in collaborative ventures that support technological development.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- The 2022 FAO publication, *A review of the impacts of crop production on the soil microbiome: Innovations and policy recommendations to address environmental degradation, climate change and human health*, provides examples of how policies can be applied to support bioeconomy innovations.
- *FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area.*

FIGURE 5. Description of substeps under Step 3: Implement with an action plan



Source: Author's own elaboration.

STEP 4. MONITOR PROGRESS AND REVISE THE STRATEGY

The first outcome in the process of effectively monitoring the progress of implementing the strategy and action plan, and revising them, if necessary, is the construction of a monitoring framework. For this, it is important to define a set of indicators for each context, and their data sources, and an effective communication channel of the results to guide the process of updating the strategy and action plan.

This step involves *ex post* monitoring, evaluating, assessing, communicating, enhancing transparency, and finally revising the objectives, targets, key sectors and/or actions of the strategy and action plan.

Monitoring the performance or progress of implementation towards the objectives of the strategy and action plan is complemented by an evaluation of sustainability impacts. An effective monitoring and evaluation framework should select different types of indicators to assess divergences between executed actions and initial targets and sustainability objectives. There are two types of indicators: key performance indicators and impact indicators.

After the monitoring framework is built and the progress and impacts are evaluated, the results should be shared in a transparent manner. Sharing the results can serve different purposes, including communicating the lessons learned, and revising or updating the strategy documents or parts of them (e.g. legislations or incentives). In revising the strategic documents consideration should be given to other data that do not come from the results of monitoring (e.g. changes in the scenario, unexpected climate or economic shocks, data from surveys with local stakeholders, or information from global fora).

There are four main processes for the revision of the bioeconomy strategy and the publishing of a new or updated version of the document (García Laverde and Szarka, 2021). These processes are to the main processes followed in of the original strategy development:

- strengthening related working groups and governance mechanisms;
- holding sessions to discuss if objectives and trade-offs remain the same and, based on data from *ex post* monitoring and evaluation, determine the objectives that have been achieved;
- holding sessions to discuss if the targets, timing, and roadmap are still relevant or should be revised; and
- repeating, as required, measuring the bioeconomy in the country through the *ex ante* assessments to refine the selection of sectors and areas of intervention.

For advocacy and communications, it is important to share the lessons that have been learned. Countries with a bioeconomy strategy should convey the lessons learned about success factors and good practices, but also on which elements of the strategy were less successful and why. Mutual learning exercises should be encouraged and all actors, including (policymakers, consumers, local communities, academics, farmers and other commercial groups empowered to exchange views and ideas to foster a sense of ownership and build commitment to improving the strategy.

A summary of this step, substeps and required inputs is presented in Figure 6.

SUBSTEP 4.1. BUILD A MONITORING FRAMEWORK

The strategy document and annexed action plan should be complemented by a monitoring framework that outlines the initial objectives, targets, and actions to be implemented. The monitoring framework outlines the criteria and indicators, as well as the available data sources, benchmarks, and methodologies, to be used for monitoring and evaluation. It is important that the monitoring and evaluation process be anticipated throughout all the steps the development of the strategy.

Just as there are two types of indicators (KPIs and impact indicators), there are also different levels of monitoring (e.g. territorial/national; products/value chains; investments/business models). Likewise, indicators can be ex-ante and ex-post. Some indicators can be considered core indicators, which are a minimum set of indicators that should be addressed, for instance in each of the dimensions of sustainability, social, economic and environmental indicators. Stakeholders could use this set of core indicators with justification for those not considered and the trade-offs made.

The main objective of building a monitoring framework is to support the achievement of sustainability objectives by promoting transparency and accountability. Countries and international organizations are increasing their efforts to build monitoring systems for the sustainable bioeconomy.

Countries and regions should aim to agree on monitoring sustainable bioeconomy through a globally harmonized set of indicators and methods. This would include using existing monitoring and evaluation frameworks and adopting sound accounting systems for products and services coming from agriculture, forestry and fisheries and the wider economy (Mubareka *et al.*, 2023). Examples include:

- indicators of impact in other frameworks (e.g. SDGs, NDCs);
- measuring changes in natural capital stocks at various territorial levels and accounting for the value of ecosystem services;
- employing blockchain in trade and market indicators and consumer use; and
- collecting sex- and age- disaggregated data to monitor the respective levels of engagement of men, women and youth in the bioeconomy and the impact of new bio-based solutions.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- FAO has developed and implemented a methodology to build indicators and monitoring systems for the bioeconomy. *The Guidance note on monitoring the sustainability of the bioeconomy at a country or macro-regional level*, published in 2021 by FAO and the EC Joint Research Centre can provide insights into carrying out this substep.
- The *Aspirational Principles and Criteria for a Sustainable Bioeconomy*, provide a checklist of what needs to be considered for developing a sustainable bioeconomy and can support in assessing trade-offs.

SUBSTEP 4.2. EVALUATE PROGRESS AND IMPACT

The results and data obtained from the monitoring should be assessed to allow for conclusions to be drawn about the progress towards targets and the impact on sustainability. To evaluate performance, both at territorial and product level, it is important to have a solid understanding of how interconnected actions (e.g. the mix of different policies that support bioeconomy development, and the establishment of bioeconomy clusters that produce a range of products and biomass feedstocks) advance the bioeconomy.

At the territorial level, *The aspirational principles and criteria for a sustainable bioeconomy* provide a useful checklist to evaluate the impact on sustainability both in terms of benefits and trade-offs. The actions undertaken in this substep are similar to the exercises done in setting up a governance mechanism and dedicated institution (Step 1) but they are carried out *ex post* instead of *ex ante* to analyse the policy implications in greater depth.

At value chain or product level, performance can be measured through the market uptake of bio-based products or through the *ex post* evaluation of how new technology and value chains improve sustainability. Impact evaluation should consider the benefits and trade-offs that bio-based innovation brings to both the consumption and production of food, feed, and bioproducts.

Data collected by countries vary substantially since the definitions and assumptions considered are different in space (e.g. different administrative levels or areas), in time (e.g. different baselines and range of years, delayed reporting), and sectorial boundaries (e.g. the classification of biological resources).

Having common elements for monitoring (e.g. robust metrics and well-defined benchmarks and boundaries) is crucial to inform future policy and business choices and promote sustainability objectives. Strategies and action plans should offer opportunities to national research institutions to develop approaches to bioeconomy monitoring and evaluation. They should also build capacity with a focus on the:

- ecological boundaries;
- the biological resource base and its sustainability;
- indicators for economic growth and greenhouse gas emission reduction monitoring the progress of the bioeconomy; and
- systemic monitoring and modelling of the bioeconomy.

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- The 2023 FAO publication, *Monitoring the sustainability of the bioeconomy - Pilot in Uruguay* can be consulted for an example of a concrete methodology used for monitoring the sustainability of the bioeconomy in Uruguay.
- The 2019 FAO publication, *Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward.*

SUBSTEP 4.3. SHARE RESULTS AND REVISE THE STRATEGY

The results of the monitoring and evaluation exercises should be widely disseminated, and the lessons learn highlighted. For some countries, this activity is included in the bioeconomy action plans. The main objective is to address the misgivings and resistance of industries that may feel threatened by bioeconomy development. Examples of potential concerns are the case of 'first-of-a-kind' infrastructure and technologies, or a contagion effect resulting from previously unpopular policies (e.g. biofuels in some contexts). Sharing the results of the monitoring can also help shape the behaviour patterns of individuals and consumers so that they increase their support bioeconomy development.

It is essential to involve the media in these activities. Different types of media are needed to develop campaigns to raise awareness of the bioeconomy and how it can have beneficial impacts on sustainability when ecological boundaries are respected, and when industrial needs and socioeconomic concerns are accounted for. A webpage is a useful channel for showcasing the results of the implementation of a strategy, the results of projects or implementation activities, investments or monitoring and evaluation efforts. It is critical to encourage the diffusion of bio-based knowledge, innovation and technological advances and opportunities in emerging bioeconomy to all age groups. Dashboards can be a useful tool in this area. For a list of examples of some dashboards, see the databases and dashboards section in Chapter 4.

Other common tools used by countries are dedicated bioeconomy weeks and days that are combined with updated online information about local bioeconomy planned developments and seasonal events. Several countries in the EU (e.g. Germany, Ireland, and Italy) have undertaken these types of activities.

As new information and innovation become available, the governance mechanism, i.e. the core interministerial group and/or the wider multistakeholder group, can evaluate the choices made on an ongoing basis. They can then decide to rewrite the strategy and the action plan or simply update parts of them. The decision to revise or update the strategy or some elements of it will comes after the monitoring and evaluationt of how the strategy is being implemented. Changes in the strategy and action plan can be made by the stakeholder group and through the governance mechanisms set up in Step 1. Changes can relate to the objectives, targets, the priority sectors of the strategy document defined in Step 2, and to the different actions and actors identified in the action plan in Step 3.

Key performance indicators (KPIs) and impact indicators are measurable values that show the progress made towards an intended result (Mubareka et al., 2023). To be meaningful, indicators should define specific, measurable, attainable, relevant, and time-bound (often described by the acronym SMART) information for planning, transparency, and decision-making by linking the vision of an organization, project or policy with the actions needed.

- KPIs help to evaluate if the strategic objectives of the bioeconomy strategy are being achieved, and if not, to identify the areas that need more work and to revise the action plan accordingly. KPIs could be, for instance, the increase of new biorefineries to meet a hypothetical target of setting up a biorefinery per region.
- Impact indicators measure the degree to which action has contributed to achieving an overarching objective (e.g. enhancing biodiversity conservation, reducing greenhouse gases, reducing competition for biological resources). It is important that the impact indicators be aligned with other frameworks (e.g. SDGs, NDCs) and make use of the latest available data and methodologies.

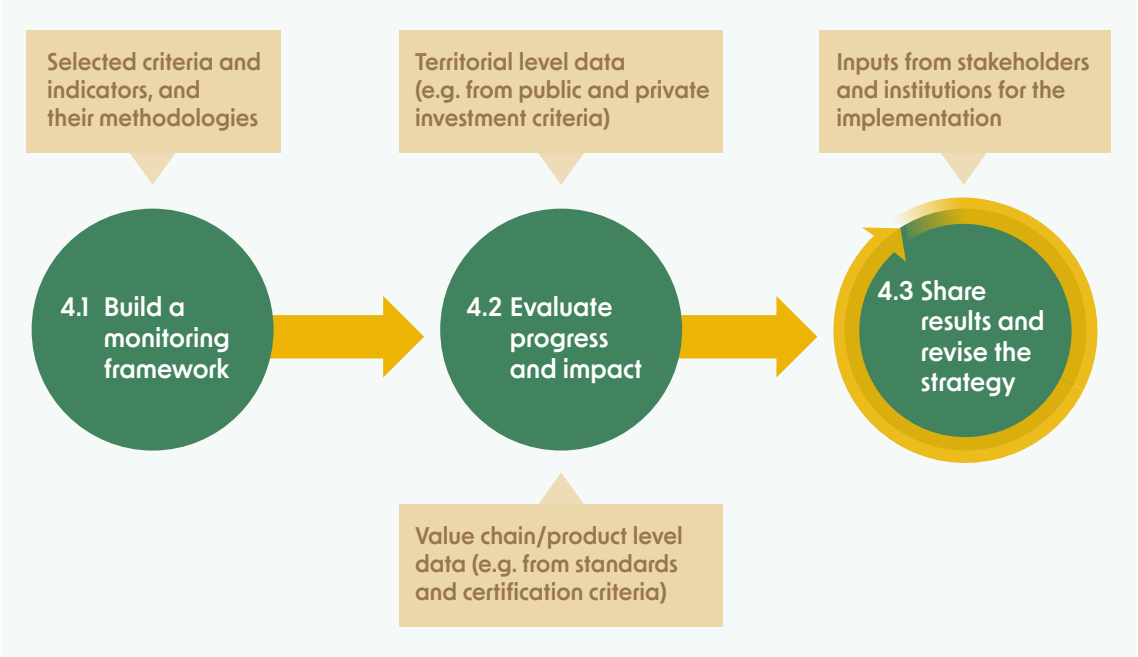
Commonly, consultations are conducted to determine if there is a need to revise the strategy. They can also be complemented by aligning the strategy to regional or national changes or new policy, priorities, and drivers. As outlined by CIRCE (2019), policymakers should ask several questions at this stage that can be shared among stakeholders to decide on the need to revise the strategy or sections of it:

- How much progress have we made towards our vision, the strategic objectives?
- Are our strategic objectives still relevant?
- Which of our objectives have we completed?
- Which objectives are no longer needed?
- Are our KPIs still effective for measuring progress towards our objectives?
- Building on the established assumptions, objectives, results and actions: how can we bring it all together?
- Which are our KPIs to evaluate the strategy?
- How can we raise awareness and communicate the content of the strategy?

See Chapter 4 for specific approaches developed by FAO and partners. Noteworthy:

- *FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area* is a vehicle for increase knowledge and support exchange of views among the 196 FAO Members, including the more than 130 country offices. The programme monitors advancements on bioeconomy in FAO and outside, and provides updates on ongoing projects, events, publications, communications materials, and news stories.

FIGURE 6. Description of substeps under Step 4: Monitor progress and revise the strategy



Source: Author's own elaboration.

Chapter 3. Case studies and examples of bioeconomy strategies

Through the *Towards Sustainable Bioeconomy Guidelines project* FAO has provided technical and policy support to the Governments of Malaysia, Namibia, Uruguay in the preparation of their bioeconomy strategies. The Organization has also been closely following the progress of Germany, the resource partner behind the project, in the progress that it has been making to refine its own well-advanced bioeconomy strategies. This chapter provides case studies on the experiences and success factors that shaped the development of bioeconomy strategies in these four countries.

Also, through the ISBWG and other international bioeconomy fora, FAO has been able to share expertise and knowledge with countries and regions in their development of bioeconomy strategies. This chapter also provides details on strategic bioeconomy documents from different countries and provides a schematic global overview of how bioeconomy-dedicated strategies have addressed the steps and substeps described in this toolbox (see Table 1). A particular emphasis to each step is given in a corresponding case study.

CASE STUDIES

STEP 1: NAMIBIA

In Namibia, an important success factor in the development of the bioeconomy strategy has been the extensive consultations that has been undertaken with all 14 regional governments and local populations. In this respect, FAO has collaborated in this process and supported the creation of multistakeholder group and a strategy document. The actions carried out by Namibia exemplify the first step in developing a bioeconomy strategy during in which all concerned stakeholders are brought together to agree on a definition, boundaries, and aspirations of a bioeconomy. The Namibian case study is noteworthy in that illustrates that bioeconomy can extend beyond production to include services, like ecotourism and biosciences, and can support broader goals for the conservation of and sustainable use of biodiversity and the equitable sharing of benefits of gained from the use of genetic resources. Namibian indigenous natural products (e.g. Devil's claw, Hoodia, Marula, Ximenia) contribute to around 4.5% towards the gross domestic product (HeerenHauser *et al.*, 2020).

Namibia is an example strategy driven by innovation. Along with the European Community and South Africa, where research, technology and innovation policies have catalysed the process of formulating a bioeconomy strategy. The country's revised National Science Technology and Innovation Policy (2020- 2030) explicitly called for the development of the National Bioeconomy Strategy.

At the outset of the process to develop the strategy, the National Commission on Research, Science and Technology (NCRST) organized a series of trilateral meetings in 2019 to raise awareness about options for developing a sustainable bioeconomy. These meetings served to identify key stakeholders and led to the formation of a multistakeholder group on bioeconomy. This group gathered information to determine and prioritize national objectives. between FAO, NRCST and managerial and technical staff from:

- The Ministry of Higher Education, Training, and Innovation.
- The Ministry of Environment and Tourism.
- The Ministry of Agriculture, Water and Forestry.
- The Ministry of Urban and Rural Development.
- The Ministry of Industrialization, Trade, and Small and Medium-sized Enterprise Development.

The NCRST follows a systematic approach that links and coordinates stakeholders across different ministries, civil society, the private sector and research agencies towards the development and implementation of the bioeconomy strategy. It also supports tapping into the potential of biodiversity and indigenous knowledge to support the sustainable use of genetic resources and ensure equitable access to benefit sharing in bio-based investment.

A national consultant then mapped the policy landscape of the country and conducted a gap analysis study and regional consultations. The wider consultative process began in January 2021 with the constitution of an interagency committee: the Bioeconomy Multisectoral Working Group (BMWG). The BMWG consisted of 24 entities: nine government ministries, five private companies, and ten non-governmental organizations, public enterprises, and higher education institutions.

The representatives of these institutions provided the technical team with a comprehensive list of policies and legislation within their scope of work that fall under the bioeconomy. *The Aspirational principles and criteria for a sustainable bioeconomy* were used as framework to assess opportunities and gaps. The BMWG also used information from a benchmarking review document of bioeconomy strategies around the world that had been conducted by the NCRST in 2016. At the initial BMWG meetings in 2021, the working group set six strategic focus areas: agriculture, health, indigenous knowledge, natural resource management, industrial and manufacturing issues, and cross-cutting issues.

Following the meetings of the BMWG, a nationwide survey was conducted to solicit inputs from a wider range of stakeholder groups and partner organizations. Around 260 stakeholders were engaged overall, through both face-to-face workshops and online meetings. The results of the survey were compiled into a stocktaking and analysis report, which informed the national strategy. Based on results from the survey, the BMWG decided to narrow the strategic focus of the bioeconomy strategy to four areas: agriculture, health, natural resource management, and cross-cutting issues related to the bioeconomy. Once the technical work was complete, eight regional consultation workshops were held with representatives from all 14 regions of Namibia. The strategy has been endorsed by the Namibian Government and is awaiting final publication.

The bioeconomy in Namibia involves many diverse stakeholders across many sectors. The NCRST, which has the responsibility for the implementation of the bioeconomy strategy, facilitates the development of research, science, technology, and innovation towards socioeconomic advancement in Namibia. The Ministry of Higher Education, Training, and Innovation has a leading role in the transformation of Namibia into a knowledge-based economy through research, development, and innovation. The ministry houses the NCRST, the Namibia Training Authority, the Namibia University of Science and Technology, and the University of Namibia and other institutions.

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STEP 2: URUGUAY

Uruguay is a major producer and exporter of bio-based goods and has positioned itself as a country committed to addressing economic, social, and environmental dimensions of sustainability in agrifood systems. Uruguay's approach to bioeconomy emphasizes the sustainability of the productive structure and social inclusion.

Uruguay's strategic approach to bioeconomy is anchored in the National Development Strategy 2050 developed by the National Planning Office. One of the five thematic areas of the 2050 Strategy is the 'transformation of the productive matrix' in which the bioeconomy and the digital economy are the two main drivers of the transformation. The International 2030 Agenda for Sustainable Development also established the framework in which the bioeconomy strategy was developed.

Uruguay's economic backbone has traditionally been agriculture production. This is reflected in several policies including:

- the 2010 strategic guidelines that support agriculture public policies developed under 'Agri-Smart Uruguay';
- the 2011 biotechnology sectoral promotion plan;
- support for business accelerators by the country's agency of innovation and research;
- innovation and biotechnology clusters by research institutes and universities;
- urban residues management at the territorial level;
- the promotion of green employment; and
- the creation of a 'Green Tourism' certification scheme.

Uruguay's Sustainable Bioeconomy Strategy, which is awaiting publication by the Government, seeks to leverage contributing policies and develop new ones to fill in the gaps. Production development policies make up the largest portion of the policies that support the bioeconomy (0.5 percent of GDP), followed by science and technology (0.1 percent of GDP), and environment and natural resources, and energy (with 0.05 percent of GDP each) (Balian and Cortelezzi, 2020).

The mapping of existing public policies that relate to bioeconomy in Uruguay was done once the definition and boundaries of bioeconomy were agreed in multistakeholder consultations through moderated workshops. The definition that was agreed on is:

> Bioeconomy is an economy based on the production of goods and services from the direct use or sustainable transformation of biological resources, taking advantage of biological principles and processes, science and technology (Balian and Cortelezzi, 2020).

The identified policies were then ranked according to the degree to which they contribute to bioeconomy.

The drafting of the National Bioeconomy Strategy involved a range of developments over several years. In 2016, the Ministry of Livestock, Agriculture and Fisheries (MGAP) entered into a cooperation agreement with the German Federal Ministry of Food and Agriculture (BMEL) to work on the issue. In 2017, Uruguay became part of the ISBWG and began participating in the Alliance for Action towards a Green Economy (PAGE), a joint initiative of the United Nations and

governments that seeks to support national efforts in the transition towards a green and inclusive economy. In 2018, it was selected as a pilot case for the FAO *Towards Sustainable Bioeconomy Guidelines* project to develop a national bioeconomy strategy with the support of the ISBWG. In 2019, the country joined the Latin American Bioeconomy Network.

An important success factor of Uruguay's bioeconomy growth has been the continuous consultations between public sector entities, the private sector, academia, and other stakeholders; and the constant exchange with international experts of the ISBWG and sharing of knowledge on bioeconomy. Uruguay formed an interinstitutional working group (GIT-BS), made up of various ministries, agencies, and scientific institutions. The group met for two years and developed the national bioeconomy strategy based on a shared vision. They selected four main areas of action for the strategy:

- inclusive territorial development (e.g. green jobs, opportunities for youth, women);
- sustainable consumption and production;
- greater participation in international markets because of the environmental added value of Uruguayan bio-based products; and
- support for science, technology, and innovation.

They also defined six sectors (productive complexes) for the strategy that generate synergies between them through bioeconomic value webs:

- valorization of waste and by-products;
- aquatic biological resources;
- food and beverages;
- forest resources;
- sustainable tourism; and
- chemicals and pharmaceuticals.

The GIT-BS also drew on the *Aspirational principles and criteria for a sustainable bioeconomy* to define the main objectives of the strategy:

- promote productive transformation from biological resources available in the country;
- build value webs to improve sustainability;
- collaborate to achieve international commitments assumed in the Paris Agreement, the SDGs and other commitments in which the country is involved; and
- enhance the country's role as a provider of bioproducts and services with added environmental value.

The strategy also proposes steps to take for its eventual implementation. This includes creating a governance mechanism, developing action plans, and developing a bioeconomy monitoring and evaluation protocol, a project that was led by MGAP and supported by FAO through 2021–2022. As an output of the latter, FAO has since published its *Monitoring the sustainability of the bioeconomy – Pilot in Uruguay* study with the support of MGAP and Thünen Institute. The publication describes how to monitor the sustainability of the bioeconomy and how to develop

monitoring systems. The FAO Bioeconomy Guidelines have been used to devise the strategy and strengthen knowledge exchange with the GIT-BS.

The Uruguay bioeconomy strategy provides noteworthy perspectives regarding the connections the bioeconomy has to international agreements (e.g. the Paris Agreement) and highlights the importance of the sustainable trade of biological resources and the instruments that acknowledge good practices in origin and traceability. Pittaluga (2020a and 2020b) provides a summary of the work carried out in the country in this regard. Uruguay was also one of the first countries that voluntarily submitted reports assessing the policies it had enacted to support the achieving the SDGs. The policies are mapped according to environmental, social, and economic criteria following the The Aspirational Principles and Criteria for a Sustainable Bioeconomy.

Uruguay is also an example, together with Argentina and most European countries, of the importance of territorial planning and rural development **in** providing opportunities to build new value chains that use natural resources efficiently and reduce waste and pollution. The strategy incorporates the 'biomass-based value webs' approach, to cover the links that are generated within and between value chains due to the cascading use and the joint use of biomass. In this way, the bioeconomy generates a higher degree of recycling and a minimization of waste, resulting in the merger of different value chains (Gomez San Juan and Bogdanski, 2019).

The Uruguayan Government has also supported national projects and programmes linked to the circular economy and the green economy. Initiatives led by the private sector focus mostly on the adoption of the circular economy in commercial enterprises (e.g. slaughterhouses, wool producers, the Center of Technological Research for Plastic, a pharmaceutical cluster, and medicinal cannabis ventures). There are also tax exemptions for activities related to innovation and the promotion of research and development for the National Agency for Innovation and Research, green economy and circular economy projects, and the support of exports and international insertion and integration.

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STEP 3: MALAYSIA

Malaysia is one of the bioeconomy pioneers in the Asia–Pacific region and has adopted specific policies made for promoting bio-based industry and bioeconomy. There are two main bioeconomy strategies in Malaysia: the Biomass Strategy and the Bioeconomy Transformation Programme. In Malaysia's bioeconomy policies, bioeconomy refers to:

> All economic activity that is derived from the continued commercial application of biotechnology. It encompasses the production of renewable biological resources and their conversion into food, feed, chemicals, energy and health care wellness products via innovative and efficient technologies (Arujanan and Singaram, 2018).

The Malaysian bioeconomy is driven by biotechnology and includes agriculture, forestry, fisheries, food, feed, health care wellness products, chemicals, and renewable energy.

Malaysia's biotechnology agenda was developed to transform its rich natural resources and biodiversity into bio-based commercial ventures and capital.

In 2005, Malaysia adopted its National Biotechnology Policy and in 2011, launched its National Biomass Strategy 2020. As a complement to the National Biotechnology Policy, the Bioeconomy Transformation Programme (BTP) was initiated in 2012 to accelerate national bioeconomy development. The BTP established the Malaysian Bioeconomy Corporation, a public agency that implements the bioeconomy in the country. The BTP contributed about USD 1.1 billion to the gross national income and created 170 000 job opportunities by 2020. After the launch of the BTP, 61 high-impact bioeconomy projects within the bio-based industry were selected: 22 agribiotech projects, 31 bioindustrial projects and 8 biomedical projects (BC, 2023).

In Malaysia, bioeconomy development is focused on forest and marine environments, and on measures to create more and innovative value chains that can deliver environmental and social benefits. Forest Research Malaysia conducts research on forest biotechnology, forest products, forest biodiversity, and natural products to identify new bio-based business opportunities. However, there are still gaps when it comes to research on conservation and ecosystem restoration. Tapping into blue carbon financing may significantly improve the economic feasibility and sustainability of a marine-based bioeconomy. For example, this may be possible for mangrove restoration, which shares a similar set of stakeholders with bioeconomy development. The country is also rich in seaweed biomass resources. A key advantage of seaweed is its ability to capture carbon in plant bodies and sediment residues in the soil, which presents opportunities for integrating the development of this sector with blue carbon mechanisms (Veraart *et al.*, 2020).

Under the BTP and the Bioeconomy Community Development Programme, The Malaysian Bioeconomy Corporation and Sarawak Biodiversity Centre formally collaborate to identify potential bio-based projects in Sarawak. These efforts are expected to establish a strong bioeconomy in Sarawak and improve the state's economic growth. Six focus areas have been identified to realize the full potential of the Sarawak bioeconomy:

- food-based industries;
- agriculture-based industry;

- oleo-resin industries;
- resource-based industries;
- integrated biorefineries; and
- natural products.

There are also other initiatives that promote bioeconomy development, such as the Sarawak Biodiversity Centre bioprospecting programme, which supports laboratories for microbiology and molecular biology, the culture of plant issue, analytical chemistry, bioinformatics, and product development.

Malaysia represents an example of embedding sustainability into bioeconomy strategies to ensure effective implementation. An important success factor has been the creation of a supra-ministerial institution (a public organism below the cabinet of the prime minister and with the mandate to coordinate several ministries) to govern the process of rolling out the bioeconomy, and related policies. The comprehensive National Biomass Strategy covers all biological resources of the country, and the Bioeconomy Community Development Programme ensures fair contracts between bio-based industries and biomass producers with the government acting as the third party in the business and farmers agreements (Gomez San Juan, Bogdanski and Dubois, 2019).

Innovative, technology-oriented start-ups are seen as the key driving force in bioeconomy development in Malaysia and in Southeast Asia in general. As with the EU and the United States of America, governments in Southeast Asia have established various types of public funding opportunities to cater to the needs of entrepreneurial activities (e.g. grants, tax breaks). However, most of these funding mechanisms cover broad areas of innovations and are not designed exclusively for bioeconomy development. This situation leads to significant trade-offs among different projects and programmes. Although sustainability and circularity are frequently emphasized, economic growth indicators (e.g. GDP, gross national income, job creation) are used to evaluating performance. in many cases, innovative bioeconomy projects and new value chains which may offer long-term benefits beyond short-term economic gains are overlooked (MIDA, 2023).

One exception is Malaysia's Bio-based Accelerator programme and BioNexus Status (Arujanan and Singaram, 2018).[3] The Bio-based Accelerator programme was created to assist bio-based companies (e.g. startups, micro-businesses, and large companies) to establish bio-based commercial ventures in agriculture, industrial and health care sectors and enable these ventures to progressively move up the value chain. BioNexus Status is accorded to companies that contribute to value-added biotechnology and/or life science activities and allows them to apply for tax breaks and funding. Companies that have secured BioNexus Status also enjoy a list of government financial privileges. Responsibility for these programmes was delegated to the Ministry of Science, Technology, and Innovation. This is a successful example of a public–private partnership that supports innovations in different sectors though enabling environment mechanisms and incentives that create jobs and increase access to international green finance. FAO has also supported the country to improve sustainability in bioeconomy implementation

3 For more information on BioNexus Status go to www.bioeconomycorporation.my/bionexus-status/

through a review of the policy support landscape and guidance on how to better position itself to obtain funding through multilateral environmental agreements.

The development of the bioeconomy in Malaysia must be considered within the wider context of the Southeast Asian region. Work in the country was focused on step 3, considered implementation of the strategy, and therefore looking at how the private sector landscape looks like also in the region.

A common regional issue in this regard is that often innovation grants that focus on RDI and start-ups, lack of consistency in follow-up, especially financial instruments for to scale up successful operations. Governments in Southeast Asia have attempted to create new markets and demand for biofuels but not for other bio-based products. Even so, the perspective of bioeconomy development in the region is still very much export oriented. Developed economies (e.g. EU, Japan, and the United States of America) are seen as the main target markets. Creating a level playing field through instruments like a carbon tax remains a very difficult problem in the region. There are still substantial funding gaps between pilot and demonstration plants, and industrial-scale projects.

The implementation stage also presents challenges regarding the selection of indicators and data collection. This stage consists of four key steps: defining criteria, selecting indicators, collecting data, and setting reference values for the indicators. In Southeast Asia, while some existing frameworks, instruments, and efforts are in place, a key challenge is making them

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interoperable (i.e. harmonizing the definitions, scopes, and other settings). Compared to other regions, the monitoring frameworks in Southeast Asia are relatively weak and incomplete and, in many cases, are in the early stage of development. The drive from the bioeconomy stakeholders may open up new opportunities to build more sophisticated monitoring systems from an institutional point of view.

Malaysia is also an example, together with Japan and Thailand, of regional collaboration in the Asia–Pacific region. In Southeast Asia, the term 'green recovery' was mentioned in the Association of Southeast Asian Nations (ASEAN) post-COVID economic planning (Najam *et al.,* 2022). Priorities are given to economic activities that are "environmentally sustainable, socially inclusive, and climate resilient". ASEAN has set up the ASEAN Catalytic Green Finance Facility to finance various infrastructure projects that align with the green recovery vision. Despite substantial growth, sustainable debt and equity markets remain relatively small compared to conventional markets (World Bank Group and Institute of Finance and Sustainability, 2022). A substantial amount of green financing has gone to the energy sector. In comparison, the potential of a green bioeconomy in ASEAN is yet to be tapped.

Recent advances in digital and smart technologies may bring new opportunities to establish a comprehensive monitoring framework and provide the building blocks for better governance of a bioeconomy. For example, the use of smart technologies and blockchain can make monitoring the entire supply chain more effective and transparent, potentially reducing transaction costs (Goh *et al.*, 2021; Ahl *et al.*, 2020). Biotechnology, like the use of biomarkers, can also be a useful complement to enhance the traceability of bio-based materials and products. Since 2020, the COVID-19 pandemic has driven the rapid adoption of digital and smart technologies in many sectors in Southeast Asia. How these technologies can help monitor and address sustainability issues of a bioeconomy will merit attention.

STEP 4: GERMANY

In 2010, Germany adopted its policy on research on the bioeconomy, which was followed by a bioeconomy strategy in 2013. Led by the Federal Ministry of Food and Agriculture (BMEL), bioeconomy became a policy work area for improving agrifood systems. The goals were to bring socioeconomic benefits to rural communities and facilitate the transfer of innovations from laboratories to the market. The German Bioeconomy Council, whose members have a wide range of perspectives on the bioeconomy, was formed in 2009 and enhanced in 2020 to advise the Government.

In January 2020, Germany's national bioeconomy strategy was revised to harmonize the various goals and link corresponding measures more closely with one another.[4] The revision strengthened the implementation of the strategy by pooling different measures to support common goals and objectives. The revised strategy also set new priorities and expands the areas of work of the bioeconomy. Both the Federal Ministry of Education and Research (BMBF) and BMEL continue to oversee the implementation of the revised strategy. An Inter-ministerial

4 Germany's National Bioeconomy Strategy is available at: www.bmel.de/EN/topics/farming/bioeconomy-renewable-resources/national-bioeconomy-strategy.html

Working Group (IMAG) also supervises the implementation process. The revised strategy was shared with various stakeholders for inputs and finalized by the German Government (IACGB, 2020b).

According to the strategy document, a product, process or service is considered part of the bioeconomy based on the type of biological resource, which include biological materials, microbial production, biogenic residues and waste materials. The definition refers not only to biological resources, but also to biological principles and processes which should be considered as part of the bioeconomy (IACGB, 2020b). Examples of how the bioeconomy has been deployed in Germany include new markets for bioproducts and bioprocesses, biomass value chains and nets, and international cooperation.

Germany, along with Canada, Ireland, and the EU, supports strong international cooperation to create a bioeconomy that leaves no one behind and ensures food security first. In Germany, many federal states have also formulated strategic documents on the bioeconomy, for example Baden-Württemberg and North Rhine-Westphalia in 2013, and Bavaria in 2015 and in 2013.

Germany provides a good example of how to carry out the fourth step in developing a bioeconomy strategy: monitoring progress and making revisions. In Germany, different metrics for monitoring the bioeconomy are used in a complementary way. The process involves several ministries and areas of expertise and covers in a coordinated way all the elements of sustainability (social, economic, and environmental) and good governance (Egenolf and Bringezu, 2019; Iost *et al.,* 2020).

To design an effective policy for bioeconomy development, especially given the requirements of different finance options, the German case study shows how comprehensive sets of data are needed to monitor the entire bioeconomy in ways that are compatible across all levels and sectors. Experience from this excersie showed many aspects of how a bioeconomy can be monitored for a holistic evaluation. First, a framework to track and trace biomass flows from the cradle to the grave is needed. However, the main challenges for the bioeconomy are the lack of data and the quality of the information collected (e.g. missing information, reliability, consistency) (Schweinle *et al.*, 2020). Industries sometimes develop their own tools, for example through associations or organizations (e.g. certification bodies). This can lead to a range of datasets with different definitions and scopes, which are often not able to be harmonized so that results can be tallies. Progress is also monitored both at community and national level using economic indicators (e.g. job creation). More subtle social indicators (e.g. inequality, changes in societal structure, land rights) are also needed in the monitoring, but they are often not be adequately captured.

The German national bioeconomy strategy involves three pillars that provide the scientific basis for a systemic monitoring and modelling of the German bioeconomy with respect to sustainability aspects on a national and international level:

- environmental indicators;
- economic indicators; and
- social and governance indicators.

The monitoring of environmental indicators is led by the Thünen Institute**,** which was commissioned by BMEL to develop material flow accounts of present and future flows of biomass. These flows cover primary production the initial steps of industrial treatment and the final goods; bioeconomy monitoring on a sectoral base; and integrated sustainability assessment (Iost *et al.*, 2020). Biomass flow tools are also used by the EC to measure the bioeconomy in different countries (Avitabile *et al.*, 2023). Currently, a second phase of the development of the monitoring system is being implemented that covers import commodities and their sustainability, and the effects of the cascading use and reuse of biological resources.

In the revised German bioeconomy strategy, there is a particular focus on how to quantify the bioeconomy and understand of biomass flows and cycles. The strategy includes assessments of:

- the availability of biomass in space and time, and it ecological importance;
- the demand for biomass (i.e. use of biomass, mixture of biomass, cascading use and reuse); and
- the ecosystem services the biomass provides (e.g. carbon dioxide fixation, biodiversity protection).

The German Bioeconomy Council (2023) in its recommendation on actions to implement the national strategy has highlighted the key role of metrics for planning and assessing biomass and carbon management. Its recommendations also highlight the need for long-term incentives for material flow management. A new biomass strategy in Germany is currently being drafted to outline what are the best uses for a range of existing or new bio- based value chains. The German government also supports the BiomassWeb project in Ethiopia, Ghana, Kenya, and Nigeria, which aims to increase productivity and efficiency across the whole system of producing, processing, and trading biomass (IACGB, 2020b).

The monitoring economic indicators is led by a consortium coordinated by the Ifo Institute for Economic Research. This involves measuring the contribution of the bioeconomy to the overall German economy and its effects on employment, value added, innovation and potential barriers or trade-offs. The monitoring of economic indicators was financed by the Federal Ministry for Economic Affairs and Energy. The German Bioeconomy Council (2023) also recommends supporting sustainable bioeconomy innovations and entrepreneurship, and notes that there is a need for reliable framework conditions and clear criteria for support investment and reducing risks.

The monitoring of social and good governance indicators and is led by the research consortium, SYMOBIO (Systematic Monitoring and Modelling of the Bioeconomy), which is funded by the BMBF. The monitoring considers national and international aspects based on the concept of "bioeconomy as societal change". As with economic indicators, SYMOBIO is implementing a second phase in the development of the monitoring system. Over the years it has delivered a comprehensive sustainability assessment of the German bioeconomy based on global footprints for land, forest, water use and greenhouse gas emissions to determine the socioeconomic balance of the bioeconomy.

Their modelling system consists of a multi-scale system for the analysis of bioeconomy sustainability. Material flow models, input–output analysis, econometric models, and land- and water-use models are integrated to delineate the impact boundaries of the bioeconomy. The analysis of the key drivers for the transition to a bioeconomy transformation led to a definition of indicators and data generated by certification processes and life-cycle assessments (Egenolf and Bringezu, 2019).

With regards to assessment and communication, the progress towards bioeconomy objectives and sustainability goals, the German government has carefully assessed its performance based on the data collected. The analysis and reporting was done on a sound scientific basis and communicated in a clear and effective way for supporting good policymaking. Lessons learned from the case study include that transparency is crucial because gaining the trust of policymakers, regulators, industries, international funders, civil society, and the public is the essential for building a sustainable bioeconomy and to reduce risk and attract investment to bioeconomy projects. Finally, this case study has shown that a clear description of the methods, assumptions, and associated uncertainties must be presented in ways that allow various parties verify the results.

EXAMPLES FROM BIOECONOMY STRATEGIES

EAST AFRICAN COMMUNITY BIOECONOMY STRATEGY: PARTICIPATION AT REGIONAL LEVEL (SUBSTEP 1.1)

The bioeconomy strategy of the East African Community (EAC), which includes Burundi, Democratic Republic of the Congo, Kenya, Rwanda, South Sudan, Uganda, and United Republic of Tanzania, has been drive by innovation. The governing body (the consortium) in charge of the development of this strategy is composed of stakeholders in the areas of research, science, technology, and innovation. The objective of the strategy is to support the development and commercialization of bioinnovations for agriculture, agroprocessing and emerging bio-based sectors. The regional strategy was drafted in consultation with national and regional stakeholders, then validated by the ministries at country level and finally approved at the regional level by the East African Science and Technology Community (EASTECO) governing board and the sectoral council of ministers. To ensure local and country ownership, and analyse different or conflicting national laws, regulations and social norms, a National Working Group was created in each country (with fifteen members from different sectors) along with a Regional Drafting Committee with twelve members from all EAC countries. (EAC, 2022)

PARA STATE BIOECONOMY STRATEGY (BRAZIL): PARTICIPATION AT SUBNATIONAL LEVEL (SUBSTEP 1.1)

The Government of the State of Para in Brazil developed a bioeconomy strategy in 2021 and an action plan in 2022 (Government of the State of Pará, 2021, and Government of the State of Pará, 2022). They were prepared by an inclusive interinstitutional working group composed of public and private organizations, local actors, and universities, nine regional ministries (secretaries of state) international partners, indigenous peoples, Quilombola, traditional communities, agro-extractivist settlements and other peoples in the region, cooperatives, family farmers and others. The strategy followed a conceptual alignment process based on the valorization of the knowledge and culture of the original populations and traditional communities. The objective of the Para bioeconomy strategy is to develop low emissions sectors while supporting poverty eradication through the 'socio-bioeconomy'.

FRENCH BIOECONOMY STRATEGY: CREATING A SHARED VISION (SUBSTEP 1.2)

The French bioeconomy strategy was developed with a clear vision of the problems and needs of the country and was based on a systemic review of the sectors involved in bioresource production. In France, it was important to consider biological resources supply and processing. The strategy was centered on the wellbeing of people and ensuring that the bioeconomy provides solutions to social challenges, increases product valorization, and maintains ecosystems. The Paris Agreement was placed at the heart of the strategy along with food security and food sovereignty. While global issues had a strong influence on the strategy, the document reflects the situations in different French regions and encourages them to develop their own strategies and plans for the bioeconomy, particularly for promoting rural dynamism linked to the EU Common Agricultural Policy (MAAF, 2017).

CANADA: PRIVATE AND PUBLIC COLLABORATION FOR A DEFINITION (SUBSTEP 1.3)

The bioeconomy in Canada has received important attention from different private and public stakeholders, including the Ministry of Agriculture and Agri-food and the Canadian Forest Service in the Ministry of Natural Resources. Two industry-led bioeconomy documents have been prepared: a national bioeconomy strategy; and a forest bioeconomy framework.

The "Canadian Bioeconomy Strategy - Leveraging our Strengths for a Sustainable Future", was produced by Bioindustrial Innovation Canada in partnership with a writing team and an advisory committee that has come together under the consortium of BioDesign. Together, the writing team and committee coordinated and hosted a series of national consultations across Canada to discuss key priorities with industry (BIC, 2018).

The strategic document "A Forest Bioeconomy Framework for Canada", was prepared by the Canadian Council of Forest Ministers Innovation Committee, which is made up of the provincial ministers responsible for forests and the federal natural resources minister (CCFM, 2017). The Canadian inventory of biological resources is another tool developed by the Government of Canada that can support policymakers and practitioners to calculate biomass and biological material in the land cover that can be used for industrial production.

The Ministry of Agriculture and Agri-Food also supports the Bioproducts AgSci Research Cluster initiative. Managed by Bioindustrial Innovation Canada, this initiative is a nationally distributed pre-commercial research cluster focused on the development of industrial bioproducts technologies and their feedstocks from the Canadian agriculture sector,

COSTA RICA'S BIOECONOMY STRATEGY: INTERNATIONALLY-DRIVEN (SUBSTEP 1.3)

In Costa Rica, the process for the formulation of the National Bioeconomy Strategy 2020 – 2030 (MICITT, 2020) was initiated as a response to OECD recommendations on developing technology-driven policies that improve innovation performance and strengthen research and development. The national bioeconomy strategy focused on creating a harmonized set of policies that support research, development, and innovation for tackling sustainability challenges. The strategy, which was launched at the 2020 Global Bioeconomy Summit, meets a range of development needs, including:

- decarbonizing the country by conserving biodiversity, preventing environmental degradation and taking climate action;
- improving balanced territorial development through the social inclusion of youth and Indigenous Peoples and greater gender equity;
- supporting value addition, diversification, production sophistication, and quality green jobs by applying the principles of circularity; and
- building a knowledge society to 'leapfrog' towards sustainable development.

UNITED STATES OF AMERICA BIOECONOMY EXECUTIVE ORDER: MAPPING BIOMASS POTENTIAL (SUBSTEP 2.1)

In 2022, The President of the United States of America issued Executive Order 14081 – "Advancing Biotechnology and Biomanufacturing Innovation for a Sustainable, Safe, and Secure Bioeconomy" (The White House, 2022). The executive order includes actions "to support the resilience of the United States biomass supply chain for domestic biomanufacturing and bio-based product manufacturing, while also advancing food security, environmental sustainability, and the needs of underserved communities."

Within the Executive Order, the publication "Bold Goals for U.S. Biotechnology and Biomanufacturing. Harnessing Research and Development to Further Societal Goals" (OSTP, 2023) aims to harness biotechnology and biomanufacturing innovation to further societal goals and transform industries related to five goals: (1) climate change solutions, (2) food and agriculture innovation, (3) supply chain resilience, (4) human health, and (5) cross-cutting advances. Each of the five sections presents bold goals that highlight what could be possible with the power of biology. These goals are intended to provide a broad vision for the U.S. bioeconomy and what can be achieved with concerted action from industry, academia, nonprofits, the Federal Government, and other organizations. The White House launched the National Bioeconomy Board in March 2024.

The Executive Order is based on years of mapping biomass availability and potential. A 2023 report by the Department of Energy estimated that 1 billion tonnes of sustainable biomass and waste resources could potentially be available by 2030 to provide domestic supply chains for fuels, chemicals, and materials (DOE, 2024). In 2023, the Bureau of Economic Analysis in the Department of Commerce estimated the economic contribution of the bioeconomy and the biomass potential per sector, based on the capacities of current biorefineries and on projections of market needs (Highfill and Chambers, 2023). Also, the National Renewable Energy Laboratory (NREL) in the Department of Energy applies geospatial data science research to produces maps, data and tools on solid biomass resources (NREL, 2023).

THAI BIOECONOMY STRATEGY: PIONEERING BIOTECHNOLOGY DEVELOPMENT (SUBSTEP 2.2)

On 19 January 2021, the cabinet endorsed the proposal to declare the Bio-Circular-Green Economy or BCG model the national agenda from 2021 onwards. As a result, this BCG Accion Plan 2021-2027 is formulated to serve as a framework for organizations to work collaboratively in order to drive the agenda to the success (NSTDA, 2022).

Thailand has been a pioneer in developing an agriculture-based bioeconomy in Southeast Asia. For instance, there are a number of sugar-based biopolymers plants running or under construction across the country and they have prioritized those in the main elements of the strategy. The country is a major producer of cassava and sugar cane and has well-developed business models and value chains for these crops. This gives investors confidence as advanced biopolymer manufacturing can be more readily integrated into the existing value chains (Thailand Board of Investment, 2020).

THE COLOMBIA BIOECONOMY STRATEGY: TOWARDS A BIOECONOMY SOCIETY (SUBSTEP 2.3)

In December 2020, the Presidency of the Republic of Colombia launched the national bioeconomy strategy "Colombia, Alive and Diverse: Towards a Society Driven by Knowledge" (Gobierno de Colombia, 2020). The strategy aims to harness the circular and sustainable use of Colombia's vast biodiversity, its ecosystem services and biomass, to generate comprehensive well- being for all Colombians. It focuses on developing products and processes of high added value through science, technology, and innovation. Actions are divided into five strategic areas and eight geographical regions.

CHINA'S BIOECONOMY ROADMAP: HARMONIZING POLICIES (SUBSTEP 3.1)

In China's new plan to spur the bioeconomy during the Fourteenth Five-Year Plan (2021–2025), the main elements that have been selected for particular focus are the use and protection of biological resources in several sectors including medicine, health care, agriculture, forestry, energy, and environmental protection and biosafety. The development of bioeconomy in the country is inseparable from the institutional guarantee for intellectual property for protecting traditional Chinese knowledge and its innovative applications.

The implementation of the strategy is explicitly linked to the Fifteenth Conference of the Parties (COP 15) to the Convention on Biological Diversity (CBD) and Post-2020 Biodiversity Framework, including the establishment of the Kunming–Montreal Global Biodiversity Framework Fund aimed at supporting the sustainable use and conservation of biodiversity in developing countries (Zhang *et al.*, 2022).

ITALY'S BIOECONOMY STRATEGY: SWOT ANALYSIS (SUBSTEP 3.1)

In 2019, Italy adopted it new bioeconomy strategy. BIT II - Bioeconomy in Italy: A new bioeconomy strategy for a sustainable Italy. (Presidency of Council of Ministers, 2019).

Forestry is key sector in the bioeconomy. A SWOT analysis has been used to identify potential drivers and barriers of the forest sector to advance the bioeconomy strategy. A robustness check of the SWOT matrix was conducted through expert interviews and surveys. Experts who participated in the survey belonged to a range of institutions and can be used by countries as an example for stakeholder mapping: the Italian Forestry Association; the Italian Agroforestry Energy Association; the Italian Federation of Forestry Communities; the General Directorate for Forests; the Ministry of Agricultural, Food and Forestry Policies; Italian forest non-governmental organizations; management centres of agricultural, forest, and fishing resources in the Friuli Venezia Giulia and Tuscany regions; forest, mountain, naturalistic system and wildlife services of the Umbria region; and the National Research Centre – Institute for Mediterranean Agricultural and Forestry Systems.

Clusters also figure into the implementation of the Italian bioeconomy strategy. Sustainable Processes and Resources for Innovation and National Growth (SPRING) is the Italian circular bioeconomy cluster. Created as a non-profit association in 2014, it was formally recognized

in 2019 by Ministry of Education, University and Research as a component of the national bioeconomy steering committee to coordinate industrial research policies at the local and national level.

IRISH BIOECONOMY STRATEGY: PROMOTING BIOECONOMY CLUSTERS (SUBSTEP 3.2)

In 2018, The Irish Government published the first National Policy Statement on the Bioeconomy (Government of Ireland, 2018). It is in line with the National Planning Framework (Project Ireland 2040), which highlights the potential of the circular bioeconomy in promoting the more efficient use of renewable resources while supporting economic development and employment in rural Ireland.

Ireland's first national Bioeconomy Action Plan was published during Bioeconomy Ireland Week 2023. Ireland is another country that has developed a comprehensive multistakeholder process, which included citizen public consultation to define the country's vision and objectives. The 'Bioeconomy Action Plan 2023-2025' includes 33 actions to accelerate support for the development of the bioeconomy. The plan has a high focus on bringing sustainable scientific practices, technologies and biobased innovation and solutions into use on farms and by biobased industries in Ireland. (Government of Ireland, 2023).

In Ireland, bioeconomy clusters have been crucial in the deployment of new technologies. In 2021, Munster Technological University (MTU), CircBio Research Group and Enterprise Ireland initiated a new first-of-a-kind regional circular bioeconomy cluster in South-West Ireland. This cluster supports commercialization, collaboration, and training.

The Irish bioeconomy cluster is a pioneering example in Europe and the world. Clusters allow for upgrading residues, by-products and waste to higher value products and services, and to optimize the utilization and value of biomass.

SOUTH AFRICAN BIOECONOMY STRATEGY: BUILT ON BIODIVERSITY AND INDIGENOUS KNOWLEDGE (SUBSTEP 3.3)

South Africa's National Bio-economy Strategy recognizes that the country's rich biodiversity and indigenous knowledge systems represent significant resources. The regulatory landscape has adjusted to the goals of the strategy to regulate bioprospecting activities that use indigenous knowledge, ensure the confidentiality of genetic information and mitigate any potential negative environmental effects of biotechnological advances. (DST, 2013).

The Farmer to Pharma Grand Challenge, which was part of South Africa's 10-year innovation plan, (2008-2018) sought to combine biotechnology with indigenous knowledge systems and South Africa's rich biodiversity to position the country to participate competitively in the emerging bioeconomy. The Farmer to Pharma Grand Challenge considered the range of existing mechanisms and regulations for bioprospecting and intellectual property rights (e.g. the National Environment Management Biodiversity Act and Access and Benefit-Sharing Regulations) that protect community rights and interests regarding indigenous biological resources and traditional knowledge.

FINNISH BIOECONOMY STRATEGY: MONITORING THE SUSTAINABILITY OF THE BIOECONOMY (SUBSTEP 4.1)

In 2014, Finland was one of the first European countries to formulate a holistic dedicated bioeconomy strategy and monitoring system. An updated version of the strategy was published in 2022, the "Finland bioeconomy strategy" (Finnish Government, 2022).

The revised strategy is focused on measuring value addition through circularity. Other indicators are EU bioeconomy strategy sustainability indicators. The Ministry of Economic Affairs and Employment is responsible for implementing the monitoring system. Finland monitors the main sectors (food, wood products, pulp and paper, bioenergy, bio-construction sectors, water, and nature tourism, recreation, recreational fishing, and hunting) with five economic indicators: output, value-added, investments, employment, and exports of bioeconomy goods.

Natural Resources Institute Finland (Luke) has been supporting the monitoring the bioeconomy strategy in Finland. One of the focus areas chosen by Finland for monitoring progress is the 'value addition' because it can measure efficiency and cascading use in the management of biological resources.

JAPAN BIOECONOMY STRATEGY: KEY PERFORMANCE INDICATORS (SUBSTEP 4.2)

One objective of Japan's bioeconomy strategy is to set KPIs for evaluation of the overall objectives. "A tentative translation of the Japan Bioeconomy" (Council for Integrated Innovation Strategy, 2020).

There are several initiatives in Japan that report progress towards bioeconomy development. For example, the Biomass Town plan is being implemented to valorize and gather data on the abundant wood resources available across Japan. The Maniwa City Biomass Initiative is a success story under this plan.

Japan is also collaborating with other countries and private sector institutions on reporting the impacts of its bioeconomy strategy. An example is a joint project between Mitsubishi Corporation from Japan and the Malaysian Sarawak Biodiversity Centre (SBC) to collect and utilize local microalgal biomass. A cultivation facility to produce high-value microalgae that is suitable to grow in tropical climates was developed through this project and started operating in 2019. The biomass harvested from this facility has been used as feed and water conditioner in shrimp production.

EUROPEAN UNION: SHARING RESULTS TO REVISE THE BIOECONOMY STRATEGY (SUBSTEP 4.3)

The European bioeconomy strategy was updated in 2018 (EC, 2018). To implement the policy, education and awareness-raising activities have been carried out through three lines of action:

- promoting the initiatives of single member states, (e.g. Science Year in Germany in 2020, the Irish Bioeconomy Week, and the Italian Bioeconomy Day);
- collaborating with different stakeholders with skills relevant for bioeconomy education, from university representatives (e.g. European Bioeconomy University) to farmers' associations, to identify knowledge gaps and provide solutions to fill these gaps; and
- financing projects on adult education and vocational farming through research framework programmes.

Examples of the research framework programmes include BIOVoices, a project that brought together policymakers, researchers, businesses, and civil society to raise awareness and improve knowledge about the bioeconomy and address societal, environmental, and economic challenges related to bio-based products; and the follow-up project, Transition2bio builds upon previous initiatives to raising awareness on bioeconomy, identify educational and training needs, and strengthen the activities of the European Bioeconomy Network.

EU efforts to monitor and communicate the results were complemented by public consultations and included in a progress report on the implementation of the EU bioeconomy strategy that was presented at the 2022 European Bioeconomy Conference. (EC, 2022).

TABLE 1. Overview of how bioeconomy-dedicated strategies have addressed the steps and substeps of the present toolbox and examples of local/subnational and regional/supra-national strategies.

Substeps / Bioeconomy strategies	1.1 Participatory process	1.2 Vision and objectives	1.3 Definition	2.1 Mapping of potential	2.2 Main elements	2.3 Final document	3.1 Action plan	3.2 Implement	3.3 Cover gaps	4.1 Monitoring system	4.2 Evaluate	4.3 Revise the strategy
At national level												
Austria	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Canada	✓	✓	✓	✓	✓	✓		✓				
China		✓	✓		✓	✓						
Colombia	✓	✓	✓	✓	✓	✓						
Costa Rica	✓	✓	✓	✓	✓	✓	✓			✓		
Estonia	✓	✓	✓	✓		✓						
Finland	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
France	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Germany	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Ireland	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Italy	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
Japan	✓	✓	✓	✓	✓	✓		✓	✓		✓	
Latvia	✓	✓	✓	✓	✓	✓						
Malaysia		✓	✓	✓	✓	✓		✓	✓		✓	
Netherlands (Kingdom of the)	✓	✓										
Norway	✓	✓	✓	✓	✓	✓						
Portugal	✓	✓	✓	✓	✓	✓		✓	✓			
South Africa	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Spain	✓	✓	✓		✓	✓	✓	✓	✓			
Thailand		✓	✓	✓	✓	✓	✓	✓	✓		✓	
United States of America		✓		✓	✓	✓		✓				
Other examples at regional/ supra-national level and at local/subnational level												
East African Countries	✓	✓	✓	✓	✓	✓						
European Union	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
State of Para (Brazil)	✓	✓	✓	✓	✓	✓	✓		✓			
Other examples of strategies under development												
Namibia	✓	✓	✓	✓	✓		✓					
Uruguay	✓	✓	✓	✓	✓		✓		✓	✓		

Source: Author's own elaboration based on FAO Bioeconomy Dashboard (December 2023).

Chapter 4. FAO resources to develop bioeconomy strategies

This chapter provides a set of specific approaches and resources developed by FAO and partners that can support policymakers and other stakeholders engaged in the process of developing a bioeconomy strategy (see Table 2). Annex 2 provides complementary approaches including *ex ante* assessment tools. These approaches are classified into three groups.

- Publications;
- International organizations, networks, and consortia; and
- Databases and dashboards

TABLE 2. FAO resources to support bioeconomy strategies development

Publications	
There are many publications that can be consulted for guidance in carrying out the four steps in the development of a bioeconomy strategy. Many of these documents have been prepared by the FAO project, Towards Sustainable Bioeconomy Guidelines. They are listed in the order in which they can support the different steps in the development of a bioeconomy strategy.	
Towards Sustainable Bioeconomy Guidelines. FAO Project Brief	The FAO *Towards Sustainable Bioeconomy Guidelines* project has led multistakeholder processes in the field work conducted. There are several examples where FAO has led multistakeholder processes in the field supported by its network of experts (***substep 1.1***) such as in Namibia and Uruguay as described also in Chapter 3 of this toolbox (FAO, 2022). This publication is in three languages (please, see French and Spanish). There are several other FAO sources on good governance and multistakeholder processes. For instance, UNEP, FAO and UNDP (2023) have developed a guide to provide guidance in how to initiate a participatory process, underpinning successful multi-stakeholder collaboration: fostering broad participation; ensuring good understanding of the system; nurturing inclusive collaboration; defining a compass and securing sustainability of the collaboration

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Aspirational Principles and Criteria for a Sustainable Bioeconomy	The Aspirational Principles and Criteria for a Sustainable Bioeconomy (FAO, 2021), which were developed in 2016 by the ISBWG, can be consulted during every step in the development of a bioeconomy strategy. They provide a checklist of issues to consider when developing a vision for a sustainable bioeconomy. They are a framework for analysing context-specific synergies and trade-offs between different sustainability objectives (***substep 1.2***) since they are linked to the most common objectives of bioeconomy strategies and their related SDG targets (Gomez San Juan and Bogdanski, 2021). The principles and criteria create a common ground for discussions on sustainability in the bioeconomy. They can be applied by policymakers and other stakeholders in different stages of the strategy development process. The principles and criteria can also be used for measuring the sustainability of the bioeconomy or to monitor and evaluate the progress being made in making this shift (***substep 4.1***).
Towards sustainable bioeconomy. Lessons learned from case studies	The FAO publication, *Towards sustainable bioeconomy. Lessons learned from case studies*, includes a glossary of key bioeconomy terms, which can be consulted to help frame the definition and expand the general understanding of sustainability in the context of the development of the bioeconomy. This can be of use when stakeholders are working to define exactly what the bioeconomy means in their context (***substep 1.3***). The publication also provides a list of lessons learned and success factors derived from the review of 24 cases of bioeconomy implementation, mainly from the private sector, but also from municipalities, indigenous groups, and trade actors. It includes 22 success factors for the sustainable implementation of bioeconomy, with examples from real-life activities and companies and an analysis of why each success factor should be prioritized when designing bioeconomy interventions. Examples of these 23 success factors on bioeconomy in-action are provided for the 15 common objectives of bioeconomy strategies and the SDGs (Appendix 2). It also gives examples of business models suitable for the bioeconomy (Appendix 3). This can be consulted when stakeholders are considering the deployment of technologies and business models (***substep 3.2***) (Gomez San Juan, Bogdanski and Dubois, 2019).
Bioeconomy for a sustainable future	This publication gives a brief overview of what sectors and activities are included in the bioeconomy, which are summarised in Box 1 of this publication (FAO, 2021b).
How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies	The *How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies* publication includes a list of 15 most common strategy objectives found in bioeconomy strategies and their links to the Aspirational Criteria and SDG targets (***substep 1.2***). It also outlines 250 sources of good practices and policies to advance the global bioeconomy, across the definition parameters of the bioeconomy (***substep 1.3***). This approach is used by FAO to provide a step-by-step approach that allows practitioners to select the best options for their own specific context. This publication can help with mapping the bioeconomy value chains potential (***substep 2.1***) It also includes a survey template that can be used to map practices and policies that already exist in the country and to collect lessons learned on what worked already and what did not work. The survey template is the FAO methodology on defining and documenting good practices including successes and failures towards sustainability. It therefore helps in building an action plan (***substep 3.1***) (Gomez San Juan and Bogdanski, 2021).

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How sustainability is addressed in official bioeconomy strategies at international, national and regional levels. An overview	The FAO publication *How sustainability is addressed in official bioeconomy strategies at international, national and regional levels. An overview* reviews 16 bioeconomy strategies worldwide in a summary table to gauge whether they consider sustainability aspects (social, economic, environmental and a particular emphasis on food security) and, if so, it explains how they are addressed under different elements of bioeconomy strategies (***substep 2.2***). The publication provides a generic structure for the action plan that policymakers can use to build the "enabling environment" part of their bioeconomy strategy (***substep 3.1***) (Dubois and Gomez San Juan, 2016).
Sustainable and circular bioeconomy in the biodiversity agenda: Opportunities to conserve and restore biodiversity in agrifood systems through bioeconomy practices	It is used by FAO to provide examples of bioeconomy practices, bioproducts and successful case studies that can support biodiversity conservation and ecosystem restoration while managing the trade-offs involved in the development of a bioeconomy (***substep 2.2***). It is intended to raise public awareness on the role bioeconomy can play in supporting the post-2020 Global Biodiversity Framework as well as the FAO strategies on biodiversity, climate change, and science and innovation (Gomez San Juan, Harnett and Albinelli, 2022a).
Sustainable and circular bioeconomy in the climate agenda: Opportunities to transform agrifood systems	This publication provides an overview of the ways bioeconomy can contribute to the climate action strategies outlined in Intergovernmental Panel on Climate Change (IPCC) recommendations and NDCs and National Adaptation Plans (NAPs), and Long Term Low Emissions Development Strategies (LT-LEDS) (***substep 2.2***) (Gomez San Juan, Harnett and Albinelli, 2022b).
A review of the impacts of crop production on the soil microbiome: Innovations and policy recommendations to address environmental degradation, climate change and human health	The 2022 FAO publication, *A review of the impacts of crop production on the soil microbiome: Innovations and policy recommendations to address environmental degradation, climate change and human health,* illustrates how policies can be applied to support bioeconomy innovations. The review can provide insights into how to cover gaps in policy and investment (***substep 3.3***). It specifically shows how scientific advances related to the soil microbiome can be driven by targeted policies in four distinct areas: public support for research, development and innovation; education and communication; commercialization of microbiome innovations, and increasing demand for microbiome practices, products and services; and regulations (Kendzior, Warren and Bogdanski, 2022).
Guidance note on monitoring the sustainability of the bioeconomy at a country or macro-regional level	The *Guidance note on monitoring the sustainability of the bioeconomy at a country or macro-regional level,* published in 2021 by FAO and the EC Joint Research Centre, can be consulted during the building of a monitoring framework (***substep 4.1***). The Guidance Note, which was commissioned by the International Bioeconomy Forum (IBF), a platform that facilitates international cooperation on research and innovation for bioeconomy, describes a system to monitor the sustainability of the bioeconomy in a country or macro-region. It takes into consideration the main outcomes of a workshop on bioeconomy indicators held at the 2018 Global Bioeconomy Summit and follows the 10 aspirational principles and 24 criteria for a sustainable bioeconomy (Bogdanski *et al.*, 2021).
Monitoring the sustainability of the bioeconomy. Pilot in Uruguay	The 2023 FAO publication, *Monitoring the sustainability of the bioeconomy - Pilot in Uruguay* describes a concrete methodology that has been used for monitoring the sustainability of the bioeconomy in Uruguay. The methodology incorporates an analysis of biomass flows and their sustainability that can be used for different value chains or sectors. The publication provides examples of indicators selected with local stakeholders to evaluate some environmental, social, and economic effects of a bio-based material flow in the country. The methodology can be applied to support the evaluate the progress being made in the implementation of the strategy and its impact (***substep 4.2***) (Pozo *et al.*, 2023).

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Indicators to monitor and evaluate the sustainability of bioeconomy. Overview and a proposed way forward	The 2019 FAO publication, *Indicators to monitor and evaluate the sustainability of bioeconomy*, provides an overview of sustainability indicators at the territorial level (e.g. SDG indicators) and the product/value chain level (e.g. indicators used for standards, certification schemes and labels). The report recommends a series of steps for selecting the best indicators, criteria and frameworks and provides examples of how the results of a country's choices of indicators would be visualized in the form of spider nets. It also mentions that, using good practices and monitoring performance as a proxy is the easiest way to start the. Policies should have performance indicators for monitoring them. This document can also help when evaluate the progress being made in the implementation and the impact (***substep 4.2***) (Bracco *et al.*, 2019a). The publication is currently being reviewed. A related article, *Standards, Certifications and Labels for Bio-based Products in the Context of Sustainable Bioeconomy* (Bracco *et al.*, 2019b), provides an approach for measuring impact at product/value chain level. The report indicates that current schemes are centred mostly on circularity, material characteristics, bio-based content, trade, or sustainability of the production of biomass and biological resources in origin. It is being updated as well. Lastly, a review of *The contribution of the bioeconomy to countries' economy* (FAO, 2018), reports and analyses how different countries are measuring the contribution of bioeconomy to their overall economy or country objectives. The analysis, which focuses on Argentina, Australia, Germany, Malaysia, the Netherlands, South Africa, and the United States of America, provides a pathway to monitor performance at territorial level. This document can provide guidance in evaluating progress and impact.
International organizations, networks and consortia There is a range of international organization that can offer support to policymakers at any stage in the bioeconomy strategy development process. These organizations provide guidance on effective public policies for national governments and insights on building public-private partnerships and business-to-business connections.	
FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area	FAO 'Bioeconomy for sustainable food and agriculture' 10-year programme priority area is the organization' framework for FAO's support on the bioeconomy to its 196 Members and how the topic is advanced with international partners (FAO, 2021a). The FAO programme website on sustainable and circular bioeconomy for agrifood systems transformation provides the latest information on the work being done in the FAO programme priority area on bioeconomy (2022-2031). It updates on ongoing projects, events, publications, communications materials, and news stories, and is a useful channel for showcasing the results of the implementation of a strategy, the results of projects (***substep 4.3***). The programme also counts with a network of experts inside and outside the organization in a range of topics, either specific to the bioeconomy or in related areas, and support capacity building (***substep 2.3***). The programme supports the deployment of sustainable pioneering bioeconomy innovations (***substep 3.2***) and the formulation and implementation of integrated evidence-based policies where economic value and social welfare are paired with environmental sustainability (***substep 3.3***) (FAO, 2021a). A foundational study on the bioeconomy summarizing these and other opportunities and work by FAO is forthcoming.

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International Sustainable Bioeconomy Working Group (ISBWG)	ISBWG, which is led by FAO, helps foster knowledge exchange on bioeconomy deployment. The multi-stakeholder expert group, which acts as an advisory body to the FAO bioeconomy programme, is composed of around 35 members with a broad range of expertise and backgrounds, from policy to research, private sector, civil society and international organizations, from all five continents. The ISBWG supports countries in building a sustainable bioeconomy by supporting the mapping of bioeconomy initiatives worldwide (***substep 1.3***) and providing capacity development (***substep 2.3***). The ISBWG organizes meetings, workshops at the Global Bioeconomy Summit, and other public information events. These encounters give stakeholders the opportunity to present and communicate the results and performance of their bioeconomy strategies and gather inputs from other countries (FAO, online).
Databases and dashboards Statistical databases can be valuable resources for scenario building and modelling. Dashboards can be useful matchmaking platforms, facilitating business-to- business connections and supporting the systematic diffusion of biomass conversion technologies in different contexts. Building online dashboards can be an effective method for communicating the results that have been achieved through the implementation of the bioeconomy strategy.	
FAO Dashboard on bioeconomy strategies and related actions for sustainable development	The FAO bioeconomy dashboard is a global public resource created to advance a sustainable bioeconomy by providing comprehensive information for decision-makers. It primarily analyzes two datasets, focusing on actions included in bioeconomy strategies at national, subnational, and regional levels and their alignment with biodiversity and climate targets and linking bioeconomy strategies to food security related documents (***substep 2.2***). Countries can therefore use the present toolbox and the new interactive FAO bioeconomy dashboard in tandem to support efforts to achieve different environmental and socioeconomic pathways. The dashboard also shows, for each strategy, how many actions are directed towards specific bioeconomy topics, themes, and sectors (FAO, 2024).
FAO Corporate Statistical Database (FAOSTAT)	FAOSTAT provides free access to food and agriculture data for over 245 countries and territories and covers all FAO regional groupings from 1961 to the most recent year available. The data can be used to identify trends when creating scenarios and assessing options (***substep 2.1***) (FAO, online).

Source: Author's own elaboration.

Chapter 5. Conclusions and proposed next steps

This document provides FAO approaches and lessons learned on how to develop and implement bioeconomy strategies. As noted in the introduction, this toolbox was developed to cover several gaps in existing supporting documents on sustainable bioeconomy development. There is considerable literature on practical tools to support bioeconomy development. But there is little reference on how these levels come together and how sustainability should be addressed in all stages of development. The objective of this Toolbox is intended to mainstream sustainability at different levels and chart a pathway that can bridge local initiatives to national and global efforts.

One of these is a lack of coordination between countries and at different levels within a country. There is a need for bioeconomy strategies to be structured in a more homogeneous way so that comparative assessments can be made on the needs and strategic objectives of each country.

In the future, FAO will use this toolbox with counties requesting support to develop, implement and monitor bioeconomy strategies in three ways.

- For countries that already have a dedicated holistic bioeconomy strategy, this toolbox will be used to provide a list of elements needed to implement and monitor it, or to improve some of the assumptions made at the beginning of the process.
- For countries that do not have a strategy explicitly dedicated to the bioeconomy but have formulated bioeconomy-related policies, this toolbox can serve to support creating a more holistic and inclusive process or to identify gaps and elements that need to be addressed.
- For countries that are in the process of developing a bioeconomy strategy, FAO can support in assessing their bioeconomy potential, biomass availability, and quantitative and qualitative analysis of bio-based value chains, socioeconomic needs, and policy mapping.

At the eighth meeting of the ISBWG in Rome in 2023, experts from countries and organizations agreed that FAO should continue working on creating tools that can be used to support several of substeps laid out in the four-step approach to bioeconomy strategy development. The main substeps that required additional attention were:

- Substep 1.1. Initiate a participatory process
- Substep 2.1. Map the bioeconomy potential and data
- Substep 3.1. Build an action plan
- Substep 4.1. Build a monitoring framework

This toolbox provides examples of how countries have navigated through some of the steps of the process, for instance how they mapped their bioeconomy potential, and value chains, as well as identify their policy gaps that are required to foster bioeconomy growth. The resources, networks and tools included in this publication will also need to be augmented on an ongoing basis as more experience is gained in the development of bioeconomy strategies.

In the future, FAO and it partners will need to support more countries to generate further case studies and share insights based on the lessons learned. The toolbox and the new FAO bioeconomy dashboard will be used to identify countries that want to develop a bioeconomy strategy, action plan or monitoring system, create a dedicated institution, or further refine or revise a strategy.

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Annex 1. The steps in the IDB and EC approaches for developing a bioeconomy strategy

The IDB (2023) and the EC (2021) sources were consulted in the preparation of the toolbox. There are several overlapping steps and substeps in the approaches to bioeconomy strategy development outlined in those two publications and the FAO approach. For example, Step 1 on stakeholder engagement is similar to the approach taken by the EC, which focuses on how to translate regional and supranational strategies into national strategies and must engage a wide range of diverse stakeholders. Step 2 on the analysis of bioeconomy potential is part of the IDB approach, which focusses on subnational/ territorial strategies and analyses the potential of biomass and biological resources in depth, such as templates used for territory characterization (***substep 2.1***). The IDB guide deals less with implementation (Step 3). The EC approach does not include technical assessments (***substeps 2.1 and 3.2***). Neither approach includes the preparation of monitoring frameworks (***substeps 4.1 and 4.2***).

A1.1 IDB (2023) APPROACH "BIOECONOMY: EXPLORING THE POTENTIAL OF EMERGING BIOTECHNOLOGIES TO STIMULATE SUSTAINABLE GROWTH"

The objective of the source was to evaluate the potential of Latin America and the Caribbean for the bioeconomy, to design new policy and regulatory instruments that help to stimulate the growth of the bioeconomy towards its potential. The results supported improved dialogue between institutions for the development of the bioeconomy, and the design of future development programs with governments to structure their bioeconomy and support a thriving bio-based sector. It provides templates to analyse several policy-related factors, for instance SWOT analyses or territorial biomass potential assessments for substep 2.1. The source has several steps and tools:

1. Analysis and estimation of the local bioeconomy potential and status quo (main aspects of the bioeconomy)
   - → Characterization of the territory
   - → Assessment of KPIs on bioeconomy
   - → Complementary analyses (social and environmental checklist)
   - → SWOT analysis

Output: Territory's SWOT

2. Stakeholders engagement and development of a common vision
   - → Creation and launch of subnational bioeconomy hubs (organizational set-up, stakeholder characterization, engagement, and expansion)
   - → Challenges and opportunities for bioeconomy policies (vision building)

Output: Subnational/territorial hub and vision

3. Subnational bioeconomy strategy development
   - → Deriving specific goals within priority areas, specific actions and actors responsible for implementation
   - → Final consultation with stakeholders and drafting a strategy

Output: Drafted strategy document

4. Development of an implementation plan
   - → Identifying and developing supporting policy in a territory
   - → Developing financial resources and enabling environment mechanisms for the defined priority areas
   - → Assigning specific policy, financial mechanisms and resources to these actions (catalogue of bio-based solutions; and portfolio of instruments

Output: Subnational/territorial bioeconomy strategy roadmap

A 1.2. EC (2021) APPROACH: "DEPLOYING THE BIOECONOMY IN THE EU: A FRAMEWORK APPROACH FOR BIOECONOMY STRATEGY DEVELOPMENT. 10 POLICY RECOMMENDATIONS FOR BUILDING NATIONAL BIOECONOMIES TOWARD A FAIR AND JUST CLIMATE NEUTRAL EUROPE"

The bioeconomy to be a catalyst for sustainable systemic change and transition, is often designed at regional (supra-national) level and then translated to national strategies and/or action plans. The European Commission has provided this guidance tool with steps and recommendations to translate the EU strategy into national strategies in Member States. It was developed based on the feedback from experts in the Mutual Learning Experience, and taking into account the principles of good governance and systems transition approaches.

It aims to guide national bioeconomy strategy and/or action plan development Each country needs to define what transition means for them, and choose between alternative visions of the future and how to get there. Therefore, this source points to the importance of public engagement to foster consultation, which implies a need for both exploratory, analytical approaches (e.g. horizon scanning), as well as adaptive governance.
It advocates for policy that supports interactions among multiple actors, including businesses, users, scientific communities, policy-makers, social movements and interest groups. The source has several steps or elements to build a strategy:

1. Ensuring stronger recognition of the importance of bioeconomy policy by decision-makers and stakeholders
2. Moving from a bioeconomy concept to developing a vision
3. Creating spaces for building collective bioeconomy awareness and leadership
4. Coordinating across government to support bioeconomy strategy design and development
5. Identification of existing bioeconomy initiatives for building a coherent action plan
6. Establishing collaborative bioeconomy partnerships for co-investment
7. Developing linkages and pathways between bioeconomy policy, funding, national and European Union strategic research, innovation and investment agendas, and rural and regional development
8. Addressing the concerns and resistance of incumbent industries and patterns of behaviour of citizens and consumers
9. Encouraging diffusion of bio-based knowledge, innovation and technological advances to support rural, coastal and regional development

Annex 2. Examples of complementary approaches

TABLE A2.1. Examples of complementary approaches

Publications	
Bioeconomy Strategies, Position Papers and Studies	The IACGB policy overview documents and analyses aim at inspiring and facilitating international collaboration and mutual exchange in all aspects of global relevance for sustainable bioeconomy development by multiple stakeholders from policy, science, civil society and the business sector. In particular, Global Bioeconomy Policy Reports (I to IV) and the Global Bioeconomy Report of April 2024 provide an in-depth analysis of bioeconomy strategies around the world (IACGB, online).
International organizations, networks, and consortia	
Bioeconomy-dedicated global and regional platforms for experience and knowledge exchange	Bioeconomy-dedicated international platforms help policy makers and practitioners to access experts on the topic from all contexts, which helps defining the knowledge base that supports national or regional actors to come up with a bioeconomy definition and foster knowledge exchange on the process of bioeconomy deployment, including the initial purpose of developing a strategy (***substep 1.3***). Examples are: **Global bioeconomy summit and the International Advisory Council on Global Bioeconomy (IACGB)** The IACGB is an independent think tank made up of about forty high-level bioeconomy leaders and experts from around the world with different backgrounds and expertise. Its works to facilitate international collaboration and mutual exchange in all aspects of sustainable bioeconomy development, organizes the Global Bioeconomy Summit (IACGB, online). **Circular bioeconomy Alliance** It is a leading collaborative platform with around fifty members including scientific organisations, corporations, banks and funds, indigenous peoples, NGOs and companies. It includes several initiatives that provide funding, expertise, and know how to facilitate projects, including living labs, in a concrete territorial context, integrating traditional knowledge, capitalizing on new research and innovation and based on public-private partnerships (CBA, online). **World Bioeconomy Association** It is a global non-profit association focusing on advancing bioeconomy holistically covering various bioeconomy visions – Bioresource, Biotechnology and Bioecology. The World Bioeconomy Forum is its associated global platform and event (WCBEF, online).

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International organizations, networks, and consortia	
Bioeconomy-dedicated global and regional platforms for experience and knowledge exchange	**OECD Working Party on Biotechnology, Nanotechnology and Converging Technologies (BNCT)** The BNCT focuses on policy issues related to biotechnology, nanotechnology, and converging technologies. It contributes original policy analysis and messages to the global community, convenes key stakeholders=, and make proposals to policymakers. One of the main themes is realising the promise of converging technologies to enable the bioeconomy, the circular economy, and the transition to better patterns of resource use (OECD, online). **APEC Goals on the Bio-Circular-Green (BCG) Economy** The declaration of the Bangkok Goals on the Bio-Circular-Green (BCG) Economy at the 2022 APEC Economic Leaders' Meeting aim to marshal existing targets and workstreams in conjunction with the goals set in four areas, environment, trade and investment, natural resources including biodiversity, and resource efficiency and sustainable waste management. There is an annual award for projects across three award categories of women, youth and micro, small and medium enterprises (APEC, 2023). **East African Science and Technology Commission (EASTECO)** promotes and coordinate the development, management and application of science and technology to support socio-economic development and regional integration in East Africa. It manages a regional strategy on bioeconomy (EASTECO, online). **Latin American Bioeconomy Network** The Inter-American Institute for Cooperation on Agriculture (IICA) serves as the executive and technical secretariat of the Latin American Bioeconomy Network, which was launched in 2023 at the 27th Annual Conference of the International Consortium on Applied Bioeconomy Research (ICABR) (IICA, online). Other efforts in the region include the Interamerican Development Bank who has a bioeconomy policy expert group and several projects to support bioinnovations deployment, such as the crowdsourcing platform *Transformar.bio*. **International Bioeconomy Forum (IBF) and European Bioeconomy Policy Forum (EBPF)** The IBF and the EBF are two international and domestic networks that the European Commission has to consult and to support the strategic advancement of a circular and sustainable bioeconomy. They bring governments together to facilitate sharing of best practices and coordinated approaches in developing bioeconomy policy solutions. EU institutions are also participating members. They were developed under Action 2.3 of the European Bioeconomy Strategy in response to Member States' requests for increased cooperation. **The Rural Bioeconomy Alliance** The Rural Bioeconomy Alliance is a partnership of EU-funded projects that supports transition to bioeconomy in rural areas. The projects that are part of the Rural Bioeconomy Alliance are also part of the larger European Bioeconomy Network (EuBioNet), which is an alliance of 150 EU-funded projects and initiatives involved with bioeconomy promotion, communication and support (BioRural, online).

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International organizations, networks, and consortia	
Bio-based Industries Consortium (BIC)	The Bio-based Industries Consortium (BIC) is a non-profit organization established in 2013 to represent the private sector in a public-private partnership with the EC (the Circular Bio-based Europe Joint Undertaking). It focuses on strengthening bio-based industries sector in Europe. BIC's industry members cover the entire value chain, from primary production to market. It provides support to a range of agro- and bio-industrial projects that valorize waste and reduce competition with food security. Its members represent diverse sectors, including agriculture and agrifood, aquaculture and marine, chemicals and materials (including bioplastics), forestry, pulp and paper and technology providers and waste management and treatment. BIC also has associate members that include research organizations, academia, and trade associations. BIC has published biomass potential report for member countries (***substep 2.1***) and a Regional Funding Platform, which is a matchmaking platform on different types of investing opportunities for different sectors, feedstocks, biorefineries and clusters (***substep 3.3***) (BIC, online).
The Sustainability Consortium (TSC)	TSC is an organization that promotes business-to-business connections among diverse stakeholders who work collaboratively to build science-based decision tools and solutions that address sustainability issues throughout a product's supply chain and lifecycle. It operates globally but it is jointly administered by Arizona State University and the University of Arkansas with additional operations at Wageningen UR in the Netherlands. There is also an advisory board of representatives from academia, industry, and civil society. The multistakeholder approach is comprehensive and standardized for many products. Stakeholders identify the steps of the product life cycle that have potentially the greatest impact (sustainability hot spots). There are several approaches and tools used. For instance, the TSC Commodity Mapping Tool helps to visualize and communicate companies' most likely risks in their product supply chains and provides insights into bio-based product supply chains for consumer trust. It also allows producers to prioritize, manage risks, and address sustainability issues. The TSC Wastewater 101 toolbox focuses on textile industry supply chain performance. Users where can find information and take action to create incentives for reducing pollution and treating wastewater (***substep 4.2***) (TSC, online).
The Economics of Ecosystems and Biodiversity	The Economics of Ecosystems and Biodiversity (TEEB), which is hosted by United Nations Environment Programme (UNEP), is a global initiative whose principal objective is to mainstream the values of biodiversity and ecosystem services into decision-making at all levels. TEEB follow a structured approach to valuation that helps decision-makers recognize the wide range of benefits provided by ecosystems and biodiversity, demonstrate their values in economic terms and, where appropriate, capture those values in decision-making. TEEB can provide insights into how to draw the boundaries around the economic sectors to be included in the definition of the bioeconomy (***substep 1.3***) (TEEB, online).

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Databases and dashboards	
Chatham House dashboards	Chatham House has created a dashboard with a global map that enables users to explore and visualize the dynamics of international trade in natural resources, its sustainability implications, and the interdependencies between importing and exporting countries and regions. It is used by UNCTAD and by different actors involved in biodiversity and trade related issues (***substep 2.1***). Complementary, Chatham House has also developed a circular economy policy map and a dashboard on waste generation, collection and recycling trends in different world regions (***substep 3.1***) (Chatham House, 2021).
EU monitoring resources	**EU Bioeconomy Monitoring System dashboards** The EU Bioeconomy Monitoring System offers a comprehensive overview of European trends in indicators related to the EU Bioeconomy. The set of indicators is organized according to a conceptual framework that allows for full coverage of the EU Bioeconomy: value chain steps, sustainability pillars, primary production sectors. It includes data on a wide range of different aspects: trade, food and organic waste, circularity and recovery, land and marine resources, uses of biomass, products, emissions by bio-based sector, among others. It also gives time series data of each of the five sustainability objectives of the European strategy to show its performance over years (EC, online). In 2020, The EC Joint Research Centre published a report on the progress being made in building a monitoring system for the EU bioeconomy, which can provide insights into approaches for building a monitoring framework and follow the steps (***substep 4.1***) (Giuntoli *et al.*, 2020). **Data/Modelling platform of resource economics (DataM)** DataM, which is a component of the EC Joint Research Centre Data Catalogue, is knowledge and data hub for research carried out by the EC and partners in resource economics and sustainability. The datasets, which cover a range of domains, including agrifood, bioeconomy, biotechnologies, climate change, food, and nutrition security, consist mainly in estimates derived from analysis or economic models (e.g. outlooks on future scenarios). It is a useful means to show data on the results of implementing the strategy, investments done, biomass flows improved, sustainability performance etc. (***substep 4.3***) (EC, online). **EU Bio-based industry and biorefineries dataset** Biorefinery maps and platforms for connecting business-to- business are useful tools to support the systematic diffusion of biomass conversion technologies in different contexts; for example, this biorefineries and bio-based industry dashboard in the European Union (***substep 3.3***) (EC, online).
Task 42 Global Biorefineries Atlas Portal	Task 42 (Biorefining in a Circular Economy) of The International Energy Agency (IEA) Bioenergy Technology Collaboration Programme (TCP) facilitates the commercialisation and market deployment of environmentally sound, socially acceptable, and cost-competitive biorefinery systems and technologies and offers advice to policymakers and industrial decision makers. The Task 42 Global Biorefineries Atlas portal (WEB GIS) includes data from a broad range of information sources. The interactive portal gives the users the capability to query, select and download subsets of selected records. Users can also produce and download customized maps and charts (***substep 3.3***) (IEA, online).

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Catalogue of bioeconomy technologies	The IICA Innovation and Program works to increase capacities to capitalize on technological innovations to support the bioeconomy. Its catalog of bioeconomy technologies is a virtual platform that aims to facilitate access to technologies for efficient and sustainable use of biological resources. It can be searched by value chain of raw material or final product by country or by project (IICA, online).

Ex ante assessment tools and modelling tools

Tools for *ex ante* evaluation and modelling can shed light on different aspects of the transition towards bioeconomy and contribute to decision-making. *Ex ante* assessment tools, which can provide assessment and scenarios of a general nature or be sector specific or impact specific, can be used for several step in the process of preparing a bioeconomy strategy. There are three principal types of modelling tools: economic models, environmental models, and integrated assessment models. Examples of economic models are general or partial equilibrium models, input-output models or agent based models. Examples of environmental models are Earth-system models, biophysical models, or spatial land allocation models. In between, there are integrated assessment models which capture the synergies and trade-offs.

Examples of tools are provided below.

Modular Applied General Equilibrium Tool (MAGNET)	MAGNET is a recursive dynamic, multi-region, multi-sector computable general equilibrium model used to analyse policy scenarios on agricultural economics, bioeconomy, food security, climate change and international trade. It was developed by the Wageningen Economic Research (WECR) in cooperation with the EC Joint Research Centre and the Thunen Institute. MAGNET, which comprises over 65 sectors and 141 countries or regions, can be used in policy formulation through *ex ante* policy analysis (***substep 1.2***). The model assesses policy scenarios related to agriculture and agrifood trade and takes into account other related fields associated with bioeconomy (e.g. bioenergy, biofuel, bio-based chemicals), the sustainable use of land and water resources, food security and nutrition and climate change, and the wider non-agricultural economy (MAGNET, online).
Global Change Assessment Model (GCAM)	GCAM, developed by the Joint Global Change Research Institute (JGCRI) at Pacific Northwest National Laboratory, is multisector and multicriteria model that can be used to examine a range of scenarios for determining the vision for the territory (***substep 1.2***). For example, how changes in population, income, or technology cost might alter crop production, energy demand, and water withdrawals, or how changes in one region's demand for energy affect energy, water, and land in other regions. It is a market equilibrium model with a global scope and operates from 1990 to 2100 in five-year time steps. It is a freely available community model (GCIMS, online).
S2Biom	The EC-funded, S2Biom project, which ran from 2013 to 2016, carried out research to facilitate integrated design and evaluation of *optimal* biomass delivery chains and networks at European, national, regional and local scale, informed by a computerized and easy-to-use toolset which helps to characterize the region and for biomass in formation (supply, cost, properties, logistics, market information, conversion technologies, etc.) (***substep 2.1***) (S2Biom, online).
Co$ting Nature	Co$tingNature, developed by Policy Support Systems in collaboration with the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), is a web-based spatial policy support system for natural capital accounting. It can be used to analyse the ecosystem services provided by natural environments, identify the beneficiaries of these services, and assess the impacts of human interventions. Co$tingNature incorporates detailed datasets at 1-square km and 1 hectare resolution for the entire world, to elaborate spatial models for biophysical and socioeconomic processes, and scenarios for climate and land use.

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Ex ante assessment tools and modelling tools	
Co$ting Nature (continues)	It calculates a baseline for current ecosystem service provision and allows a series of policy options or scenarios of change to be analysed to understand their impact on ecosystem services. Typical applications include ecosystem service assessment, conservation prioritization, the analysis of co-benefits, pressures and threats on carbon and biodiversity in general and for specific planned agricultural, industrial or extractive interventions (***substep 4.2***) (Policy Support Systems, online).
Examples of *FAO ex ante* assessment tools	FAO sectoral assessment tools can provide partial information on the potential and sustainability for specific sectors. **The Adaptation, Biodiversity and Carbon Mapping Tool (ABC-Map)** ABC-Map is a geospatial app based on Google Earth Engine that holistically assesses the environmental impact of national policies, plans, and investments on changes in the agriculture, forestry, and other land use (AFOLU) sector. The app was developed by FAO and partners within the Framework for Ecosystem Restoration Monitoring (FERM) which tracks progress of efforts to restore degraded ecosystems (***substep 3.2***) (FAO, online). ***Ex Ante* Carbon-Balance Tool (Ex-ACT)** Ex-ACT, a tool developed by FAO is based on the Intergovernmental Panel on Climate Change (IPCC) methodology for greenhouse gas emissions inventories. It offers a consistent way of estimating and tracking the outcomes of agricultural interventions on greenhouse gas emissions. EX-ACT is the only greenhouse gas accounting tool to cover the entire agricultural sector including agriculture, forestry and other land use (AFOLU) inland and coastal wetlands, fisheries and aquaculture, agricultural inputs and infrastructure. It provides a carbon balance by module, which allows to identify how activities contribute to carbon emissions and sinks (***substep 3.2***) (FAO, online). **Sectoral assessments: bioenergy** The Bioenergy and Food Security (BEFS) Approach has been developed by FAO and consists of tools and guidance to support countries through the main stages of the bioenergy policy development and implementation process. For instance, it assesses the impacts of bioenergy developments on food security through four different analyses (diagnostic, natural resources, techno-economic and environmental, and socioeconomic). Food security is usually analysed in terms of its four dimensions: availability, access, stability and utilization, and this tool focuses on availability and access dimensions (FAO, online). **Sectoral assessments: livestock** The Global Livestock Environmental Assessment Model (GLEAM), developed by FAO, is a GIS framework that simulates the bio-physical processes and activities along livestock supply chains under a life cycle assessment approach. It helps to calculate GHG emissions to support investment and policy planning in animal husbandry, feed, and manure management to identify ways to improve efficiency. GLEAM can be used to quantify production and use of natural resources in the livestock sector and identify environmental impacts of livestock to contribute to the assessment of adaptation and mitigation scenarios to move towards a more sustainable livestock sector (***substep 3.2***) (FAO, online).

Source: Author's own elaboration.

Appendix 1. Steps, substeps, FAO publications and case studies

The graphic summary on the following two pages outlines FAO's step-wise approach to guide policymakers in the development of local, national and regional sustainable bioeconomy strategies. The graphic summary shows the four main steps (and related substeps) needed to build a bioeconomy strategy; and four case studies of countries representing each step of the process. It also includes a map of FAO approach and resources linked to each of the four steps of sustainable bioeconomy strategy development.

FOUR OVERALL STEPS
TO GUIDE POLICYMAKERS

FAO APPROACH AND RESOURCES
FOR EACH STEP AND SUBSTEP

STEP 1 — Set up a governance mechanism and dedicated institution

Bioconomy concepts, principles and criteria

- **1.1** Initiate a participatory process
- **1.2** Create a vision and sustainability objectives
- **1.3** Agree on a definition

- **1.1** FAO multistakeholder processes approach
- **1.2** FAO Principles and Criteria for trade-offs analysis
- **1.3** FAO glossary and key terms used in bioeconomy development

STEP 2 — Devise the strategy

How sustainability is addressed in strategies and goals

- **2.1** Map the bioeconomy potential and data
- **2.2** Select the main elements of the strategy
- **2.3** Write the final document

- **2.1** FAO mapping tool for existing good practices and policies
- **2.2** FAO analysis of strategies and how sustainability is addressed worldwide
- **2.3** FAO-led International Sustainable Bioeconomy Working Group (ISBWG)

STEP 3 — Implement with an action plan

Compendium of good practices, policies, and lessons from innovation

- **3.1** Build an action plan
- **3.2** Deploy technologies and business models
- **3.3** Cover gaps in policy and investment

- **3.1** FAO compendium and guide to select context-specific good practices and policies
- **3.2** FAO list of success factors for implementing bioeconomy
- **3.3** FAO examples on how to apply a mix of policies to implement bioeconomy innovations

STEP 4 — Monitor progress and revise the strategy

Monitoring and evaluating sustainability in the bioeconomy

- **4.1** Build a monitoring framework
- **4.2** Evaluate progress and impact
- **4.3** Share results and revise the strategy

- **4.1** FAO-JRC guide on how to build a monitoring system
- **4.2** FAO review of indicators applied at territorial and value-chain levels, and example of biomass flows
- **4.3** FAO outreach work that provides inputs for strategy revision

STAKEHOLDER INVOLVEMENT THROUGHOUT THE PROCESS (AT LOCAL LEVEL AND IN ISBWG)

KEY MESSAGES
FROM FOUR CASE STUDIES IN PARTNER COUNTRIES

Namibia
Biodiversity targets and bioprospecting for investment

Namibia illustrates the **first step of developing a bioeconomy strategy**, in which the definition, boundaries and aspirations of a bioeconomy have to be created. An important success factor has been the extensive **consultation with all regional governments** and local populations, in collaboration with FAO, which has supported the country in developing a multistakeholder group and a strategy document.

The case study of Namibia brings interesting perspectives regarding the **equitable share of benefits from the use and conservation of biodiversity**. It shows that bioeconomy goes beyond production and includes **services**, like ecotourism, biosciences and data.

Namibia is also an example, together with South Africa or the Eastern Africa countries, of the important role of the **research, technology and innovation policy** to initiate the process of building a bioeconomy and mainstream it.

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Uruguay
Environmental added value for international trade

Uruguay illustrates the **second step**, in which the strategy document is formulated based on a shared vision. A success factor of bioeconomy growth has been the combination of consultations with national actors as well as **with international experts** of the ISBWG.

Further, given FAO's support in devising the strategy, this case study brings interesting perspectives regarding **bioeconomy links to international agreements** such as the Paris Agreement on climate change, and shows the importance of the **sustainable trade of biological resources** with instruments that acknowledge good practices in origin and traceability.

Uruguay is also an example, together with Argentina and most European countries, of the importance of **territorial planning and rural development** to build new value chains – or "value webs" – to improve efficiency and reduce waste and pollution.

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Malaysia
New value chains and regional leader

Malaysia represents the **third step**, the implementation of the strategy and associated efforts to ensure this happens in a sustainable way. An important success factor has been the creation of a **supra-ministerial institution to govern** the process of developing the bioeconomy, and related policies such as the comprehensive National Biomass Strategy for all biological resources of the country.

The case study of Malaysia also includes many examples in different sectors of innovations deployed thanks to **public–private partnerships (PPPs)** and other mechanisms and incentives to create innovative jobs as well as access to international green finance. FAO has supported the country to improve sustainability in bioeconomy implementation.

Malaysia is also an example, together with Japan and Thailand, of **regional collaboration** in the Asia–Pacific region.

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Germany
Bioproducts and bioprocesses in the market

Germany is an example of **fourth step**, showing how a bioeconomy is conceived, developed, implemented, monitored and then revised. An important success factor in this step is to **raise awareness and communicate** the progress made.

This case study shows how different **metrics for the bioeconomy** are used in a complementary way, involving several ministries and areas of expertise, as well as all the elements of sustainability – social, economic and environmental – as well as elements of good governance, in a coordinated way and with a comprehensive set of data covering all the bioeconomy sectors.

Germany's success, together with that of Canada and Ireland, is also an example of strong **international cooperation** to create a bioeconomy that leaves no one behind and ensures food security first.

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Source: Author's own elaboration.

Appendix 2. Fifteen common bioeconomy strategy objectives and links with sustainability

Economic dimension
To increase profitability by adding value to biomass
a. Criterion 3.1 (Economic development is fostered) b. SDG8 (Decent work and economic growth, target 8.2) and SDG9 (Industry, innovation and infrastructure, target 9.b), and to some extent SDG2 (Zero hunger, target 2.3)
To create and secure employment through in situ value addition and enhance rural and urban economic resilience
a. Criterion 3.2 (Inclusive economic growth is strengthened) b. SDG5 (Gender equality, target 5.a) and SDG8 (Decent work and economic growth, target 8.5), and to some extent SDG14 (Life below water, target 14.2) and SDG15 (Life on land, target 15.9)
To promote actions that contribute to the revitalization and development of rural areas
a. Criterion 3.3 (Resilience of the rural and urban economy is enhanced) b. SDG7 (Affordable and clean energy, target 7.b) and SDG11 (Sustainable cities and communities, target 11.a), and to some extent SDG2 (Zero hunger, target 2.a)
To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
a. Criterion 8.1 (Local economies are not constrained but rather expanded through the trade of raw and processed biomass, and related technologies) b. SDG10 (Reduced inequalities, target 10.3) and SDG17 (Partnerships for the goals, targets 17.11 and 17.17)
Environmental dimension
To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
a. Criterion 1.2 (Sustainable intensification of biomass production is promoted) and Criterion 9.1 (Consumption patterns of bioeconomy goods match sustainable supply levels of biomass) b. SDG12 (Sustainable consumption and production, targets 12.6 and 12.c) and to some extent SDG7 (Affordable and clean energy, target 7.2)
To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
a. Criterion 2.1 (Biodiversity conservation is ensured), Criterion 2.3 (Water quality and quantity are maintained, and, as much as possible enhanced), and Criterion 2.4 (The degradation of land, soil, forests and marine environments is prevented, stopped or reversed) b. SDG2 (Zero hunger, target 2.5), SDG12 (Sustainable consumption and production, targets 12.2 and 12.c), SDG14 (Life below water, targets 14.1 and 14.4), and SDG15 (Life on land, targets 15.2, 15.3, 15.5 and 15.6)
To mitigate and adapt to the effects of climate change and reduce environmental pollution
a. Criterion 2.2 (Climate change mitigation and adaptation is pursued) b. SDG13 (Climate action, target 13.2) and SDG12 (Sustainable consumption and production, target 12.4), and to some extent SDG1 (No poverty, target 1.5), SDG3 (Good health and well-being, target 3.9) and SDG 11 (Sustainable cities and communities, 11.6)

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To move towards a more circular bioeconomy
a. Criterion 5.1 (Resource use efficiency, waste prevention and waste re-use 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); Criterion 4.1 (The sustainability of urban centers is enhanced) b. SDG6 (Clean water and sanitation, target 6.3 and 6.4), SDG9 (Industry, innovation and infrastructure, target 9.4), SDG11 (Sustainable cities and communities, target 11.6), SDG12 (Sustainable consumption and production, targets 12.3, 12.4 and 12.5) and SDG13 (Climate action, target 13.1)
Social dimension
To safeguard food security
a. Criterion 1.1 (Food security and nutrition are supported) b. SDG2 (Zero hunger, targets 2.4 and 2.a), SDG3 (Good health and well-being, target 3.4) and to some extent SDG12 (Sustainable consumption and production, target 12.3)
To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
a. Criterion 1.3 (Adequate land rights and rights to other natural resources are guaranteed) and Criterion 4.2 (Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened in rural areas) b. SDG15 (Life on land, target 15.6 and 15.9) and SDG1 (No poverty, target 1.3) and to some extent SDG10 (Reduced inequalities, targets 10.1)
To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
a. Criterion 7.1 (Existing knowledge is adequately valued and proven sound technologies are fostered) and Criterion 7.2 (Knowledge generation and innovation are promoted) b. SDG3 (Good health and well-being, target 3.b), SDG4 (Quality education, targets 4.4 and 4.b), SDG9 (Industry, innovation and infrastructure, targets 9.5 and 9.b) and SDG17 (Partnerships for the goals, target 17.6), and to some extent SDG2 (Zero hunger, target 2.5), and SDG14 (Life below water, target 14.a)
To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy
a. Criterion 1.4 (Food safety, disease prevention and human health are ensured) and 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) b. SDG3 (Good health and well-being, target 3.4), SDG8 (Decent work and economic growth, target 8.4), SDG12 (Sustainable consumption and production, targets 12.1 and 12.7), SDG13 (Climate action, target 13.3) and SDG17 (Partnerships for the goals, target 17.14)
Governance dimension
To promote synergies and reduce trade-offs between biomass uses, while meeting the growing demand for food and non-food goods
a. 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) b. SDG8 (Decent work and economic growth, target 8.3), SDG16 (Peace, justice and strong institutions, target 16.7) and SDG17 (Partnerships for the goals, target 17.14), and up to some extent SDG1 (No poverty, target 1.b)

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To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets
a. Criterion 6.3 (Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented) b. SDG12 (Sustainable consumption and production, targets 12.6 and 12.b), SDG16 (Peace, justice and strong institutions, target 16.6) and SDG17 (Partnerships for the goals, target 17.19)
To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research
a. Criterion 10.1 (Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate) and to some extent Criterion 8.1 (Local economies are not constrained but rather expanded through the trade of raw and processed biomass, and related technologies) b. SDG10 (Reduced inequalities, target 10.6) and SDG17 (Partnerships for the goals, targets 17.7, 17.9 and 17.16) and to some extent SDG12 (Sustainable consumption and production, targets 12.8 and 12.a)

Source: Adapted from **Gomez San Juan, M. & Bogdanski, A.** 2021. *How to mainstream sustainability and circularity into the bioeconomy. A compendium of bioeconomy good practices and policies.* Rome, FAO.

Appendix 3. Twenty-two common success factors in the implementation of bioeconomy

1.	The use, when viable, of biomass residues and food that are otherwise lost or wasted
2.	The use and valorization of all by- and co-products obtained in the processing stage
3.	The use of local, indigenous and underutilized plants and animal breeds in ways that protect genetic resources, respect local communities' intellectual property rights and support nature conservation
4.	The harnessing of the microbiome and microbiological processes, including processes that support renewable carbon capture and use
5.	The application of innovative practices and technologies for biomass production, processing and use
6.	The preservation of traditional knowledge in innovations and practices through the active involvement of indigenous and local communities
7.	Tests for circularity, including the biodegradability, compostability and disintegration of products
8.	The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
9.	Clustering and the integration of sectors and levels
10.	The adoption of territorial and landscape approaches in national or local planning
11.	The adoption of integrated systems
12.	The promotion of a value web approach
13.	Collaboration between public sector entities for interministerial coordination
14.	Collaboration between private sector and public sector to increase bioeconomy competitiveness
15.	Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
16.	Purchasing agreements between small-scale farmers and buyers
17.	Purchasing agreements between public entities and bioproduct manufacturers
18.	Purchasing agreements between technological intellectual property providers and investors
19.	The fair distribution of benefits among value chain actors
20.	Certification of sustainability and compliance with national law through monitoring and evaluation
21.	Policy interventions that provide incentives and establish supportive public mechanisms
22.	The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Source: Based on **Gomez San Juan, M., Bogdanski, A. & Dubois, O.** 2019. *Towards sustainable bioeconomy - Lessons learned from case studies.* Rome, FAO.

The objective of the *Bioeconomy Toolbox* is to guide policymakers in the process of developing a context-appropriate definition of bioeconomy, setting up a sustainable bioeconomy strategy, implementing said strategy, and monitoring and revising the strategy as appropriate.

Not one bioeconomy is the same. There are many bioeconomies in the world and even in the same region or country. Bioeconomy strategies create the enabling conditions for new cross-sectoral value chains, bio-based technologies, and knowledge science and innovation that valorize and efficiently use biological resources, while ensuring its conservation and regeneration.

This publication aims to guide policymakers in the transition to a comprehensive bioeconomy that enhances sustainability and mitigates detrimental trade-offs, by providing them with a set of tools, approaches and examples from FAO and partner countries. It compiles lessons learned from the implementation of the *Towards Sustainable Bioeconomy Guidelines* project, supported by Germany's Federal Ministry of Food and Agriculture (BMEL). The project has created guiding products to develop and implement bioeconomy strategies and has tested them in pilot countries, based on multi-stakeholder processes and gearing towards the Aspirational Principles and Criteria of Sustainable Bioeconomy.

This toolbox serves to ensure the sustainability of the bioeconomy at different stages of development. It shows how bioeconomy in different contexts can address trade-offs and maximize the benefits in terms of food security, rural development, innovation, climate and biodiversity action, agrifood systems transformation, and greener and more equitable societies that support the goals of the 2030 Agenda for Sustainable Development.

Office of Climate Change, Biodiversity and Environment (OCB)

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