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BIOECONOMY

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TOWARDS SUSTAINABLE BIOECONOMY

Lessons learned from case studies

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ABBREVIATIONS AND ACRONYMS

AIM	Agensi Inovasi Malaysia
ASA	Alternative Set of Assistance Initiative (Ghana)
BBI JU	Bio-Based Industries Joint Undertaking
BCDP	Bioeconomy Community Development Programme (Malaysia)
BERST	Bioeconomy Regional Strategy Toolkit
BMEL	German Ministry for Food and Agriculture
CBD	Convention on Biological Diversity
CCU	Carbon capture and use
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FLW	Food loss and waste
GHG	Greenhouse gas
ISIC	International Standard Industrial Classification
ISBWG	International Sustainable Bioeconomy Working Group
LCA	Life cycle assessment
NBS	National Biomass Strategy (Malaysia)
NGO	Non-governmental organization
P&Cs	Principles and Criteria for Sustainable Bioeconomy
PE	Polyethylene
PET	Polyethylene terephthalate
PHA	Polyhydroxyalkanoate
R&D&I	Research, development and innovation
SDG	Sustainable Development Goal
SSA	Sub-Saharan Africa
USDA	United States Department of Agriculture

WHAT IS THE BIOECONOMY? KEY TERMS AND CONCEPTS

This report uses the definition of **bioeconomy** that was adopted at the 2018 Global Bioeconomy Summit:

> *Bioeconomy is the production, utilization and conservation of biological resources, including related knowledge, science, technology, and innovation, to provide information, products, processes and services across all economic sectors aiming toward a sustainable economy (GBS, 2018, p.2).*

BIOLOGICAL RESOURCES

Biological resources are material of biological origin. They represent the feedstock for the bioeconomy. These resources do not include organic material that has been embedded in geological formations and fossilized (e.g. fossil fuels, such as coal, petroleum and natural gas).

Article 2 of the 1992 Convention on Biological Diversity (CBD) notes that biological resources "include genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity".[1] These genetic resources include crops, forests, land and aquatic animals and micro-organisms.

Biomass is an important element of world's biological resources. Biomass, which can be based on plant or animal life, encompasses, but is not limited to, agricultural crops and trees, including dedicated energy crops, food, feed and fibre crop residues; aquatic plants and animals, algae, fish bones and other fish residues; forestry and wood residues; agricultural waste, including animal manure; processing by-products and any other non-fossil organic material. Biological resources can be used as feedstock for processing and in microbiological and biotechnological processes. These resources also include microorganisms, such as bacteria.

PRODUCTS

The term '**bioproduct**' encompasses all products made from biological resources, and includes food, feed, biofuels and bio-based products. **Biofuel** is fuel that is produced from biomass either directly (e.g. wood) or indirectly through the fermentation of sugars (e.g. ethanol). The term '**bioenergy**' is used for all energy derived from biofuels.

The term **'bio-based products'** refers to products that are wholly or partly derived from biomass and other biological resources, which are not used for food, feed and fuel. Some bio-based products are not new, such as, pulp and paper, timber for construction, bio-based cosmetics and fibres for clothing. However, there are many new kinds of bio-based products that are emerging. These include bio-based materials and biochemicals with new functionalities and properties, new substances used for medicinal purposes, and new ingredients used for cosmetics and functional food ingredients. According to the European Standard EN 16575, if the term 'bio-based product' is used to refer to a product, which is partly bio-based, the claim should be accompanied by a quantification of the bio-based content, normally expressed as a percentage of the total mass of the product (CEN, 2014). The **bio-based economy** is a subset

[1] The complete text of the CBD is available at: https://www.cbd.int/convention/text/default.shtml

of the bioeconomy that is concerned with the production of bio-based products and the generation of bioenergy (i.e. all bioproducts except food and feed) (Dubois and Gomez San Juan, 2016).

Bio-based materials are the intermediate products that are used to make bioproducts. Traditional bio-based materials include wood for the production of furniture and construction materials, and textiles, such as leather, cotton, linen and fish skin. Novel bio-based materials include a range of intermediate materials (e.g. building blocks and polymers) that are used to produce a wide range of bio-based products, including bio-based plastics, biolubricants and solvents (Müller *et al.*, 2015).

Building blocks are 'the core of the new bioeconomy' (Aeschelmann and Carus, 2015). Building blocks are the bio-based materials needed to manufacture some of the most common bioproducts. For instance, ethylene, which can be made from sugar cane, is a building block used in the manufacturing of the polymer polyethylene (PE).

A **polymer** is a chemical compound consisting of repeating monomers, a class of molecule that can bond in long chains. Along with PE, there are a number of other polymers used in the production of commodity plastics, such as polystyrene (PS), polypropylene (PP), polyvinyl chloride (PVC) and polyethylene terephthalate (PET). Examples of polymers used in the production of specialty or engineering plastics include polytetrafluoroethylene (PTFE, also known as Teflon), polycarbonate (PC, also known as Lexan) and polyesters and polyamides (Nylon).

A **bio-based plastic** is a blend of one or more bio-based polymers and additives. Examples of bio-based plastics include polyhydroxybutyrate (PHB), polyhydroxyalkanoates (PHAs) and polylactic acid (PLA), which is used for a number of purposes, including food packaging, cups, mulch films and tea bags, and can be biodegradable (Kabasci, 2013). Other applications of bio-based plastics include biomedical uses (e.g. implants) and 3D printing (Avérous, 2008).

PROCESSES

Biological resources are used in processes that are based on traditional knowledge and in the application of modern, innovative technologies in the life sciences and biotechnology. The biological resources that are used in microbiological and biotechnological processes are an essential element of the bioeconomy. These resources include **microbiota** (the ecological community of microorganisms or microbes), **microbiomes** (the genomes of all microorganisms in the microbiotic community) and **enzymes,** which serve as catalysts for biochemical reactions.

Technological innovations and traditional knowledge that use microbiological and biotechnological processes include the development of dietary approaches to preventive medicine (e.g. the production of fermented foods and precision nutrition) (Flandroy *et al.*, 2018; de Toro-Martín *et al.*, 2017). Microbiological and biotechnological processes are also used in agricultural production (e.g. to enhance plant nutrient uptake and nutrient use efficiency) and in post-harvest operations (e.g. to suppress storage pathogens and lengthen the shelf life of food products). These processes also play a role in the processing of biomass (e.g. the use of bacteria for fermentation processes or enzymes for catalysing processes), the application of electrochemical reactions (e.g. the use of microbes to generate electricity) and microbial fuel cell technologies (e.g. electroactive bacteria or proteins that form biofilms).

Carbon-based gases, such as carbon dioxide (CO_2), can also be considered as a biological resource in cases where a biotechnological process harnesses microorganisms that use these gases to derive specific compounds. This relates to carbon capture and use (CCU) processes involved in the production of bioproducts.

SERVICES

The delivery of **ecosystem services,** which are the benefits people derive from ecosystems, is a critical component of the bioeconomy. Ecosystem services include provisioning services of essential goods (e.g. food, water, timber and fibre); regulating services that affect climate, flooding, the spread and control of pests and diseases, waste management, and water quality; cultural services that provide recreational, aesthetic and spiritual benefits; and supporting services, such as soil formation, photosynthesis, and nutrient cycling (UNDP, 2018a).

Biological resources can be involved in the application of microbiological and biotechnological processes and the delivery of ecosystem services. For example, environmental microbiota from the air, the soil and the ocean influence the composition of the human microbiome and the microbiomes in larger ecosystems. The microbiome influences human and ecosystem health. It plays a role in preventing or contributing to malnourishment, including obesity, and other non-communicable diseases. The microbiome also affects the soil and terrestrial plants and animals, including those used in agriculture. In the oceans, the microbiome plays a key role in biogeochemical processes, such as carbon and nutrient cycling (Lal, 2009).

Biologic carbon sequestration in the soil, a process in which carbon is stored in the soil through improved agricultural practices and soil management, enhances soil quality and promotes the interlinked cycling of water and nutrients, which strengthens the delivery of ecosystem services. When the level of the soil organic carbon falls below a certain threshold soil ecological processes are adversely affected, which has negative impacts on numerous ecosystem services. Additional carbon can be captured in crop residues, animal manure and biochar, and then be stored in the soil.

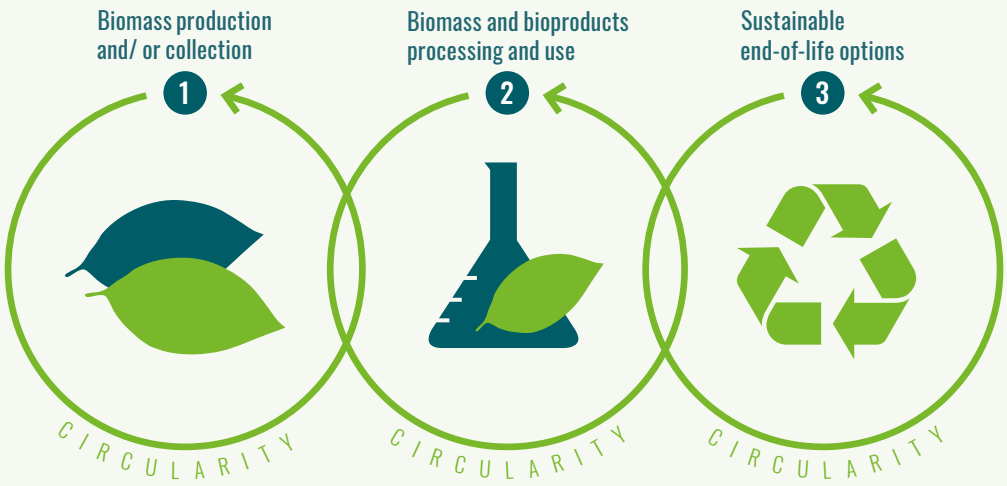
THE BIOMASS VALUE CHAIN

In the bioeconomy, biological resources, including biomass, enter into a value chain. **Figure 1** illustrates the three main stages in the **biomass value chain**, in which circularity aspects are cross-cutting.

Biomass is produced through agriculture, which encompasses crop production, livestock

FIGURE 1.

STAGES OF THE BIOMASS VALUE CHAIN



production, forestry, and aquaculture and fisheries. Biomass can also be collected from residues, waste and by-products generated at all three stages of the biomass value chain. Biomass collection also includes the small-scale gathering of indigenous plants for food, feed, fuel and bio-based products, such as cosmetics and healthcare products. The term '**biomass producer**' refers to anyone who is engaged in crop production, livestock production, forestry, and fisheries and aquaculture. In many of the case studies in the report, the biomass producers are crop farmers or cattle producers.

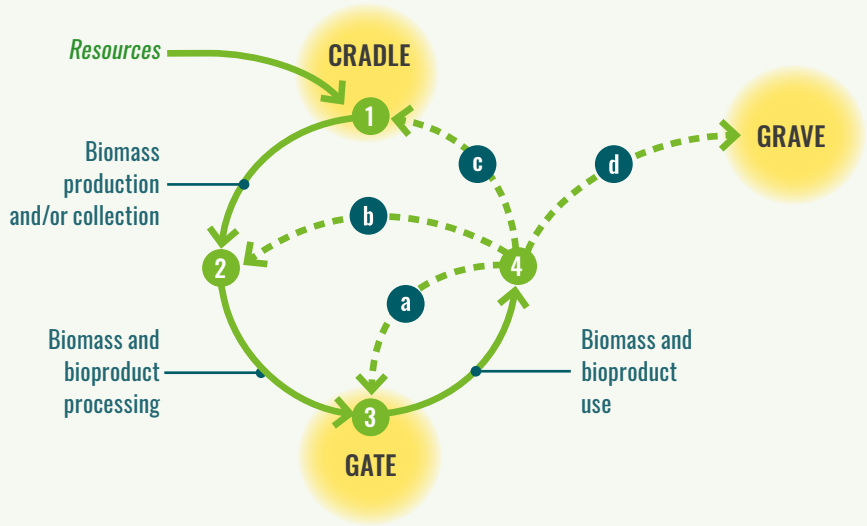
Biomass residues include agricultural residues from crop and livestock production and fisheries, and wood residues from forest harvesting, forest plantations and wood processing. The availability of both types of residues can be calculated with the FAO Bioenergy and Food Security Rapid Appraisal (BEFSRA) tools (FAO, 2014). Other residues include agro-industrial residues from food processing and bio-industrial residues from the processing of other bioproducts.

By-products are the waste streams from a manufacturing process or chemical reaction. They are materials that are not considered to be the principal product or service. In some cases, by-products can have harmful ecological consequences. Some by-products, through additional processing, can acquire added value and be converted into marketable products, which are referred to as **co-products** (EC, 2018a). For example, when vinasse, a by-product of sugar cane processing in ethanol factories, is disposed of in the soil and water bodies, it creates significant pollution problems. Vinasse can be treated so that it can be used in a number of ways, including as a fertilizer (for fertigation) and a soil amendment (for soils with low-potassium). In these cases, the fertilizer and soil amendment derived from the vinasse represent co-products of the sugar cane processing. Other examples of co-products are bioenergy and compost.

Processing refers to any kind of processing of biomass in small-, medium- or large-scale processing facilities. Use can range from the use of unprocessed biomass or biomass that has undergone very limited processing to the use of highly processed bioproducts. Therefore, biomass processing and use can be grouped as

FIGURE 2.

CIRCULAR END-OF-LIFE OPTIONS IN THE BIOECONOMY



a reuse b reuse or recycling c recycling or recovery d reduction of linear end-of-life options

one stage; yet, depending on the context, they can refer to two separate stages. The processing and use stage of the value chain involves activities that are critical for the successful implementation of the bioeconomy, such as local value addition, logistics and transportation, marketing, awareness-raising campaigns geared to consumers and manufacturers, and commercialization.

Sustainable end-of-life options refer to waste management procedures that follow non-conventional disposal routes, including biodegradation, aerobic or anaerobic composting, anaerobic digestion, and other waste management methods (InnProBio, 2017) associated with the '**4R approach**': the reduction, reuse, recycling and recovery of materials, nutrients, water and energy (EC, 2008; EC, 2018b). **Figure 2** builds on the last element of **Figure 1**, detailing four end-of-life options, reuse, recycling, recovery and reduction.

Circularity is a principle that is applied to all the steps of the biomass value chain. Achieving circularity in the value chain involves retaining the value of different kinds of resources (not only biological resources) in the economic cycle as long as possible before these resources reach the end-of-life stage. Applying the principles of circularity is a key aspect of making the bioeconomy sustainable. Circularity, which is focused on 'designing out' waste by adding value to biological waste and by-products flows, increases resource use efficiency in the biomass value chain; less inputs are used and less waste is produced. A central element for achieving circularity in the bioeconomy is the adoption of the 4R approach. In the circular bioeconomy, biological nutrients are returned to the biosphere, directly or in a cascade of consecutive operations that optimize the use of biomass (Ellen MacArthur Foundation, 2013, Figure 6; Kirchherr, Reike and Hekkert, 2017). A circular bioeconomy also creates opportunities for consumers to reduce their overall food waste and lower their consumption of resources (De Schoenmakere *et al.*, 2018).

The system boundaries determine the aspects that are included in the assessments of the sustainability of biomass value chains (EC, 2013). Typical types of boundaries for life cycle assessments (LCAs), environmental footprint and other assessments are described in the following terms:

- **Cradle to gate**: "A partial product supply chain, from the extraction of raw materials ('cradle') up to the manufacturer's 'gate'. The distribution, storage, use stage and end-of-life stage of the supply chain are omitted." (EC, 2013).
- **Cradle to grave**: "A product's life cycle that includes raw material extraction, processing, distribution, storage, use, and disposal or recycling stages. All relevant inputs and outputs are considered for all of the stages of the life cycle." (EC, 2013). Conventionally, LCAs address "the environmental aspects and potential impacts throughout a product's life, i.e. from cradle to grave" (ISO, 2006).
- **Cradle to cradle:** "A specific kind of cradle-to-grave, where the end-of-life disposal step for the product is a recycling process." (EC, 2013). This follows the model of the circular economy, where products are designed in a way so that at the end of their initial life they can be readily reused or recycled.

Cascaded use involves the reuse of residues and the recycling of materials across the value chain. The cascaded use of biomass and bio-based materials increases the efficiency in the use of resources and can reduce the need to introduce new materials into the economy (Ellen MacArthur Foundation, 2013). In a cascading approach, the biomass is processed into a bioproduct that is used at least once more (single-stage use) or several more times (multi-stage use), either for materials or energy, before disposal. The cascading approach extends the total availability of biomass within a given system (Carus, 2017). A differentiation can be made between cascading-in-value, cascading-in-function and cascading-in-time, depending on the preferences for the sequence in the use of biomass (Olsson *et al.*, 2016; De Schoenmakere *et al.*, 2018). However, the choice in the sequence is very context-specific and should be decided through an inclusive local multi-stakeholder process.

'**Biomass-based value web'** is a term that has been coined to describe the extension of the

concept of the biomass value chain to encompass the links that are created within and between value chains as a result of the cascading use and the joint use of biomass. As the degree of recycling and the cascading use of biomass in the bioeconomy increases, especially during the processing stage and the marketing of bioproducts, the point of 'zero waste' will be approached. As this happens, different value chains will merge and it will no longer sufficient to analyse value chains by using a conventional, linear approach that largely focuses on a single product.

There is a range of cross-cutting activities that apply to all stages of the biomass value chain. These cross-cutting activities include: research, development and innovation (R&D&I) and training, which can be done both by the private sector or the public sector; logistics and infrastructure; and government-led actions to create the enabling environment (e.g. adequate governance, effective institutions, transparency) that is needed for the bioeconomy to function effectively.

The term '**agro-industries'** refers to production systems that transform products from crop cultivation and livestock, forestry and fisheries, commonly into food and feed. The term '**bio-based industries**' refers to the application of biotechnology in production systems to make bio-based products or generate bioenergy from biofuels. In this report, the terms 'bio-based industries' and 'bio-industries' have been used interchangeably. A **biorefinery** is a bio-industrial plant that is engaged in "the sustainable processing of biomass into a spectrum of marketable bio-based products and energy" (De Jong and van Ree, 2009).

Bioprospecting or biodiversity prospecting is the systematic search for biochemical and genetic information in nature to develop commercially valuable products for pharmaceutical, agricultural, cosmetic and other applications (UNDP, 2018b). The term **biotrade** includes those activities of collection and production, transformation and commercialization of goods and services derived from native biodiversity (genes, species and ecosystems) under the criteria of environmental, social and economic sustainability (UNCTAD, 2005). **Access and benefit sharing (ABS)** relates to the arrangements that determine how genetic resources may be accessed and how users and providers reach agreements on the fair and equitable sharing of the benefits that might result from their use. ABS can take various forms (e.g. royalties, joint ventures, technology transfer, capacity building) (UNDP, 2018a).

EXECUTIVE SUMMARY

Bioeconomy activities are not necessarily sustainable. The use of biological resources and the production of biomass for food, feed, fuel and bio-based products can have both positive and negative environmental and socio-economic impacts. Of paramount concern is that the development of the bioeconomy does not undermine food security, especially in areas with high levels of malnutrition.

In 2015, at the Global Forum for Food and Agriculture (GFFA) meeting in Berlin, 62 ministers of agriculture recommended that FAO coordinate international work on sustainable bioeconomy (GFFA, 2015). The German Ministry for Food and Agriculture (BMEL) has provided support to FAO to assist countries in the development of sustainable bioeconomy strategies and programmes.

To this end, this report offers lessons from 26 case studies of sustainable bioeconomy interventions from around the world and from a range of different sectors. The overall aim of the report is to use these case studies to expand the general understanding of sustainability in the context of the development of the bioeconomy. The report presents an overview of a number of interventions in different sectors; the objectives that these interventions were seeking to achieve; the main actors involved; the context in which they were carried out; the success factors that enabled them to deliver sustainable socio-economic and environmental benefits; and the lessons learned from this analysis. This document provides policy makers and people working directly in bioeconomy initiatives with examples of the elements that need to be considered when implementing bioeconomy activities.

The selected interventions were reviewed to determine the extent to which they reflected the Aspirational Principles and Criteria (P&Cs) for Sustainable Bioeconomy, which were formulated in collaboration with the International Sustainable Bioeconomy Working Group (ISBWG) in 2016. The 26 case studies are also reviewed to determine the extent to which they support the Sustainable Development Goals (SDGs), which provide overall guidance for FAO work on sustainable bioeconomy.

There are many lessons that have been drawn from these case studies and they cover a diverse range of issues. This diversity reflects the nature of the growing bioeconomy. There is no single blueprint for developing and implementing a bioeconomy. However, there are number of indications on how a sustainable transition to a bioeconomy can be achieved.

The lessons learned from the 26 case studies provide an idea of what the shift toward sustainability can look like in practice. The lessons also clearly show that sustainability is not something that happens automatically. A multi-stakeholder effort, wherever possible, is needed to achieve synergies and reduce trade-offs between different sustainability goals.

This work is based on successful bioeconomy interventions. Consequently, the lessons from the case studies are not derived from aspects that lead to failure, but rather on success factors. However, there is no doubt that bioeconomy development carries with it a number of risks. The debates and experience on bioenergy over the last decade attest to this. Risks will be taken into account as deemed appropriate throughout the report.

In this executive summary, the lessons drawn from the review of the case studies have been structured according six major non-exclusive themes associated with most of the objectives of bioeconomy development: food security, natural resources management, climate change, responsible consumption and production, economic growth, and good governance.

FOOD SECURITY

The production of bioproducts can entail both risks and opportunities. There is no feedstock that is inherently good or bad. Results will depend on how the biomass is produced. The impact of bioeconomy initiatives on food security is not automatically defined by whether food-based or non-food-based feedstocks are used. This is important to bear in mind when addressing concerns that are similar to the 'food versus fuel' debate that has arisen over biofuels.

- The production of bioproducts should contribute to food production, not hinder it. This contribution can be made through the intensification of land use; the use of different types of land, including marginal land, to produce food and non-food goods; and the shift to integrated production systems that combine the production of food and non-food goods (e.g. integrated food-energy systems). This can be done either by using the land for multiple purposes (e.g. combining feedstocks for food and non-food goods) or using the biomass for a variety of purposes (e.g. the cascading use of biomass or the use of multi-purpose crops). In this regard, there are two key points that need to be made.
  - The notion of what constitutes marginal land is complex (e.g. can land that is used occasionally be called marginal?) and dynamic, in that it can change over time. Land can become non-marginal after it has been restored or after it is has become more accessible, for example, through the construction of a nearby road. The decision to qualify land as marginal and define its use should be undertaken through an inclusive process that involves all primary stakeholders. When planning for its use, consideration should be given to the time when the land may no longer be marginal and the possibility that more options for its use (e.g. food production) might become available.
  - The use of food by-products or agricultural residues for bioproducts is generally considered a no-regret alternative to the use of food crops. However, great care should be given to the issue of possible competition between different uses (e.g. soil management, animal feed, bioenergy and bioproducts) of these residues. The increasing demand for diverse bioproducts can increase competition for biomass and natural resources among different bioeconomy sectors, including the food sector. Biomass that was not previously used (e.g. food by-products and agricultural residues) can suddenly be mobilized and acquire a new market value. The existing and potential uses of residues should always be included in the feasibility analysis of residue-based bioeconomy initiatives, as these residues may already provide important goods and services to local communities.
- Ensuring adequate access to food is a dimension of food security that is often as challenging, if not more so, as ensuring the adequate production and availability of food. Access to food can be enhanced by improving tenure security, which is a commonly overlooked precondition for bioeconomy development. It can also be enhanced by creating opportunities to earn greater income from food and non-food goods through the adoption of technologies that make the most out of each component of the biomass.
- The proper utilization of food is another dimension of food security that the development of the bioeconomy can contribute to. The adequate utilization of food refers to the ability of the human body to ingest and metabolize food. Bioeconomy development can enhance access to sustainable bioenergy for cooking and stimulate the increased production of bio-nutrients. The knowledge connected to bioeconomy development can be applied to support healthy microbiomes. To avoid diseases, nutritious diets should be complemented by activities that safeguard a healthy microbiome and a biological environment that can properly moderate the interactions between food, the body and the environment.
- Both traditional and innovative processes and technologies used in the bioeconomy can help to use biomass more efficiently and effectively

by using every part of a given feedstock, which often begins as a food product. Local knowledge, including the knowledge held by indigenous communities, must be respected and valued. This knowledge can deliver significant benefits to the development of the bioeconomy, particularly in initiatives related to the production of bio-pharmaceuticals and bio-cosmetics.

NATURAL RESOURCES MANAGEMENT

- The sustainable management of natural resources (land, forest, water, biodiversity) clearly underpins sustainable bioeconomy development. However, sustainable natural resource management it is often not a primary objective of bioeconomy initiatives. It is often viewed as an issue that needs to be addressed to guarantee the sustainability of biomass production and processing. As a result, good practices related to the sustainable management of land, water, forests and biodiversity are often part of bioeconomy operations. On the other hand, direct and indirect land-use change is usually not taken into account when local bioeconomy development involves a shift in biomass production.
- The case studies analysed in this report show that the sustainable management of natural resources and inputs related to bioproducts can benefit the environment and support the business case of bioeconomy initiatives. This is particularly true in cases where biomass is extremely important to the local economy, and where natural resources play a key role in the sustainability of long-term operations (e.g. oceans in the case of sea-based bioproducts, forests and biodiversity in the case of bio-pharmaceuticals, and land for crop-based bioproducts).
- Small-scale biomass producers, including indigenous people, who are the custodians, users and beneficiaries of natural resources, should be given due considerations and decision-making power in bioeconomy development.
- The sustainable management of natural resources is a precondition for ensuring that the bioeconomy contributes to addressing the challenges associated with climate change.

CLIMATE CHANGE

- Contributing to climate change mitigation by using bio-based products as substitutes for products derived from fossil fuels is often a primary objective of bioeconomy strategies and operations. Making a shift to bioenergy is an explicit approach for mitigating climate change. Other means of mitigating climate change (e.g. soil carbon sequestration and reduced deforestation) are seldom considered.
- Bioproducts are not climate-smart *per se*. **Table 7** summarizes the main climate change trade-offs and synergies associated with bioproducts. The table shows that the final GHG balance of bioproducts depends on the different processes involved in their production. This balance takes into account emissions from the biomass production stage, and from the amount of energy used and the type of energy (fossil versus renewable). A shift to low-carbon biomass production, and the climate-smart management of the natural resources required to make this shift, along with the use of clean energy at all stages of the bioeconomy value chains are the main factors that affect the performance of the bioeconomy in supporting climate change mitigation. Other factors are reduced deforestation, the rehabilitation of degraded land, carbon capture and use, and the elimination of the burning of residues.
- Bioeconomy activities usually do not openly address climate change adaptation. However, the impacts of bioeconomy activities often improve adaptation. Sustainable natural resource management improves local environmental resilience, and the additional income and employment opportunities generated from bioproduct production and marketing enhances livelihood resilience.

RESPONSIBLE CONSUMPTION AND PRODUCTION

Lessons in this area relate primarily to the importance of establishing links between producers and consumers during the different steps of bioeconomy activities in a way that balances their respective rights and responsibilities, and benefits in bioeconomy.

- Using a value web approach that considers the interlinked value chains of a particular type of biomass, as opposed to a value chain approach, is better suited to the complex and multifaceted nature of bioeconomy activities. The value web approach considers two ways of addressing the growing demand and competition for biomass that results from bioeconomy development: seeking a higher level of integration of all value web components; and promoting the cascading use of biomass.
- Partnerships are an important mechanism to promote and connect responsible consumption and production. Partnerships between biomass producers and other actors (e.g. government, manufacturers and retailers) throughout the bioeconomy value web play an essential role in ensuring effectiveness and inclusiveness. They are also a means to promote bioproducts. An adequate market should be developed for sustainable bioproducts through purchasing agreements that connect and promote responsible consumption and production. These partnerships can take different forms. Contract farming is an important type of associative mechanism. Other types of partnerships include partnerships between technological intellectual property providers and investors; between public entities and bioproduct manufacturers through public procurement programmes; and between a company that sells and intermediate product to another company that shares similar sustainability objectives (business-to-business partnerships).
- The creation of regional bioeconomy clusters favours the formation of partnerships. These types of clusters currently exist mainly in developed countries, and are considered in the governance subsection.
- Voluntary or mandatory certification schemes and standards are becoming more and more common for the bioeconomy. Experience shows that certification has serious limitations in terms of scope, affordability and reliability. Certification alone cannot guarantee sustainability of bioeconomy value chains on a meaningful scale. Certification schemes should be combined with other types of support (e.g. policies, regulations, institutions and communication activities) to create an enabling environment that can support the scaling up of a sustainable bioeconomy.

ECONOMIC GROWTH

Lessons in this respect concern three aspects: value addition, employment and the circular economy.

Value addition

- The use of feedstock that has multiple purposes is advantageous for adding value to biomass, as it allows for the manufacturing of several bioproducts. With multi-purpose feedstocks, the production of new and old products can be combined, which reduces the risks associated with new technologies.
- The production of multiple bioproducts can occur either in a sequence (the cascading approach) or simultaneously, as in some biorefinery operations. Adopting a cascading use of biomass is easier said than done, particularly if it is to be done an inclusive manner. The sequence in the cascading use of the biomass should not be decided only on the basis of economic value addition. Other criteria uses, and can be equally or more important for different stakeholders. The sequencing in biomass processing should not be predefined but rather decided through a participatory process that involves all stakeholders.

Employment

- It is often the case that women are key players in the use of local knowledge, particularly in the processing stage of the biomass value chain. New bioeconomy activities offer many opportunities for employment, particularly for rural women and youth. The jobs can require various levels of qualification, and usually include both direct and indirect employment. However, training is often mentioned as a key requirement for job creation in bioeconomy initiatives that introduce new technologies. Public research also often makes important contributions to charting locally appropriate bioeconomy development pathways.
- Urban populations are largely responsible for driving the demand for bioproducts. Economic resilience can be enhanced by strengthening rural-urban links and improving territorial cohesion through robust local value chains.
- There are potential risks related to employment in the new bioeconomy.
  - Competition may arise between traditional jobs (e.g. in conventional food production) and new types of jobs (e.g. in the bioproduct value chain); and new technologies may reduce employment opportunities, while more conventional technologies that are more labour-intensive may be less cost-effective.
  - Attention may focus on increasing the number of job opportunities without adequate consideration to ensuring the quality of these new jobs.

Circular economy

- Microbiological and biotechnological processes are essential elements in applying circularity principles to the bioeconomy. These processes concern the use of residues and increasingly the production of carbon dioxide-based bioproducts through carbon capture and use.
- Applying circularity principles often helps foster the sustainability of bioeconomy initiatives. However, applying circularity principles to the use of residues is not easy. Challenges relate to the possible competing uses of these residues, and the costs and logistics of their use (e.g. the distances that need to be travelled for their collection and their quality). Competition for residues can be addressed by establishing partnerships with companies that handle the residues; organizing farmers to handle the residues themselves; and ensuring sufficient feedstock is available from nearby locations. The quality of residues has to do with their lack of homogeneity. Overcoming this challenge often requires public sensitization, particularly in the case of urban waste. Incorporating a relatively simple step at the biomass processing stage to separate the different biomass fractions can also help improve the homogeneity of the residues.
- The quality of the bioproducts influences the degree to which they are biodegradable and compostable. These features should not be taken for granted as they can significantly influence the operationalization of circularity principles in bioeconomy.

GOOD GOVERNANCE

The governance of biomass production and use addresses the following questions: What decision-making processes will be established? What are the roles, rights and responsibilities of the different stakeholders? What policies, regulations and institutions, and information and communication channels that need to be in place?

The following success factors on governance have emerged from the review of the case studies.

- Inclusive decision-making, as well as broad social agreement and engagement at all relevant levels are critical in the design and implementation of the bioeconomy.
- A territorial/landscape approach to rural bioeconomy development should be followed. Several case studies emphasize rural development as an important objective, and the involvement of all primary stakeholders, with equal decision-making power, is crucial to ensure sustainability and fairness in the territorial planning processes.

- Regional bioeconomy clusters can play an important part in biomass value webs.
- Contract farming is a mechanism that can be beneficial to both biomass producers in that it can give them a guaranteed market and sometimes technical support, and to bioproduct manufacturers and retailers in that it can ensure a consistent and regular supply of biomass. Governments often have a role in ensuring that contract farming arrangements are fair to both parties.
- A supra-ministerial body close to the top level of the government is important for managing and coordinating the development and implementation of bioeconomy strategies.
- Public mechanisms (e.g. public procurement programmes and public awareness campaigns) play an important role in reaching the desired levels of market uptake and consumer awareness of bioproducts. Awareness-raising activities are critical to ensure that consumption patterns for bioeconomy goods match sustainable supply levels for the biomass.
- Mechanisms for stakeholder collaboration, including public-private partnerships, which are often part of regional bioeconomy clusters, can build bridges that connect biomass producers, bioproduct manufacturers and retailers. These mechanisms can also support research on innovative technologies and products. Developing and coordinating bioeconomy platforms helps to share information and knowledge in a transparent way, and these platforms can play an important role in decision-making.

The monitoring and evaluation of the impact and performance of bioeconomy is normally carried out for a range of different purposes:

- to monitor financial performance;
- to monitor the degree of implementation of policies, programmes and regulations, as well as donor-funded initiatives and the implementation of good practices;
- to monitor market requirements, particularly with respect to certification;
- to manage risks, including securing a stable supply of inputs that can meet the demand for bioproducts; and
- to communicate to consumers (e.g. through certification and labelling) information that can help them identify bioproducts with particular characteristics.

Government programmes often have an important role in promoting the use of local plants, including indigenous crops and varieties. This role can be fulfilled in a number of ways.

- The public sector can act as a bridge between producer communities, which can benefit from additional sources of income, and companies, which are familiar with markets and can receive a constant supply of raw materials for the production of bioproducts.
- The transfers of public funds to family farmers can enable them to adopt sustainable practices and increase their resilience.
- When local governments formulate biomass utilization policies according to local conditions, good bioeconomy practices are more suitable for producers in the area and can facilitate a farm-oriented utilization of biomass.
- Research that complements local knowledge on bioproducts can be undertaken.

Local processing of biomass is an element common to all the case studies. Many countries seek to utilize their available biomass and biological resources to improve their national economies and become more competitive internationally and, in some cases, world leaders. Some case studies show that international partnerships can create opportunities for the international trade of bioproducts.

Government efforts to ensure policy coherence between supply and demand targets (e.g. through mandates, incentives and taxes) are currently relatively scarce for bioproducts. For biofuels, they are more common.

CHAPTER

1

INTRODUCTION

In and of themselves, bioeconomy activities are not necessarily sustainable. The use of biological resources and the production of biomass for food, feed, fuel and bio-based products can have both positive and negative environmental and socio-economic impacts. Of paramount concern is that the development of the bioeconomy does not undermine food security, especially in areas with high levels of malnutrition.

In 2015, at the Global Forum for Food and Agriculture meeting in Berlin, 62 ministers of agriculture recommended that FAO coordinate international work on sustainable bioeconomy (GFFA, 2015). The German Ministry for Food and Agriculture (BMEL) has provided support to FAO to assist countries in the development of sustainable bioeconomy strategies and programmes.

To this end, this report presents lessons from 26 case studies of sustainable bioeconomy interventions from around the world and from a range of different sectors. Subsection 3.1 provides a summary of all case studies. A full description of each case study and the background material used to draw the lessons learned can be found in Gomez San Juan (forthcoming). The selected interventions were reviewed to determine the extent to which they reflected the Aspirational Principles and Criteria (P&Cs) for Sustainable Bioeconomy, which were formulated in collaboration with the International Sustainable Bioeconomy Working Group (ISBWG) in 2016 and have been incorporated in the FAO sustainability framework for bioeconomy (see **Table 1** on p.3). The 26 case studies are also reviewed to determine the extent to which they support the Sustainable Development Goals (SDGs), which can be considered as providing the overall guiding framework for FAO work on sustainable bioeconomy.

The overall aim of the report is to use these case studies to expand the general understanding of sustainability in the context of the development of the bioeconomy.

The specific objectives of this report are to:

- document case studies from a range of different types of bioeconomy interventions (e.g. research projects, private sector initiatives and government programmes);
- describe the objectives that these interventions were seeking to achieve;
- show how the interventions in the case studies were designed and implemented to meet their different objectives and identify the success factors that were key to their sustainable development and implementation;
- provide an analysis on the extent to which sustainability was addressed in each case study, using the P&Cs and the SDGs as reference sustainability frameworks; and
- draw a set of lessons from the analysis on how to implement sustainable bioeconomy activities to meet different objectives.

The report targets national and international audiences including:

- policy makers in countries that are developing or seeking to develop programmes, strategies, action plans or policies for promoting a sustainable bioeconomy;
- producers of biomass and/or bioproducts who want to carry out bioeconomy projects or activities in a sustainable way; and
- international bodies (e.g. United Nations agencies, financial organizations, non-profit organizations and research institutions) that have an interest in supporting the development of a sustainable bioeconomy.

It is important to keep in mind that this report does not attempt to collect all existing examples of bioeconomy interventions or evaluate existing bioeconomy projects. Its purpose is to draw lessons regarding the sustainable development of the bioeconomy based on an analysis of a set of specifically selected interventions.

The report includes:

- a description of the methodology used to select the 26 bioeconomy case studies and the analytical approach that was followed (Chapter 2);
- a presentation of the results the analysis (Chapter 3);
- a set of lessons on how to carry out sustainable bioeconomy interventions to meet objectives that are in line with sustainability goals (Chapter 4); and
- a conclusion (Chapter 5).

TABLE 1.

ASPIRATIONAL PRINCIPLES AND CRITERIA (P&Cs) FOR SUSTAINABLE BIOECONOMY AGREED BY THE INTERNATIONAL SUSTAINABLE BIOECONOMY WORKING GROUP

PRINCIPLE 1. SUSTAINABLE BIOECONOMY DEVELOPMENT SHOULD SUPPORT FOOD SECURITY AND NUTRITION AT ALL LEVELS
Criterion 1.1. Food security and nutrition are supported
Criterion 1.2. Sustainable intensification of biomass production is promoted
Criterion 1.3. Adequate land rights and rights to other natural resources are guaranteed
Criterion 1.4. Food safety, disease prevention and human health are ensured
PRINCIPLE 2. SUSTAINABLE BIOECONOMY SHOULD ENSURE THAT NATURAL RESOURCES ARE CONSERVED, PROTECTED AND ENHANCED
Criterion 2.1. Biodiversity conservation is ensured
Criterion 2.2. Climate change mitigation and adaptation are pursued
Criterion 2.3. Water quality and quantity are maintained, and, in as much as possible, enhanced
Criterion 2.4. The degradation of land, soil, forests and marine environments is prevented, stopped or reversed
PRINCIPLE 3. SUSTAINABLE BIOECONOMY SHOULD SUPPORT COMPETITIVE AND INCLUSIVE ECONOMIC GROWTH
Criterion 3.1. Economic development is fostered
Criterion 3.2. Inclusive economic growth is strengthened
Criterion 3.3. Resilience of the rural and urban economy is enhanced
PRINCIPLE 4. SUSTAINABLE BIOECONOMY SHOULD MAKE COMMUNITIES HEALTHIER, MORE SUSTAINABLE, AND HARNESS SOCIAL AND ECOSYSTEM RESILIENCE
Criterion 4.1. The sustainability of urban centres is enhanced
Criterion 4.2. Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened
PRINCIPLE 5. SUSTAINABLE BIOECONOMY SHOULD RELY ON IMPROVED EFFICIENCY IN THE USE OF RESOURCES AND BIOMASS
Criterion 5.1. Resource efficiency, waste prevention and waste re-use along the whole bioeconomy value chain is improved
Criterion 5.2. Food loss and waste is minimized and, when unavoidable, its biomass is reused or recycled
PRINCIPLE 6. RESPONSIBLE AND EFFECTIVE GOVERNANCE MECHANISMS SHOULD UNDERPIN SUSTAINABLE BIOECONOMY
Criterion 6.1. Policies, regulations and institutional set up relevant to bioeconomy sectors are adequately harmonized
Criterion 6.2. Inclusive consultation processes and engagement of all relevant sectors of society are adequate and based on transparent sharing of information
Criterion 6.3. Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented
PRINCIPLE 7. SUSTAINABLE BIOECONOMY SHOULD MAKE GOOD USE OF EXISTING RELEVANT KNOWLEDGE AND PROVEN SOUND TECHNOLOGIES AND GOOD PRACTICES, AND, WHERE APPROPRIATE, PROMOTE RESEARCH AND INNOVATION
Criterion 7.1. Existing knowledge is adequately valued and proven sound technologies are fostered
Criterion 7.2. Knowledge generation and innovation are promoted
PRINCIPLE 8. SUSTAINABLE BIOECONOMY SHOULD USE AND PROMOTE SUSTAINABLE TRADE AND MARKET PRACTICES
Criterion 8.1. Local economies are not hampered but rather harnessed by the trade of raw and processed biomass, and related technologies
PRINCIPLE 9. SUSTAINABLE BIOECONOMY SHOULD ADDRESS SOCIETAL NEEDS AND ENCOURAGE SUSTAINABLE CONSUMPTION
Criterion 9.1. Consumption patterns of bioeconomy goods match sustainable supply levels of biomass
Criterion 9.2. Demand and supply- side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced
PRINCIPLE 10. SUSTAINABLE BIOECONOMY SHOULD PROMOTE COOPERATION, COLLABORATION AND SHARING BETWEEN INTERESTED AND CONCERNED STAKEHOLDERS IN ALL RELEVANT DOMAINS AND AT ALL RELEVANT LEVELS
Criterion 10.1. Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate

CHAPTER

2

METHODOLOGY

In preparing this report, a four-step methodology was followed.

The first step was the selection of case studies that would be best suited for analysis. The 26 case studies included in this report were chosen from over more than 200 cases studies that were compiled through a systematic literature review. The screening and selection process used an iterative approach and was done in consultation with members of the ISBWG. The ISBWG provided advice on what can be considered a successful and replicable sustainable bioeconomy case study. To that end, the report only describes case studies that could be classified as good examples for sustainable bioeconomy development.

FIGURE 3.

STEP-WISE METHODOLOGICAL APPROACH

The considerations that were taken into account in selecting the cases studies are listed below.

- It was important that, taken as a whole, the case studies covered of all three stages of the biomass value chain. Each intervention that was included in the set of case studies involved at least two stages of the value chain. The different practices and technologies identified within the case studies can apply to the all or some of the stages of the value chain or to a single stage.
- The set of case studies covers a range of bioeconomy sectors (see Subsection 3.1) and the most common uses of different types of biomass. The bioeconomy sectors covered are:
  1. agricultural sectors (crop production, livestock production, forestry, aquaculture and fisheries), which include not only biomass production but the links to the communities that depend on the production system;
  2. food and agro-industry;
  3. bio-based construction materials and furniture, including the use of other-than-wood materials (e.g. fungi) and techniques for designing of materials, structures and systems;
  4. pulp and paper;
  5. bio-based textiles, including plant-based textiles and leather;
  6. bio-based chemicals and polymers, including bio-based materials;
  7. healthcare and biopharmaceuticals, including products derived from food sources that are purported to provide health benefits beyond nutrition (nutraceuticals) and cosmetic products that have purported medicinal benefits (cosmeceuticals);
  8. bioenergy;
  9. waste management, which includes the collection, treatment and disposal of biomass, and the recovery of materials; and
  10. recreation associated with ecotourism.
- All the interventions included in the selected case studies produce more than one bioproduct within the same facility or the same parcel of land. The processing and end-of-life options for bio-based products have been given particular attention in this report. As FAO has been tasked with coordinating international work on sustainable bioeconomy, it was important for the Organization to improve its knowledge on sustainability practices in the second and third stages of the biomass value chain, and on bioproducts other than food, feed and fuel (bio-based products).
- The interventions included in the case studies are all in operation and have been running for a sufficient time to allow for lessons to be drawn from their implementation. As much as possible, the focus has been placed on interventions that are currently being carried out or that have reached the commercial stage. Activities related to R&D&I are considered as an element of the enabling environment for the bioeconomy.
- The set of case studies was designed to provide a good geographical balance. The case studies cover almost all regions: Africa, Asia and the Pacific, Latin America and the Caribbean, Europe and North America.
- The case studies have been carried out at variety of scales and for a range of purposes. They include enabling policies and government programmes, commercial production facilities, and development programmes.
- Innovation plays an important role in the interventions selected for the case studies. Innovation does not only refer to technologies, but also to improvements in existing practices, such as adding a simple extra step in an existing process to obtain a new co-product. Innovation can also involve holistic policies, institutional settings, communication media, business models, or logistical arrangements that build circularity (e.g. managing common waste, exchanging materials, concentrating biomass, and knowledge and information sharing between different bioeconomy sectors and activities).
- The case studies were selected to provide coverage of both the technical aspects of sustainable bioeconomy development and its enabling environment. Elements of the enabling environment include the institutional set up, policies, governance, communication, organizational specifications, a combination of regulations and incentives, financing schemes, instruments and mechanisms, and financial arrangements and business plans.

The case studies were not selected on the basis of:

- the extent of their geographical scale (regional, national, sub-national or local);
- the type of biomass used;
- the stage of development (e.g. research, demonstration activity or fully operational); nor
- the business model adopted, although business models are considered in the identification of the success factors.

Once the information for the intervention had been collected, the stakeholders responsible for each intervention were contacted and interviewed. The vast majority of the stakeholders provided additional grey literature related to the intervention (e.g. project reports, sustainability reports and online documents) and offered insights about the factors that made the activity successful and sustainable. A full description of each case study can be found in a complementary document that highlights the 'technological' and 'the enabling environment' aspects of the interventions that contribute to the successful and sustainable implementation of bioeconomy (Gomez San Juan, forthcoming). The complementary document contains the background material that has been used to prepare chapters 3 and 4 of this report. The descriptions of the case studies were later validated by the stakeholders.

The second step of the methodology involved clearly identifying the context-specific characteristics, particularly the objectives the selected interventions were seeking to achieve. To situate the bioeconomy sustainability analysis within the proper context, it was essential to clearly determine the original objectives for each intervention. Examples of objectives include: to safeguard food security; to mitigate and adapt to the effects of climate change and reduce environmental pollution; and to promote actions that contribute to the revitalization and development of rural areas. It is these objectives, irrespective of any sustainability considerations, that shaped the design and implementation of the project, programme or business case. For this reason, the second step involves describing the original objectives that motivate the case studies; the type of intervention they are linked to; and the main stakeholders that lead the intervention and benefit from it.

In the third step of the methodology, the case studies were screened for elements that contribute to achieving sustainability criteria that have been articulated in the P&Cs and the SDGs, as well as the in the case study objectives. These elements are the strengths and opportunities that the intervention must have in order to reach their various objectives. When these 'must-have' elements have been shown to successfully address or achieve a specific sustainability criterion from the P&Cs across several case studies, they are labelled 'success factors'.

The fourth step of the methodology involved drawing lessons from the case studies on how the bioeconomy can be developed and implemented in a sustainable way.

CHAPTER

3

RESULTS

3.1 OVERVIEW OF CASE STUDIES

The 26 cases studies reviewed in this report are summarized in this subsection and are described in detail in Gomez San Juan (forthcoming). This subsection presents an overview of the 26 case studies in table form. **Table 2** shows the 26 selected case studies at a glance, organized by bioeconomy sectors.

The sectors used in this overview are based on categories in the International Standard Industrial Classification of All Economic Activities (ISIC) that have been developed by the Statistics Division of the United Nations Department of Economic and Social Affairs (UN, 2008). **Table 2** shows ten broad sectors of the bioeconomy, which correspond to various ISIC categories. The final wording for each broad sector is based on the 'distinguished bioeconomy sectors' outlined in the European Union (EU)-funded BioEconomy Regional Strategy Toolkit (BERST, 2016), as well as in several bioeconomy strategies (Dubois and Gomez San Juan, 2016; EC, 2018c; German Bioeconomy Council, 2018a). Case studies in which compost, soil amendments and biofertilizers are co-products that are applied to soil are included in the 'agricultural sectors' not in the bio-based chemical sector. It is important to keep in mind that each case study can be associated with a number of sectors.

The following considerations can be drawn from the overview of the sectors covered by the 26 case studies in **Table 2**:

- Almost all case studies (23) are connected with the agricultural sectors (crop production, livestock production, forestry, fisheries and

aquaculture), which are responsible for the production of the biomass in the value chain. This is true even for the case studies that deal primarily with industry and policy, as interventions in these sectors often include aspects of biomass production.

- Eighteen case studies focus on food production. Food is often one of several co-products derived from bioeconomy activities.
- Many case studies (16) are concerned with the bio-based chemicals and polymers, since they are used in the production of a wide range of bio-based products, as well as bio-based materials that are used as building blocks for further processing into bio-based products.
- There are 15 case studies linked to the bioenergy sector. Bioenergy is often one of the several co-products of bioeconomy activities. It is a well-established bio-based industry and a common end-of-life option for bioproducts (e.g. biogas from anaerobic digestion of organic residues). There are case studies for the bioenergy sector from all regions.
- More than half the case studies (16) involve waste management with particular attention given to the application of circularity principles.
- There is no case study that is directly associated with recreation and ecotourism.
- The cases studies from Africa, Asia and Latin America predominantly deal with the production of biomass from agriculture. All of the African case studies and most of the Latin American case studies are linked to the food and agro-industry sector. The case studies that deal with bio-based construction materials, pulp and paper, bio-based textiles and bio-based chemicals and polymers are located mostly in Europe, the United States of America, and Asia. The majority of the case studies related to the healthcare and biopharmaceutical sector are from Asia and Latin America. Asia has the highest number of case studies related to bioenergy and waste management.

Following **Table 2**, a summarized description of each case study is presented. Information includes the title of the case study, its location and the year it started, the type of intervention it is, the stakeholders involved, the sectors covered, and basic information on its activities and the biomass value chain it deals with. The table also includes the results of a review of the P&Cs the case study covers and the SDGs it supports. For each case study, there is a list of objectives that it sought to achieve and that are shared in common by a number of other case studies, along with a list of success factors it shares with other interventions. The full lists of these 'common' objectives and success factors are presented in subsections 3.2 and 3.3.

TABLE 2.

OVERVIEW OF THE SELECTED 26 CASE STUDIES, ORGANIZED BY REGION AND BIOECONOMY SECTORS

CASE STUDIES / BIOECONOMY SECTORS (✓ = The sector is addressed)	AGRICULTURAL SECTORS	FOOD AND AGRO-INDUSTRY	BIO-BASED CONSTRUCTION MATERIALS	PULP AND PAPER	BIO-BASED TEXTILES	BIO-BASED CHEMICALS AND POLYMERS	HEALTHCARE AND BIOPHARMACEUTICALS	BIOENERGY	WASTE MANAGEMENT	RECREATION
BIOCHAR PRODUCTION AND USE, GHANA	✓	✓	-	-	-	-	-	✓	✓	-
BIOMASSWEB, SUB-SAHARAN AFRICA	✓	✓	-	-	-	-	-	✓	✓	-
INTEGRAL USE OF OIL PALM, GHANA	✓	✓	-	-	-	✓	-	✓	✓	-
SEAWEED VALUE ADDITION, UNITED REPUBLIC OF TANZANIA	✓	✓	-	-	-	✓	-	-	-	-
FROM FARMER TO PHARMA, SOUTH AFRICA	✓	✓	-	-	-	-	✓	-	-	-
BIOECONOMY COMMUNITY DEVELOPMENT PROGRAMME, MALAYSIA	✓	✓	-	✓	-	✓	✓	✓	-	-
NATIONAL BIOMASS STRATEGY, MALAYSIA	✓	-	-	-	-	✓	✓	✓	-	-
BIO-INDUSTRIAL CLUSTERS TO ADD VALUE, MALAYSIA	✓	✓	✓	-	-	✓	✓	✓	✓	-
TOWARDS SECOND-GENERATION BIOFUELS, INDIA	✓	-	-	-	-	✓	-	✓	✓	-
FROM BIOMASS TOWNS TO INDUSTRIAL AREAS, JAPAN	✓	-	-	-	-	✓	-	✓	✓	-
BIOFIBRE FOR CLOTHING, PHILIPPINES	✓	✓	-	-	✓	-	-	✓	✓	-
ALTERNATIVES TO BURNING STRAW, CHINA	✓	✓	✓	✓	-	✓	-	✓	✓	-
AGROFORESTRY AND CONSERVATION, INDONESIA	✓	✓	✓	✓	-	-	-	✓	✓	-
MESA SUCROALCOHOLERA, ARGENTINA	✓	✓	-	-	-	-	-	✓	✓	-
BEEKEEPING DERMOCOSMETICS, COLOMBIA	✓	✓	-	-	-	-	✓	-	-	-
BIO-BASED PLASTICS FROM AGAVE RESIDUES, MEXICO	✓	-	-	✓	-	✓	-	-	✓	-
SUNFLOWER PROTEIN, BRAZIL	✓	✓	-	-	-	✓	✓	✓	✓	-
FUNCTIONAL USE OF PASSION FRUIT, BRAZIL	✓	✓	-	-	-	-	✓	-	-	-
FAMILY CATTLE PRODUCERS AND CLIMATE CHANGE, URUGUAY	✓	✓	-	-	✓	-	-	-	-	-
FROM GAS TO BIO-BASED PLASTIC, UNITED STATES OF AMERICA	-	-	✓	-	-	✓	-	-	✓	-
PROMOTING BIOPRODUCT USE, UNITED STATES OF AMERICA	-	-	✓	-	-	✓	-	-	-	-
THE USE OF CARDOON AS BIOMASS, EUROPEAN UNION AND ITALY	-	✓	-	-	-	✓	-	✓	✓	-
RUBBER FROM DANDELIONS, GERMANY	✓	-	-	-	-	✓	-	-	-	-
BLUE BIOECONOMY DEVELOPMENT, ICELAND	✓	✓	-	-	-	-	✓	-	-	-
URBAN CIRCULAR BIOECONOMY, UNITED STATES OF AMERICA	✓	✓	✓	✓	✓	✓	-	-	✓	-
FOREST BIOECONOMY CLUSTER, FINLAND	✓	-	✓	✓	-	✓	-	✓	✓	-
TOTAL FOR 26 CASE STUDIES	**23**	**18**	**7**	**6**	**3**	**16**	**8**	**15**	**16**	**0**

Biochar production and use (Ghana)

Type of intervention:

- Development project
- R&D&I activity

Since: 2014

Stakeholders involved:

- Leading parties: ASA Initiative (NGO) and University of Udine
- Beneficiaries: Small-scale farmers, poor households, communities and small- and medium-scale industries
- Others: Economic Community of West African States (ECOWAS) and other 'BeBi' and 'BiocharPlus' project partners

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2; C 1.4
C 2.2; C 2.3; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- An innovative type of cooking stove (slow pyrolysis, low-temperature) that generates heat for cooking and produces biochar has been developed through scientific cooperation and is transferred to communities by the NGO, Alternative Set of Assistance Initiative (ASA), under the 'BeBi' and 'BiocharPlus' projects.
- This small-scale co-production technology offers farmers benefits in terms of improved efficiency in the use of resources and environmentally friendly soil management, as biochar can be used as soil amendment and biofertilizer. It is a smoke-free stove that can improve health because it produces relatively little indoor air pollution compared to traditional stoves.
- Before the project was implemented, detailed information was collected regarding current and traditional uses of biomass. There is no competition for resources needed to ensure food security as only unused residues are required as fuel. Crop residues are gathered by local farmers and are used to produce pellets, which supports income diversification for farmers.
- The stove can be easily replicated and adapted to local conditions. Capacity development activities are carried out by project partners to ensure the ownership of the technology by local communities. Women are encouraged to adopt the stoves in their households. Local small- and medium-scale enterprises start stove manufacturing businesses that have created local jobs.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Crop and crop residues (corn cobs and empty palm bunches)

Biomass and bioproducts processing and use:

- Food: corn
- Corn cob pellets used in the cooking stoves
- Cooking energy from biomass and pellets burned in improved stoves, with the co-production of biochar

Sustainable end-of-life options and cross-cutting circularity aspects:

Biochar can be sold as fuel to blacksmiths

RESULTS OF THE REVIEW

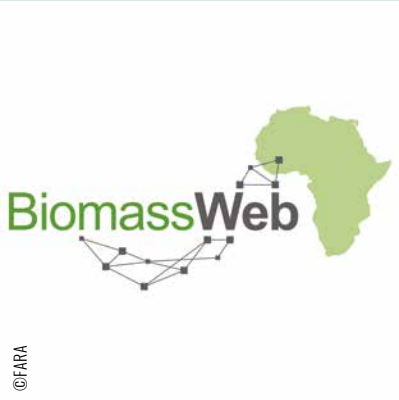
Objectives shared with other case studies:

- To safeguard food security
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholders and indigenous peoples
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The adoption of integrated systems
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- Certification of sustainability and compliance with national law through monitoring and evaluation
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

BiomassWeb (Sub-Saharan Africa)



©FARA

Type of intervention:

- Development project
- R&D&I activity

Since: 2013

Stakeholders involved:

- Leading parties: Forum for Agricultural Research in Africa and Center for Development Research of University of Bonn
- Beneficiaries: African institutions, small- and medium- scale farmers and related value web actors
- Others: 9 partner institutions in Germany and 14 in Africa

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2; C 1.3
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1; C 5.2
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- A biomass value web (interlinked value chains of a specific biomass) aims at improving food security in Africa by increasing productivity and efficiency throughout the biomass-producing, processing and trading system.
- The research comprises 27 work packages and is organized in seven research clusters. It is part of GlobE - Research for the global food supply programme.
- Studies are developed to understand the functioning of biomass webs, particularly regarding the expected increase in demand for biomass and how this will transform traditional agriculture. Also, different land-use scenarios are analysed and alternative biomass sources to meet demand are identified.
- Its objective is to make contributions to food security in sub-Saharan Africa based on solid evidence that has been used to develop field projects in Ghana, Ethiopia and Nigeria. The main actions implemented include increased integration of all value web components and the cascading use of biomass. Farmers are involved in biomass value addition through the implementation of innovative production systems at medium- and small-scale processing plants, which differs from a typical supply chain approach.
- It is a demand-driven R&D&I activity that integrates target groups and stakeholders in the research process. It seeks to improve the capacity of African institutions and actors in value webs to participate in the emerging international bioeconomy. It also unites different agricultural research systems in the continent through BiomassNet knowledge-sharing platform.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

A wide range of food and non-food biomass is considered in the project. Some examples are cassava, corn, banana, enset and bamboo

Biomass and bioproducts processing and use:

Optimized processing of biomass is the main element of the value webs (e.g. the production of food, feed and bioethanol based on cassava in Nigeria)

Sustainable end-of-life options and cross-cutting circularity aspects:

Reducing post-harvest losses for corn, cassava and plantain is considered in the different projects

RESULTS OF THE REVIEW

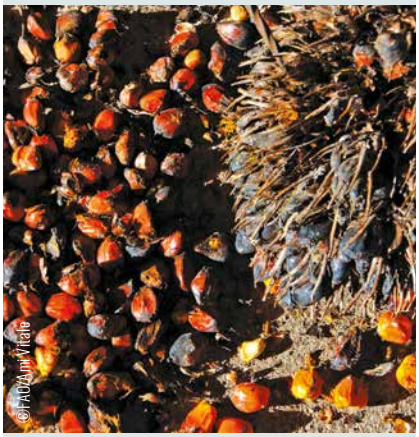
Objectives shared with other case studies:

- To safeguard food security
- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To move towards a more circular bioeconomy
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- The application of innovative practices and technologies for biomass production, processing and use
- The adoption of integrated systems
- The promotion of a value web approach
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- The fair distribution of benefits among value chain actors
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Integral use of oil palm (Ghana)



Type of intervention:

- Private sector activity

Since: 2004

Stakeholders involved:

- Leading parties: Building Business on Values, Integrity and Dignity (B-BOVID Ltd)
- Beneficiaries: Small-scale farmers and local communities
- Others: NGO 'TRACTOR'

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2; C 1.3
C 2.2; C 2.3; C 2.4
C 3.1; C 3.2
C 5.1
C 6.1; C 6.2; C 6.3
C 7.1
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- B-BOVID is an agricultural medium-scale enterprise. Its main objective is to use agribusinesses to solve social and environmental problems through innovation, increased incomes and greater youth entrepreneurship.
- It has two oil mills and two processing factories for fertilizer and feed. The company buys raw material from out-growers and shares the net profit of the entire operation with them in proportion to the amount of raw material they deliver. In addition, farmers receive the market price for their produce.
- B-BOVID also provides farmers with opportunities to process their own oil palm fresh fruit bunches, and the company has its own plantation.
- Training activities for farmers are developed in an innovation centre by the NGO, TRACTOR. The activities focus on conserving the landscape, stopping soil degradation with forest cover and reducing greenhouse gas (GHG) emissions.
- GHG emissions are reduced through the recycling of the palm oil mill effluent and empty fruit bunches for the production of organic fertilizers.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Oil palm fresh fruit bunches, kernel cake, fronds, empty bunches and effluent

Biomass and bioproducts processing and use:

- Food: palm oil
- Palm kernel oil for oleochemical industries (detergent, herbicides, cosmetics)
- Animal feed from palm kernel cake
- Organic fertilizer from empty fruit bunches
- Briquettes from palm kernel shells, to generate heat for the processing plant
- Biogas from palm oil effluent to generate electricity for the processing plant

Sustainable end-of-life options and cross-cutting circularity aspects:

The fertilizer is applied back to the farm soil, and energy is recovered and used

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To increase profitability by adding value to biomass
- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To promote actions that contribute to the revitalization and development of rural areas
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- 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
- The application of innovative practices and technologies for biomass production, processing and use
- The adoption of territorial and landscape approaches in national or local planning
- Purchasing agreements between small-scale farmers and buyers
- The fair distribution of benefits among value chain actors
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Seaweed value addition (United Republic of Tanzania)

Type of intervention:

- Private sector activity
- R&D&I activity

Since: 2006

Stakeholders involved:

- Leading parties: Seaweed farmers, small-scale processors and researchers in the cluster
- Beneficiaries: Women farmers and coastal communities
- Others: Public entities

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based chemicals and polymers

Principles and criteria covered:

C 1.1; C 1.2; C 1.3; C 1.4
C 2.2; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- Zanzibar Seaweed Cluster Initiative (ZaSCI) was created to tap the existing scientific knowledge and farming experience on seaweed production to bring innovation into seaweed farming. It helps farmers (80-90% of whom are women) produce, process and market seaweed, and diversify their incomes.
- Before the cluster, farmers only sold one product, dry seaweed. Afterwards, more than 50 products are being made and marketed, including cosmetics and food.
- The cluster encourages coastal people to engage in innovations in the seaweed industry by making products with added value, which not only provides them with jobs but also gives women financial clout and independence. The cluster also supports farmers in negotiating agreements with exporters.
- This vital industry for the country is now struggling with decreasing yields due to warmer waters resulting from climate change. The national University of Dar es Salaam supports women farmers in adopting new growing techniques that can enable them to shift from traditional shallow water farms to deep water cultivation using bamboo rafts or tubular water nets.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Seaweed (*Eucheuma spinosum* and *Kappaphycus cottonii*)

Biomass and bioproducts processing and use:

- Food: cookies, cake, pudding, jam, jellies, juice and salad
- Soap scented with spices, such as cinnamon, lemon grass, clove and lime
- Body cream
- Seaweed powder (intermediate product sold for other applications)
- *K. cottonii* is used to extract carrageenan gel (E407), which is used as an emulsifier, a stabilizer and gel for food, pharmaceuticals and cosmetics

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Clustering and the integration of sectors and levels
- The fair distribution of benefits among value chain actors
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

From Farmer to Pharma (South Africa)

Type of intervention:

- Government programme

Since: 2008

Stakeholders involved:

- Leading parties: Department of Science and Technology
- Beneficiaries: Local communities and groups, including indigenous people, and pharmaceutical businesses
- Others: N/A

Sectors:

- Agriculture sectors
- Food and agro-industry
- Healthcare and biopharmaceuticals

Principles and criteria covered:

C 1.1; C 1.3; C 1.4
C 2.1
C 3.1; C 3.2; C 3.3
C 4.2
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.2

SDGs supported:

BASIC INFORMATION

- From Farmer to Pharma is one of the five Grand Challenges of South Africa's Ten Year Innovation Plan. It promotes the commercial use of national plant resources and related indigenous or traditional knowledge by capitalizing on natural biodiversity and applied biotechnologies to create a viable national bioeconomy and deepen the role of indigenous crops in food security.
- It is complemented by a national target set in the National Bioeconomy Strategy (2013) that seeks to replace up to 25% of pharmaceutical imports within a decade of implementation.
- The programme includes engaging in the equitable exploration and sound exploitation of biological resources (bioprospecting) in ways that do not have negative impacts on other species and are replicable since they conform to the Convention on Biological Diversity. South Africa is part of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization.
- International partnerships are sought to connect global funding and technical expertise to local innovators.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Indigenous plants

Biomass and bioproducts processing and use:

Healthcare and biopharmaceutical products (e.g. nutraceuticals, food additives, flavours, fragrances, biopesticides). For instance, *hoodia* is a plant used as an appetite suppressant. Its active compound has been developed into a weight loss product

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- 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
- The preservation of traditional knowledge in innovations and practices through the active involvement of indigenous and local communities
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Collaboration between public sector entities for interministerial coordination
- Collaboration between private sector and public sector to increase bioeconomy competitiveness
- The fair distribution of benefits among value chain actors

Bioeconomy Community Development Programme (Malaysia)

Type of intervention:

- Government programme

Since: 2014

Stakeholders involved:

- Leading parties: Bioeconomy Corporation (public agency)
- Beneficiaries: Low-income farmers and bio-industries
- Others: Projects collaborators

Sectors:

- Agriculture sectors
- Food and agro-industry
- Pulp and paper
- Bio-based chemicals and polymers
- Healthcare and biopharmaceuticals
- Bioenergy

Principles and criteria covered:

C 1.1; C 1.2; C 1.3
C 2.1
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- The Bioeconomy Community Development Programme (BCDP) involves enlisting farmers to cultivate raw materials in idle lands to produce inputs for biotechnology companies and projects that are part of the BioNexus and Bioeconomy Transformation Programme.
- Through the contract farming mechanism with guaranteed buyback, farmers and producer associations obtain additional sources of income, and the bio-industries receive a constant supply of raw materials to produce bioproducts. It improves incomes for people in the bottom 40% of the national income bracket. The Bioeconomy Corporation acts as the facilitator and provides advisory services.
- The rural community is linked to the local bio-industry and farmers' skills are upgraded through training and technology provided by the companies.
- The projects are targeted to local conditions and needs. They seek to increase economic opportunities in the areas in which they operate and are focused on strategic sub-sectors, such as high-value herbs, seeds, mushroom farming, dairy, bee keeping and aquaculture. Examples of related technologies include tissue culture, DNA fingerprinting, the extraction of active compounds and selective breeding.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Any raw material for bio-industries, from rice straw to fish waste and seaweed

Biomass and bioproducts processing and use:

Outputs of bio-industries, from carrageenan to herbal supplements and feed

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To promote actions that contribute to the revitalization and development of rural areas
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
- To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- 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
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- Purchasing agreements between small-scale farmers and buyers
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

National Biomass Strategy (Malaysia)

Type of intervention:

- Government programme

Since: 2011

Stakeholders involved:

- Leading parties: National Biomass Strategy Delivery Unit in Agensi Inovasi Malaysia
- Beneficiaries: Biomass producers, including foresters and idle land owners, and related industry
- Others: Relevant government partners and agencies

Sectors:

- Agriculture sectors
- Bio-based chemicals and polymers
- Healthcare and biopharmaceuticals
- Waste management

Principles and criteria covered:

C 1.1
C 2.1; C 2.2; C 2.3; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 6.1; C 6.2; C 6.3
C 7.1; C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- The aim of the National Biomass Strategy (NBS) is to increase revenue from the country´s palm oil, rubber, wood and rice husk industries by promoting biomass use and providing support to industries to explore commercial opportunities in biomass value chains across all sectors.
- The execution of the NBS was tasked to the Agensi Inovasi Malaysia (AIM), a statutory body administered by a supraministerial governance council, which is chaired by the Prime Minister and consists of seven ministers and representatives from agencies, industries and scientific communities. The National Biomass Strategy Delivery Unit in AIM is in charge of the execution of the NBS.
- AIM has the primary role to serve as the central government agency for all aspects related to biomass in Malaysia and coordinate with relevant government counterparts, agencies and industries. It does not provide financial support but consolidates all available grants and incentives programmes.
- The NBS promotes the creation of a balanced portfolio of downstream industries that include bioenergy, advanced fuels, biochemicals and end products to position Malaysia as a biomass processing hub.
- The bioeconomy is institutionally organized at national and sub-national levels by AIM. At the sub-national level, the tailor-made State Biomass Industry Development Plans are governed by steering committees and cover feedstock sources, conversion technologies and potential markets.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

All potential biomass from the agriculture and forestry sectors

Biomass and bioproducts processing and use:

Biodiesel; second-generation bioethanol; bio-based chemicals; biogas; pellets; improved feed; fertilizers; second-generation sugars

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- The adoption of territorial and landscape approaches in national or local planning
- The adoption of integrated systems
- Collaboration between public sector entities for interministerial coordination
- Collaboration between private sector and public sector to increase bioeconomy competitiveness
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Bio-industrial clusters to add value (Malaysia)

Type of intervention:

- Government programme
- Private sector activity

Since: 2005

Stakeholders involved:

- Leading parties: Bioeconomy Corporation (public agency)
- Beneficiaries: Low-income farmers and bio-industries
- Others: Projects collaborators

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based construction materials
- Bio-based chemicals and polymers
- Healthcare and biopharmaceuticals
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.4
C 3.1; C 3.2; C 3.3
C 4.1; C 4.2
C 5.1
C 6.1; C 6.2
C 7.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- Palm Oil Industrial Clusters (POICs) are industrial networks for all biomass-based related activities in which biorefineries and bio-industries have a central role in value addition in downstream biomass processing.
- Centralized shared infrastructures and utilities are developed in the POICs, which improves logistics, decreases transportation costs and allows for large-scale biomass mobilization, which is critical for attracting bio-based chemical companies into the POIC.
- The value of the POIC lies in its proximity to the feedstock and industrial plants. The strategic location includes shipping routes to suppliers and markets, abundant biomass in neighbouring areas and proximity to processing facilities and bio-industries.
- It is an important stakeholder platform that includes companies, estate owners, millers, technology providers and financial investors. Working through this platform, the stakeholders facilitate innovation that can diversify businesses and promote investments in downstream and upstream activities.
- POICs follow the AIM'S Biomass Joint Venture Cluster model and receive support from AIM. It was also developed within the national Bioeconomy Transformation Programme. The POICs are part of a wider 'Sabah State economic corridor'.
- Companies in the POICs and cooperatives can access various government support programmes that support the implementation of bioeconomy initiatives. An example of such a programme is the Bio-accelerator Programme, which is designed to enhance participants' commercial profile in the marketplace.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Oil palm fresh fruit bunches and other oil palm biomass, and by-products from the palm oil biorefinery

Biomass and bioproducts processing and use:

Palm oil; oleochemicals; trans-free food; nutraceuticals; phytonutrients; solid biofuel; biodiesel and biogas

Sustainable end-of-life options and cross-cutting circularity aspects:

Each cluster has a common waste management plant to treat residues from industries operating within the cluster

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To increase profitability by adding value to biomass
- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- The use and valorization of all by-and co-products obtained in the processing stage
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Towards second-generation biofuels (India)

Type of intervention:

- Government programme
- Private sector activity

Since: 2016

Stakeholders involved:

- Leading parties: Indian oil Public Sector Undertaking-enterprises and Praj Industries Limited (technology provider)
- Beneficiaries: Farmers and society as a whole
- Others: N/A

Sectors:

- Agriculture sectors
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

BASIC INFORMATION

- Indian oil Public Sector Undertaking (PSU) enterprises have set up 12 second-generation ethanol biorefineries in eleven states through memoranda of understanding with well-established private technology providers.
- The initiative follows the vision established in the 2009 National Policy on Biofuels and helps to achieve biofuel (bioethanol and biodiesel) targets, which cannot be reached with first-generation biofuels.
- Praj Industries Limited is a technology partner involved with a number of the twelve biorefineries. The PSU enterprises are financial partners and investors.
- 'Enfinity' is Praj's multi-product smart (integrated) ethanol biorefinery, which uses cellulosic feedstock. Enfinity technology includes proprietary modified microorganisms and a patented enzymatic pre-treatment process created through the Praj Matrix research and development centre. R&D&I is carried out to produce biochemicals, biofertilizer and other bioproducts. Praj has already supplied the wider bioeconomy with feed products and healthy foods.
- Praj's adds 'bolt-on' modules to existing first-generation bioethanol plants, sugar factories or co-generation plants to build second-generation biorefineries. The model can be replicated in different contexts.
- Depending on the business model followed, the biorefinery can use the same biomass supply. Biomass aggregation, which is a challenge for second-generation biofuel production, is key to building small-scale plants where biomass is available, as it builds markets for agricultural residues, creates local jobs and increases incomes for farmers.
- Efforts to shift away from the burning of residues are intended to reduce GHG emissions and air pollution.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Feedstocks for second-generation bioproducts, mainly crop residues

Biomass and bioproducts processing and use:

- Bioethanol
- Biochemicals and intermediates

Sustainable end-of-life options and cross-cutting circularity aspects:

- Shift from burning agriculture residues to using them as biomass feedstock
- Optimization and recycling of water and zero liquid discharge system
- Circularity is fostered as organic fertilizer is applied to local farms
- Thermally integrated process to achieve low net energy usage

Principles and criteria covered:

C 1.2
C 2.2; C 2.3; C 2.4
C 3.1
C 4.2
C 5.1
C 6.1
C 7.1; C 7.2
C 9.1
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To safeguard food security
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To increase profitability by adding value to biomass
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- Purchasing agreements between technological intellectual property providers and investors

From biomass towns to industrial areas (Japan)

Type of intervention:

- Government programme

Since: 2012

Stakeholders involved:

- Leading parties: Local government and implementation agencies
- Beneficiaries: Local communities and industrial businesses
- Others: National government

Sectors:

- Agriculture sectors
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

BASIC INFORMATION

- In its 2012 Biomass Industrialization Strategy, the government of Japan has sought to overcome the challenges it encountered in establishing Biomass Towns, a concept first articulated in the Biomass Nippon Strategy in 2002. In the 2012 strategy, the government has shifted to fostering Biomass Industrial Areas to revitalize sub-national areas or territories on the basis of the bioeconomy by promoting commercially feasible, inter-regional biomass use.
- The challenges encountered with biomass town plans included the high cost of collecting biomass and the lack of experience in biogas plant operations, among others. Designing a comprehensive and recycle-oriented system for biomass use is considered more feasible at a wider level. Industrial level use is particularly appropriate for waste management and electricity generation with biogas. The establishment of biomass industrial communities is intended to contribute to the further development of the biomass town concept, which is still carried out by local governments when appropriate.
- A Biomass Industrial Area is territory with an integrated system of agro- and bio-industries that improves the economy of the area in ways that are environmentally friendly and resilient to disasters. It includes efficient technologies for processing biomass, improved logistics and the horizontal deployment of new businesses centered on circularity of the biomass.
- Stakeholders are linked through institutional arrangements including cooperatives, regional clusters and scientific institutes. The plans also foster greater public awareness and promote the empowerment of the civil society.
- The Japanese Biomass Town Plan model has been applied in other four countries (Indonesia Malaysia, Thailand and Viet Nam) in the Association of Southeast Asian Nations (ASEAN) through a supporting ministry in these countries.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

A variety of biomass (either waste or unused biomass) for second-generation processing

Biomass and bioproducts processing and use:

Feed; fertilizer; compost; biofuels; electricity generation; other bioproducts

Sustainable end-of-life options and cross-cutting circularity aspects:

The whole society participates in systems to recycle and reuse biomass

Principles and criteria covered:

C 2.2
C 3.1; C 3.2; C 3.3
C 4.1; C 4.2
C 5.1; C 5.2
C 6.2
C 7.1
C 8.1
C 9.1; C 9.2
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To promote actions that contribute to the revitalization and development of rural areas
- To move towards a more circular bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between public sector entities for interministerial coordination
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions

Biofibre for clothing (Philippines)

Type of intervention:

- Private sector activity

Since: 2013

Stakeholders involved:

- Leading parties: Ananas Anam Ltda
- Beneficiaries: Cooperatives and local community
- Others: Textile finishing companies

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based textiles
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.3
C 2.2; C 2.3; C 2.4
C 3.2; C 3.3
C 4.2
C 5.1
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- Inspired by local traditional clothes and crafts made from pineapple leaves, Piñatex™ is a leather alternative developed and commercialized by Ananas Anam. Piñatex™, which took seven years of R&D&I, is intended to meet the increasing demand for leather, whose production has negative social and environmental impacts.
- The Philippines has year-round pineapple production. The large amount of residues are often burnt. By using the residues, there is no impact on land use.
- Local cooperatives produce fibres from the leaves through decortication (extraction of biomass fibres). This gives farmers the chance to generate higher and more sustainable earnings. It also improves women's participation, as women are familiar with the decortication processes.
- Piñatex™ is certified as 'Vegan Fashion Label' by People for the Ethical Treatment of Animals (PETA)

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Pineapple leaves

Biomass and bioproducts processing and use:

- Textile material that can be substitute for leather used in footwear, fashion and accessories, furnishing, car and aeronautic industries
- Biogas and organic fertilizer

Sustainable end-of-life options and cross-cutting circularity aspects:

- The final textile product is recyclable and compostable, and the company is working to make it also biodegradable, as the material currently includes a non-biodegradable protective top layer for durability
- There is no runoff, or water and air pollution from the manufacturing process
- The circular economy model follows the Cradle-to-Cradle approach

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To safeguard food security
- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To increase profitability by adding value to biomass
- To promote actions that contribute to the revitalization and development of rural areas
- To move towards a more circular bioeconomy
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The preservation of traditional knowledge in innovations and practices through the active involvement of indigenous and local communities
- Tests for circularity, including the biodegradability, compostability and disintegration of products
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- The fair distribution of benefits among value chain actors
- Certification of sustainability and compliance with national law through monitoring and evaluation

Alternatives to burning straw (China)

Type of intervention:

- Government programme

Since: 2016

Stakeholders involved:

- Leading parties: National- province- and county-level governments
- Beneficiaries: Organizations of farmers, manufacturers, others
- Others: Service organizations

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based construction materials
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2
C 2.2
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 6.1; C 6.2; C 6.3
C 7.1; C 7.2
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- The Ministry of Agriculture and the Ministry of Finance have selected ten provinces to implement pilot projects to test and promote the use of straw and prohibit its burning. The pilots are carried out during the 13th Five-Year Plan (2016-2020).
- The aim is to reduce air pollution from burning straw and create an ecological barrier that prevents the pollution from spreading to large cities.
- Each provincial government selects key counties for the pilots. The uses of straw are scientifically determined based on local conditions. Emphasis is given to farm-oriented uses of straw. Examples include: the use of straw as fertilizer to increase soil organic matter and improve the quality of cultivated land; as fodder; and for energy production in rural areas to improve livelihoods.
- The national government provides guidance through policies and measures (e.g support for purchasing machinery, storage and transportation) that expand industries and technologies that use straw. A technical support system and advisory service has been established at the provincial level to support technologies and build knowledge. At the county level, technical models are promoted based on the specific characteristics of the area.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Crop residues, mainly corn, rice and wheat straw

Biomass and bioproducts processing and use:

Solid biofuels; biogas; biofertilizer; fodder; substrate for mushroom or plant cultivation; artificial boards, composite material and paper; biochemicals

Sustainable end-of-life options and cross-cutting circularity aspects:

- Agricultural residues are used as feedstocks instead of being burnt
- Straw used as fertilizer and feed contributes to circulating nutrients through agricultural production systems

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To safeguard food security
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To promote actions that contribute to the revitalization and development of rural areas
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- The application of innovative practices and technologies for biomass production, processing and use
- Tests for circularity, including the biodegradability, compostability and disintegration of products
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The fair distribution of benefits among value chain actors
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Agroforestry and conservation (Indonesia)

Type of intervention:

- Private sector activity

Since: 2008

Stakeholders involved:

- Leading parties: Kutai Timber
- Beneficiaries: Cooperatives
- Others: Related industries

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based construction materials
- Pulp and paper
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2; C 1.4
C 2.2
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 7.1; C 7.2
C 8.1
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- Kutai Timber is a forest company in East Java, Indonesia that has shifted from harvesting wood in primary forests to sustainably managing planted forests in combination with agroforestry. This move is in line with a priority for the national bioeconomy: biomass sustainability certifications to meet the requirements of export markets.
- In 2107, the company established a fully integrated mill, where waste is used to develop bioproducts following a cascading approach. The products from the tertiary transformation of biomass (e.g. furniture parts, doors and musical instruments) and secondary transformation (e.g. pellets, particleboard) increase revenues and reduce transport costs, but they require residues from primary transformation processes (e.g. sawn wood, log processing waste).
- Clustering is key to involving producers and reducing costs, and stimulates the development of small- and medium-scale enterprises. The organization of small-scale farming activities into cooperatives also increases the engagement of the local population in the cluster. Producers plant fast-growing trees and food crops in agroforestry systems using agro-ecological practices, which increases food security and supports ecosystem services.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Wood-based feedstock; and agricultural products from agroforestry systems

Biomass and bioproducts processing and use:

Forest and fruit tree seedlings; wood products; and food

Sustainable end-of-life options and cross-cutting circularity aspects:

Cascading use of wood and wood products

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To increase profitability by adding value to biomass
- To promote actions that contribute to the revitalization and development of rural areas
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets

Success factors shared with other case studies:

- The use and valorization of all by- and co-products obtained in the processing stage
- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Clustering and the integration of sectors and levels
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- Certification of sustainability and compliance with national law through monitoring and evaluation
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Mesa Sucroalcoholera (Argentina)

Type of intervention:

- Government programme

Since: 2016

Stakeholders involved:

- Leading parties: Ministry of Agro-industry
- Beneficiaries: Sugar cane producers and sugar and alcohol industrial businesses
- Others: Sub-national governmental and research institutions

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bioenergy
- Waste management

BASIC INFORMATION

- Mesa Sucroalcoholera is a roundtable organized by the Ministry of Agro-industry that brings together sugar cane producer organizations, representatives from the sugar and alcohol (mainly bioethanol) industries, sub-national governments and research institutions. The roundtable meets regularly to set priorities for the sector, promote compliance with targets that have been mandated for bioethanol's share in biofuels for transport, and establish the quantities of sugar for export.
- It results from the government plan (*Plan de Belgrano*) to develop the poorer northeast and northwest areas of Argentina and the national mandate (Decree 543/16) to increase bioethanol's share in biofuels for transport from 10% to 12%. Ideally, the 2% increase should come from sugar cane feedstock and be distributed between companies from the country's three northern provinces, Tucuman, Salta and Jujuy, where most of the country's sugar cane production is concentrated.
- The main objective of Mesa Sucroalcoholera is to help ensure that the benefits derived from the 2% increase are fairly distributed among all sectors and levels within the sugar cane value chain and address the main issues within the sector.
- A territorial approach has been followed as the value chains in the three provinces have different productive and socio-economic characteristics. Unlike Salta and Jujuy, Tucuman is characterized by smallholder producers who do not own sugar processing factories and cannot benefit from the value that is added to sugar cane production through its processing into bioethanol.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Sugar cane

Biomass and bioproducts processing and use:

- Food: sugar
- Bioethanol
- Energy from vinasse and bagasse by-products

Sustainable end-of-life options and cross-cutting circularity aspects:

To address pollution associated with waste disposal, the vinasse is treated so that it can be used as a fertilizer or a soil amendment in low-potassium soils

Principles and criteria covered:

C 1.1; C 1.2
C 2.2; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 7.1; C 7.2
C 8.1
C 9.2
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To promote actions that contribute to the revitalization and development of rural areas
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows

Success factors shared with other case studies:

- The use and valorization of all by- and co-products obtained in the processing stage
- The application of innovative practices and technologies for biomass production, processing and use
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between public sector entities for interministerial coordination
- The fair distribution of benefits among value chain actors
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Beekeeping dermocosmetics (Colombia)

Type of intervention:

- Private sector activity

Since: 2008

Stakeholders involved:

- Leading parties: APIFLOWER
- Beneficiaries: Beekeeper organizations
- Others: Government agencies

Sectors:

- Agriculture sectors
- Food and agro-industry
- Health care and biopharma

Principles and criteria covered:

C 1.4
C 3.1; C 3.2
C 4.2
C 6.1
C 7.1; C 7.2
C 8.1
C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- APIFLOWER is a company that develops and distributes innovative natural cosmetics. It uses beekeeping products and flora native to the Colombian Amazon and taps into their beneficial properties for health.
- The company started out producing and marketing honey and other beekeeping products before shifting to the production of high-value cosmetics.
- Dermocosmetics can be obtained by combining a variety of apicultural products with native indigenous Amazon plant species with therapeutically beneficial properties. The products are certified.
- APIFLOWER employs families in two regions in Colombia in a fair trade value chain. Beekeeper associations receive training to build their capacities.
- Government supports has enabled this bioeconomy start-up company to enter international markets. Products are exported to Egypt, the EU, the Republic of Korea, the Russian Federation and the United States of America.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

- Beekeeping derivatives: propolis (a resin containing balsam, wax and oil), royal jelly and honey
- Native Amazon tree species with therapeutically beneficial properties, such as cupuazu (*Theobroma grandiflorum*), buriti (*Mauritia flexuosa*), borojó (*Alibertia patinoi*), muru-muru (*Astrocaryum murumuru*) and chontaduro (*Bactris gasipaes*)

Biomass and bioproducts processing and use:

Natural dermocosmetics (e.g. cleansing foams and soaps, regenerative and nourishing creams, tonics, exfoliants and moisturizers)

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To increase profitability by adding value to biomass
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:

- The application of innovative practices and technologies for biomass production, processing and use
- The preservation of traditional knowledge in innovations and practices through the active involvement of indigenous and local communities
- Clustering and the integration of sectors and levels
- Purchasing agreements between small-scale farmers and buyers
- The fair distribution of benefits among value chain actors
- Certification of sustainability and compliance with national law through monitoring and evaluation
- Policy interventions that provide incentives and establish supportive public mechanisms

Bio-based plastics from agave residues (Mexico)


© Flickr/Arvanite Darmanin

Type of intervention:

- Private sector activity

Since: 2016

Stakeholders involved:

- Leading parties: Jose Cuervo® and Ford Motor Company
- Beneficiaries: Farmers and consumers
- Others: Local artisans

Sectors:

- Agriculture sectors
- Pulp and paper
- Bio-based chemicals and polymers
- Waste management

BASIC INFORMATION

- In Mexico, the industrial multi-sectoral partnership between Jose Cuervo® and Ford Motor Company aims to develop and produce bio-based materials with by-products from the cultivation and processing of agave to make liquor. Currently in an initial research phase, the initiative plans to follow a territorial approach, and transform agave residues into bio-based plastics for Mexican industries and Ford's Mexican assembly plants.
- Harvesting agave, which is done every five years on average, produces large amounts of residues, which are difficult to dispose of. Much of the residue, which comes from both the agave plantations and liquor production process, is burnt or sent to landfills, and this contributes to pollution.
- Jose Cuervo currently uses the bagasse from the agave pineapple root, which remains after the extraction of the sugar, as compost in their plantations. Local artisans also use the fibre remnants from the plant to make crafts, paper, clothes and other products. Using the by-products for bio-based plastics provides another option for diversifying farmers' incomes and benefits producers by creating greater demand for lignocellulosic residues from agave production.
- The bio-based plastic is lightweight and reduces the overall weight of the vehicle, which lowers fuel consumption and GHG emissions.
- Only some of the vehicle's plastic parts are replaced with bio-based plastic. Consumers pay the same price for the vehicle and do not have to make the choice to buy bio-based plastics. This situation serves to improve the market for bio-based plastics.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Agave plant residues from liquor production

Biomass and bioproducts processing and use:

- Bio-based plastic used in interior and exterior components of vehicles (e.g. wiring harnesses, cup holders, heating, ventilation, and air conditioning units, and storage bins).
- Other uses include crafts, clothes and agave paper made by local artisans

Sustainable end-of-life options and cross-cutting circularity aspects:

Compost is applied to local agave farms

Principles and criteria covered:

C 1.1
C 2.2
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To increase profitability by adding value to biomass
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- The fair distribution of benefits among value chain actors

Sunflower protein (Brazil)

Type of intervention:

- R&D&I activity

Since: 2013

Stakeholders involved:

- Leading parties: Food Technology Institute and the Fraunhofer Institute
- Beneficiaries: Small- and medium-sized companies
- Others: Consumers and the 17 partners from both countries involved in the value chain

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based chemicals and polymers
- Healthcare and biopharmaceuticals
- Waste management

Principles and criteria covered:

C 1.1; C 1.4
C 3.1; C 3.2; C 3.3
C 5.1
C 6.1; C 6.3
C 7.2
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- The research collaboration between the public Food Technology Institute of the State of São Paulo (ITAL) and the Fraunhofer Institute for Process Engineering and Packaging IVV focuses on the integrated use of all biomass fractions in agricultural production chains to reduce competition for resources needed for food production.
- To promote partnerships between industry in both countries, the innovative products and processes that are developed in joint projects are application-oriented. They are intended to diversify business opportunities, integrate and support small-and medium-scale enterprises and support the transfer of innovations and research activities to Brazil.
- An example is the SunflowerProtein (SunPro) project dealing with the "sustainable cultivation and innovative processing of sunflower seeds for the simultaneous recovery of sunflower oil, solid fuel, and protein-rich food ingredients". The project is under the research line dealing with the health aspects of foods, focusing on technologies that can develop food products that can contribute to reducing obesity and nutrition-related illnesses. Protein from sunflower is a healthy food that is in line with current consumer trends.
- Flexibility exists to shift from corn to sunflower and diversify business opportunities. This can only be done if the products obtained from sunflower are of enough high-value to compete with the higher price for corn, and if farmers have contracts with trusted processors.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Sunflower seeds

Biomass and bioproducts processing and use:

Oil for food or biofuel; protein-rich food ingredients and high-quality bioactive animal feed; fuel from husks and molasses; polyphenols for healthcare

Sustainable end-of-life options and cross-cutting circularity aspects:

A no-waste strategy in the process is pursued

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To increase profitability by adding value to biomass
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- The adoption of integrated systems
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- Policy interventions that provide incentives and establish supportive public mechanisms

Functional use of passion fruit (Brazil)


©Flickr/Guudmorning!

Type of intervention:
- Government programme
- R&D&I activity

Since: 2008

Stakeholders involved:
- Leading parties: Passitec Network
- Beneficiaries: Local passion fruit producers
- Others: N/A

Sectors:
- Agriculture sectors
- Food and agro-industry
- Healthcare and biopharmaceuticals

BASIC INFORMATION

- The Passitec Network, coordinated by Embrapa Cerrados, includes more than 30 public and private researchers, producer associations, rural extension institutions, and sub-national and village institutions.
- Its objectives are to develop technologies for the functional use of Brazilian passion fruit (*Passiflora spp.*), generate information and increase knowledge about its uses in order to strengthen the value chain.
- The Network's four research areas are: biological information; production systems; technology and processing; and functional and medicinal studies.
- Research is undertaken to characterize the genetic resources of different species and develop new cultivars that can serve different functional and medicinal purposes, and have enhanced nutritional properties.
- The development of commercial varieties is done in ways that conserve the traditional knowledge that local communities possess about wild varieties. The network works to structure the production and the supply chain so that the products can be introduced into national and international markets.
- The different varieties of passion fruit are produced in the savanna biome (Cerrado region) by local farmers and are used by local communities for food and for medicinal and cosmetic purposes. Passion fruit is becoming a profitable option for producers, especially small-scale producers. The network supports producer organizations to market their produce.

BIOMASS VALUE CHAIN

Biomass production and/or collection:
Wild species of passion fruit (*Passiflora spp.*)

Biomass and bioproducts processing and use:
The pulp and peel, and sometimes the seeds, flowers and leaves, are used to make: enriched fibres, natural antioxidants, enriched bioactive extract, and other intermediate products used in a range of foods, medicines and cosmetics, including dairy, bread, and oils for the cosmetic industry and phytotherapeutic and anti-stress medicines.

Sustainable end-of-life options and cross-cutting circularity aspects:
N/A

Principles and criteria covered:
C 1.1
C 3.1; C 3.2
C 4.2
C 5.1
C 7.1; C 7.2
C 8.1
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

Success factors shared with other case studies:
- 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
- The application of innovative practices and technologies for biomass production, processing and use
- The preservation of traditional knowledge in innovations and practices through the active involvement of indigenous and local communities
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- The fair distribution of benefits among value chain actors

Family Cattle Producers and Climate Change (Uruguay)

©Flickr/Jimmy Baikovicius

Type of intervention:

- Government programme

Since: 2013

Stakeholders involved:

- Leading parties: Ministry of Livestock, Agriculture and Fisheries
- Beneficiaries: Family cattle producers
- Others: Medium cattle producers

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based textiles

Principles and criteria covered:

CC 1.1
C 2.2; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 6.1; C 6.2; C 6.3
C 7.1; C 7.2

SDGs supported:

BASIC INFORMATION

- Grassland ecosystems make up about 70% of Uruguay's total area. Half of these pastures are located in two eco-regions: the *Cuestas Basalticas* in the north and the *Sierras del Este* in the east. These eco-regions have low water storage capacity and are sensitive to water stress and increases in rainfall variability. Animal breeds raised there are characterized by low-productivity.
- 'Family Cattle Producers and Climate Change', a programme led by the Ministry of Livestock, Agriculture and Fisheries, provides incentives for improving infrastructure and implementing good pasture and livestock management practices in these two eco-regions.
- Good practices (e.g. grazing by lots or planting shade trees) are implemented by cattle producers in order to increase the productivity of meat per hectare, improve their resilience to adverse weather conditions, and increase soil organic carbon by restoring degraded grasslands.
- To enhance the effectiveness of the implementation of good practices, 'landscape units' are defined within each eco-region where the programme is applied. To determine these areas of intervention, vulnerability assessments are done on climate variability and unfavourable climatic conditions. To prioritize the beneficiaries, baseline surveys are carried out on different production systems and current practices.
- Progress indicators are used to monitor the implementation of good practices (e.g. Normalized Difference Vegetation Indices; participation in associations).

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Cattle and sheep farming in grasslands affected by drought

Biomass and bioproducts processing and use:

Meat production is the main activity. Milk, wool and leather are also produced

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To promote actions that contribute to the revitalization and development of rural areas
- To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
- To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets

Success factors shared with other case studies:

- The use and valorization of all by- and co-products obtained in the processing stage
- The harnessing of the microbiome and microbiological processes, including processes that support renewable carbon capture and use
- The application of innovative practices and technologies for biomass production, processing and use
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between public sector entities for interministerial coordination
- The fair distribution of benefits among value chain actors
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

From gas to bio-based plastic (United States of America)

©Flickr/Daniel Hsia and ShareAlike

Type of intervention:

- Private sector activity

Since: 2013

Stakeholders involved:

- Leading parties: Newlight Technologies, LLC.
- Beneficiaries: Licencing partners
- Others: N/A

Sectors:

- Bio-based construction materials
- Bio-based chemicals and polymers
- Waste management

BASIC INFORMATION

- Newlight Technologies started in 2003 with the idea of replacing oil-based plastics with plastics based on carbon from GHGs and contributing to global climate action. Ten years of research led to the development of a high-yield proprietary biocatalyst that converts air and GHGs into PHA-based plastics.
- The carbon is captured from methane and CO_2 emissions from biogas from landfills, farms, wastewater treatment plants and anaerobic digestion facilities.
- The carbon is then used in a gas-to-plastic bioconversion technology, a type of CCU technology. Newlight´s '9X biocatalyst' is the microorganism that pulls carbon out of the methane and CO_2 molecules and then re-assembles the carbon with hydrogen and oxygen to synthesize the PHA biopolymer.
- The group of thermoplastic bio-based materials developed by Newlight is called AirCarbon™. It has been the first PHA bio-based plastic material that is not derived from food or food residues.
- AirCarbon is certified Bronze under the Cradle to Cradle Certified Product Standard V.3.0 (2015), a specific circular economy standard that includes requirements related to the use of reutilized material and renewable energy, the content of renewable or recyclable materials, and the percentage of material that can be reused, recycled or composted.
- An independent third party conducted a GHG emission footprint analysis from cradle to grave (including energy use, transportation, disposal), and AirCarbon has been verified as a carbon-negative material.
- To scale up the technology, Newlight has licencing agreements with companies to produce AirCarbon bio-based material with the patented technology.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Bio-based residual GHGs from landfills and CO_2

Biomass and bioproducts processing and use:

AirCarbon, a bio-based PHA made with a bioconversion technology

Sustainable end-of-life options and cross-cutting circularity aspects:

Circularity is fostered as AirCarbon is Cradle to Cradle (C2C) certified

Principles and criteria covered:

C 2.2; C 2.3
C 3.1
C 4.1
C 5.1
C 7.1; C 7.2
C 9.1; C 9.2
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To increase profitability by adding value to biomass
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy

Success factors shared with other case studies:

- The harnessing of the microbiome and microbiological processes, including processes that support renewable carbon capture and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Purchasing agreements between technological intellectual property providers and investors
- Certification of sustainability and compliance with national law through monitoring and evaluation

Promoting bioproduct use (United States of America)

Type of intervention:

- Government programme

Since: 2002

Stakeholders involved:

- Leading parties: The United States Department of Agriculture (USDA)
- Beneficiaries: Farmers and manufacturing businesses from the participating states
- Others: The buying federal agencies and their contractors

Sectors:

- Bio-based construction materials
- Bio-based chemicals and polymers

BASIC INFORMATION

- The United States Department of Agriculture (USDA) manages a national public procurement programme for bioproducts. The BioPreferred® Program consists of mandatory purchasing requirements for federal agencies and their contractors.
- Different resources and tools are offered to support bioproduct procurement, including the BioPreferred Catalog and other training resources. The Program serves as a source for business-to-business knowledge and a platform for exchanging good practices.
- The main objectives of the Program are to reduce country's reliance on fossil fuels, increase the use of renewable agricultural resources, provide incentives for economic development and job creation and create new markets for agricultural commodities.
- The Program is complemented by voluntary labelling for bioproducts that includes a certification system for carbon content.
- To address the insecurity of national biomass suppliers regarding multi-year contracts with cellulosic biorefineries, a Biomass Crop Assistance Program was set up to provide financial support to establish and maintain annual or perennial crops and woody biomass.
- The BioPreferred Program was created in the 2002 Farm Bill and then expanded in the 2014 Farm Bill to include other-than-biofuels biorefinery products and traditional (mainly forestry) products. Since then, all bioproducts seeking eligibility to participate in the Program must demonstrate innovative approaches in the growing, harvesting, sourcing, procuring, processing, manufacturing and the application of the bioproduct.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

The type of biomass is not specified for the mandatory procurement. In the voluntary labelling, specifications are required on the quantity of grain and oilseed inputs used in bio-based production

Biomass and bioproducts processing and use:

- There are more than one hundred categories of bio-based products (e.g. packaging, cleaners, carpet, lubricants, paints, fertilizers, soil amendments). They do not include food, feed and motor vehicle fuels, heating oil, or electricity produced from biomass
- Only some products under the Mandatory Federal Purchasing Initiative are also certified by the Voluntary Labelling Initiative

Sustainable end-of-life options and cross-cutting circularity aspects:

N/A

Principles and criteria covered:

C 1.1; C 1.4
C 3.1; C 3.2; C 3.3
C 5.1
C 6.1; C 6.3
C 7.2
C 9.1
C 10.1

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Purchasing agreements between public entities and bioproduct manufacturers
- Certification of sustainability and compliance with national law through monitoring and evaluation

The use of cardoon as biomass (EU and Italy)


Public domain photo

Type of intervention:

- Government programme
- Private sector activity
- R&D&I activity

Since: 2013

Stakeholders involved:

- Leading parties: The six members of project consortium
- Beneficiaries: Local farmers
- Others: Local government

Sectors:

- Food and agro-industry
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

Principles and criteria covered:

C 1.1; C 1.2
C 2.1; C 2.2; C 2.3; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 5.1
C 7.1; C 7.2
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- Partnership between the European Commission and the Bio-based Industries Consortium (BIC). The partnership contributes to meeting EU climate change targets and promotes more environmentally friendly growth.
- This Partnership is one of the funding mechanisms of the EU programme for research and innovation called 'Horizon Europe' (formerly 'Horizon 2020') under the pillar 'Industrial Leadership'. The objective is to develop new biorefining technologies to sustainably transform renewable resources into bioproducts.
- One BBI JU-supported project is the First2Run project, which seeks to demonstrate the agricultural and industrial sustainability of a value chain based on cardoon, a low-input and underutilized oil crop that is grown in marginal land in Sardinia and used in an integrated biorefinery to produce bio-based materials. The project is led by the Novamont company, which works with local farmers.
- The project includes a market assessment to evaluate the profitability and the competitiveness of bio-based materials compared to oil-based compounds.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Cardoon - *Cynara cardunculus* L. var. *Altilis* (DC)

Biomass and bioproducts processing and use:

- Mono and dicarboxylic acids from the oxidation of cardoon oil are used to produce bio-based plastics, plasticizers, biolubricants, and nutraceuticals.
- Co-products are used for energy, feed, and added value ester chemicals

Sustainable end-of-life options and cross-cutting circularity aspects:

The biodegradability and compostability of all bio-based products is tested

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The use and valorization of all by- and co-products obtained in the processing stage
- 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
- The application of innovative practices and technologies for biomass production, processing and use
- Tests for circularity, including the biodegradability, compostability and disintegration of products
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between private sector and public sector to increase bioeconomy competitiveness
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Rubber from dandelions (Germany)

Type of intervention:
- Private sector activity
- R&D&I activity

Since: 2011

Stakeholders involved:
- Leading parties: Continental
- Beneficiaries: Local communities
- Others: Research partners

Sectors:
- Agriculture sectors
- Bio-based chemicals and polymers

BASIC INFORMATION

- This joint pilot project of the tire manufacturer Continental and the Fraunhofer Institute at Münster University works to produce natural rubber from dandelion roots. The rubber bio-based material produced is called Taraxagum™ and is used to make tires.
- Dandelion is an undemanding plant can be grown in temperate regions in marginal land. The objective is to have a commercially viable substitute for conventional imported rubber obtained from rubber trees, which are cultivated in monocultures in sub-tropical regions. Taraxagum™ substitutes rubber obtained from cultivation methods that contribute to deforestation and biodiversity loss in rainforest areas. It also reduces CO_2 emissions associated with transport.
- Continental scales up the industrial production of dandelion rubber in their laboratory site, 'Taraxagum Lab Anklam'. Research at the facilities in Anklam, which started operations in December 2018, is carried out on dandelion farming and the extraction process. It is expected that dandelion tires will be ready for series production in 5 to 10 years. This activity can bring positive socio-economic and environmental benefits to local communities.
- Continental conducts research in collaboration with the Fraunhofer Institute in Münster, the Julius Kühn-Institute in Quedlinburg, the plant breeder ESKUSA in Parkstetten and other partners with support from the German Federal Ministry of Education and Research as well as the German Federal Ministry of Food and Agriculture.

BIOMASS VALUE CHAIN

Biomass production and/or collection:
Russian dandelion (*Taraxacum kok-saghyz*), a wild herbaceous local plant

Biomass and bioproducts processing and use:
- Rubber is produced from the latex sap of the roots of the locally sourced russian dandelion instead of from conventional rubber trees (*Hevea brasiliensis*)
- Other products from Taraxagum include engine mounts that have been tested during preliminary experiments and insulin for nutraceuticals and food products

Sustainable end-of-life options and cross-cutting circularity aspects:
N/A

Principles and criteria covered:

C 1.1; C 1.2
C 2.1; C 2.2; C 2.3; C 2.4
C 3.1; C 3.2; C 3.3
C 4.2
C 6.2
C 7.1; C 7.2
C 9.1; C 9.2

SDGs supported:

RESULTS OF THE REVIEW

Objectives shared with other case studies:
- To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To increase profitability by adding value to biomass
- To create and secure employment through in situ value addition and enhance rural and urban economic resilience

Success factors shared with other case studies:
- 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
- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Blue bioeconomy development (Iceland)

Type of intervention:

- Private sector activity

Since: 2012

Stakeholders involved:

- Leading parties: Codland
- Beneficiaries: National fish processing industries
- Others: Related national fisheries, partner research companies and high-value products manufacturers

Sectors:

- Agriculture sectors
- Food and agro-industry
- Health care and biopharma

Principles and criteria covered:

C 1.1; C 1.4
C 2.2; C 2.3
C 3.1; C 3.3
C 5.1; C 5.2
C 6.3
C 7.1; C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- Within the Iceland Ocean Cluster, waste from traditional cod fisheries and cod processing is used for biomass feedstock. Several companies in the cluster created Codland, a start-up company, to obtain the maximum value from every part of the fish and increase revenues.
- Iceland has year-round cod production, but the capture level is limited, so there is a need for an integral utilization of the fish. Codland aims to promote progress in the fishing industry through collaboration and the production of innovative bioproducts.
- In the business model, facilities are set up near the port and beside a cod drying plant. This model, which allows for the processing of almost all fishery by-products at a single location, can be replicated in other coastal areas.
- Biotechnology is used to produce high-value products. This includes a new method for hydrolization using enzymes to replace chemical methods.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Waste from sustainable fisheries of whitefish, particularly local wild-caught cod

Biomass and bioproducts processing and use:

- Fish oil from the liver and viscera with omega-3 fatty acids
- Fish meal from the viscera for feed supplement and organic fertilizer
- Mineral supplements, mainly calcium from the bones
- Collagen peptides from the skin produced by enzymatic hydrolization

Sustainable end-of-life options and cross-cutting circularity aspects:

Fish waste from well-established companies is used in a closed-loop system

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To safeguard food security
- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To increase profitability by adding value to biomass
- To create and secure employment through *in situ* value addition and enhance rural and urban economic resilience
- To move towards a more circular bioeconomy
- To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- 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
- The harnessing of the microbiome and microbiological processes, including processes that support renewable carbon capture and use
- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Urban circular bioeconomy (United States of America)

Type of intervention:

- Government programme

Since: 2002

Stakeholders involved:

- Leading parties: The San Francisco Department of the Environment ('SF Environment')
- Beneficiaries: Communities in the city and bay
- Others: Recology

Sectors:

- Agriculture sectors
- Food and agro-industry
- Bio-based construction materials
- Pulp and paper
- Bio-based textiles
- Bio-based chemicals and polymers
- Waste management

Principles and criteria covered:

C 1.4
C 2.2; C 2.3
C 3.3
C 4.1
C 5.1; C 5.2
C 6.1
C 7.1
C 9.1; C 9.2
C 10.1

SDGs supported:

BASIC INFORMATION

- The San Francisco Department of the Environment has established a zero waste target for 2020 and a package of policies to reduce marine pollution of toxic material in the bay near the city and other coastal and rural communities.
- The aim is to improve waste management through recycling and composting to reduce landfill waste, groundwater pollution and methane emissions. The model can be replicated in other coastal cities facing similar problems.
- For recycling, waste is separated into three categories (compostable, recyclable, landfill). All residents, businesses and public departments are required to separate their garbage into the three bins. Materials are recovered in the recycling plant and then sold to different manufacturers to be reused for new products (e.g. paper, glass).
- A network of plants is used to transform the organic waste into compost. The use of compost in local farms increases carbon storage in the soil and reduces the use of inorganic fertilizers. The compost is approved for use in certified organic soil, which helps establish an urban-rural link.
- In parallel, a ban of polystyrene and plastic for food products contributes to the use of compostable bio-plastics, which facilitates waste separation.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Urban organic waste, including food waste, and wastewater

Biomass and bioproducts processing and use:

- Feedstock for other industries, such as pulp and paper
- Biofertilizer
- Bio-based compostable or recyclable plastic food packaging and food ware

Sustainable end-of-life options and cross-cutting circularity aspects:

Waste prevention and recycle through an improved collection programme

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
- To mitigate and adapt to the effects of climate change and reduce environmental pollution
- To promote actions that contribute to the revitalization and development of rural areas
- To move towards a more circular bioeconomy
- To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by-and co-products obtained in the processing stage
- The application of innovative practices and technologies for biomass production, processing and use
- The creation and development of markets for bioproducts, including assessing market potential and carrying out dissemination activities
- The adoption of territorial and landscape approaches in national or local planning
- Collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

Forest bioeconomy cluster (Finland)

Type of intervention:

- Government programme

Since: 1992

Stakeholders involved:

- Leading parties: The cluster in Central Finland
- Beneficiaries: Local communities and small, medium and large industries involved in the wood value chain
- Others: The Central Finland regional government, national initiatives and research projects

Sectors:

- Agriculture sectors
- Bio-based construction materials
- Pulp and paper
- Bio-based chemicals and polymers
- Bioenergy
- Waste management

Principles and criteria covered:

C 2.2; C 2.3; C 2.4
C 3.1; C 3.2; C 3.3
C 5.1
C 6.1; C 6.2
C 7.1; C 7.2
C 8.1
C 9.1
C 10.1

SDGs supported:

BASIC INFORMATION

- The Central Finland region (Keski-Suomen) hosts traditional forestry operations, machinery production, pulp and paper and bioenergy industries, as well as new companies and technologies connected to the bioeconomy.
- The cluster in Central Finland, which began operating in 1992, is expanding with the setup of new bio-based industries that complement the traditional bioenergy and pulp and paper sector, and attract both private and public funding. Innovative products include biopolymers, biochemicals and enzymes.
- New activities in the cluster respond to changes in demand and the need to diversify businesses. The cluster fosters cross-sectoral interactions and includes an incubator and a training centre.
- The regional (sub-national) council has included bioeconomy in their 2040 development plan and supports the cluster. The cluster is important for the development of the bioeconomy and knowledge-based economy in the region. Extensive cooperation between academic institutions, the public sector and private actors, fosters expertise and innovative thinking.
- Programmes, projects and studies support the initiative, including a national bioeconomy cluster for forestry 'FIBIC' and EU-funded projects, such as Bioclus, S2Biom and BERST, which assess the transferability of clusters and other practices.

BIOMASS VALUE CHAIN

Biomass production and/or collection:

Wood-based materials (mainly pulpwood, both softwood and hardwood)

Biomass and bioproducts processing and use:

- Sawmill products, such as timber for construction and masts for ships
- Pulp and paper for conventional paper products (e.g. printing paper, packaging materials) and innovative paper products (e.g. sensitive label materials, sticker laminates)
- Wood fuel, such as briquettes and pellets
- Bioenergy from residues, bark, black liquor, saw dust and other waste
- High-value products, such as polymers, chemicals, enzymes from wood and plywood products

Sustainable end-of-life options and cross-cutting circularity aspects:

Circularity is fostered as waste is used for further transformation processes (in the same mill or in other facilities) following a cascading approach

RESULTS OF THE REVIEW

Objectives shared with other case studies:

- To create and secure employment through in situ value addition and enhance rural and urban economic resilience
- To promote actions that contribute to the revitalization and development of rural areas
- To move towards a more circular bioeconomy
- To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods

Success factors shared with other case studies:

- The use, when viable, of biomass residues and food that are otherwise lost or wasted
- The use and valorization of all by- and co-products obtained in the processing stage
- Clustering and the integration of sectors and levels
- The adoption of territorial and landscape approaches in national or local planning
- Policy interventions that provide incentives and establish supportive public mechanisms
- The involvement of all relevant stakeholders in the transition towards sustainable bioeconomy

3.2 IDENTIFIED OBJECTIVES

This subsection presents the common objectives that the interventions documented in the case studies have sought to achieve (e.g. to safeguard food security or adapt to climate change). Bioeconomy interventions, whether they are actions at the policy level or concrete activities in the field, are prompted by a driver (e.g. the need to improve food security, reduce air pollution, address climate change impacts or reduce rural poverty). When considering bioeconomy actions and their implementation, it is important to have a clear understanding of the distinction between the initial drivers of the intervention and the objectives that are subsequently formulated in responses to these drivers.

The common objectives identified from the review of the 26 case studies are:

1 To safeguard food security
2 To substitute fossil-based or unsustainably sourced products with sustainable bioproducts
3 To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil
4 To mitigate and adapt to the effects of climate change and reduce environmental pollution
5 To increase profitability by adding value to biomass
6 To create and secure employment through *in situ* value addition and enhance rural and urban economic resilience
7 To promote actions that contribute to the revitalization and development of rural areas
8 To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples
9 To move towards a more circular bioeconomy
10 To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods
11 To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows
12 To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets
13 To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy
14 To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research
15 To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

These common objectives have been used to structure the lessons learned from the case studies in Chapter 4.

Along with the common objectives, the leading stakeholders and beneficiaries in each case study have been identified. The list below shows the multiple actors involved in the implementation of activities on the ground that help achieve the objectives in each of the case studies. The common stakeholders presented below have been identified from the review of the 26 case studies and complemented with inputs from Gerdes *et al.* (2018) and Benoit and Mazijn (eds., 2009). The stakeholders have been categorized into the following groups:

- policy makers (regional, national, sub-national, local and municipal);
- researchers;
- start-up manufacturing businesses, small-, medium- or large-scale manufacturing businesses, service providers, including logistics services;
- small-, medium-, large-scale farmers, including family farmers, women farmers and young farmers, farmer and producer associations and rural organizations, and labourers;
- consumers;
- local communities and groups, including indigenous people, urban communities and poor households, and the society as a whole;

- NGOs or civil society organizations;
- extensionists;
- financing institutions;
- certification bodies; and
- hybrid organizations (e.g. clusters and innovation hubs) that bring together a variety of types of stakeholder types (e.g. public organizations, research and educational institutes, and businesses).

The case studies or interventions can be divided into four basic types, or a combination of types:

- development project;
- R&D&I activity;
- private sector activity; and
- government programme.

Annex 2 presents the case studies that have sought to achieve the fifteen identified objectives, the type of case study, and the leading stakeholders and the beneficiaries of the intervention. The table in **Annex 2** reflects the fact that the bioeconomy is implemented by multiple actors that participate in different activities carried out through the intervention.

3.3 SUCCESS FACTORS

Common 'success factors' were compiled from all 26 case studies. They support achieving the objectives of the case study, the ISBWG-agreed P&Cs and/or sustainable development goals (see Subsection 3.4).

The 22 success factors identified in the case studies are presented in **Table 3**, along with the list of all the case studies where they were identified; a description of how they were implemented in selected case studies; and a note as to why these activities are considered important for sustainable bioeconomy development. The points presented in **Table 3** are based on Gomez San Juan (forthcoming).

In **Table 3**, common success factors are divided into topics that correspond to the different elements mentioned in the definition of the bioeconomy put forward by the Global Bioeconomy Summit (GBS, 2018):

- **A** the production, utilization and conservation of biological resources;
- **B** knowledge, science, technology, and innovation related to bioeconomy;
- **C** tools and concepts to provide and manage information, products, processes and services across all sectors;
- **D** stakeholder relations among different sectors; and
- **E** strategies and policies aiming toward a sustainable bioeconomy.

The success factors that have been identified were implemented in different ways in each case study, depending on local circumstances. The third column of **Table 3** provides examples of case studies that reflect how the success factor was implemented in different ways depending on the context. For example, the success factor 'The use, when viable, of biomass residues and food that are otherwise lost or wasted' can be addressed by assessing the potential competition for biomass among different users and its impact on food security (Biochar production and use, Ghana) or by using food waste from fisheries where the constant generation of waste creates problems for waste management (Blue bioeconomy development, Iceland).

This contextualization of success factors serves to define the P&Cs that they help address. Success factors are actions the interventions carry out to achieve a given objective and support a particular P&C, but these actions are highly dependent on the context. This can be seen in the full description of each case study (Gomez San Juan, forthcoming), where after a description of how each success factor is implemented, the P&Cs addressed in that particular context are shown.

TABLE 3.

LIST OF THE COMMON SUCCESS FACTORS IDENTIFIED; THE CASE STUDIES WHERE THEY WERE IMPLEMENTED; EXAMPLES OF HOW THEY WERE IMPLEMENTED; AND THEIR IMPORTANCE FOR THE DEVELOPMENT OF SUSTAINABLE BIOECONOMY

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
A. THE PRODUCTION, UTILIZATION AND CONSERVATION OF BIOLOGICAL RESOURCES		
SUCCESS FACTOR A.1. THE USE, WHEN VIABLE, OF BIOMASS RESIDUES AND FOOD THAT ARE OTHERWISE LOST OR WASTED		
▶ Biochar production and use (Ghana) ▶ Integral use of oil palm (Ghana) ▶ Towards second-generation biofuels (India) ▶ From biomass towns to industrial areas (Japan) ▶ Biofibre for clothing (Philippines) ▶ Alternatives to burning straw (China) ▶ Bio-based plastics from agave residues (Mexico) ▶ Sunflower protein (Brazil) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America) ▶ Forest bioeconomy cluster (Finland)	**Biochar production and use (Ghana)**: The availability of different biomass feedstocks was assessed to identify those that are not used for food security and other biomass end-use sectors important for the local community. The ASA Initiative facilitates the haulage by farmers of corn cobs and other biomass from commercial farms to the pelletizer factory. **Blue bioeconomy development (Iceland)**: The feedstock is food waste from wild caught cod, which is sustainably caught throughout the year by local fisheries. These well-established fisheries and cod processing industries produce a constant stream of waste that has to be managed. Industries with innovative technologies, such as Codland, can transform this waste into high-value compounds. To gain access to a secure a constant supply of the waste generated by cod processing industries, Codland is situated close to them in the port.	Using biomass residues and waste, including food loss and waste (FLW), when it is both economically and environmentally feasible and viable, can allow producers to diversify their incomes without changing their production. It can also reduce competition for biomass among the different end-use sectors (Bringezu *et al.*, 2009; Howarth and Bringezu, eds., 2009). Information on current and traditional uses of biomass is required to understand which parts of the biomass should be used. This information is needed to understand the actual availability of biomass and deal with the issue of competition, particularly in relation to food security. This can also include actions to reduce FLW, which is connected to climate change mitigation and adaptation (FAO, 2017a).
SUCCESS FACTOR A.2. THE USE AND VALORIZATION OF ALL BY- AND CO-PRODUCTS OBTAINED IN THE PROCESSING STAGE		
▶ Integral use of oil palm (Ghana) ▶ Bio-industrial clusters to add value (Malaysia) ▶ Towards second-generation biofuels (India) ▶ From biomass towns to industrial areas (Japan) ▶ Alternatives to burning straw (China) ▶ Agroforestry and conservation (Indonesia) ▶ Mesa Sucroalcoholera (Argentina) ▶ Sunflower protein (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ The use of cardoon as biomass (EU and Italy) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America) ▶ Forest bioeconomy cluster (Finland)	**Alternatives to burning straw (China):** The uses given to biomass for non-food goods vary depending to local conditions. For example, in Huoqiu county, straw is normally used for biogas energy and feed, while in Lingbi county there has been an industrialization of the use of straw for pulp and paper recycling. **The use of cardoon as biomass (EU and Italy):** Through an integrated biorefinery approach, value is added to by-products and co-products to produce energy and high-value compounds. The cascading use of biomass and by-products from the processing minimizes carbon losses and reduces the competition for biomass.	From the same biomass, several co-products can be obtained within the same processing site. Processors often use a cascading approach to add value to manufacturing waste and by-products. This management of the residues increases resource use efficiency and helps solve the potential environmental and social problems that their disposal can pose. The cascading approach can use single-stage and multi-stage cascades, depending on the number of material applications (De Schoenmakere *et al.*, 2018). Enzymes are often used in industrial processes for fermentation and the bio-catalysis of waste and by-products to make them easier to be used in further processing (e.g. the production of chemical building blocks). Residues can also obtain value if waste is separated into different categories, such as recyclable and compostable material.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
SUCCESS FACTOR A.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		
▶ Integral use of oil palm (Ghana) ▶ From Farmer to Pharma (South Africa) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ Functional use of passion fruit (Brazil) ▶ The use of cardoon as biomass (EU and Italy) ▶ Rubber from dandelions (Germany) ▶ Blue bioeconomy development (Iceland)	**From Farmer to Pharma (South Africa):** The government of South Africa has promoted the use of native plant species, the country's rich biodiversity and indigenous knowledge to become a global leader in biopharmaceutical products. It has done this by applying biotechnology and engaging in careful bioprospecting, and by setting national targets for reducing imports. International partnerships have been sought to attract technology investors and improve international trading. **The use of cardoon as biomass (EU and Italy):** A low-input and underutilized drought-resistant crop (cardoon), which can be alternated with other crops, provides biomass. The targeted land was considered marginal due to the local weather conditions and sloping terrain.	When biomass is processed in the country, the country benefits from the added value. Domestic processing brings in more revenue than simply exporting the raw biomass. To boost the local economy, non-food crops grown locally or on unused or marginal land can be used for biomass. This can be done near factories, which can address issues related to the security of the biomass supply, its availability and transport costs. Reversing soil degradation can be also achieved through the sustainable cultivation of non-food crops used in other bioeconomy sectors. To resolve conflicting goals in the non-food use of arable land, experts in emerging bioeconomies have suggested improved land-use planning, particularly with regards to the exploitation of marginal land (German Bioeconomy Council, 2018b). Indigenous and local biodiversity, traditions and knowledge are sometimes not protected. Governments and foreign companies should support these resources, traditional practices and know-how, particularly if there is an increase in demand for products based on biomass traditionally produced on a small scale. Biodiversity can also be preserved in the bioeconomy by following ecosystem-based approaches. These approaches are widely used in the fisheries sector to sustainably manage and protect marine and coastal ecosystems. Ecosystem-based adaptation to climate change also involves the harnessing of biodiversity and ecosystem services (FAO, 2018).

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
SUCCESS FACTOR A.4. THE HARNESSING OF THE MICROBIOME AND MICROBIOLOGICAL PROCESSES, INCLUDING PROCESSES THAT SUPPORT RENEWABLE CARBON CAPTURE AND USE		
▶ Family Cattle Producers and Climate Change (Uruguay) ▶ From gas to bio-based plastic (United States of America) ▶ Blue bioeconomy development (Iceland)	**Family Cattle Producers and Climate Change (Uruguay):** Overgrazing and droughts associated with climate change have caused soil degradation. Good soil management practices that restore grassland, and good cattle management practices can improve carbon sequestration (0.7 tonnes of carbon per ha per year in the form of increased soil organic matter). Soil microorganism activity in the soil carbon cycle has an impact on the concentration of CO_2 in the atmosphere. **From gas to bio-based plastic (United States of America):** GHGs are converted into a bio-based material using a biocatalyst that combines composites of air and methane. The carbon, hydrogen and oxygen molecules are reassembled into a bio-based material called AirCarbon. AirCarbon is a group of PHA-based thermoplastic materials. This is a CCU technology. The carbon is captured from bio-based GHGs coming from the biogas from landfills using a patented gas-to-plastic bioconversion technology. **Blue bioeconomy development (Iceland):** Some of the products obtained from the waste from cod manufacturing industries are beneficial for human health (e.g. nutraceuticals, such as collagen peptides) and can improve the soil microbiome. To produce these nutraceuticals, the process uses enzymes instead of chemicals. Fish oil with omega-3 fatty acids and mineral supplements (mainly calcium) are also produced.	Microbial systems, or microbiomes, have great potential for ensuring the sustainability of food systems and bioproduct processing, and creating new products and services (EC, 2017). The human microbiome plays a key role in disease prevention. The environmental microbiome has the potential to be harnessed for: ▶ agriculture production (e.g. to improve plant capacities, maximize the value of marginal lands, produce food with potential to enhance the human microbiome, provide substitutes for inorganic agrochemicals and increase soil carbon storage); ▶ food safety, health and nutrition (e.g. the use of wastewater in agriculture and biomarkers); ▶ biomass processing (e.g. for fermentation and other biotechnological processes); ▶ the development of the 'blue bioeconomy' and the discovery of new drugs and materials from the ocean; and ▶ waste treatment (e.g. for catalysis). Specific compounds can be derived from carbon-based gas using microorganisms to produce a bio-based product (e.g. through CCU). Renewable CCU technologies use non-photosynthetic biotechnological processes for the capture and conversion of non-fossil-based gases into valuable platform chemicals. The technology delivers carbon capture benefits and can be used to produce goods that can act as substitutes for fossil-based products.
B. KNOWLEDGE, SCIENCE, TECHNOLOGY, AND INNOVATION RELATED TO BIOECONOMY		
SUCCESS FACTOR B.1. THE APPLICATION OF INNOVATIVE PRACTICES AND TECHNOLOGIES FOR BIOMASS PRODUCTION, PROCESSING AND USE		
▶ BiomassWeb (Sub-Saharan Africa) ▶ Integral use of oil palm (Ghana) ▶ Seaweed value addition (United Republic of Tanzania) ▶ Alternatives to burning straw (China) ▶ Agroforestry and conservation (Indonesia) ▶ Mesa Sucroalcoholera (Argentina) ▶ Beekeeping dermocosmetics (Colombia) ▶ Sunflower protein (Brazil) ▶ Functional use of passion fruit (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ The use of cardoon as biomass (EU and Italy) ▶ Rubber from dandelions (Germany) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America)	**Integral use of oil palm (Ghana):** The adoption of new practices and technologies create profitable new businesses for farmers. The capacity of farmers needs to be developed to promote the adoption of new approaches. This can involve actions that support integrated land use and management, improvements in farming resilience, and the scaling up of agroforestry practices. **Sunflower protein (Brazil):** Instead of adopting high-tech industrial pathways or biotechnology for the manufacture of high-value bioproducts, a single, relatively easy step is added to an existing process. In this case, during the oilseed processing, the husk is simply removed before de-oiling to produce a protein-rich cake that can be used for feed and food products.	Applying research and innovation to biomass production and collection, the manufacture of bioproducts, and activities related to the end-of-life stage and logistics can bring several benefits that are often related to the optimization of resources (e.g. water and energy use). Sometimes innovations can involve simply adding an extra step in an existing process to obtain more by-products. It is not only technological innovations that can be put in place, but also innovative practices, such as new financial measures to increase market access or institutional changes to improve management. The location and the amount of value added to biomass through processing have an impact on local and national socio-economic conditions. Innovations can be applied to minimize these impacts while optimizing bioeconomy activities.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
SUCCESS FACTOR B.2. THE PRESERVATION OF TRADITIONAL KNOWLEDGE IN INNOVATIONS AND PRACTICES THROUGH THE ACTIVE INVOLVEMENT OF INDIGENOUS AND LOCAL COMMUNITIES		
▶ From Farmer to Pharma (South Africa) ▶ Biofibre for clothing (Philippines) ▶ Beekeeping dermocosmetics (Colombia) ▶ Functional use of passion fruit (Brazil)	**Biofibre for clothing (Philippines):** A seven-year research was carried out to develop the technology, which was inspired by local craft making (i.e. the extraction of biomass fibres and the production of clothes). Pineapple-farmers sell the decorticated fibres to the company Ananas Anam. This activity improves womens' participation in the value chain, as they are familiar with the traditional process. **Beekeeping dermocosmetics (Colombia):** This commercial venture started as a small honey and pollen company that decided to add value to their products by producing natural dermocosmetics. Other family beekeepers aggregated their production and started adding therapeutic native plant species from the Amazon to the dermocosmetics. They have obtained a designation of origin and geographic indication and export their products internationally.	When traditional knowledge about local biomass is incorporated into new local bioeconomy activities, it can optimize the use and value of biomass. Local communities often have valuable knowledge about products and processes. Their traditional 'recipes' can be used to improve innovations. This requires involving all stakeholders in the process of designing new bioproducts, improving participation and fostering social inclusion.
SUCCESS FACTOR B.3. TESTS FOR CIRCULARITY, INCLUDING THE BIODEGRADABILITY, COMPOSTABILITY AND DISINTEGRATION OF PRODUCTS		
▶ Biofibre for clothing (Philippines) ▶ Alternatives to burning straw (China) ▶ The use of cardoon as biomass (EU and Italy)	**The use of cardoon as biomass (EU and Italy):** The company produces bio-based materials (monomers and esters) that are transformed into bio-based products by other companies. Tests are done on the technical performances and the biodegradability and compostability of the material and the final product.	It is important to test the biodegradability, compostability and disintegration of bio-based products to understand the characteristics of the product and ensure that it can meet market demand, either as a substitute for a similar fossil-based product or as a new product in untapped markets. This testing is also important for ensuring easier and better waste management and reducing water, air and soil pollution.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
C. TOOLS AND CONCEPTS TO PROVIDE AND MANAGE INFORMATION, PRODUCTS, PROCESSES AND SERVICES ACROSS ALL SECTORS		
SUCCESS FACTOR C.1. THE CREATION AND DEVELOPMENT OF MARKETS FOR BIOPRODUCTS, INCLUDING ASSESSING MARKET POTENTIAL AND CARRYING OUT DISSEMINATION ACTIVITIES		
▶ Seaweed value addition (United Republic of Tanzania) ▶ From Farmer to Pharma (South Africa) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ Towards second-generation biofuels (India) ▶ From biomass towns to industrial areas (Japan) ▶ Biofibre for clothing (Philippines) ▶ Alternatives to burning straw (China) ▶ Agroforestry and conservation (Indonesia) ▶ Bio-based plastics from agave residues (Mexico) ▶ Sunflower protein (Brazil) ▶ From gas to bio-based plastic (United States of America) ▶ Promoting bioproduct use (United States of America) ▶ The use of cardoon as biomass (EU and Italy) ▶ Rubber from dandelions (Germany) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America)	Bio-based plastics from agave residues (Mexico): The bio-based material matches market needs and is competitive with equivalent fossil-based materials. **Rubber from dandelions (Germany):** The bio-based material matches market needs and is competitive with equivalent unsustainably-sourced bio-based materials. **Sunflower protein (Brazil):** The initiative involves small- and medium-scale enterprises in the analysis of demand and the development of methods for optimizing the bio-based material to match market needs. **The use of cardoon as biomass (EU and Italy):** The project includes a market assessment to ensure the economic profitability of the whole process. Standardization (e.g. with LCAs) increases consumer awareness. **From biomass towns to industrial areas (Japan):** The initiative includes a comprehensive biomass (waste and/or unused biomass) utilization system (generation, conversion, distribution and use). It also includes the establishment of recycling systems. Waste is valorized by promoting its use as a feedstock and encouraging new trade and market streams. The towns are conceived as societies based on the recycling and reuse of biomass. **Urban circular bioeconomy (United States of America):** A combination of legislations that ban plastics and incentives that encourage public procurement and building of public infrastructure was used.	Bioproducts are becoming more and more marketable as consumers seek socially and environmentally sustainable goods. Thanks to greater consumer awareness, these products have the potential to capture a large share of global markets. Market-driven mechanisms are important for reducing competition for biomass. Competition can be reduced either by creating markets for new products or substituting fossil-based products for bio-based products. An adequate supply of biomass in quantity, type and quality is important to ensure the supply of a bioproduct meets the needs of the market. For a sustainable deployment of the bioeconomy, it is important to assess the market potential and monitor the social acceptability of bioproducts in order to adjust business activities and bioproduct characteristics. Consumers may prefer bioproducts as a substitute to other products because they are more sustainable, have better characteristics due to their natural origin and are less expensive. When a company substitutes fossil-based materials with bio-based materials to build their products, the consumer does not even have to make a choice. Products can also gain competitive advantages through quality standards or market regulations. Promotional campaigns that raise public awareness about bio-based goods and other dissemination activities can be done by the private or the public sector to promote the concept of sustainable consumption and production (UN Environment, 2014). These activities can help increase the market share of bio-based products. A common practice is the combination of 'sticks' (legislative or regulatory schemes that ban certain products or processes) and 'carrots' (legislation that provides incentives for more sustainable products and processes). These actions are important to remove market barriers for bioproducts.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
SUCCESS FACTOR C.2. CLUSTERING AND THE INTEGRATION OF SECTORS AND LEVELS		
▶ Seaweed value addition (United Republic of Tanzania) ▶ Bio-industrial clusters to add value (Malaysia) ▶ From biomass towns to industrial areas (Japan) ▶ Agroforestry and conservation (Indonesia) ▶ Beekeeping dermocosmetics (Colombia) ▶ Functional use of passion fruit (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ Blue bioeconomy development (Iceland) ▶ Forest bioeconomy cluster (Finland)	**Bio-industrial clusters to add value (Malaysia):** Clusters are formed by associations of producers or operators and seek support from the government. There is government interest in exploring downstream opportunities and creating clusters, such as the palm oil industrial clusters. The joint venture cluster model reduces competition between sectors and stimulates the market. **Forest bioeconomy cluster (Finland):** The government has developed a sub-national bioeconomy by promoting clusters that support cross-sectoral interactions, improved logistics and new production pathways in existing well-established pulp and paper, and bioenergy companies. There is the need to diversify the products obtained from the forestry sector to meet fluctuating demands, improve the local economy, create jobs and support small- and medium-scale enterprises.	Clustering and integration of sectors, industries and levels can reduce competition for biomass. Clustering involves the sharing of infrastructure, knowledge and risk. A cluster also often helps biomass producers or collectors become more organized. A cluster or a closed system of industries is conducive to the cascading use of industrial by-products obtained by different industrial sectors in the same area.
SUCCESS FACTOR C.3. THE ADOPTION OF TERRITORIAL AND LANDSCAPE APPROACHES IN NATIONAL OR LOCAL PLANNING		
▶ Integral use of oil palm (Ghana) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ National Biomass Strategy (Malaysia) ▶ Bio-industrial clusters to add value (Malaysia) ▶ Towards second-generation biofuels (India) ▶ From biomass towns to industrial areas (Japan) ▶ Mesa Sucroalcoholera (Argentina) ▶ Bio-based plastics from agave residues (Mexico) ▶ Sunflower protein (Brazil) ▶ Functional use of passion fruit (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ The use of cardoon as biomass (EU and Italy) ▶ Rubber from dandelions (Germany) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America) ▶ Forest bioeconomy cluster (Finland)	**Bioeconomy Community Development Programme (Malaysia):** Projects are tailored to the local biomass potential, landscape and local circumstances. This supports a circular bioeconomy. Anchor companies sometimes prefer to have the farmers and the community near their processing facility. In this way, farmers minimize the waste and can utilize remaining biomass wherever possible. The anchor company is encouraged to follow the National Green Technology initiative regarding the sustainable disposal of the bioproducts. **Mesa Sucroalcoholera (Argentina):** The value chains in the different regions of the country are diverse and have different needs. The Mesa Sucroalcoholera framework, which includes roundtables and national and sub-national coordination, follows a territorial approach for the formation of the roundtables and the implementation of different regulations, schemes and partnerships between ministries. All actions are based on the landscape conditions and the specific socio-economic and biophysical needs of the communities living in the area.	Bioeconomy production systems are designed and assessed based on the characteristics of a given territory or landscape. The outcome of a policy implemented in a geographic area depends on its characteristics (Cistulli, 2015). In a territorial approach to the bioeconomy, actions are implemented according to the specificities and needs of the area, for example to process biomass where it is produced. This approach makes the most out of an area's natural resources, locally available biomass and infrastructure. It can involve either changing an already developed sector (e.g. pulp and paper) or starting a new bioeconomic activity in an area by developing a new value chain. When developing a new value chain, projects often include a participatory rural appraisal to select the areas and products of interest. The agro-ecological zoning methodology and geographic information systems can be used for land-use planning in a territorial approach (FAO, 2017b). Participants at the Group of Seven Agriculture Ministers' Meeting in 2017 (G7, 2017) considered that sustainable agricultural practices, and local and sub-national production systems that are closely linked to the territory should be preserved to revitalize rural communities and curb the abandonment of rural areas. The role of women and youth is essential in this regard. The territorial approach is seen as being wider than the landscape approach. It often addresses a larger area and includes the development of rural infrastructure and regional land-use planning. The landscape approach includes spatial planning, supply chain optimization, and performance analyses (Dale *et al.*, 2015). It is often used in the implementation of climate-smart agriculture systems (FAO, 2017c).

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SUCCESS FACTOR C.4. THE ADOPTION OF INTEGRATED SYSTEMS		
▶ Biochar production and use (Ghana) ▶ BiomassWeb (Sub-Saharan Africa) ▶ National Biomass Strategy (Malaysia) ▶ Sunflower protein (Brazil)	**Biochar production and use (Ghana):** Food crop residues (corn cobs) are used as fuel for improved stoves, and the remaining biochar is used as soil amendment and fertilitizer. The biofertilizer can be produced by mixing biochar and chicken manure. The technology can be adapted to local conditions by the users when capacity development activities are carried out. This supports local decision making. **National Biomass Strategy (Malaysia):** The national biomass policy includes projects that take a multi-feedstock and multi-product approach and involve planning based on the landscape.	Integrated production systems can be of two types (Bogdanski *et al.*, 2010): i) systems that produce multiple feedstocks on the same land and follow an ecosystem approach. Most practices applied in integrated agricultural production systems are often considered to be climate-smart (FAO, 2017d). ii) systems that produce multiple products from the same feedstock by adopting technologies that allow for the maximum utilization of by-products, encourage recycling and maximize synergies between food, energy and bioproducts. In integrated biorefineries a wide range of products are manufactured with or without a cascading approach to optimize the use of raw materials (EC, 2015). In the global expert survey undertaken by the German Bioeconomy Council in 2018b, suggestions for solving conflicts in the non-food use of arable land considered equally the 'food-first' principle and holistic approaches that focused on the simultaneous production of food and non-food goods.
SUCCESS FACTOR C.5. THE PROMOTION OF A VALUE WEB APPROACH		
▶ BiomassWeb (Sub-Saharan Africa)	**BiomassWeb (Sub-Saharan Africa):** A study was undertaken to determine the current and future supply and demand of food and non-food interlinked biomass value chains. The results of the biomass value web study lead to the optimization of biomass processing into food and non-food uses with a higher integration and the cascading use of biomass. Results can also be used to address the issue of competition among biomass end-use sectors.	The value web is a non-linear approach and business perspective that involves the social and technical sharing of resources between businesses. This exchange creates a web of value that benefits all actors in a bio-based business and supports the addition of value to biomass by increasing processing activities. It can bring opportunities to low-income, agrarian countries to diversify their economy (Virchow *et al.*, 2014). A biomass web, which represents a broadening of the value chain approach, can merge several value chains in the cascading use and recycling of the biomass materials and contribute to making progress towards zero waste and a circular bioeconomy. Building relationships between different companies involved in a network has the added advantage of increasing the sharing of information.
D. STAKEHOLDER RELATIONS AMONG DIFFERENT SECTORS		
SUCCESS FACTOR D.1. COLLABORATION BETWEEN PUBLIC SECTOR ENTITIES FOR INTERMINISTERIAL COORDINATION		
▶ From Farmer to Pharma (South Africa) ▶ National Biomass Strategy (Malaysia) ▶ From biomass towns to industrial areas (Japan) ▶ Mesa Sucroalcoholera (Argentina) ▶ Family Cattle Producers and Climate Change (Uruguay)	**National Biomass Strategy (Malaysia):** AIM is a supraministerial agency under the Prime Minister's cabinet that designs and implements tailor-made bioeconomy strategies at the sub-national level. This central governmental institution administers and institutionalizes the bioeconomy in the country. It is made up of multiple ministries and agencies at both federal and state level. This government agency collaborates with citizens, academia and industry, in what is called a 'quadruple helix model'. **Mesa Sucroalcoholera (Argentina):** Ministries of agriculture and environment collaborate to find options for the treatment of vinasse to tackle the environmental problems posed by its disposal and explore potential uses (e.g. in fertilizer production).	Collaboration between different ministries is important because of the cross-cutting nature of the bioeconomy (Dubois and Gomez San Juan, 2016). An institutional arrangement that supports bioeconomy development can be achieved by establishing supraministerial agencies that coordinate efforts at the national level. The participation of all relevant ministries in specific activities (e.g. selecting priority areas of intervention within a country and priority sectors) is also critical. Collaborative interactions are particularly important for tackling challenges that arise from the trade-offs that must often be made to reach a number of shared development objectives. Governance structures need to be in place to enable the efficient and transparent sharing of information.

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SUCCESS FACTOR D.2. COLLABORATION BETWEEN PRIVATE SECTOR AND PUBLIC SECTOR TO INCREASE BIOECONOMY COMPETITIVENESS		
▶ From Farmer to Pharma (South. Africa) ▶ National Biomass Strategy (Malaysia) ▶ The use of cardoon as biomass (EU and Italy)	**From Farmer to Pharma (South Africa):** Public efforts are directed at connecting global funding and technical expertise to local innovators. **The use of cardoon as biomass (EU and Italy):** The research project is backed-up by the BBI JU, a Public-Private Partnership between the EU and the Bio-based Industries Consortium. This Public-Private Partnership is a joint undertaking that invests in bio-based innovation focusing on three aspects, feedstock, biorefineries, and markets and policies.	Collaboration between the private and public sectors can serve to combine and raise the financial resources needed for the development of innovative agro- and bio-industrial value chains. Public-private partnerships, partnerships that include the both public and private sector and the general public (public-private-people partnerships), consortiums, and research networks between farmers, public bodies, researchers and buyers are other mechanisms that can unite efforts to develop new products or new business models to make the bioeconomy more competitive.
SUCCESS FACTOR D.3. COLLABORATION BETWEEN STAKEHOLDERS FOR CAPACITY DEVELOPMENT, KNOWLEDGE SHARING AND COOPERATIVE ACTIONS		
▶ Biochar production and use (Ghana) ▶ BiomassWeb (Sub-Saharan Africa) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ From biomass towns to industrial areas (Japan) ▶ Biofibre for clothing (Philippines) ▶ Agroforestry and conservation (Indonesia) ▶ Bio-based plastics from agave residues (Mexico) ▶ Sunflower protein (Brazil) ▶ Urban circular bioeconomy (United States of America)	**Bioeconomy Community Development Programme (Malaysia):** In this type of contract farming, the bio-based technologies from the anchor companies enable the farmers to improve their yields, production standards and productivity. This arrangement is important for the development of the bioeconomy because it promotes the production of biomass that farmers may be unfamiliar with. Projects increase farmers' market access. A long-term objective is to enhance farmers' social mobility through technology-based entrepreneurship. **Sunflower protein (Brazil):** The aim of the institutional collaboration between research centres from different continents is to increase the number of protein-rich products in the market. Higher added value is obtained by all the countries involved as new ingredients enter the market in response to consumer needs and preferences. This collaboration supports knowledge-sharing activities. It also increases opportunities for small- and medium-scale enterprises to access technology.	Unlike economic development that focuses on a single-sector, the development of the bioeconomy involves a coordinated multi-sectoral approach. Moreover, sustainability is often understood in different ways. Intersectoral, intergovernmental and international coordination is the key to uniting efforts geared towards developing a sustainable bioeconomy. Interactions between biomass producers and processing companies create stronger biomass value chains. The transfer of technology can help add value to the biomass by processing it in situ. It can also promote sustainable agriculture, for example, by enabling production to expand into marginal land. Carrying out capacity development activities is also important for the cultivation of new types of crops needed for emerging markets and the adoption of innovative farming methods.
SUCCESS FACTOR D.4. PURCHASING AGREEMENTS BETWEEN SMALL-SCALE FARMERS AND BUYERS		
▶ Integral use of oil palm (Ghana) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ Beekeeping dermocosmetics (Colombia)	**Integral use of oil palm (Ghana):** The company buys raw material directly from the farmers. It shares the net profits from the entire operation with them in proportion to the amount of raw material that they deliver. In addition, farmers receive market prices for their produce. The price is linked to the international market price and paid directly upon delivery. Farmers can also use the mill, and receive capacity development in the company's innovation centre. **Bioeconomy Community Development Programme (Malaysia):** The type of contract farming includes a buyback guarantee agreement and the application of bio-based technologies. It provides farmers with an additional income from planting the material that is needed by the anchor company. Anchor companies also increase their income thanks to a constant and sustainable supply of raw materials and the reduction of imports. Farmers must follow a national standard operating procedure, which also supports, at a later stage, the promotion of the products internationally.	When a new bioproduct is to be commercialized, farmers may not know which feedstock to produce to meet the new demand for bioproducts, and industries may not have sufficient biomass of a suitable quality to develop their production chains at scale. Contract farming, along with other financial schemes and business plans (e.g. credit guarantee, social entrepreneurship), is a way of addressing this situation. A contract farming agreement between a buyer and farmers establishes conditions for the production quantities and the marketing of biomass. Some aspects of contract farming can contribute to the success of bioeconomy initiatives, but some aspects can create challenges. Although contract farming can benefit farmers by ensuring they have a secure buyer, the arrangement may not be always advantageous to them. Overall, it is important that the business model is economically self-sustaining. Appropriate regulatory frameworks may be needed to ensure transparent and balanced contract farming operations.

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SUCCESS FACTOR D.5. PURCHASING AGREEMENTS BETWEEN PUBLIC ENTITIES AND BIOPRODUCT MANUFACTURERS		
▶ Promoting bioproduct use (United States of America)	**Promoting bioproduct use (United States of America):** The USDA manages a national public procurement programme for bio-based products (BioPreferred). Federal purchasing requirements for bio-based products are part of purchasing solicitations, agreements, contracts, specifications and other procurement vehicles of federal agencies. All federal agencies and contractors should purchase a required amount of bio-based products. The BioPreferred programme serves as an information source for both the best procurement options for government agencies, their contractors, the general public, and for business-to-business knowledge and the exchange of good practices.	National public procurement for bio-based products can increase farmers' confidence in the markets for bio-based products. It can also raise public awareness about the benefits of purchasing bio-based products. Requirements, for example regarding the use of innovative approaches, are can be applied in all stages of the value chain, including the growing, harvesting, sourcing, procuring, processing, manufacturing, and application of bio-based products.
SUCCESS FACTOR D.6. PURCHASING AGREEMENTS BETWEEN TECHNOLOGICAL INTELLECTUAL PROPERTY PROVIDERS AND INVESTORS		
▶ Towards second-generation biofuels (India) ▶ From gas to bio-based plastic (United States of America)	**Towards second-generation biofuels (India):** The business model of behind Praj's cellulosic ethanol multi-purpose integrated biorefinery is based on technology licensing between Praj, the technological partner or technology licensors, and the investor partners, which are public sector oil enterprises. **From gas to bio-based plastic (United States of America):** The agreements between Newlight and contractors support the scaling up of the technology, as contractors have the license to produce AirCarbon bio-based material with the patented technology.	Technology licenses are agreements whereby an owner of a technological intellectual property (the licensor) allows another party (the licensee) to use, modify, and/or resell that property in exchange for some form of compensation. Agreements between technology providers and financial investors can support the development of infrastructure and help scale up and commercialize proven technologies that have been created through R&D&I activities, or bring them from the demonstration phase to commercial use.
SUCCESS FACTOR D.7. THE FAIR DISTRIBUTION OF BENEFITS AMONG VALUE CHAIN ACTORS		
▶ BiomassWeb (Sub-Saharan Africa) ▶ Integral use of oil palm (Ghana) ▶ Seaweed value addition (United Republic of Tanzania) ▶ From Farmer to Pharma (South Africa) ▶ Biofibre for clothing (Philippines) ▶ Alternatives to burning straw (China) ▶ Mesa Sucroalcoholera (Argentina) ▶ Beekeeping dermocosmetics (Colombia) ▶ Bio-based plastics from agave residues (Mexico) ▶ Functional use of passion fruit (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay)	**Mesa Sucroalcoholera (Argentina):** The roundtable is a tool for distributing income evenly among the stakeholders in the value chain because it increases the transparency of information and political actions. The roundtable monitors sugar stocks and evaluates the potential end uses of sugar and export capacity. **Functional use of passion fruit (Brazil):** The Passitec network provides sustainable technologies used in the production of two improved varieties of wild passion fruit. This activity has helped strengthen the supply chain. The network also has given support to the development of agro-industry for processing wild passion fruit. This has made it possible to use the entire fruit and produce more ingredients that have passiflora as their base. The network has helped connect all stakeholders in the value chain and build facilities with the necessary processing equipment.	The sustainable bioeconomy includes the equitable distribution of benefits along the value chain. A particular challenge for biomass producers, especially in poor rural indigenous communities, is capturing a significant share of the value of the final products. The value added to the biomass should be distributed to the different actors involved in all stages of the value chain. An equitable and fair distribution of the benefits can foster the development of rural areas that have traditionally depended entirely on the production of raw biomass. Achieving an equitable and fair distribution of the benefits involves developing local processing facilities that can enable local people to engage in the processing of biomass; establishing fair trade arrangements; and acknowledging the producers' ownership of the biomass.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
E. STRATEGIES AND POLICIES AIMING TOWARD A SUSTAINABLE BIOECONOMY		
SUCCESS FACTOR E.1. CERTIFICATION OF SUSTAINABILITY AND COMPLIANCE WITH NATIONAL LAW THROUGH MONITORING AND EVALUATION		
▶ Biochar production and use (Ghana) ▶ Biofibre for clothing (Philippines) ▶ Agroforestry and conservation (Indonesia) ▶ Beekeeping dermocosmetics (Colombia) ▶ From gas to bio-based plastic (United States of America) ▶ Promoting bioproduct use (United States of America)	**Agroforestry and conservation (Indonesia)**: The Kutai Timber company has around 100 legal forest concessions. This supports Indonesia's efforts to eliminate illegal logging, which includes establishing a national timber legality assurance system. Indonesia is the only country that has a Voluntary Partnership Agreement with the EU to promote trade in legal timber products and improve forest governance. Since Indonesia began issuing Forest Law Enforcement, Governance and Trade (FLEGT) licences in November 2016, it only exports to the EU verified legal timber products. **From gas to bio-based plastic (United States of America):** AirCarbon is certified 'Bronze' under the Cradle to Cradle Certified Product Standard V.3.0 (2015), which is a specific circular economy standard. The Cradle to Cradle certification includes requirements related to a number of criteria, including material reutilization, the use of renewable energy, the management of the carbon flows, the content of renewable or recyclable material and the percentage that can be reused, recycled or composted in the end-of life stage.	Public or private certification can be a guarantee of quality and sustainability, and enable the product to penetrate international markets. When a product occupies a unique product niche, certification can increase consumer acceptance in specialized markets. Certification can also help the product to obtain higher prices or earn price premiums. Certification that includes requirements of bio-based content or recyclable content, which improves circularity, is of particular importance for the bioeconomy.
SUCCESS FACTOR E.2. POLICY INTERVENTIONS THAT PROVIDE INCENTIVES AND ESTABLISH SUPPORTIVE PUBLIC MECHANISMS		
▶ BiomassWeb (Sub-Saharan Africa) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ Alternatives to burning straw (China) ▶ Beekeeping dermocosmetics (Colombia) ▶ Sunflower protein (Brazil) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ Urban circular bioeconomy (United States of America) ▶ Forest bioeconomy cluster (Finland)	**Alternatives to burning straw (China):** Several national policy measures have been taken to stop the burning of straw outdoors. These include bans on burning straw in combination with pilot projects in provinces to disseminate technologies for the comprehensive use of straw and raise awareness about the issue. The local government is responsible for monitoring the straw that is burned or used. **Family Cattle Producers and Climate Change (Uruguay):** The implementation of the support programme to increase the resilience of family cattle producers includes an impact evaluation. Its objective is to measure the programme's effect on the adoption and performance of cattle and pasture management practices and the production of meat per hectare. Two types of indicators are used: result indicators for the former, and impact indicators for the latter.	Policy measures (e.g. incentives and regulations) and policy instruments (e.g. guidelines and outreach) are channels for mainstreaming bioeconomy in ways that can optimize opportunities to establish new industries and value chains. Regulations can also have specific requirements and targets to guide the implementation of the bioeconomy towards the desired sustainability goals and outcomes. Monitoring the implementation of policy measures is an essential part of pubic interventions. Moreover, public efforts are needed for the overall monitoring and evaluation of the sustainability of the bioeconomy and its development at the national level.

CASE STUDIES WHERE THE SUCCESS FACTOR WAS IMPLEMENTED	EXAMPLES OF HOW THE SUCCESS FACTOR WAS IMPLEMENTED IN SELECTED CASE STUDIES	WHY THE SUCCESS FACTOR IS IMPORTANT FOR SUSTAINABLE BIOECONOMY
SUCCESS FACTOR E.3. THE INVOLVEMENT OF ALL RELEVANT STAKEHOLDERS IN THE TRANSITION TOWARDS SUSTAINABLE BIOECONOMY		
▶ Biochar production and use (Ghana) ▶ BiomassWeb (Sub-Saharan Africa) ▶ Integral use of oil palm (Ghana) ▶ Seaweed value addition (United Republic of Tanzania) ▶ Bioeconomy Community Development Programme (Malaysia) ▶ National Biomass Strategy (Malaysia) ▶ Bio-industrial clusters to add value (Malaysia) ▶ Alternatives to burning straw (China) ▶ Agroforestry and conservation (Indonesia) ▶ Mesa Sucroalcoholera (Argentina) ▶ Family Cattle Producers and Climate Change (Uruguay) ▶ The use of cardoon as biomass (EU and Italy) ▶ Rubber from dandelions (Germany) ▶ Blue bioeconomy development (Iceland) ▶ Urban circular bioeconomy (United States of America) ▶ Forest bioeconomy cluster (Finland)	**National Biomass Strategy (Malaysia)**: The creation of an industrial consortium involving all stakeholders in the value chain maximizes synergies. Stakeholders across different sectors participate in the integration of sectoral policies. **Seaweed value addition (United Republic of Tanzania):** Seaweed is the third most important industry in terms of revenue for the country. Between 80-90% of the seaweed producers are women, and small-scale processing is done by women. The cluster-based research helps producers connect to research, which is then tailored to their needs. It also builds links to other companies, exporters, and the sub-national government. The cluster facilitates the transfer of technology (e.g. machines to make soap) and capacity development (e.g. techniques on how to cultivate seaweed in deeper colder waters, which is needed due declines in production caused by climate change).	Stakeholder participation in activities to integrate the bioeconomy within existing policies and infrastructure in different sectors is important for consolidating and leveraging available resources in a given territory. For a transition towards a sustainable bioeconomy to happen at a meaningful scale, a transformational change must take place that affects the economy and the well-being of a community. This change can be brought about in in two ways: ▶ involving the industries that are the most important (e.g. in terms of gross domestic product, competitiveness and exports) in the country or region in sustainable bioeconomy activities will have significant impacts and support the creation of innovative products of global importance; and ▶ transforming a given region or area into a 'pot of gold', which can be accomplished, for example, by introducing new types of biomass production systems to supply new bio-based industries. The harvesting or processing of the biomass in some cases can be carried out by local communities or women to give them an extra income. Also, value addition can be done at a scale that allows the communities to gain perceptible benefits.

Along with helping to meet sustainability objectives, some of the success factors can contribute to overcoming the existing or potential risks arising from bioeconomy development. Those responsible for the case studies have considered a number of different risk management options (e.g. multi-cropping systems for income diversification, multi-product biorefineries, education and training, inclusive consultation processes).

A risk assessment and the selection of risk reduction actions should be carried out by local stakeholders. This review of 26 bioeconomy case studies highlights the most relevant success factors that can support risk management.

▶ Increased capacity to manage risk can be gained by diversifying the incomes of farmers and industrial actors. This can be achieved by the success factors:

  - the use, when viable, of biomass residues and food that are otherwise lost or wasted;
  - the use and valorization of all by-and co-products obtained in the processing stage;
  - the adoption of integrated systems; and
  - the application of innovative practices and technologies for biomass production, processing and use in combination with the involvement of all relevant stakeholders in the transition towards sustainable bioeconomy.

For example, multi-cropping systems along with transparent information sharing can allow farmers to choose the crops based on market demand (e.g. Sunflower protein, Brazil). Farmers can use the extra income obtained from crop diversification to adopt biomass processing technologies. This can make the farmers more economically resilient since they can market the final products instead of exporting raw biomass (e.g. Seaweed value addition, United Republic of Tanzania).

- The risk of having an intermittent supply of raw materials, particularly when the raw material is a waste or a residue, can be mitigated by improving logistics and strengthening viable waste and residue value chains. Activities in this area are grouped under the success factor 'the application of innovative practices and technologies for biomass production, processing and use'.
- When the bioeconomy involves new and uncertain investments, the associated risks can be mitigated by ensuring that the processing technology is adaptable to different types of feedstock and establishing mechanisms to create an enabling environment that can support new activities in the area. Activities in this area are grouped under the success factors, 'purchasing agreements between small-scale farmers and buyers' and 'the adoption of integrated systems'. Viability analyses are also crucial. These analyses should take into account the economic, environmental and social aspects of the new activities, and particular attention should be given to food security and competition among biomass end-use sectors (e.g. Biochar production and use in Ghana and sunflower protein in Brazil).
- Once new opportunities to add value to biomass have been explored, their implementation requires new skills, new techniques and new facilities. Some ways to mitigate risk in this area are:
  - collaborating with strategic partners that have technological know-how;
  - integrating programmes or clusters of development for novel technologies; and
  - developing technologies in tandem with creating innovative business models to enhance the economic value of products.

  These activities are grouped under the success factors 'purchasing agreements between technological intellectual property providers and investors' and 'clustering and the integration of sectors and levels'. These two success factors can also reduce competition among biomass end-use sectors, increase synergies and mitigate individual risk. For instance, in the case study of bio-industrial clusters in Malaysia, risk mitigation from partnering and combining resources is the main benefit perceived by oil palm plantation companies and manufacturing processors. In the case study from Iceland, the risk associated with the supply of raw materials for the biorefinery, which is particularly important when using residues as feedstock, was minimized by using residues already available from other well-established industries of traditional Icelandic cod, and having year-round cod production.
- Actions under the success factor 'the use and valorization of all by-and co-products obtained in the processing stage' can include pilot projects for new processes and non-profit spin-offs that can demonstrate the market potential of innovative bioproducts. These actions can reduce financial, technological and operational risks. Research on the optimization of processing and the creation of new products is key to implementing the bioeconomy. It is particularly important to find ways to process and market previously unused biomass feedstocks (e.g. organic waste streams).
- The success factor 'the adoption of territorial and landscape approaches in national or local planning' can reduce the risk caused by a new bioeconomy activity, if local biophysical characteristics and socioeconomic dynamics are mapped, and biological diversity is taken into account. Even if this occasionally requires making a risky investment, industrialization in rural areas can improve farmers' economic resilience and reduce migration. This is exemplified in Malaysia's National Biomass Strategy, which reduces the risk of feedstock security by involving biomass producers in the business model. This gives the producers a stake in developing the industry, rather than leaving them as outsiders who only provide the feedstock.
- The risk success factor 'the fair distribution of benefits among value chain actors' can reduce the risk of exclusion. It can be achieved by strengthening collaboration between agro-industries and bio-industries and farmers, or by down-scaling technologies from larger producers to small-scale producers.
- The success factor 'the creation and development of markets for bioproducts,

including assessing market potential and carrying out dissemination activities' encompasses activities, such as market assessments and market adjustments, that are essential for mitigating the risks associated with new bioeconomy products (e.g. National Biomass Strategy, Malaysia). Some entrepreneurs have a short-term business mind set due to the risks associated with market uncertainties.

- The success factor 'policy interventions that provide incentives and establish supportive public mechanisms' that deals specifically with the bioeconomy deployment. The Bioeconomy Community Development Programme in Malaysia offers an example of a government institution that manages contracts between industry and producers in ways that mitigate the risk for both groups of stakeholders.
- The success factor 'collaboration between stakeholders for capacity development, knowledge sharing and cooperative actions' can reduce the financial risk producers may encounter when acquiring new technology, machines or tools or engaging in new practices. This can help promote the adoption of these technologies and practices.

3.4 OVERVIEW OF HOW SUSTAINABILITY IS ADDRESSED IN THE CASE STUDIES

At the 9th International Conference on Biological Based Materials in Cologne, Germany, the expert and international advisor on bioeconomy Christian Patermann (2016) presented an overview of the lessons that had been learned in ten years, since the first conference, in which he made the following statements:

> *We were always aware of the enormous potentials of the increased use and production of biological resources in relation to sustainable development, but never claimed the Bioeconomy to be sustainable automatically. We always formulated that there is a strong, maybe unique closeness, vicinity to Sustainability, but each practical case would have to demonstrate it (p.3).*

> *The Bioeconomy was not conceived 10 years ago to save our planet, as a silver bullet, but in a very humble way as an offer to contribute to solving the so-called grand challenges (p.4).*

This subsection reviews the P&Cs and SDGs that the case studies address.

3.4.1 Principles and criteria

In 2016, FAO analysed the social, economic and environmental pillars of sustainability of various bioeconomy strategies and roadmaps at local, national and international levels (Dubois and Gomez San Juan, 2016). A similar analysis of these three pillars of sustainability of the 26 case studies is presented in this subsection. The relation of the P&Cs to the different case studies is intended to demonstrate the connection between sustainability and the bioeconomy to which Patermann (2016) refers.

The main finding of this analysis is that the sustainable implementation of bioeconomy, depends highly on the context. The activities that make the bioeconomy sustainable in each case study and adhere to the P&Cs are the success factors. However, the implementation of these success factors does not directly lead to sustainability. To contribute to sustainability, the success factors should be implemented in a way that is tailored to the local setting. As shown in Subsection 3.3, the success factors can be implemented in different ways. The criteria addressed depend on how the success factors were implemented under each particular context.

Tables 4.1, 4.2 and 4.3 show the P&Cs (see **Table 1** and **Annex 1**) that are addressed by each case study under each sustainability pillar. This has been done to identify the aspects of sustainability that are covered in the individual case studies, based on available literature, and in the overall selection of the case studies.

After each table, a discussion of the results is presented. Although each case study is unique, an overview of the case studies that address each criterion is presented at the end of each table. The discussion of the results is based on Gomez San Juan (forthcoming). The fact that some P&Cs are mentioned more frequently than others is not an indication of their relative importance. The table merely indicates the most commonly addressed aspects of sustainably, and by extension sheds light on those aspects most at risk of being forgotten. The most covered Principles are 3 (economic growth), 7 (knowledge and innovation) and 10 (cooperation, collaboration and sharing), along with Criteria 1.1 (food security), 2.2 (climate change mitigation and adaptation), 5.1 (resource use efficiency) and 9.1 (sustainable consumption matches sustainable production). The least covered Criteria are 1.3 (rights to natural resources), 2.1 (biodiversity), 4.1 (sustainability of urban areas), 5.2 (food loss and waste) and 6.3 (risk management).

TABLE 4.1.

RELATION BETWEEN THE CASE STUDIES AND THE SUSTAINABLE BIOECONOMY P&Cs - SOCIAL PILLAR

SOCIAL CRITERIA (✓ = The criterion is covered) / CASE STUDIES	C.1.1 FOOD SECURITY AND NUTRITION ARE SUPPORTED	C.1.3 ADEQUATE LAND RIGHTS AND RIGHTS TO OTHER NATURAL RESOURCES ARE GUARANTEED	C.1.4 FOOD SAFETY, DISEASE PREVENTION AND HUMAN HEALTH IS ENSURED	C.3.2 INCLUSIVE ECONOMIC GROWTH IS STRENGTHENED	C.4.1 THE SUSTAINABILITY OF URBAN CENTERS IS ENHANCED	C.4.2 RESILIENCE OF BIOMASS PRODUCERS, RURAL COMMUNITIES AND ECOSYSTEMS IS DEVELOPED AND/OR STRENGTHENED	C.6.1 POLICIES, REGULATIONS AND INSTITUTIONAL SET UP RELEVANT TO BIOECONOMY SECTORS ARE ADEQUATELY HARMONIZED	C.6.2 INCLUSIVE CONSULTATION PROCESSES AND ENGAGEMENT OF ALL RELEVANT SECTORS OF SOCIETY ARE ADEQUATE AND BASED ON TRANSPARENT SHARING OF INFORMATION	C.7.1 EXISTING KNOWLEDGE IS ADEQUATELY VALUED AND PROVEN SOUND TECHNOLOGIES ARE FOSTERED	C.10.1 COOPERATION, COLLABORATION AND SHARING OF RESOURCES, SKILLS AND TECHNOLOGIES ARE ENHANCED WHEN AND WHERE APPROPRIATE
BIOCHAR PRODUCTION AND USE, GHANA	✓	-	✓	✓	-	✓	✓	✓	✓	✓
BIOMASSWEB, SUB-SAHARAN AFRICA	✓	✓	-	✓	-	✓	✓	✓	✓	✓
INTEGRAL USE OF OIL PALM, GHANA	✓	✓	-	✓	-	-	✓	✓	✓	✓
SEAWEED VALUE ADDITION, UNITED REPUBLIC OF TANZANIA	✓	✓	✓	✓	-	✓	✓	✓	✓	✓
FROM FARMER TO PHARMA, SOUTH AFRICA	✓	✓	✓	✓	-	✓	✓	✓	✓	-
BIOECONOMY COMMUNITY DEVELOPMENT PROGRAMME, MALAYSIA	✓	✓	-	✓	-	✓	✓	✓	✓	✓
NATIONAL BIOMASS STRATEGY, MALAYSIA	✓	-	-	✓	-	✓	✓	✓	✓	✓
BIO-INDUSTRIAL CLUSTERS TO ADD VALUE, MALAYSIA	✓	-	✓	✓	✓	✓	✓	✓	✓	✓
TOWARDS SECOND-GENERATION BIOFUELS, INDIA	-	-	-	-	-	✓	✓	-	✓	✓
FROM BIOMASS TOWNS TO INDUSTRIAL AREAS, JAPAN	-	-	-	✓	✓	✓	-	✓	✓	✓
BIOFIBRE FOR CLOTHING, PHILIPPINES	✓	✓	-	✓	-	✓	✓	✓	✓	✓
ALTERNATIVES TO BURNING STRAW, CHINA	✓	-	-	✓	-	✓	✓	✓	✓	✓
AGROFORESTRY AND CONSERVATION, INDONESIA	✓	-	✓	✓	-	✓	-	-	✓	✓
MESA SUCROALCOHOLERA, ARGENTINA	✓	-	-	✓	-	✓	-	-	✓	✓
BEEKEEPING DERMOCOSMETICS, COLOMBIA	-	-	✓	✓	-	✓	✓	-	✓	✓
BIO-BASED PLASTICS FROM AGAVE RESIDUES, MEXICO	✓	-	-	✓	-	✓	-	-	-	✓
SUNFLOWER PROTEIN, BRAZIL	✓	-	✓	✓	-	-	✓	-	-	✓
FUNCTIONAL USE OF PASSION FRUIT, BRAZIL	✓	-	-	✓	-	✓	-	-	✓	✓
FAMILY CATTLE PRODUCERS AND CLIMATE CHANGE, URUGUAY	✓	-	-	✓	-	✓	✓	✓	✓	-
FROM GAS TO BIO-BASED PLASTIC, UNITED STATES OF AMERICA	-	-	-	-	✓	-	-	-	✓	✓
PROMOTING BIOPRODUCT USE, UNITED STATES OF AMERICA	✓	-	-	-	-	-	✓	-	-	-
THE USE OF CARDOON AS BIOMASS, EUROPEAN UNION AND ITALY	✓	-	-	✓	-	✓	-	-	✓	✓
RUBBER FROM DANDELIONS, GERMANY	✓	-	-	✓	-	✓	-	✓	✓	-
BLUE BIOECONOMY DEVELOPMENT, ICELAND	✓	-	✓	-	-	-	-	-	✓	✓
URBAN CIRCULAR BIOECONOMY, UNITED STATES OF AMERICA	-	-	✓	-	✓	-	✓	-	✓	✓
FOREST BIOECONOMY CLUSTER, FINLAND	-	-	-	✓	-	-	✓	✓	✓	✓
TOTAL FOR 26 CASE STUDIES	**20**	**6**	**9**	**21**	**4**	**19**	**17**	**14**	**23**	**22**

Social Pillar

PRINCIPLE 1. SUSTAINABLE BIOECONOMY DEVELOPMENT SHOULD SUPPORT FOOD SECURITY AND NUTRITION AT ALL LEVELS

Criterion 1.1. Food security and nutrition are supported (20/26).

Criterion 1.3. Adequate land rights and rights to other natural resources are guaranteed (6/26).

Criterion 1.4. Food safety, disease prevention and human health are ensured (9/26).

Food security and nutrition is highly relevant for the vast majority of bioeconomy cases, interestingly, through the use of both food and non-food feedstocks. Within this compilation of case studies, government programmes are the type of interventions that seek to support food security the most, by promoting the use of locally available biomass that respects already existing land uses. In case studies that involve biomass production, the private sector addresses food security in terms of food availability by implementing good agricultural practices. Nutrition is supported mainly by private sector activities (e.g. companies specializing in new products, such as food supplements and nutraceuticals).

Adequate land rights and rights to other natural resources is considered only in very few cases. Rights are guaranteed at the territorial level when governmental programmes include small producers and indigenous communities in the development of value chains for new bioproducts. At the local or project level, case studies that explicitly address this criterion are led either by NGOs or by private companies with a strong social component in activities connected to biomass production.

Food safety, disease prevention and human health are addressed by only a few case studies and only in relation to the management of health risks. This is done by promoting pharmaceutical, nutraceutical and cosmeceutical products, and preventing hazards during work operations (e.g. biomass harvesting and processing and waste treatment).

PRINCIPLE 3. SUSTAINABLE BIOECONOMY SHOULD SUPPORT COMPETITIVE AND INCLUSIVE ECONOMIC GROWTH

Criterion 3.2. Inclusive economic growth is strengthened (21/26).

Most of the case studies work to foster inclusive economic growth. This is particularly true when the goal is to improve access to stable and productive jobs. It also includes efforts towards improving equality and gender balance. For those case studies that focus on processes that use high technology, the issue of inclusive growth is less pronounced. Private sector activities contribute the most to promoting inclusive economic growth, followed by government programmes.

PRINCIPLE 4. SUSTAINABLE BIOECONOMY SHOULD MAKE COMMUNITIES HEALTHIER, MORE SUSTAINABLE, AND HARNESS SOCIAL AND ECOSYSTEM RESILIENCE

Criterion 4.1. The sustainability of urban centres is enhanced (4/26).

Criterion 4.2. Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened (19/26).

The sustainability of urban centres is addressed less frequently than the resilience of rural biomass producers, rural communities and ecosystems. The issue figures mainly in government-led cases studies. An important component of all these programmes is the creation of circular bioeconomy systems at the territorial level that make the most out of available waste and residues. These programmes also seek to change consumer behaviour and improve access to services to implement the bioeconomy in urban areas.

Most of the case studies (19) deal with rural settings. The case studies that involve larger-scale initiatives do not have a rural focus. In general, the case studies are more concerned with social resilience (i.e. resilience of biomass producers, rural communities and ecosystems) than economic resilience (Criterion 3.3). Several case studies that are private sector initiatives contribute to supporting social and ecosystem resilience.

PRINCIPLE 6. RESPONSIBLE AND EFFECTIVE GOVERNANCE MECHANISMS SHOULD UNDERPIN SUSTAINABLE BIOECONOMY

Criterion 6.1. Policies, regulations and institutional set up relevant to bioeconomy sectors are adequately harmonized (17/26).

Criterion 6.2. Inclusive consultation processes and engagement of all relevant sectors of society are adequate and based on transparent sharing of information (14/26).

Regulatory frameworks and institutions are often taken into account in the case studies, particularly with regard to supportive political mechanisms. When the case studies are government programmes, the implementation of these mechanisms (e.g. public procurement) is more central to the work. The public sector can also support effective cross-sectoral collaboration.

Transparency and inclusive consultation processes are also often taken into account. Several cases include consultation processes that are inclusive and engage all relevant stakeholders. Transparency is particularly important when stakeholders at different levels are unaware of the potential opportunities bioeconomy development can offer. Roundtables or awareness-raising activities are common practices carried out by the public sector.

PRINCIPLE 7. SUSTAINABLE BIOECONOMY SHOULD MAKE GOOD USE OF EXISTING RELEVANT KNOWLEDGE AND PROVEN SOUND TECHNOLOGIES AND GOOD PRACTICES, AND, WHERE APPROPRIATE, PROMOTE RESEARCH AND INNOVATION

Criterion 7.1. Existing knowledge is adequately valued and proven sound technologies are fostered (23/26).

Innovations in the implementation of well-known technologies are taken into account by almost all the case studies, either by applying technologies and knowledge or improving access to education and training. The bioeconomy is perceived in some case studies as an opportunity to deploy technologies and practices in new industries. Capacity development and extension activities are also used to disseminate knowledge. The case studies that promote well-known technologies are equally led by government programmes and the private sector.

PRINCIPLE 10. SUSTAINABLE BIOECONOMY SHOULD PROMOTE COOPERATION, COLLABORATION AND SHARING BETWEEN INTERESTED AND CONCERNED STAKEHOLDERS IN ALL RELEVANT DOMAINS AND AT ALL RELEVANT LEVELS

Criterion 10.1. Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate (22/26).

Cooperation between stakeholders is an important aspect of sustainability in most of the case studies, particularly in the case studies that consider the replicability of activities and good practices. Private sector activities contribute the most to this aspect, using different collaborative mechanisms (e.g. joint ventures or licensing) followed by government programmes that seek international cooperation in transferring skills and knowledge.

TABLE 4.2.

RELATION BETWEEN THE CASE STUDIES AND THE SUSTAINABLE BIOECONOMY P&Cs - ECONOMIC PILLAR

CASE STUDIES / ECONOMIC CRITERIA (✓ = The criterion is covered)	C.3.1 ECONOMIC DEVELOPMENT IS FOSTERED	C.3.3 RESILIENCE OF THE RURAL AND URBAN ECONOMY IS ENHANCED	C.6.3 APPROPRIATE RISK ASSESSMENT AND MANAGEMENT, MONITORING AND ACCOUNTABILITY SYSTEMS ARE PUT IN PLACE AND IMPLEMENTED	C.7.2 KNOWLEDGE GENERATION AND INNOVATION ARE PROMOTED	C.8.1 LOCAL ECONOMIES ARE NOT HAMPERED BUT RATHER HARNESSED BY THE TRADE OF RAW AND PROCESSED BIOMASS, AND RELATED TECHNOLOGIES	C.9.1 CONSUMPTION PATTERNS OF BIOECONOMY GOODS MATCH SUSTAINABLE SUPPLY LEVELS OF BIOMASS GOODS	C.9.2 DEMAND- AND SUPPLY-SIDE MARKET MECHANISMS AND POLICY COHERENCE BETWEEN SUPPLY AND DEMAND OF FOOD AND NON-FOOD GOODS ARE ENHANCED WHEN AND WHERE APPROPRIATE
BIOCHAR PRODUCTION AND USE, GHANA	✓	✓	-	✓	✓	-	✓
BIOMASSWEB, SUB-SAHARAN AFRICA	✓	✓	-	✓	✓	✓	✓
INTEGRAL USE OF OIL PALM, GHANA	✓	-	✓	-	✓	✓	-
SEAWEED VALUE ADDITION, UNITED REPUBLIC OF TANZANIA	✓	✓	-	✓	✓	✓	-
FROM FARMER TO PHARMA, SOUTH AFRICA	✓	✓	-	✓	✓	-	✓
BIOECONOMY COMMUNITY DEVELOPMENT PROGRAMME, MALAYSIA	✓	✓	-	✓	✓	✓	✓
NATIONAL BIOMASS STRATEGY, MALAYSIA	✓	✓	✓	✓	✓	-	✓
BIO-INDUSTRIAL CLUSTERS TO ADD VALUE, MALAYSIA	✓	✓	-	-	-	✓	-
TOWARDS SECOND-GENERATION BIOFUELS, INDIA	✓	-	-	✓	-	✓	-
FROM BIOMASS TOWNS TO INDUSTRIAL AREAS, JAPAN	✓	✓	-	-	✓	✓	✓
BIOFIBRE FOR CLOTHING, PHILIPPINES	-	✓	-	✓	✓	✓	-
ALTERNATIVES TO BURNING STRAW, CHINA	✓	✓	✓	✓	-	✓	✓
AGROFORESTRY AND CONSERVATION, INDONESIA	✓	✓	-	✓	✓	✓	✓
MESA SUCROALCOHOLERA, ARGENTINA	✓	✓	-	✓	✓	-	✓
BEEKEEPING DERMOCOSMETICS, COLOMBIA	✓	-	-	✓	✓	-	✓
BIO-BASED PLASTICS FROM AGAVE RESIDUES, MEXICO	✓	✓	-	✓	✓	✓	-
SUNFLOWER PROTEIN, BRAZIL	✓	✓	✓	✓	-	✓	-
FUNCTIONAL USE OF PASSION FRUIT, BRAZIL	✓	-	-	✓	✓	-	-
FAMILY CATTLE PRODUCERS AND CLIMATE CHANGE, URUGUAY	✓	✓	✓	✓	-	-	-
FROM GAS TO BIO-BASED PLASTIC, UNITED STATES OF AMERICA	✓	-	-	✓	-	✓	✓
PROMOTING BIOPRODUCT USE, UNITED STATES OF AMERICA	✓	-	✓	-	-	✓	✓
THE USE OF CARDOON AS BIOMASS, EUROPEAN UNION AND ITALY	✓	✓	-	✓	-	✓	✓
RUBBER FROM DANDELIONS, GERMANY	✓	✓	-	✓	-	✓	✓
BLUE BIOECONOMY DEVELOPMENT, ICELAND	✓	✓	✓	✓	✓	✓	-
URBAN CIRCULAR BIOECONOMY, UNITED STATES OF AMERICA	-	✓	-	-	-	✓	✓
FOREST BIOECONOMY CLUSTER, FINLAND	✓	✓	-	✓	✓	✓	-
TOTAL FOR 26 CASE STUDIES	**24**	**20**	**7**	**21**	**16**	**19**	**15**

Economic Pillar

PRINCIPLE 3. SUSTAINABLE BIOECONOMY SHOULD SUPPORT COMPETITIVE AND INCLUSIVE ECONOMIC GROWTH

Criterion 3.1. Economic development is fostered (24/26).

Criterion 3.3. Resilience of the rural and urban economy is enhanced (20/26).

Because the implementation of the bioeconomy is currently largely concerned with reaching economic stability, Principle 3 predominates in the case studies. Almost all cases support economic growth (personal incomes, gross domestic product, business revenues), and they strongly focus on value addition. Case studies that are private sector activities and government programmes are the main types of case studies that seek to support economic growth.

The resilience of the rural and urban economy is a prominent concern across the case studies. The selected interventions often seek to diversify incomes and improve financial stability. The links between urban and rural areas is pertinent mainly in the case studies in which the feedstock is waste that is managed in a way that benefits the whole area and rural agriculture. To strengthen rural-urban links, case studies have also improved existing infrastructure to facilitate greater circularity of biomass, and raised the awareness of urban consumers. Case studies that are private sector activities and government programmes are the main types of interventions that seek to enhance the resilience of rural and urban economies.

PRINCIPLE 6. RESPONSIBLE AND EFFECTIVE GOVERNANCE MECHANISMS SHOULD UNDERPIN SUSTAINABLE BIOECONOMY

Criterion 6.3. Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented (7/26).

The criterion on monitoring and risk assessment is addressed in those case studies that have some sort of monitoring and evaluation framework in place, or consider risk mitigation as an important aspect of bioeconomy implementation, particularly when technologies and practices are new and require financial initial investments. Fostering the implementation of monitoring and accountability systems is done in relatively few case studies, which are mostly government programmes.

PRINCIPLE 7. SUSTAINABLE BIOECONOMY SHOULD MAKE GOOD USE OF EXISTING RELEVANT KNOWLEDGE AND PROVEN SOUND TECHNOLOGIES AND GOOD PRACTICES, AND, WHERE APPROPRIATE, PROMOTE RESEARCH AND INNOVATION

Criterion 7.2. Knowledge generation and innovation are promoted (21/26).

Knowledge generation and innovation is an element in most of the case studies that deal exclusively with new technologies. The search of new innovative technologies and practices is an inherent part of many bioeconomy activities. Only when a sector of the bioeconomy has already been implemented for a long period of time (e.g. bioenergy) does the innovation component become less prominent. The case studies that promote knowledge generation at different stages of the value chain and by different stakeholders are equally led by government programmes and the private sector.

PRINCIPLE 8. SUSTAINABLE BIOECONOMY SHOULD USE AND PROMOTE SUSTAINABLE TRADE AND MARKET PRACTICES

Criterion 8.1. Local economies are not hampered but rather harnessed by the trade of raw and processed biomass, and related technologies (16/26).

The trade of raw and processed biomass and related technologies is addressed in more than half of the case studies. The interventions indicate that it is important to engage with the local economies and use locally produced biomass in the trade of bioproducts or partially processed biomass. The case studies that promote the sustainable trade of raw materials and the products obtained throughout the value chain are equally led by government programmes and the private sector.

PRINCIPLE 9. SUSTAINABLE BIOECONOMY SHOULD ADDRESS SOCIETAL NEEDS AND ENCOURAGE SUSTAINABLE CONSUMPTION

Criterion 9.1. Consumption patterns of bioeconomy goods match sustainable supply levels of biomass (19/26).

Criterion 9.2. Demand and supply- side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced (15/26).

A majority of case studies seek to balance the consumption and supply of bioproducts. Considerable attention is given to promoting markets and sustainable consumption and production practices that can ensure a sustainable match between biomass supply and demand. Issues of supply and demand are frequently dealt with in those cases in which the feedstock is a former waste product that has entered the market. These types of case studies are private sector activities.

More than half of the case studies work to achieve policy coherence in matters related to the supply and demand for food and non-food goods. Policy coherence is addressed mainly by case studies that are government programmes and are linked to supportive public mechanisms. Both the public and the private sector are equally interested in achieving an equilibrium in the market.

TABLE 4.3.

RELATION BETWEEN THE CASE STUDIES AND THE SUSTAINABLE BIOECONOMY P&Cs - ENVIRONMENTAL PILLAR

ENVIRONMENTAL CRITERIA (✓ = The criterion is covered) / CASE STUDIES	C.1.2 SUSTAINABLE INTENSIFICATION OF BIOMASS PRODUCTION IS PROMOTED	C.2.1 BIODIVERSITY CONSERVATION IS ENSURED	C.2.2 CLIMATE CHANGE MITIGATION AND ADAPTATION IS PURSUED	C.2.3 WATER QUALITY AND QUANTITY ARE MAINTAINED, AND, IN AS MUCH AS POSSIBLE ENHANCED	C.2.4 THE DEGRADATION OF LAND, SOIL, FORESTS AND MARINE ENVIRONMENTS IS PREVENTED, STOPPED OR REVERSED	C.5.1 RESOURCE EFFICIENCY, WASTE PREVENTION AND WASTE RE-USE ALONG THE WHOLE BIOECONOMY VALUE CHAIN IS IMPROVED	C.5.2 FOOD LOSS AND WASTE IS MINIMIZED AND, WHEN UNAVOIDABLE, ITS BIOMASS IS REUSED OR RECYCLED
BIOCHAR PRODUCTION AND USE, GHANA	✓	-	✓	✓	✓	✓	-
BIOMASSWEB, SUB-SAHARAN AFRICA	✓	-	-	-	-	✓	✓
INTEGRAL USE OF OIL PALM, GHANA	✓	-	✓	✓	✓	✓	-
SEAWEED VALUE ADDITION, UNITED REPUBLIC OF TANZANIA	✓	-	✓	-	✓	-	-
FROM FARMER TO PHARMA, SOUTH AFRICA	-	✓	-	-	-	-	-
BIOECONOMY COMMUNITY DEVELOPMENT PROGRAMME, MALAYSIA	✓	✓	-	-	-	✓	-
NATIONAL BIOMASS STRATEGY, MALAYSIA	-	✓	✓	✓	✓	✓	-
BIO-INDUSTRIAL CLUSTERS TO ADD VALUE, MALAYSIA	-	-	-	-	-	✓	-
TOWARDS SECOND-GENERATION BIOFUELS, INDIA	✓	-	✓	✓	✓	✓	-
FROM BIOMASS TOWNS TO INDUSTRIAL AREAS, JAPAN	-	-	✓	-	-	✓	✓
BIOFIBRE FOR CLOTHING, PHILIPPINES	-	-	✓	✓	✓	✓	-
ALTERNATIVES TO BURNING STRAW, CHINA	✓	-	✓	-	-	✓	-
AGROFORESTRY AND CONSERVATION, INDONESIA	✓	-	✓	-	-	✓	-
MESA SUCROALCOHOLERA, ARGENTINA	✓	-	✓	-	✓	✓	-
BEEKEEPING DERMOCOSMETICS, COLOMBIA	-	-	-	-	-	-	-
BIO-BASED PLASTICS FROM AGAVE RESIDUES, MEXICO	-	-	✓	-	-	✓	-
SUNFLOWER PROTEIN, BRAZIL	-	-	-	-	-	✓	-
FUNCTIONAL USE OF PASSION FRUIT, BRAZIL	-	-	-	-	-	✓	-
FAMILY CATTLE PRODUCERS AND CLIMATE CHANGE, URUGUAY	-	-	✓	-	✓	-	-
FROM GAS TO BIO-BASED PLASTIC, UNITED STATES OF AMERICA	-	-	✓	✓	-	✓	-
PROMOTING BIOPRODUCT USE, UNITED STATES OF AMERICA	-	-	-	-	-	-	-
THE USE OF CARDOON AS BIOMASS, EUROPEAN UNION AND ITALY	✓	✓	✓	✓	✓	✓	-
RUBBER FROM DANDELIONS, GERMANY	✓	✓	✓	✓	✓	-	-
BLUE BIOECONOMY DEVELOPMENT, ICELAND	-	-	✓	✓	-	✓	✓
URBAN CIRCULAR BIOECONOMY, UNITED STATES OF AMERICA	-	-	✓	✓	-	✓	✓
FOREST BIOECONOMY CLUSTER, FINLAND	-	-	✓	✓	✓	✓	-
TOTAL FOR 26 CASE STUDIES	**11**	**5**	**18**	**11**	**11**	**20**	**4**

Environmental Pillar

PRINCIPLE 1. SUSTAINABLE BIOECONOMY DEVELOPMENT SHOULD SUPPORT FOOD SECURITY AND NUTRITION AT ALL LEVELS

Criterion 1.2. Sustainable intensification of biomass production is promoted (11/26).

The sustainable intensification of biomass production is associated with the case studies in which the biomass is important to the local economy or when the biomass can be grown on marginal land. The case studies that address this criterion are mainly the led by the private sector, NGOs and R&D&I institutions. To a lesser extent, case studies that are government programmes also promote sustainable intensification when the local biomass has the potential to be harnessed in biotechnological processes.

PRINCIPLE 2. SUSTAINABLE BIOECONOMY SHOULD ENSURE THAT NATURAL RESOURCES ARE CONSERVED, PROTECTED AND ENHANCED

Criterion 2.1. Biodiversity conservation is ensured (5/26).

Criterion 2.2. Climate change mitigation and adaptation are pursued (18/26).

Criterion 2.3. Water quality and quantity are maintained, and, in as much as possible, enhanced (11/26).

Criterion 2.4. The degradation of land, soil, forests and marine environments is prevented, stopped or reversed (11/26).

Only a few case studies explicitly deal with biodiversity conservation. It is more common for government programmes to address this issue through territorial interventions, rather than the private sector, which focuses on product value chains.

Climate change mitigation and adaptation are considered in many case studies. The case studies that are private sector activities or government programmes promote bioeconomy practices that reduce GHG emissions and, in some cases, carbon sequestration. Sometimes measures to ensure proper accountability for the contribution to GHG emission reduction are overlooked. Adaptation to climate change is explicitly addressed only by a few case studies.

Safeguarding water resources is an issue that is considered in many case studies, even if indirectly in the processing stage, particularly in those case studies that involve bio-industries. Environmental actions related to the soil are more common in the case studies where the public sector is involved to some extent.

PRINCIPLE 5. SUSTAINABLE BIOECONOMY SHOULD RELY ON IMPROVED EFFICIENCY IN THE USE OF RESOURCES AND BIOMASS

Criterion 5.1. Resource efficiency, waste prevention and waste re-use along the whole bioeconomy value chain is improved (20/26).

Criterion 5.2. Food loss and waste is minimized and, when unavoidable, its biomass is reused or recycled (4/26).

Achieving greater efficiency in the use of resources is a very common concern in the case studies. Efficiency is gained either by increasing circularity (e.g. waste prevention and reuse); improving efficiency in the use of resources (e.g. energy and water) and in processing; or adopting sustainable end-of-life options (e.g. recycling). The number of case studies that promote improved efficiency are equally divided between private sector activities and government programmes. Both the public and the private sector have an interest in improving efficiency in the use of resources and increasing the rate of reutilization of biomass and bio-based materials in all stages of the value chain.

Food loss and waste is only addressed in a few case studies that are linked to the urban bioeconomy and do so by applying circularity principles. The relatively little consideration accorded to this criterion is partly due to the fact that the majority of case studies are carried out in rural areas and use residues from crop and livestock production rather than food waste. Actions that promote the use of food that is otherwise lost or wasted are generally associated with anaerobic digestion and composting. Progress is also being made in improving infrastructure and logistics for separating different types of waste and using it to make a range of bioproducts, including bio-based plastics.

3.4.2 Sustainable Development Goals

In the Foreword of the Sustainable Development Goals Report 2016 (UN, 2016), the Secretary-General of the United Nations presented the 2030 Agenda for Sustainable Development as a roadmap for people and the planet that will ensure sustainable social and economic progress worldwide. The Agenda seeks to integrate and balance the three dimensions of sustainable development — economic, social and environmental — in a unified global vision. All nations will need to incorporate the SDGs into their national policies and plans.

This subsection presents a review of the links between the SDGs and the case studies. **Table 5.1** indicates the key SDGs that are connected to the sustainable development of the bioeconomy based on the case studies. After the table, a discussion of the results, based on Gomez San Juan (forthcoming), is presented.

Table 5.1 shows that the seven most covered SDGs are SDG2, SDG7, SDG8, SDG9, SDG12, SDG13 and SDG15. Those that are most frequently supported by the case studies, SDG8, SDG9 and SDG12, are strongly linked to economic development. In this review, the link to the SDG targets that the activities carried out in the case studies can potentially support is indicated for the seven most covered SDGs, and examples are given of case studies that contribute to achieving that SDG. At the end of this subsection, in **Box 1**, these 7 key SDGs are compared to key links between SDGs and bioeconomy found by similar sources. It can be concluded that different sources point to the same SDGs.

TABLE 5.1

SUMMARY OF THE RELATION BETWEEN THE CASE STUDIES AND THE SDGs BY REGION
Highlighted are the most commonly addressed SDGs

SDGs	ALL REGIONS (TOTAL FOR 26 CASE STUDIES)	AFRICA (5 CASE STUDIES)	ASIA AND THE PACIFIC (8 CASE STUDIES)	LATIN AMERICA AND THE CARIBBEAN (6 CASE STUDIES)	EUROPE AND NORTH AMERICA (7 CASE STUDIES)
SDG1: End poverty in all its forms everywhere	8	4	2	2	-
SDG2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture	10	3	3	3	1
SDG3: Ensure healthy lives and promote well-being for all at all ages	9	3	1	3	2
SDG4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4	1	3	-	-
SDG5: Achieve gender equality and empower all women and girls	4	4	-	-	-
SDG6: Ensure availability and sustainable management of water and sanitation for all	5	-	3	-	2
SDG7: Ensure access to affordable, reliable, sustainable and modern energy for all	12	2	5	2	3
SDG8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	21	5	7	5	4
SDG9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	22	5	6	4	7
SDG10: Reduce inequality within and among countries	8	2	3	2	1
SDG11: Make cities and human settlements inclusive, safe, resilient and sustainable	5	-	2	1	2
SDG12: Ensure sustainable consumption and production patterns	20	3	5	6	6
SDG13: Take urgent action to combat climate change and its impacts	16	4	4	3	5
SDG14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development	3	1	-	-	2
SDG15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	12	3	3	3	3
SDG16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels	8	1	3	1	3
SDG17: Strengthen the means of implementation and revitalize the global partnership for sustainable development	8	2	1	2	3

TABLE 5.2

RELATION BETWEEN THE CASE STUDIES AND THE SDGs

SDGs (✓ = The goal is supported) / CASE STUDIES	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
BIOCHAR PRODUCTION AND USE, GHANA	✓	✓	✓	-	✓	-	✓	✓	✓	✓	-	✓	✓	-	✓	-	-
BIOMASSWEB, SUB-SAHARAN AFRICA	✓	✓	-	✓	-	-	-	✓	✓	✓	-	-	✓	-	-	-	✓
INTEGRAL USE OF OIL PALM, GHANA	✓	-	-	-	✓	-	✓	✓	✓	-	-	✓	✓	-	✓	-	-
SEAWEED VALUE ADDITION, UNITED REPUBLIC OF TANZANIA	✓	✓	✓	-	✓	-	-	✓	✓	-	-	-	✓	✓	-	✓	-
FROM FARMER TO PHARMA, SOUTH AFRICA	-	-	✓	-	✓	-	-	✓	✓	-	-	✓	-	-	✓	-	✓
BIOECONOMY COMMUNITY DEVELOPMENT PROGRAMME, MALAYSIA	✓	✓	-	✓	-	-	-	✓	✓	-	-	✓	-	-	-	✓	-
NATIONAL BIOMASS STRATEGY, MALAYSIA	-	-	-	✓	-	-	✓	✓	✓	✓	✓	-	-	-	✓	✓	-
BIO-INDUSTRIAL CLUSTERS TO ADD VALUE, MALAYSIA	-	-	-	-	-	✓	✓	✓	✓	-	-	-	-	-	-	-	✓
TOWARDS SECOND-GENERATION BIOFUELS, INDIA	-	-	-	-	-	✓	✓	✓	✓	✓	-	✓	✓	-	-	-	-
FROM BIOMASS TOWNS TO INDUSTRIAL AREAS, JAPAN	-	-	-	-	-	-	✓	✓	✓		✓	✓	✓	-	-	✓	-
BIOFIBRE FOR CLOTHING, PHILIPPINES	-	-	-	-	-	✓	-	✓	-	-	-	✓	-	-	✓	-	-
ALTERNATIVES TO BURNING STRAW, CHINA	-	✓	✓	-	-	-	✓	-	-	-	-	-	✓	-	-	-	-
AGROFORESTRY AND CONSERVATION, INDONESIA	✓	✓	-	✓	-	-	-	✓	✓	✓	-	✓	✓	-	✓	-	-
MESA SUCROALCOHOLERA, ARGENTINA	✓	-	-	-	-	-	✓	✓	✓	-	-	✓	✓	-	✓	✓	-
BEEKEEPING DERMOCOSMETICS, COLOMBIA	-	-	✓	-	-	-	-	✓	✓	-	-	✓	-	-	✓	-	-
BIO-BASED PLASTICS FROM AGAVE RESIDUES, MEXICO	-	-	-	-	-	-	-	✓	✓	-	-	✓	✓	-	-	-	✓
SUNFLOWER PROTEIN, BRAZIL	-	✓	✓	-	-	-	✓	✓	✓	✓	-	✓	-	-	-	-	✓
FUNCTIONAL USE OF PASSION FRUIT, BRAZIL	✓	✓	✓	-	-	-	-	✓	-	-	✓	✓	-	-	-	-	-
FAMILY CATTLE PRODUCERS AND CLIMATE CHANGE, URUGUAY	-	✓	-	-	-	-	-	-	-	✓	-	✓	✓	-	✓	-	-
FROM GAS TO BIO-BASED PLASTIC, UNITED STATES OF AMERICA	-	-	-	-	-	-	-	-	✓	-	✓	✓	✓	-	-	-	✓
PROMOTING BIOPRODUCT USE, UNITED STATES OF AMERICA	-	-	-	-	-	-	-	✓	✓	✓	-	✓	✓	-	-	✓	-
THE USE OF CARDOON AS BIOMASS, EUROPEAN UNION AND ITALY	-	-	-	-	-	✓	✓	✓	✓	-	-	✓	✓	-	✓	-	✓
RUBBER FROM DANDELIONS, GERMANY	-	-	-	-	-	-	-	-	✓	-	-	✓	✓	-	✓	✓	-
BLUE BIOECONOMY DEVELOPMENT, ICELAND	-	-	✓	-	-	-	-	✓	✓	-	-	✓	-	✓	-	-	✓
URBAN CIRCULAR BIOECONOMY, UNITED STATES OF AMERICA	-	✓	✓	-	-	✓	✓	-	✓	-	✓	✓	-	✓	-	-	-
FOREST BIOECONOMY CLUSTER, FINLAND	-	-	-	-	-	-	✓	✓	✓	-	-	-	✓	-	✓	✓	-

SDG1: END POVERTY IN ALL ITS FORMS EVERYWHERE (8/26)

Almost all African case studies contribute to SDG1, as do the cases studies from Argentina, Brazil, Indonesia and one of the case studies from Malaysia. These interventions seek to combat poverty by adding value to locally available biomass. The Malaysian case study aims at lifting biomass producers out of the bottom 40 percent income group.

SDG2: END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE (10/26)

Key SDG for the bioeconomy

Promoting sustainable agriculture is key for the development of a sustainable bioeconomy. This SDG is important for many case studies and goes hand in hand with food security. There are variations in how the case studies address food security and improve nutrition, particularly between the different types of intervention and the level at which they operate. For example, the NGO-led cluster in Zanzibar supports the adoption of technology for food processing. The regional research project 'BiomassWeb' in sub-Saharan Africa carries out studies on increased system productivity of biomass-based value webs to improve food security. Case studies in Asia (China, Indonesia and Malaysia) involve the co-production of food and non-food products. In Latin America, a case study in Brazil focuses on high-quality, nutritious food and feed products.

Examples of case studies that support specific targets set under SDG2

- In the 'Seaweed value addition' case study from the United Republic of Tanzania, the cluster that has been established helps women to cultivate and process seaweed and diversify their incomes. This activity empowers the women and enables them to pay for goods and services to meet their daily needs, improve their housing and pay for school fees for their children. It has given women greater independence and recognition within the family. This case study supports SDG target 2.3: By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment.
- The case study, 'Functional use of passion fruit' from Brazil taps into the economic potential of local wild passion fruit varieties and supports the participation of local communities in its activities. The network contributes to the development of the supply chain, supports the marketing of products and strengthens rural producer organizations. This case study supports SDG target 2.5: By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

SDG3: ENSURE HEALTHY LIVES AND PROMOTE WELL-BEING FOR ALL AT ALL AGES (W9/26)

The case studies address health issues in two ways. One way is through the reduction of hazards, pollution and other health risks, such as indoor air pollution (Biochar production and use, Ghana); improved farming conditions (Seaweed value addition, United Republic of Tanzania); and the reduction of ocean pollution with plastics (Urban circular bioeconomy, United States of America). The other way is through the production of biopharmaceuticals, nutraceuticals and other healthcare bio-based products, as in the case studies from Brazil, Iceland and South Africa.

SDG4: ENSURE INCLUSIVE AND EQUITABLE QUALITY EDUCATION AND PROMOTE LIFELONG LEARNING OPPORTUNITIES FOR ALL (4/26)

The role of adequate education, interdisciplinary knowledge and skills and vocational training for bioeconomy implementation was emphasized in several case studies. The Kutai timber company in the case study from Indonesia, for example, considers the absence of technical education and training to be a major hindrance to the development of bio-based industry. Two case studies from Malaysia and the BiomassWeb initiative in sub-Saharan Africa place particular importance on vocational training and capacity development for the implementation of the bioeconomy.

SDG5: ACHIEVE GENDER EQUALITY AND EMPOWER ALL WOMEN AND GIRLS (4/26)

Women's empowerment is explicitly described only in four out of five African case studies. These case studies highlight the importance of the post-harvest processing activities for women for increasing their income and independence. Case studies in other regions do not take into account gender issues in the implementation of bioeconomy, which poses challenges to achieving this SDG. This gap has been already identified in literature. Alvarez (2013) underlined in the summary that women are more likely to be impacted by sustainable or unsustainable bioeconomy practices "mainly because of their involvement in managing and using natural resources, their role in small-scale agriculture and the production of food, and their lack of formal land tenure and involvement in decision-making processes".

SDG6: ENSURE AVAILABILITY AND SUSTAINABLE MANAGEMENT OF WATER AND SANITATION FOR ALL (5/26)

Issues related to water figure prominently in the case studies from Asia, Europe and the United States of America. All these case studies include advanced technologies, and all of them adhere to circularity principles for water use efficiency in bio-based industries and support sustainable end-of-life options for wastewater treatment.

SDG7. ENSURE ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL (12/26)

Key SDG for the bioeconomy

SDG7 is a key SDG for the bioeconomy and is supported by many case studies in all regions. Of particular importance in the case studies is the use of modern bioenergy, which is one of the most important bioeconomy sectors. Sometimes a well-established bioenergy sector is the precursor of bioeconomy development in an area. Increasing energy efficiency and using renewable energy in biomass production and processing are often objectives in sustainable bioeconomy interventions. Energy concerns are more prevalent in the case studies from Asia, Europe and the United States of America.

Example of a case study that supports specific targets set under SDG7

- The Mesa Sucroalcoholera in Argentina contributes to fulfilling a 2016 government decree that sets a total annual share of bioethanol in fuel used for transport at 12 percent in volume. Previously, the share had been set at 10 percent. The 2 percent increase must come from companies from the North-West of the country, a poorer area with a high concentration of biorefineries that produce sugar cane ethanol. This case study supports the SDG target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix.

SDG8. PROMOTE SUSTAINED, INCLUSIVE AND SUSTAINABLE ECONOMIC GROWTH, FULL AND PRODUCTIVE EMPLOYMENT AND DECENT WORK FOR ALL (21/26)

Key SDG for the bioeconomy

SDG8 is critical for achieving sustainable bioeconomy and is one of the SDGs most covered by these 26 case studies. Current efforts to implement the bioeconomy often aim at adding value to biomass, which in many cases is labour-intensive, and upgrading technology through

innovation and entrepreneurship. The impacts of biomass use, bioproduct development, technology deployment and international trade on local communities and working conditions are seldom taken into account. Innovation is considered by many case studies in the end-of-life stage of the value chain with regard to the efficient and circular use of resources, including the reuse and recycling of bio-based materials.

Examples of case studies that support specific targets set under SDG8

- The Bioeconomy Community Development Programme (BCDP) in Malaysia promotes projects that involve the processing of added value by-products so that companies can provide greater support to rural communities in the area. These projects foster sustainable agriculture, youth training and women's employment. This approach ensures local ownership of bioeconomy activities, which is critical for sustainable development. This case study supports the SDG target 8.3: Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services. The BCDP also enhances the participation of highly competitive companies with innovative bioproducts of global importance in international markets, which supports the SDG target 8.2: Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labour-intensive sectors.
- The case study on the use of cardoon as biomass in Italy uses a crop grown in marginal land to produce bio-based polymers plasticizers, bio-based plastics, biolubricants, additives, nutraceuticals and cosmetics. The project contributes to achieving EU targets (e.g. the replacement of a minimum of 30 percent of oil-based chemicals and materials with bio-based and biodegradable ones by 2030). It also helps the EU meet climate change targets and leads to greener and more environmentally friendly economic growth. This case study supports the SDG target 8.4: Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead.

SDG9. BUILD RESILIENT INFRASTRUCTURE, PROMOTE INCLUSIVE AND SUSTAINABLE INDUSTRIALIZATION AND FOSTER INNOVATION (22/26)

Key SDG for the bioeconomy

SDG9 on sustainable industrialization and innovation is another key SDG for the bioeconomy and is the most widely supported SDG in the 26 case studies. Innovation in these cases does not only refer to innovative technologies, but also to improvements in existing practices, policies, institutional settings, means of communication, business models and logistical arrangements.

Example of a case study that supports specific targets set under SDG9

- In the 'Sunflower protein' case study in Brazil, research on new technologies is carried out by public and private institutions to demonstrate the potential and capacity of new technologies. The research projects are geared toward practical applications, and the innovative products and processes developed are intended to diversify business opportunities and support small- and medium-scale enterprises. This case study supports SDG target 9.B: Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities.
- In Malaysian the case study on bio-industrial palm oil clusters offer companies shared infrastructure and knowledge, better logistics, common waste disposal operations, licensing agreements and access to government support though different programmes and

mechanisms. Efforts are also made to mobilize biomass to bring bio-based industries and other service companies into the cluster. This case study supports SDG target 9.1: Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

SDG10: REDUCE INEQUALITY WITHIN AND AMONG COUNTRIES (8/26)

The case studies that support SDG 10 work to reduce inequalities within national borders by targeting the most vulnerable areas (e.g. those affected by climate change). Only two case studies consider the potential global benefits of their bioeconomy activities: the research project BiomassWeb in sub-Saharan Africa, which seeks to connect value chains among countries; and the intervention from Brazil, which produces protein from sunflower to meet the growing international demand for plant-based protein.

SDG11: MAKE CITIES AND HUMAN SETTLEMENTS INCLUSIVE, SAFE, RESILIENT AND SUSTAINABLE (5/26)

SDG11 is supported by many of the case studies with two of the case studies explicitly targeting cities. The case study from Japan (From biomass towns to industrial areas) seeks to convert towns and industrial areas into biomass-processing hubs to spur economic growth and better manage organic waste. In the United States of America, the case study dealing with the urban circular bioeconomy is intended to reduce waste and improve different waste management systems. Cities where the expansion of the bioeconomy is significant are often referred to as 'biocities' or 'bio-principled' cities (GBS, 2018). SDG11 is also linked to the case studies that contribute to improving rural-urban links, such as the case studies on passion fruit in Brazil and the National Biomass Strategy in Malaysia, which address the urban demand for bioproducts.

SDG12. ENSURE SUSTAINABLE CONSUMPTION AND PRODUCTION PATTERNS (20/26)

Key SDG for the bioeconomy

SDG12 is the SDG most widely supported by the 26 case studies. It is a key SDG for the sustainable bioeconomy. All the case studies from Latin America and the Caribbean and most of the case studies from Europe and the United States of America are linked to SDG12. Sustainable consumption and production is relevant for different types of interventions included in the case studies, particularly for the production of new bioproducts that can replace fossil-based products, as well as policy-level interventions. Consumer acceptance is critical to bioeconomy development. For this reason, many interventions in the case studies were supported by communication campaigns, certification schemes, or a combination of legislations that ban certain products or processes and incentives to other more sustainable approaches.

Examples of case studies that support specific targets set under SDG12

- The case study from Iceland uses an innovative business model based on an association of companies that jointly manage their waste and create high-value products. The factory is owned in large part by the fisheries in an arrangement similar to a co-op model. The model ensures processors have secure access to the raw material (cod waste) and the interests of the fisheries are better aligned with activities that support sustainable solutions for managing by-products. This case study supports SDG target 12.5: By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.
- In the case study on agroforestry and conservation in Indonesia, certification schemes have been established with wood producers to facilitate the trade of final products by ensuring the products meet both consumer expectations and national regulations in importing countries. New practices, such as combining fast-growing

tree plantations and community agroforestry, have also been put in place. This case study supports SDG target 12.2: By 2030, achieve the sustainable management and efficient use of natural resources.

SDG13. TAKE URGENT ACTION TO COMBAT CLIMATE CHANGE AND ITS IMPACTS (16/26)

Key SDG for the bioeconomy

SDG13, which is another key SDG for the bioeconomy, is supported by case studies in all regions. The actions taken in most African case studies (e.g. United Republic of Tanzania) focus on climate change adaptation. In Europe and the United States of America, as well as Latin America and the Caribbean, the focus is on climate change mitigation through the reduction of GHG emissions (e.g. Germany and Mexico), carbon sequestration (e.g. Uruguay) and the capture and use of carbon (e.g. 'From gas to bio-based plastic' in the United States of America).

Example of a case study that support specific targets set under SDG13

- In the case study on oil palm in Ghana, the B-BOVID company supports farmers in adopting climate-smart agriculture practices. Climate change is having direct impacts on rural livelihoods in Western Ghana, causing food insecurity and poverty. A local NGO that is a partner of B-BOVID provides training and helps promote climate-smart agriculture. Intercropping and agroforestry were the two practices that were the most widely implemented. The project collaborated with the Coastal Sustainable Landscape Project (CSLP) of the United States Forest Service International Programme through USAID Ghana, whose objective is to improve Ghana's forest cover and address the negative impacts of climate change. This case study supports SDG target 13.3: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.

SDG14: CONSERVE AND SUSTAINABLY USE THE OCEANS, SEAS AND MARINE RESOURCES FOR SUSTAINABLE DEVELOPMENT (3/26)

SGD14 is supported by all the case studies that are centred in or on coastal areas, as these case studies deal with the production stage of the biomass value chain. Activities in three cases cover issues related to life below water: seaweed cultivation and processing in the United Republic of Tanzania); full utilization of Icelandic cod in Iceland; and the reduction of coastal contamination in San Francisco bay in the United States of America.

SDG15. PROTECT, RESTORE AND PROMOTE SUSTAINABLE USE OF TERRESTRIAL ECOSYSTEMS, SUSTAINABLY MANAGE FORESTS, COMBAT DESERTIFICATION, AND HALT AND REVERSE LAND DEGRADATION AND HALT BIODIVERSITY LOSS (12/26)

Key SDG for the bioeconomy

SDG15, which is critically important for the sustainable development of the bioeconomy, is pertinent for many case studies as they deal with biomass production from the land. It is particularly important for the African case studies and for the case studies that deal with specific biodiversity issues, including: bioprospecting (e.g. South Africa); the restoration of degraded lands (e.g. Uruguay); the sound management of hazardous waste from agricultural activities (e.g. the Philippines), biorefineries (e.g. Argentina and Italy) and the conservation of ecosystem services, such as pollination (e.g. Colombia). There are two case studies on multi-purpose forestry systems (Finland and Indonesia).

Examples of case studies that support specific targets set under SDG15

- 'Family Cattle Producers and Climate Change' in Uruguay is a government programme that focuses on two regions that are particularly affected by droughts. The main actions that have undertaken to stop and reverse soil

degradation are the provision of support for the implementation of good practices to improve grassland and livestock management, and activities to increase capacities related to agroclimatic information. This case study supports SDG target 15.3: By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world.

- 'From Farmer to Pharma' in South Africa is a government programme that considers the range of mechanisms and regulations for bioprospecting and intellectual property rights (e.g. the National Environment Management Biodiversity Act and Access and Benefit-Sharing Regulations) that have been put in place to protect community rights and interests regarding indigenous biological resources and traditional knowledge. This case study supports SDG target 15.6: Promote fair and equitable sharing of the benefits arising from the utilization of genetic resources and promote appropriate access to such resources, as internationally agreed.

SDG16: PROMOTE PEACEFUL AND INCLUSIVE SOCIETIES FOR SUSTAINABLE DEVELOPMENT, PROVIDE ACCESS TO JUSTICE FOR ALL AND BUILD EFFECTIVE, ACCOUNTABLE AND INCLUSIVE INSTITUTIONS AT ALL LEVELS (8/26)

Eight case studies are connected to SDG 16. In Africa and Asia, some case studies focus on inclusive and equitable societies and give support to small rural communities. Case studies from Latin America and the Caribbean and Europe and the United States of America have a stronger link to SDG 16 in terms of building sustainable institutions. This is particularly true for those case studies that have the success factor E.2: Policy interventions that provide incentives and establish supportive public mechanisms (see **Table 3**).

SDG17: STRENGTHEN THE MEANS OF IMPLEMENTATION AND REVITALIZE THE GLOBAL PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT (8/26)

Across different regions, SDG 17 is addressed by several case studies that include a strong component on collaboration to strengthen co-development efforts. These case studies indicate that building strong partnerships is important for the effective and rapid implementation of the bioeconomy, and involves aspects of sustainability that are of concern to other countries.

BOX 1. PRIORITIZATION OF SDGs ACCORDING TO DIFFERENT GLOBAL INITIATIVES

All SDGs are relevant to the development of a sustainable bioeconomy, and every SDG is covered to a certain extent by the 26 case studies. This review can serve partly as an indication of the goals that may be considered as the most pertinent for bioeconomy, if they need to be prioritized. Seven SDGs (SDG2, SDG7, SDGs 8, SDG9, SDG12, SDG13, and SDG15) in particular were extensively covered by most case studies. Because the sustainable production and use of biomass is essential for making progress toward SDG2, SDG7, SDG8 and SDG15, these SDGs are especially linked to the sustainable development of the bioeconomy.

Making progress toward achieving SDGs 9 and SDG12 also partly linked to the sustainable production and use of biomass. This is particularly the case when bioeconomy development is focused on the sustainable industrialization of the second and third stages of the biomass value chain in rural agricultural areas. When a national bioeconomy strategy aligns with the country's Nationally Determined Contribution to the United Nations Framework Convention on Climate Change (UNFCCC) it can support SDG13. Table 6 presents a list of international sources of information on the links between SDGs and bioeconomy. They all prioritize similar SDGs, particularly SDG2, SDG7, SDG8, SDG12, SDG13 and SDG15. Next in priority are SDG3, SDG9, SDG11 and SDG14. Activities to achieve the majority of these ten SDGs directly rely on biomass production in rural areas, which underlines the importance of sustainably produced biomass for achieving a sustainable bioeconomy.

TABLE 6.

INTERNATIONAL SOURCES OF INFORMATION ON THE KEY SDGs LINKED TO BIOECONOMY

	SDG1	SDG2	SDG3	SDG4	SDG5	SDG6	SDG7	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG14	SDG15	SDG16	SDG17
Findings from this report (Table 5.1)		✓					✓	✓	✓			✓	✓		✓		
FAO Sustainable Bioeconomy Guidelines Project (FAO, 2017e)		✓					✓	✓	✓			✓	✓	✓	✓		
Communiqué of the Global Bioeconomy Summit (GBS, 2015)		✓	✓			✓	✓					✓	✓	✓	✓		
Global Expert Survey (German Bioeconomy Council, 2018b)			✓				✓	✓	✓		✓	✓	✓				
Five cornerstones of a global bioeconomy (El-Chichakli *et al.*, 2016)		✓	✓			✓	✓	✓		✓	✓	✓	✓	✓			
Bioeconomy and SDGs (BIC, 2018)		✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓		
The crucial role of the bioeconomy in achieving the SDGs (EUBA, 2018)		✓					✓	✓	✓			✓	✓		✓		✓
SDG impact on biomass, regarding drivers (Fritsche *et al.*, 2018)		✓					✓	✓			✓	✓	✓		✓		
TOTAL TIMES LINKS ARE MENTIONED		**7**	**4**			**3**	**8**	**7**	**6**		**4**	**8**	**8**	**4**	**7**		**1**

However, it should be kept in mind that some SDGs relate specifically to certain types of bioeconomy development. The number of times an SDG is mentioned in table 5.1 is therefore not an indication of its importance. For example, SDG 14 would be crucial for development of a sustainable a blue bioeconomy. While the development of the bioeconomy can support the fulfilment of SDGs or pose challenges to their achievement, several SDGs can drive and/or safeguard sustainable increases in biomass production and use.

CHAPTER

4

LESSONS LEARNED

This chapter presents the lessons that have been drawn after completing a review of the case studies (Gomez San Juan, forthcoming). These lessons are based on a review of the core case study objectives, their relationship with broader sustainability goals and the common success factors presented in **Table 3**. Matching the objectives of the case studies with wider sustainability frameworks (P&Cs and SDGs) serves to identify the aspects of sustainability that are well covered by the bioeconomy interventions and those aspects of sustainability that receive relatively little attention.

Understanding these match-ups is important, as trade-offs between the actual objectives of bioeconomy initiatives and the different sustainability goals are unavoidable. Trade-offs may need to be made even among different sustainability goals. The sustainability goals would ideally represent a selection of P&Cs (see **Annex 1**) that are balanced in a way that addresses the three pillars of sustainability (social, economic and environmental) equally. The lessons are listed under headings that correspond to the case study objectives presented in Subsection 3.2.

As explained in the methodology chapter, this review is based on successful bioeconomy cases. As a result, the lessons from the case studies are somewhat biased in that they are based not on the reasons for failure but rather on success factors. However, there is no doubt that bioeconomy development entails risks. The debates and experience related to bioenergy attest to this. These risks must be taken into account, and they have been briefly addressed earlier in this report (Subsection 3.2.). When necessary, the major risks will also be highlighted in this chapter.

1. To safeguard food security

Safeguarding food security relates to SDG2 (Zero Hunger), and is closely linked to the first ISBWG-agreed sustainability principle on food security, particularly Criterion 1.1 (Sustainable bioeconomy development should support food security and nutrition at all levels).

A number of important lessons have been learned from the extensive work FAO has done on bioenergy and food security that can be apply to other bio-products and to bioeconomy development as a whole. First, the production of bioproducts can entail both risks and opportunities. Second, there is no good or bad feedstock *per se*; its impact depends on how it is produced. Third, the production of bioproducts should contribute to food production, not hinder it. These lessons can are also reflected in the case studies, as they show that bioeconomy interventions can safeguard and enhance food security in different ways.

A The production of bioproducts that contribute to food production rather than replace it has been achieved through a number of pathways:

- the production of non-food goods from the processing of food by-products (e.g. 'Integral use of oil palm' case study in Ghana, which uses oil palm kernel cake, oil and shells for feed, biochemicals and briquettes respectively; the 'Sunflower protein' case study in Brazil, which uses husks and molasses for biofuels and polyphenols for healthcare products; and the 'Blue bioeconomy development' case study in Iceland, which uses fish bones, skins, liver and viscera for collagens);
- the production of non-food goods out of agricultural residues (e.g. 'Biochar production and use' in Ghana, which uses corn cob pellets; 'Biofibre for clothing' case study in the Philippines, which uses pineapple leaves; and the 'Alternatives to burning straw' case study in China, which uses corn, rice and wheat straw).

The use of food by-products or agricultural residues for bioproducts is generally considered a no-regret alternative to the use of food crops. Nevertheless, an important lesson here is that great care should be given to the issue of possible competition between different uses of these residues, including soil management, animal feed, bioenergy and bioproducts. The increasing demand for diverse bioproducts can increase competition for biomass and natural resources among different bioeconomy sectors, including the food sector. Biomass that was not previously used, such as food by-products and agricultural residues, can suddenly be mobilized and acquire a new market value. The existing and potential uses of residues should always be included in the feasibility analysis of residue-based bioeconomy initiatives, as these residues may already provide important goods and services to local communities.

The production and use of multi-purpose crops allows producers to react in a flexible manner to changing demands, as they can use the same biomass resource for food and non-food bio-products. This has been exemplified in the case studies from Ghana, 'Integral use of oil palm' where oil is produced for food or biofuel; the United Republic of Tanzania, 'Seaweed value addition', where the seaweed is used to produce food as well as a number of other products, such as soap, cream and gel; and Argentina, 'Mesa Sucroalcoholera', where sugar is used for food or bioethanol.

The production of different types of feedstock for food and non-food goods can be done on the same farm. This can be carried out in two different ways. In one approach, the production of food and non-food crops is carried out on the same piece of land. This is done in the 'Agroforestry and conservation' case study in Indonesia where both wood and agricultural products are produced. The other approach is to produce food and non-food crops on different plots of land. In this approach, the production of non-food goods often occurs on land deemed not suitable for food. 'The use of cardoon as biomass' case study in the EU and Italy, and 'Rubber from dandelions' in Germany are examples of this approach. The land used for non-food crops is often defined as marginal. However, a very important lesson here is that the notion of what constitutes marginal land is both complex (e.g. can land that is used occasionally

be called marginal?) and dynamic, in that it can change over time. Land can become non-marginal after it has been restored or after it is has become more accessible, for example, through the construction of a nearby road. Two key lessons concerning the use of so-called marginal land are: (i) the decision to qualify land as marginal and define its use should be undertaken through an inclusive process that involves all relevant primary stakeholders; and (ii) when planning for its use, consideration should be given to the time when the land would no longer be marginal and the possibility that more options for its use (e.g. food production) might become available.

Another lesson with regards to food production is that traditional and innovative processes and technologies used in a bioeconomy can help to make most out of one feedstock by using every part of the given feedstock, often starting with a food product. Some case studies clearly illustrate that more than one type of food and non-food product can be simultaneously processed from the same resource. Examples include the 'Sunflower protein' case study in Brazil, where both protein-rich food ingredients and cooking oil and fats are produced; the other Brazilian case study of 'Functional use of passion fruit' where juice, a range of foods, enriched fibers, natural antioxidants and cosmetics are produced; the 'Family Cattle Producers and Climate Change' case study in Uruguay where meat, milk, wool and leather is produced; and the 'Blue bioeconomy development' case study in Iceland, where fish as well as mineral supplements from fish bones are produced.

B Another key lesson is that in bioeconomy strategies and indicators access to food is an often overlooked aspect of food security compared to food production, even though greater access to food is often more important to food security than increased food production. Improved food access is usually related to additional income to buy food. Increased income can be generated either from food feedstock as in the above-mentioned examples, or non-food feedstock. A noteworthy point here is that using crop residues to produce bioproducts can give farmers the opportunity to earn extra income without changing their farming practices, which can make it easier for them to adopt new approaches. The risk is that farmers may prioritize income over other beneficial uses of crop residues, such as soil improvement and source of animal feed.

C The utilization of food is a dimension of food security is addressed in different ways is some of the case studies. Adequate utilization refers to the ability of the human body to ingest and metabolize food. Nutritious and safe diets, an adequate biological and social environment, a proper health care to avoid diseases ensure adequate utilization of food. Some example are:

- Having enough sustainable energy to ensure adequate cooking is mentioned in the 'Biochar production and use' case study in Ghana.
- Safeguarding a healthy microbiome that can moderate in the interactions between food, our body and the environment. Science is just starting to understand the crucial role of micro-organisms for human well-being and our food system, especially their essential role in controlling malnutrition and non-communicable diseases, as well as maintaining a healthy natural environment (Dubilier, Mc Fall-Ngai and Zhao, 2015; Flandroy *et al.*, 2018), for instance in soil ecosystems as shown in the 'Family Cattle Producers and Climate Change' case study in Uruguay and in the 'Blue bioeconomy development' case study in Iceland.
- The production of food supplements is a component of some case studies (e.g. the 'Blue bioeconomy development' case study in Iceland, and 'Functional use of passion fruit' case study in Brazil). Medical or physiological benefits, other than purely nutritional benefits, are often used in the characterization of nutraceuticals. The production of nutraceuticals is included in two case studies: 'From Farmer to Pharma' in South Africa and 'Bio-industrial clusters to add value' in Malaysia. Research and development on nutraceuticals has been gaining momentum, and is mentioned in two case studies: 'The use of cardoon as biomass' in the EU and Italy, and 'Rubber from dandelions' in Germany.

D Some additional key lessons related to food security that have been drawn from the case studies are listed below.

- The review of the case studies shows that the influence of bioeconomy initiatives on food security is not automatically defined by the distinction between food based and non-food based feedstock. In some cases, the feedstock is primarily used for food (e.g. sunflower, palm oil or sugarcane) while, in others, for non-food goods (e.g. products made from cardoon or dandelion). This is important to bear in mind when addressing potential concerns that are similar to the food versus fuel debate that has arisen around biofuels.
- It is also important to appreciate the value of local knowledge, including the knowledge from indigenous people, and apply it effectively, particularly at the biomass production and processing and use stages. This was demonstrated in the case studies 'From Farmer to Pharma' in South Africa and the 'Bioeconomy Community Development Programme' in Malaysia. It is important to preserve and use local and traditional knowledge as a component of the overall knowledge that is needed to develop bioeconomy projects. This requires that indigenous and local people become actively involved in bioeconomy interventions in their communities. This is all the more important given that consumer knowledge and habits increasingly influence the bioeconomy debate. The promotion of sustainably produced food and the importance of healthy diets are key to sustainable bioeconomy.
- Another issue of importance is the key role of integration in the production and multiple use of biomass. Food and nutrition security can be reinforced by using the same feedstock to produce food, energy and other bioproducts in integrated production systems. When small-scale diversified farming systems are integrated into a larger value chain or web, producers have greater flexibility to react to shifting demands, and their resilience increases, particularly with regard to food security. Multi-use systems for biomass have been developed in several case studies, including 'Integral use of oil palm' in Ghana, 'Biofibre for clothing' in the Philippines, and 'Alternatives to burning straw' in China.
- Research activities can help identify ways to meet the future demand for food and non-food biomass in different regions. Research can also be applied in the investigation of different bioeconomy development pathways. This would include assessments of potential approaches to producing several bio-based goods from one feedstock and assessments of potential multifunctional landscapes under different land-use scenarios. Such assessments have been carried out in the case studies: 'Biochar production and use' in Ghana, 'BiomassWeb' in sub-Saharan Africa, 'National Biomass Strategy' in Malaysia, and 'The use of cardoon as biomass' in the EU and Italy.

2. To substitute fossil-based or unsustainably sourced products with sustainable bioproducts

This case study objective relates to the sustainable supply of and demand for bioproducts, and is consequently closely linked to SDG12 (consumption and production), and to some extent, the SDGs related to inputs used in biomass production: SDG6 (water), SDG7 (energy), SDG14 (oceans), and SDG 15 (land resources). It also relates to several ISBWG-agreed sustainability principles:

- Principle 1 (Sustainable bioeconomy development should support food security and nutrition at all levels), particularly Criterion 1.2 (Sustainable intensification of biomass production is promoted).
- All criteria of Principle 2 (Sustainable bioeconomy should ensure that natural resources are conserved, protected and enhanced);
- Principle 8 (Sustainable bioeconomy should use and promote sustainable trade and market practices); and
- Both criteria related to Principle 9 (Sustainable bioeconomy should address societal needs and encourage sustainable consumption).

The following lessons emerge from the case studies regarding this objective.

A From the supply and production side

There is growing recognition of the importance of sustainably sourced biomass. Ensuring the sustainable management of land and other natural resources needed to produce biomass is critical in this regard. Other important aspects concern the use of 'underutilized and marginalized land' to produce bioproducts feedstocks, and the efficient use of residues, particularly to address competition for biomass. The lessons described in the food security objective are also pertinent for the supply side of bioeconomy value chains.

B From the demand and consumption side

An important lesson in this respect is the importance of creating an adequate market for sustainable bioproducts. Successful bioeconomy development depends on marketing bioproducts in a way that highlights the advantages sustainability brings to these products compared to conventional products, without compromising their business case. For instance, in the 'Bio-based plastics from agave residues' case study in Mexico, only some of the final car parts are replaced with bio-based plastic, which means there is no increase in the price consumers pay for the cars. Another aspect that is shaping the demand and consumption of bioproducts is the fact that consumers are becoming increasingly interested in who is producing the goods they are using, and when, where and how these goods are manufactured.

Purchasing agreements are an important mechanism to promote and connect responsible consumption and production. Different types of purchasing agreement can be found in the case studies:

- between biomass producers and bioeconomy processing and retailing companies (e.g. the 'Bioeconomy Community Development Programme' in Malaysia; 'Integral use of oil palm' case study in Ghana; and the 'Beekeeping dermocosmetics' case study in Colombia);
- between public entities and bioproduct manufacturers through public procurement (e.g. the 'Promoting bioproduct use' case study in the United States of America); and
- between technological intellectual property providers and investors (e.g. 'From gas to bio-based plastic' in the United States of America).

Voluntary or mandatory certification schemes and standards are becoming more and more common. This is because certification of bioproducts can help ensure sustainability (e.g. 'From gas to bio-based plastic' in the United States of America; 'Biofibre for clothing' in Philippines; and 'Agroforestry and conservation' in Indonesia). However, certification has some limitations regarding:

- its scope, which usually concerns a single operation and consequently does not have meaningful impact at national or even subnational levels;
- its costs, which can be high for small-scale biomass producers;
- the differences in the reliability of various schemes; and
- the affordability of certified products compared to conventional ones.

The lesson here is that certification alone cannot guarantee sustainability of bioeconomy value chains on a meaningful scale. Certification schemes should be combined with support to create an enabling environment (i.e. policies, regulations, institutions and communication) to achieve a sustainable bioeconomy at a large scale. An example of this is the 'Agroforestry and conservation' case study in Indonesia, which includes a requirement for compliance with national laws (i.e. the verification of legal provenance for the export of timber products).

C From both production and consumption sides

- The concept of a 'value web', which is central to the 'BiomassWeb' case in sub-Saharan Africa, appears to be better suited to the bioeconomy than the concept of value chains. Value webs capture the potential to use the same feedstock to produce different bioproducts, as well as to produce the same type of bioproduct from different types of feedstocks (e.g. cosmetics

from seaweed in the 'Seaweed value addition' case study in the United Republic of Tanzania; or honey in the 'Beekeeping dermocosmetics' case study in Colombia).

- Feasibility studies need to take into account not only the existing situation in terms of supply and demand of biomass, but also the future demand for bio-products and associated biomass. Tools for carrying out these types of analyses already exist, and they can be used to gain a realistic outlook on biomass potential. The 'BiomassWeb' in sub-Saharan Africa case illustrates this point.

3. To incentivize the sustainable and efficient use of biological resources while protecting biodiversity, water and the soil

This case study objective concerns primarily the SDGs related to natural resources: SDG6 (water), SDG14 (oceans), and SDG 15 (land resources). Regarding the ISBWG-agreed P&Cs, it is closely linked to the sustainability Criterion 1.2. on sustainable intensification under Principle 1 (Sustainable bioeconomy development should support food security and nutrition at all levels). It is also connected to Principle 2 (Ensuring that natural resources are conserved, protected and enhanced), particularly Criterion 2.1. on biodiversity, Criterion 2.3. on water, and Criterion 2.4. on the degradation of land, soil, forests and marine environments. This objective is also indirectly linked to Criterion 5.1 on resource use efficiency.

A The first lesson related to this objective is that natural resource management is often not explicitly stated as a case study objective, but rather as an issue that needs to be addressed to guarantee the sustainability of biomass production and processing. Only a few bioeconomy cases studies mention as their primary objective preventing, stopping or reversing the degradation of land, soil, forests and marine environments. However, several case studies indirectly address these goals through a number of activities, for example:

- the promotion of sustainable land practices through improved pasture management ('Family Cattle Producers and Climate Change', Uruguay);
- the use of residues to improve soil quality ('Mesa Sucroalcoholera' in Argentina); and
- the cultivation of land not suitable for growing food crops ('Rubber from dandelions' in Germany).

However, direct and indirect land-use change is usually not taken into account when local bioeconomy development involves a shift in biomass production.

- Water conservation and water-saving measures are often not a primary objective of bioeconomy interventions. However, stakeholders in the case studies where water is a significant issue are aware of the importance of these activities. This can be noted for instance in actions related to soil water conservation in the 'Family Cattle Producers and Climate Change' case study in Uruguay, and water-saving manufacturing processes in the 'Towards second-generation biofuels' case study in India. In addition, the risk of water pollution is often mentioned in the context of circular bioeconomy business models, especially in situations where water runoff during the manufacturing process can have negative environmental impacts (e.g. 'Mesa Sucroalcoholera' in Argentina).
- It is noteworthy that the conservation of biodiversity does not feature as a direct objective in any of the case studies. However, in some case studies, the sustainable use of biodiversity (e.g. integrating natural biodiversity into applied biotechnologies) contributes to local and/or national economic growth, particularly in projects and programmes related to bio-pharmaceuticals (e.g. 'Functional use of passion fruit' in Brazil) and food supplements (e.g. 'Blue bioeconomy development' in Iceland). Several national agencies and private companies have capitalized on the country's abundant natural biodiversity, for example through bioprospecting (e.g. 'From Farmer to Pharma' in South Africa). These examples indicate that, in the healthcare sector,

treatments are being developed using natural remedies that indigenous people have known about for centuries. However, overharvesting of biomass has been noted as a frequent risk.

B Another important lesson in this area is that the sustainable management of natural resources and the inputs related to bioproducts is beneficial not only for the environment, but can also support the business case of bioeconomy initiatives. The crucial need to produce more biomass in a sustainable way to meet the growing demand for food, feed, fuels and fibres is particularly relevant in the case studies where biomass is extremely important to the local economy. In this situation, private and public efforts are being made to harness biomass. Several case studies illustrate how this is being done in relation to different environments and types of biomass:

- forests and woody biomass ('Agroforestry and conservation' in Indonesia and the 'Forest bioeconomy cluster' in Finland);
- oceans and related biomass ('Seaweed value addition' in United Republic of Tanzania, 'Blue bioeconomy development' in Iceland, and 'Urban circular bioeconomy in the United States of America);
- land and crops ('Biochar production and use' in Ghana, 'Towards second-generation biofuels' in India, 'Family Cattle Producers and Climate Change' in Uruguay, and 'Rubber from dandelions' in Germany.

4. To mitigate and adapt to the effects of climate change and reduce environmental pollution

This case study objective relates primarily to SDG13 (climate change). However, it is worth pointing out that support to this SDG is often achieved through bioeconomy activities that directly contribute to other areas of sustainable development that are supported by the SDGs, particularly bioenergy (SDG7) and the sustainable land and forest management (SDG15). It is also closely linked to the ISBWG-agreed Principle 2 on ensuring that natural resources are conserved, protected and enhanced, particularly Criterion 2.2 (Climate change mitigation and adaptation is pursued).

A GHG emission reductions are often considered one of the main drivers of bioeconomy programmes, and this has been confirmed by the review of the case studies. However, bioproducts are not climate-smart per se. **Table 7** summarizes the main climate change trade-offs and synergies of bioproducts.

Table 7 shows that the final GHG balance of bioproducts depends on the different processes involved in their production. This takes into account emissions from the biomass production stage and from the amount energy used and the type of energy (fossil versus renewable). As regards biomass production, in the case study 'Alternatives to burning straw' in China emission reductions are sought from the shift from burning crop residues. In some case studies, measures were adopted to sequester carbon by improving soil management ('Family Cattle Producers and Climate Change' in Uruguay), rehabilitating the land ('Rubber from dandelions' in Germany, and 'The use of cardoon as biomass' in the EU and Italy), planting fast-growing tree species ('Agroforestry and conservation' in Indonesia), or storing carbon in bioproducts, typically wood buildings ('Forest bioeconomy cluster' in Finland). Other case studies have achieved GHG emission reductions through biogas production from agricultural by-products (e.g. palm oil effluents in Ghana and Malaysia), or municipal waste (Japan Biomass Towns). However, significant reductions in atmospheric carbon dioxide will also require removing carbon from the atmosphere. This can be done partly through the capture and use of GHGs to produce bioplastics. 'From gas to bio-based plastic' in the United States of America is the only reviewed case study that uses a highly sophisticated and often expensive way to produce negative emissions through CCU and Carbon Capture and Storage (CCS) technologies in industrial processes. It is worth noting that none of the selected case studies deals with the production of bioenergy along with carbon capture and storage (BECCS).

B It is important to ensure that climate change is not addressed at the expense of other

TABLE 7.

MAIN CLIMATE CHANGE TRADE-OFFS (-) AND SYNERGIES (+) BETWEEN BIOPRODUCTS AND CLIMATE CHANGE

STAGES OF THE BIO-BASED ECONOMY VALUE CHAIN	GHG EMISSION REDUCTION	SEQUESTRATION	CLIMATE CHANGE ADAPTATION
Overall	+ Most bio-based products have a lower GHG footprint compared to fossil products	+ Bioproducts sequester CO_2 during their lifetime	+ Higher environmental and livelihood resilience
Biomass production	– Production of biomass can increase GHG emissions + Biomass production can be optimized by climate-smart practices	+ Carbon sequestration in agricultural soils (if good soil and water management practices), forests and oceans	+ Higher environmental resilience if natural resources are sustainably managed – Climate change impacts can reduce the possibility for producing local bioproducts and force production to shift to new locations
Bioproduct processing	+ Most bio-based fuels, chemicals and polymers show lower GHG emissions in comparison to their petrochemical counterparts – The manufacturing of bioproducts uses significant amounts of fossil energy in an inefficient manner + There are important potential options for improvements in this with new biotech pathways + Localized production reduces GHG emissions reduction from transport	+ Future carbon capture and use technologies will use renewable CO_2 sources	+ Localized production increases employment opportunities and improves rural economies
Use phase (cascading)	+ Long-lasting bioproducts that follow circularity principles show lower GHG emissions – Recycling can lead to additional energy consumption and additional GHG emissions	+ Long-lasting products can sequester carbon over the long-term + Cascading use of biomass can increase CO_2 sequestration	+ Specific benefits of locally used (traditional) bioproducts (e.g. construction materials, medicine, energy)
End of Life	+ Incineration substitutes fossil energy + / – Biodegradation is only a good option in certain applications		

Source: (adapted from Carus, 2017)

environmental objectives, such as those related to water, biodiversity and soil fertility. Experience from the bioenergy sector and related debates on indirect land-use change have shown that LCAs are needed to determine GHG emission balances. At the same time, an excessive reliance on LCAs and related model-based analysis should be avoided, as these oversimplify realities that are inherently complex. It is important to complement model-based conclusions with ground truthing, and use existing knowledge and tools to embrace rather than oversimplify realities.

C A final lesson regarding this objective is that, although climate change adaptation is not usually explicitly addressed by bioeconomy activities, adaptation is often improved through other stated objectives. These objectives are associated with either the sustainable management of natural resources (e.g. 'Family Cattle Producers and Climate Change' in Uruguay) or income generation from bioeconomy activities where non-food bioproducts are marketed at the community level (e.g. 'Seaweed value addition' in the United Republic of Tanzania).

D Ocean 'pollution' is addressed in the 'Urban circular bioeconomy' case study in the United States of America, where the San Francisco Department of the Environment has established a zero waste target for 2020 and a package of policies to reduce marine pollution of toxic material in the bay.

5. To increase profitability by adding value to biomass

Not surprisingly, increasing profitability is at the heart of the bioeconomy. A particular feature of many interventions is obtaining added value from biomass. This objective, which relates primarily to SDG8 (economic growth and job creation), also clearly reflects the ISBWG-agreed sustainability Principle 3 (Sustainable bioeconomy should support competitive and inclusive economic growth), particularly Criterion 3.1 (Economic development is fostered).

A The use of multi-purpose feedstock is advantageous in adding value to biomass, as it allows for the manufacturing of several bioproducts.

- This can be done in a cascading manner that adheres to circular economy principles. This is illustrated in several case studies: 'Blue bioeconomy development' in Iceland where mineral supplements are produced from fishbone; 'Alternatives to burning straw' in China where wheat straw is used for a variety of purposes; 'Biofibre for clothing' in the Philippines where biofibers are produced from pineapple leaves; and 'Biochar production and use' in Ghana where biochar is generated from crop residues. However, a key lesson regarding cascading use of biomass is that the sequence of uses should not be decided only on the basis of the amount of economic value added to the biomass. Other criteria can be equally or more important (e.g. carbon storage, local needs, such as wood energy for cooking, and processing costs). For this reason, the sequencing in biomass processing should not be pre-defined before the intervention but rather decided by local stakeholders.
- Producing different products can be relatively simple (e.g. biochar). However, in many cases, innovations in processing technologies that can separate biomass into different fractions play an important role. Introducing a relatively simple step at the biomass processing stage to separate the different biomass fractions is also important (e.g. 'Sunflower protein' in Brazil).
- Producing several bioproducts can be done in the same place to reduce operational costs (the biorefinery concept). In some cases, biorefinery operations are familiar and relatively simple (e.g. palm oil bio-industrial clusters in the 'Bio-industrial clusters to add value' case study in Malaysia). In other case studies, the biorefineries are much more sophisticated (e.g. ethanol and other bioproducts from crop residues in the Indian case study, 'Towards second-generation biofuels' and the 'Forest bioeconomy cluster' case study in Finland).

B If residues are not located near biomass processing facilities, there are usually high costs and logistical challenges associated with the collection of these residues when they are produced over a wide area (e.g. from different small farms). In the case study on bioproducts from crop residues in India ('Towards second-generation biofuels'), the challenge has been addressed through partnerships with companies that have traditionally collected the biomass residues (e.g. pulp and paper). Another challenge concerns the quality of the residues (e.g. the 'Urban circular bioeconomy' initiative in the United States of America).

C As discussed in the subsection on food security, great caution should be exerted regarding the possible competing uses of agricultural residues. The increased demand for bioproducts is likely to result in new market value being created for residues or by-products. This requires a comprehensive and inclusive analysis of current and possible future uses of this biomass.

Three broad approaches that have been followed in a number of case studies to address the challenges associated with value addition.

- Contract farming agreements between biomass producers and bioproduct manufacturers and traders aim to establish fair prices and stable biomass market conditions for biomass producers, and guaranteed quality biomass supply for bioproduct manufacturers and traders.

Contract farming is seen as an important governance mechanism in situations where there is a high level of uncertainty owing to the low number of buyers and unstable number of biomass producers. Contract farming is important for the development of the bioeconomy in that it can facilitate the production of biomass for which farmers usually have no expertise or market access and accelerate the commercialization of bioproducts to meet the growing demand. It is a component in several case studies. The Malaysian 'Bioeconomy Community Programme' is a noteworthy example, as it includes a buyback guarantee agreement that provides a distinct advantage over other conventional contract farming. When a company shares the net profit of the entire operation with biomass out-growers in amounts that are proportional to the amount of raw material supplied, it motivates producers to supply adequate good quality bioproducts and gives them a secure income from guaranteed markets.

In countries with well-developed primary production sectors, there is a tendency to strengthen links between farmers and agro- and bio- industries through licensing agreements. These types of agreements can also be developed with local communities in cases where private companies make use of indigenous knowledge and biological resources. However, contract farming also bears risks for both parties:

- free riding from the producers (i.e. they break the contract by selling to other parties than the contractual buyer(s); and
- the imposition of unfair conditions (particularly the buying price) on producers who are often closely tied to the buyer as their sole guaranteed market outlet .

Ensuring fairness in contracts and their implementation often requires that governments play a mediating and regulatory role.

- Using a value web approach that takes into account the interlinked value chains of a particular biomass may be better than a value chain approach in bioeconomy development. A conventional value chain approach to sustainable bioeconomy development may not completely capture the rapidly growing demand and competition for biomass. Local biomass value chains, and the stakeholders involved with biomass production, processing and use, should be interlinked in ways that ensure that the development of the bioeconomy increases the availability of biomass and does not have a negative impact on food security. The value web approach considers two ways of addressing the growing demand for biomass: seeking a higher level of integration of all value web components; and promoting the cascading use of biomass. The biomass value web approach promoted by the 'BiomassWeb' case study in sub-Saharan Africa is an applied research programme that is doing this, for instance, in Nigeria for food, feed and bio-ethanol.
- Developing the bioeconomy through regional clusters involves collaboration between bioeconomy stakeholders (biomass producers, bioproduct manufacturers, governments and research bodies) at different stages of the biomass value chain. Clusters help address the challenges of biomass value addition, such as competition for biomass use and residue handling, through different types of partnerships, including:
  - between biomass producers and manufacturing companies, for instance in matters related to providing information on market conditions, securing market opportunities through contract farming (e.g. the Malaysian 'Bioeconomy Community Development Programme'), and supporting farmers in investing in machinery for residue collection (e.g. 'Towards second-generation biofuels' in India, and 'Alternatives to burning straw', China);
  - between companies that produce biomass, those that trade it, and researchers (e.g. the 'Forest bioeconomy cluster' case study in Finland); and
  - between farmers and researchers to help address challenges in biomass production (e.g. 'Seaweed value addition' in the United Republic of Tanzania).

Local governments are often part of bioeconomy clusters (e.g. 'Forest bioeconomy

cluster' in Finland and 'Bio-industrial clusters to add value' in Malaysia). They can play an important role in supporting the outreach and visibility of bioeconomy initiatives and creating local platforms for sharing knowledge.

Clusters offer a range of supportive measures including: bioeconomy and bio-industry development action plans or land-use strategies; financial support to start-ups; and public investment for new businesses through public-private ownership. Bioeconomy clusters are more common in heavily industrialized areas, but are becoming increasingly used in rural settings.

6. To create and secure employment through *in situ* value addition and enhance rural and urban economic resilience

As with the previous objective, this objective relates primarily to SDG8 (economic growth and job creation) and SDG5 (gender equality), as well as the ISBWG-agreed sustainability Principle 3 (Sustainable bioeconomy should support competitive and inclusive economic growth), particularly Criterion 3.2 (Inclusive economic growth is strengthened) and Criterion 3.3 (Resilience of the rural and urban economy is enhanced). In several case studies, the social focus of Criterion 3.2 (and to some extent 3.3) complements the purely economic Criterion 3.1. Across the selected case studies, building economic resilience is a predominant objective.

The review of the case studies confirms that the bioeconomy offers many opportunities for rural employment. These jobs can be of different level of qualification, and usually include both direct and indirect employment. The lessons that have been drawn regarding this objective respect are listed below.

A The development of new bioproducts often provides great job opportunities for rural youth.

B However, training and access to machinery and technology is often mentioned as a key requirement for job creation in bioeconomy initiatives that introduce new methods for producing and processing biomass (e.g. initiatives under the 'BiomassWeb' Programme in sub-Saharan Africa, the Malaysia 'Bioeconomy Community Development Programme' and the 'Forest bioeconomy cluster' in Finland).

C One risk associated with the creation of new bioproducts is the possible competition between conventional job opportunities (e.g. the production of staple foods) and new employment in non-food bioproduct value chains. For young people in rural areas, this competition comes at the expense of conventional jobs. This situation can arise when a non-food crop is added to a food crop, as in the case study, 'The use of cardoon as biomass', in the EU and Italy.

D Competition can also exist in the choice of biomass processing technologies. Some of the more mechanized or sophisticated technologies do not generate many jobs, but can add significant value to the biomass and benefit the environment. An example of this trade-offs is the introduction of integrated mechanized sugarcane harvesters, which have reduced employment. This was considered in the 'Mesa Sucroalcoholera' case study in Argentina.

E Ensuring that an increase in the quantity of jobs is matched with an increase in the quality of these jobs is also important. The quality of employment, which relates to working conditions and safety, is often not included in the information about the case studies. One example in this regard, is the 'Agroforestry and conservation' case study in Indonesia, where the company provides mill workers with training in basic skills, mill operations and occupational safety and health.

Income diversification through the production of new bioproducts and related job opportunities can contribute to improved economic resilience of rural communities. Economic resilience can also be enhanced by strengthening rural-urban links and improving territorial cohesion through robust local value chains. Rural and urban areas are linked by reciprocal exchanges of products and services that rely on a common infrastructure. For instance, in the 'Urban circular bioeconomy' case study in San Francisco, United States of America, the compost produced from urban food waste is approved for use with certified organic soil that is used

in local farms. This activity is in line with a growing preference of consumers for locally grown organic food.

7. To promote actions that contribute to the revitalization and development of rural areas

This case study objective focuses on rural development in its links to SDG8 (economic growth and job creation) and SDG5 (gender equality) as well as the ISBWG-agreed sustainability Principle 3 (Sustainable bioeconomy should support competitive and inclusive economic growth), particularly Criterion 3.2 (Inclusive economic growth is strengthened) and Criterion 3.3 (Resilience of the rural and urban economy is enhanced).

The lessons concerning contract farming, the value web approach and rural bioeconomy clusters mentioned in relation to objective 5 (To increase profitability by adding value to biomass) are also relevant to this objective. Three additional lessons apply to this objective.

A Several case studies that emphasize rural development as an important objective have used a territorial approach, which starts with the evaluation of biomass potential of rural areas (e.g. 'National Biomass Strategy' in Malaysia, 'Mesa Sucroalcoholera' in Argentina, and 'Sunflower protein' and 'Functional use of passion fruit' in Brazil). By adopting a territorial approach, local governments in agreement with local stakeholders can design territorial plans for the production and use of biomass and the sustainable management of local natural resources. These activities can make use of agro-ecological zoning to define 'landscape units', as was done in the 'Family Cattle Producers and Climate Change' case study in Uruguay.

B Urban populations are largely responsible for driving the demand for bioproducts, particularly bio-cosmetics, bio-pharmaceuticals and biofibers. This aspect is often included in rural bioeconomy development planning, and is reflected in several case studies: 'Seaweed value addition' in the United Republic of Tanzania, 'Beekeeping dermocosmetics' in Colombia, biopharmaceuticals from the 'From Farmer to Pharma' case study in South Africa, and the 'Bioeconomy Community Development Programme' in Malaysia.

C The involvement of all primary stakeholders, with equal decision-making power, is crucial to ensure sustainability and fairness in the territorial planning processes. This often requires establishing ways and means to address power differences between stakeholders. The 'Mesa Sucroalcoholera' case study in Argentina illustrates efforts that can be made in this area.

8. To support vulnerable stakeholders who act as guardians of natural resources, including low-income communities, smallholder agricultural producers and indigenous peoples

This case study objective is linked to SDG8 (economic growth and job creation) and SDG5 (gender equality). It is also connected to the SDGs associated with the sustainable management of natural resources: SDG6 (water), SDG14 (oceans) and SDG15 (land resources). This objective is also relevant to the ISBWG-agreed sustainability Principle 4 (Sustainable bioeconomy should make communities healthier, more sustainable, and harness social and ecosystem resilience), particularly Criterion 4.2 (Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened in rural areas).

The importance of local livelihoods and knowledge is implicit in rural case studies. However, only a few case studies explicitly define the important role of local communities in the successful implementation of value chains. These examples are limited to the role that rural communities play in the biomass production stage; and almost none refer to their role in the development of the sustainable bioeconomy within the wider surrounding territory. The case studies that address this issue are associated with biopharmaceuticals derived from indigenous plants ('Farmer-to-Pharma' in South Africa) and bio-cosmetics (e.g. honey-based products in Colombia, and seaweed-based products in the United Republic of Tanzania).

Some lessons from these case studies are presented below.

A Incorporating traditional knowledge into new local bioeconomy activities can optimize the use and value of biomass. Local communities often have valuable knowledge about products and processes. Their traditional 'recipes' can be used to improve innovations. This requires involving all stakeholders in the process of designing new bioproducts, and often providing them with some training on the processing of bioproducts (e.g. the Malaysian 'Bioeconomy Community Development Programme' in Malaysia and 'Biofibre for clothing' in The Philippines).

B It is often the case that, in emerging economies and developing countries, women are key players in the use of local knowledge, particularly in the processing stage of the biomass value chain. This is illustrated by several case studies: the Malaysian 'Bioeconomy Community Development Programme'; 'Seaweed value addition' in the United Republic of Tanzania; and 'Biofibre for clothing' in the Philippines.

C Different mechanisms exist for ensuring that intellectual property rights are enforced and local communities receive their fair share of benefits. However, these mechanisms are not often mentioned in the case studies. Inclusive approaches can be used by private sector actors to ensure the fair distribution of profits and consolidate the production chain. For example, the South African Buchu plant used by indigenous peoples is now included under a benefit-sharing agreement with a private company that provides a fair and equitable share of the benefits. Communities facing poverty, discrimination and violence can also benefit, if biomass producers are given a role in the biomass processing stages (e.g. the 80 family beekeepers who supply the raw material for dermocosmetics in the 'Beekeeping dermocosmetics' case study in Colombia).

D These and other examples show that government programmes often have an important role in promoting the use of local plants, including indigenous crops and varieties. This role can be fulfilled in a number of ways.

- The public sector can act as a bridge between producer communities, which would benefit from additional sources of income, and companies, which that are familiar with markets and would receive a constant supply of raw materials for the production of bioproducts.
- The transfers of public funds to family farmers can enable them to adopt sustainable practices and increase their resilience.
- When local governments formulate biomass utilization policies according to local conditions, good bioeconomy practices are more suitable for producers in the area and can facilitate a farm-oriented utilization of biomass.
- Research that complements local knowledge on bioproducts can be undertaken (e.g. 'Seaweed value addition' in the United Republic of Tanzania).

E Several cases show that the application of innovative practices and technologies can revitalize vulnerable communities. For instance, private companies can work with NGOs to carry out capacity development activities for local farmers, create opportunities for sharing knowledge and provide agricultural inputs (e.g. 'Integral use of oil palm', Ghana). Innovation is not only for large companies; for many small companies, innovation may be the only way they can compete in an already established sector.

F Training is critical when new crops, and innovative production systems and processing procedures to add value are introduced. 'Training of trainers' is one option sometimes used to demonstrate the benefits of good bioeconomy practices and technologies to local small-scale biomass producers.

Capacity development activities are often designed in ways that ensure women are not neglected and are the main beneficiaries. This is the case in most bioeconomy case studies dealing with bio-based cosmetics (e.g. honey-based cosmetics in Colombia and seaweed-based cosmetics in the United Republic of Tanzania). These activities can enable women to engage in biomass transformation processes, obtain post-harvest employment and increase their independence.

Public research often makes important contributions to charting locally appropriate bioeconomy development pathways. In addition, private companies often transfer technology to contracted farmers to increase yields and improve the quality of the biomass. The Malaysian Bioeconomy Community Development Programme provides several examples of this.

Any effort to build capacities should not neglect local knowledge but rather complement it. This is particularly true for bio-pharmaceuticals (e.g. 'From Farmer to Pharma' in South Africa).

The absence of vocational education and technical training is a common hindrance to the development of bio-based industries. To address this, companies should provide workers with training on operations, basic skills as well as occupational safety and health.

9. To move towards a more circular bioeconomy

This case objective is connected to SDG8 (economic growth and job creation), but it is also linked to several other SDGs, including SDG2 (Zero Hunger) due to its links with food loss and waste. It is also linked to SDG3 (health) due to the use of sewage water to produce bioproducts, and consequently to SDG6 (water), SDG7 (energy), SDG9 (urban environments), SDG12 (consumption and production), and SDG13 (climate change). This objective also reflects the thinking behind ISBWG-agreed sustainability Principle 5 (Sustainable bioeconomy should rely on improved efficiency in the use of resources and biomass), in particular Criterion 5.1 (Resource efficiency, waste prevention and waste re-use along the whole bioeconomy value chain is improved), and to some extent Criterion 5.2 (Food loss and waste is minimized and, when unavoidable, its biomass is reused or recycled).

The lessons regarding the use of residues related to the objectives food security and value addition objectives are also relevant here. Additional lessons related to circular economy are listed below.

A Applying circularity principles helps foster the sustainability of bioeconomy initiatives. This has been shown in the case studies: 'Bio-based plastics from agave residues' in Mexico, the 'Blue bioeconomy development' in Iceland, and 'Biofibre for clothing' in the Philippines.

B However, applying circularity principles to the use of residues is easier said than done. There are a number of issues that need to be addressed.

- The quality of residues can often be a challenge, particularly if they come from urban waste, as attested in the cases study, 'Urban circular bioeconomy', in the United States of America and the Biomass Town Programme described in Japanese case study 'From biomass towns to industrial areas'. In most cases, the separation of residues becomes a crucial element in the transition to a circular bioeconomy. It is very important to engage local consumers, industry and public institutions to ensure that the activities needed to achieve circularity in the bioeconomy are carried out on a daily basis. Public mechanisms should promote comprehensive biomass utilization systems at the municipal level, with the management of residues and waste making up the central element. A good separation system is particularly important since having differentiated fractions of waste and residues makes each fraction more homogeneous, and consequently improves their quality for processing. Challenges associated with the quality of residues can also arise when there are several types of crop residues that are more or less suitable for a range of specific uses, such as improving soil quality (e.g. 'Biochar production and use' in Ghana).
- The use of residues from agro- and bio-industries to produce high-value materials and products can be a good practice in industrial processes that generate large amounts of waste. Waste can often be difficult to manage and its disposal can become an increasingly difficult problem. Outsourcing waste management can lower costs for traditional industries and provide opportunities for new industries to use it for other bioproducts. However, these new industries often need a homogeneous feedstock to produce

biomaterials (e.g. 'Bio-based plastics from agave residues' in Mexico, and the 'Blue bioeconomy development' in Iceland).
- Reducing the distance between the collection and the processing of residues is often crucial to ensure regular supply and reduce costs. The use of cod residues in the 'Blue bioeconomy development' initiative in Iceland illustrates this.

C It is important to test the biodegradability, compostability and disintegration of bio-based products to understand the characteristics of the product and ensure that it can meet market demand, either as a substitute for a similar fossil-based product (e.g. 'Bio-based plastics from agave residues', Mexico) or as a new product in untapped markets (e.g. 'The use of cardoon as biomass', EU and Italy). This testing also helps to ensure easier and improved waste management and reduce water, air and soil pollution.

D Microbiological and biotechnological processes are an essential element of the bioeconomy. Microbiota play a significant role in bioeconomy, particularly in biotechnological processes; both traditional processes, such as fermentation in agro-industries, and innovative processes, such as specific enzymatic pre-treatment processes. Microbiota are also important in the application of some circularity principles, including those related to the processing of biomass residues or food waste (e.g. biogas produced through anaerobic digestion), and, increasingly, the production of CO_2-based bioproducts through CCU (e.g. the patented microorganism used to convert gas into bioplastics in the American case study 'From gas to bio-based plastic').

10. To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods

Aspects of this objective relate to two broad areas:

- The efficient production and use of biomass and related inputs. The more technical aspects regarding the objectives on food security (objective 1), sustainable management of natural resources (objective 2), value addition (objective 5) and circular economy (objective 9) are relevant here, but will not be considered under this objective.
- The governance of biomass production and use. This involves identifying decision-making processes; stakeholder roles, rights and responsibilities; the appropriate policies regulations and institutions; and information and communication mechanisms, which are the subject of this subsection.

The governance aspects of this objective underpin several SDGs, but are of particular concern to SDG8 (economic growth and job creation) and SDG12 (consumption and production). They are also linked to the ISBWG-agreed sustainability Principle 6 (Responsible and effective governance mechanisms should underpin sustainable bioeconomy).

The following success factors on governance have emerged from the review of the case studies:

A inclusive decision-making, as well as broad social agreement and engagement at all relevant levels in the design and implementation of bioeconomy (e.g. 'Mesa Sucroalcoholera' in Argentina, and bioeconomy platforms such as the one established in the Malaysian case study 'Bio-industrial clusters to add value');

B a territorial approach to rural bioeconomy development (e.g. 'Mesa Sucroalcoholera' in Argentina, and 'Sunflower protein' and 'Functional use of passion fruit' in Brazil);

C regional bioeconomy clusters as part of biomass value webs (see the lessons related to objective 5 on value addition);

D contract farming (see objective 5) which can be beneficial to biomass producers, in that it can provide them with guaranteed market and sometimes technical support, and biomass manufacturers and retailers, in that it can ensure a consistent and regular supply of biomass. As already mentioned, governments often have a role in ensuring that such contracts are fair to both parties.

E a supra-ministerial body close to the top level of the government, to manage and coordinate the development and implementation of

bioeconomy strategies (e.g. the 'National Biomass Strategy' in Malaysia);

F public mechanisms to achieve the desired levels of market uptake and consumer awareness of bioproducts (e.g. the American Bio-Preferred programme's with its policy of using public procurement of bioproducts to create bioeconomy markets);

G stakeholder collaboration, including Public-Private Partnerships, which are often part of regional bioeconomy cluster (e.g. 'Blue bioeconomy development' in Iceland and 'The use of cardoon as biomass' in the EU and Italy). Public-Private Partnerships can also help connect biomass producers and bioproduct manufacturers and retailers (e.g. the Malaysian 'Bioeconomy Community Development Programme'), and support research on innovative technologies or products (e.g. 'Seaweed value addition' in the United Republic of Tanzania, and 'From gas to bio-based plastic' in the United States of America).

11. To establish local fair and equitable value chains or webs by increasing inclusiveness and information flows

Many aspects related to the governance component of the previous objective are also relevant to this objective. They include the links to SDGs and to ISBWG–agreed sustainability principles. Lessons in this respect concern success factors related to bioeconomy clusters, value webs and contract farming. Of particular importance regarding this objective is the key role public authorities can play in a number of areas, including:

- building bridges between biomass producers and companies that process and sell bioproducts (e.g. 'From Farmer to Pharma' in South Africa), and supporting research that helps biomass producers and small-scale bioproduct operations (e.g. 'Seaweed value addition' in the United Republic of Tanzania);
- developing campaigns to raise public awareness on bioeconomy and create markets for bioproducts (e.g. the Malaysian 'National Biomass Strategy'); and
- developing and coordinating bioeconomy platforms to share information and knowledge in a transparent way, establish partnerships and, most importantly, play a role in decision-making (e.g. 'Mesa Sucroalcoholera' in Argentina).

12. To promote a transparent monitoring system for bioeconomy development and compliance with national and/or international sustainability targets

The monitoring and evaluation of the impact and performance of bioeconomy is linked to the SDGs that are commonly accepted as being especially linked to bioeconomy (see Tables 5 and 6 and Subsection 3.4.2). This objective is also linked to almost all ISBWG-agreed Principles, particularly to Principle 6 and its Criterion 6.3 on risk management, monitoring and evaluation.

A Monitoring is mentioned in only a few cases that are government-led initiatives. However, this does necessarily mean that monitoring is seldom done. The monitoring of financial performance is likely of particular importance in initiatives that are led by the private sector.

B Bioeconomy monitoring can have different purposes, including:

- government monitoring of the performance of its own policies, programmes and regulations (e.g. 'Alternatives to burning straw' in China; the BioPreferred programme in the 'Promoting bioproduct use' in the United States of America, and the economic performance of the 'National Biomass Strategy' in Malaysia);
- market requirements, particularly with respect to certification (e.g. the bioproducts intended for European markets in the Indonesian case study, 'Agroforestry and conservation');
- project implementation performance, particularly for donor-funded initiatives (e.g. 'The use of cardoon as biomass', EU and Italy);
- performance in terms of the implementation of good practice (e.g.

'Family Cattle Producers and Climate Change' in Uruguay); and

- risk management, which is an important component in several case studies. Monitoring risk can concern essential inputs, such as specific feedstock (e.g. honey for 'Beekeeping dermocosmetics' in Colombia, or cod populations in 'Blue bioeconomy development' in Iceland), natural resources (e.g. 'Forest bioeconomy cluster', Finland), or residue supply (e.g. 'Towards second-generation biofuels', India). It can also concern market risks related to ensuring supply can meet demand (e.g. 'Sunflower protein' in Brazil), and financial risks, particularly when high investments were needed for new technologies (e.g. 'From gas to bio-based plastic' in the United States of America). At the end of Subsection 3.3, several success factors that can help identify and mitigate risks are noted.

C Public procurement programmes can include voluntary labelling to make it easier for consumers to identify bioproducts with certain characteristics that have been verified by third parties and monitored by the public entity in change of the procurement programme (e.g. 'Promoting bioproduct use', United States of America).

D Certification can be cost-effective and is often the preferred way for national or international bodies to monitor and evaluate sustainability. However, it can exclude small-scale producers who often cannot afford to participate in certification schemes.

E Patenting and certifying a technological innovation can contribute to a wider adoption of the technology by clearly detailing the specific function it has in supporting sustainability. However, as discussed in the subsection concerning the objective 2 (finding substitutes for fossil-based or unsustainably sourced products**)** certification is not a panacea. There are some strong limitations involved in measuring the sustainability performance of an intervention, especially its impact at the territorial level (as opposed to the industrial operation level).

F LCAs and other modelling approaches are often the preferred approach to monitor environmental impact and draw scenarios. However, they have limitations, in particular due to their frequent reliance on (over) simplified assumptions at the expense of a detailed understanding of the reality on ground. LCAs should not be used as sole basis to derive policies, and should always be complemented with ground truthing activities.

G Significant amounts of time, knowledge and financial resources are often needed to monitor impacts. Indicators on the performance of measures to implement good practices are increasingly used to complement impact measurement. This type of indicator is part of the new indicators framework of the 2021-2027 European Commission Common Agricultural Policy, which will include Strategic Plans and Annual Performance Reports to be drawn up by Member States. Public mechanisms that fund the implementation of good practices must monitor and evaluate their activities and the impact they have on rural development. These mechanisms often place great emphasis on the technical assistance to biomass producers and processors that is provided by private technical staff, as the adoption rate of good practices is strongly related to this type of assistance.

H The government can be a legitimate third party for verifying fair conditions in contracts (e.g. contract farming), the quality of employment and trade agreements.

13. To support research, development and innovation and put it into practice to accelerate the deployment of sustainable bioeconomy

Supporting R&D&I is a prominent objective in many case studies. This is not surprising, as research and innovation underpin many of the other common bioeconomy objectives of the case studies. This objective on development relates to the main SDGs that are relevant to the bioeconomy (see Subsection 3.4.2). Regarding the ISBWG-agreed P&Cs, the need to support research and innovation is reflected by sustainability Principle 7 (Sustainable bioeconomy should make good use of existing relevant knowledge and proven sound technologies and good practices and, where appropriate, promote research and innovation).

To some extent, the lessons regarding local knowledge and related capacity building presented under objective 8 (support to vulnerable stakeholders) are also relevant here. Additional lessons are listed below.

- Different types of agreements can exist in making innovations, including:
  - agreements between innovators and investors. These agreements are commonly developed to support research and development. Companies in traditional sectors sign agreements with start-ups that have developed an innovative bioeconomy technology to test the technology in their production process.
  - agreements between the public and the private sector. Most high-tech bioeconomy activities are either carried out by large companies or as public-private projects. In the innovative 'quadruple helix' approach, the government works with citizens, academia and industry to capitalize on existing policies and use infrastructure more effectively, instead of building more infrastructure. This helps deliver high-impact and low-cost sustainable services and projects that can be carried out quickly. This approach also helps ensure the various players do not work in 'silos'.
  - joint ventures between two companies that apply their respective expertise to new biomass feedstocks or bioproducts.

  These types of agreements are often found in bioeconomy clusters.

- To put innovations into practice and enter the market often requires certification (e.g. 'From gas to bio-based plastic', United States of America). A proven business model for market uptake of sustainable products is the 'brand-to-brand model'. In this model, a sustainable product is sold to other companies that share the same vision of sustainability, which is based on certification of sustainability and compliance with required criteria. However, the costs of certification can be prohibitive for small rural enterprises.

14. To position the country as an international leader in the bioeconomy and improve its global competitiveness in trade and research

This objective relates to some extent to SDG10 (reduce inequalities) and SDG 8 (economic growth and job creation). It is also linked to the ISBWG-agreed sustainability Principle 3 (Sustainable bioeconomy should support competitive and inclusive economic growth) and Principle 8 (Sustainable bioeconomy should use and promote sustainable trade and market practices).

A Local processing of biomass is an element common to all the case studies. This involves adding value to the biomass locally and engaging in the trading of bioproducts, including their export in some cases, instead of simply exporting the raw biomass. This clearly benefits local economies in exporting countries. However, only a few case studies consider the potential risks that could arise in the countries that export the biomass feedstock. The use of certification in the few case studies that export bioproducts is an indirect acknowledgment of such risks. An example of this is the national timber legality assurance system and a voluntary partnership agreement with the EU to promote trade of legal timber products in the 'Agroforestry and conservation' case study in Indonesia.

B Some case studies show that international partnerships can create opportunities for the international trade of bioproducts. Sometimes bio-based start-up ventures form partnerships with experienced producers in the fossil-based chemical and polymers sector because these producers are familiar with the market and can provide financial resources (e.g. 'Towards second-generation biofuels' in India, 'From gas to bio-based plastic', United States of America). Companies that transform residues into higher-value products do not necessarily produce the residues themselves. Instead, they establish strategic partnerships with companies or operators that generate and own the residues.

C Clusters have proven to be an efficient approach to increase the competitiveness of bioproducts, in domestic and international markets.

When countries are exploring downstream opportunities, clusters can be an especially useful way to unlock the potential of traditional sectors and steer them towards the production of high-value bioproducts. Clusters also reduce the costs of transportation and processing due to economies of scale and can promote new businesses, investment and innovation.

D Many countries seek to utilize their available biomass and biological resources to improve their national economies and become more competitive internationally and, in some cases, world leaders ('National Biomass Strategy', Malaysia).

E Competitively priced bioproducts with properties that are similar or better than those of fossil-based products are more likely to find a market and allow the sector to become more competitive internationally. For instance, biochemical companies sometimes focus on specialty biomaterials rather than commodities to reduce costs and compete with fossil-based products (e.g. substitution of harmful chemicals in the 'The use of cardoon as biomass' case study in the EU and Italy). This can also relate to the substitution of unsustainable production of biomass (e.g. 'Rubber from dandelions' in Germany) or unsustainable manufacturing processes (e.g. the replacement of leather in the 'Biofibre for clothing' case study in the Philippines, which also provides an alternative to unsustainable primary production practices as it is a certified 'Vegan Fashion Label' by People for the Ethical Treatment of Animals).

15. To promote sustainable consumption and raise the awareness and acceptance among consumers and manufacturers about the goods and services provided by the bioeconomy

This objective relates particularly to SDG12 (consumption and production) and to the ISBWG-agreed sustainability Principle 9 (Sustainable bioeconomy should address societal needs and encourage sustainable consumption).

The lessons regarding demand-side aspects of bioeconomy briefly discussed with regarding to objective 2 on the substitution of fossil fuel-based goods, also apply here. Other lessons are listed below.

- Awareness-raising activities are critical to ensure that consumption patterns of bioeconomy goods match sustainable supply levels of biomass goods. The American case study, 'Promoting bioproduct use' illustrates this.
- Government efforts to ensure policy coherence between supply and demand targets (e.g. through mandates, incentives and taxes) are currently relatively scarce for bioproducts. On the other hand, for biofuel, they are more frequent (e.g. 'Towards second-generation biofuels', India).
- Mechanisms that show the sustainability of bioproducts, such as certification and labels, provide important information that can stimulate consumption of bioproducts (e.g. 'Agroforestry and conservation' in Indonesia, and 'From gas to bio-based plastic' in the United States of America).
- Consumers are usually sympathetic to the idea of buying bioproducts. However they will actually only purchase the products if:
  - their performance is at least as good as that of fossil fuel-based products (e.g. 'The use of cardoon as biomass', EU and Italy, and 'Rubber from dandelions', Germany cases); and
  - their additional cost is not too high (e.g. 'From gas to bio-based plastic', United States of America), that is, usually not more than 15 percent higher than fossil fuel-based goods (Bracco *et al.*, forthcoming).
- Private companies can engage with civil society by signing agreements with local governments to sell their products in the area where the biomass is produced and raise the awareness of local communities about the positive effects that investments in the bioeconomy can have on their lives and livelihoods.
- Producers and industrial actors more readily adopt innovative technologies and practices when public efforts have been undertaken beforehand to prepare the market for the new bioproducts (e.g. 'Forest bioeconomy cluster', Finland).

Other considerations

Many objectives in the case studies respond to one or more sustainability goals. However, there are some aspects of sustainability that are rarely considered or only superficially addressed.

Under Principle 1 (Sustainable bioeconomy development should support food security and nutrition at all levels), Criterion 1.3 (Adequate land rights and rights to other natural resources are guaranteed) and Criterion 1.4 (Food safety, disease prevention and human health is ensured) are not properly covered in the case studies.

Another area of concern that was not widely addressed in the different case studies was Criterion 2.1 (Biodiversity conservation is ensured) under Principle 2 (Sustainable bioeconomy should ensure that natural resources are conserved, protected and enhanced). This is somewhat surprising given that several countries are seeking to capitalize on their abundant natural biodiversity (e.g. through bioprospecting programmes).

Another aspect of the sustainable bioeconomy that is commonly and surprisingly overlooked relates to Principle 4 (Sustainable bioeconomy should make communities healthier, more sustainable, and harness social and ecosystem resilience). The case studies have a strong focus on rural areas. However, the links between rural areas and urban centres seem to be largely neglected. This is surprising given that most of the consumers of bioproducts live in cities. The few existing examples relate to government-led programmes that focus on Criterion 4.1 (The sustainability of urban centres is enhanced). An important component of all of these programmes is the creation of circular systems that make the most out of available waste and residues. These programmes also seek to change consumer behaviour and provide improved access to services in order to implement the bioeconomy in urban areas.

Principle 10 (Sustainable bioeconomy should promote cooperation, collaboration and sharing between interested and concerned stakeholders in all relevant domains and at all relevant levels), and Criterion 10.1 (Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate), are aspects of sustainability that are addressed in the majority of case studies. However, activities in this area are seen more as a means to an end, rather than an end in itself. The lessons learned regarding this objective are included to a certain extent under several other objectives, in particular objective 10 on the synergic uses of biomass and objective 14 on global competitiveness.

CHAPTER

5

CONCLUSION

There are many lessons that have been drawn from these case studies and they cover a diverse range of issues. This diversity reflects the nature of the growing bioeconomy. There is no single blueprint for developing and implementing a bioeconomy. However, there are number of indications on how a sustainable transition to bioeconomy can be achieved.

The lessons learned from the 26 case studies provide an idea of what the shift toward sustainability can look like in practice. The lessons also clearly show that sustainability is not something that happens automatically. A multi-stakeholder effort, wherever possible, is needed to achieve synergies and reduce trade-offs between different sustainability goals.

The results of this report are based on evidence and will serve as the foundation for other elements of the FAO 'Sustainable Bioeconomy Guidelines'. These elements of the guidelines, which include a selection of good practices, policies, tools and indicator frameworks for sustainable bioeconomy, will help countries, and the producers and users of biomass and bioproducts develop and implement national bioeconomy strategies, policies and programmes in a sustainable way.

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ANNEX 1

ASPIRATIONAL PRINCIPLES AND CRITERIA FOR SUSTAINABLE BIOECONOMY

The list of Principles and Criteria for Sustainable Bioeconomy were developed and validated in November 2016 by the ISBWG under Phase I of the German-funded 'Bioeconomy That Works for People, Food Security and Climate Change' (BTW) Programme:

PRINCIPLE 1. SUSTAINABLE BIOECONOMY DEVELOPMENT SHOULD SUPPORT FOOD SECURITY AND NUTRITION AT ALL LEVELS

Criterion 1.1. Food security and nutrition are supported

It is crucial that bioeconomy development does not hamper but rather strengthens food security as a basic human need and right. This concerns adequate and simultaneous fulfilment of the four dimensions of food security (food availability, access, utilization and stability). Bioeconomy developers should make use of existing food security early warning and monitoring systems to ensure adequate fulfilment of these dimensions, and apply corrective measures whenever necessary.

Criterion 1.2. Sustainable intensification of biomass production is promoted

At the global level, agricultural production and consumption in 2050 are projected to be around 50 percent higher than in 2013, and most of this increase will have to come from yield increase. Sustainable yield increase in biomass production, in particular for food purposes is needed, as availability of land for agricultural production will often be the core-limiting factor to feed the increasing world population in the future. This need is even more prevalent for the production of non-food goods.

Criterion 1.3. Adequate land rights and rights to other natural resources are guaranteed

Adequate tenure security is crucial to ensuring food security, and for investments in the production of both food and non-food goods. Therefore, sustainable bioeconomy should not hamper but rather harness land, forests and water rights.

Criterion 1.4. Food safety, disease prevention and human health is ensured

Food safety is a cornerstone for healthy societies. Innovative bio-based strategies, technologies and tools should be in place to protect consumers from health risks, exposure to food-borne hazards and the health-related consequences of climate change. They should also ensure a sustainable management of the whole food chain process. This can lead to a reduction of food-borne diseases, a decrease of citizens' exposure to food-borne hazards and overall healthier diets.

PRINCIPLE 2. SUSTAINABLE BIOECONOMY SHOULD ENSURE THAT NATURAL RESOURCES ARE CONSERVED, PROTECTED AND ENHANCED

Criterion 2.1. Biodiversity conservation is ensured

The sustainability of producing food and non-food goods depends on a number of crucial factors, including the conservation and sustainable use of biological diversity, as a fundamental requirement to ensure sufficient diversity and resilience of biomass production systems.

Criterion 2.2. Climate change mitigation and adaptation is pursued

There is a global agreement that adapting to and mitigating climate change are imperative and must be addressed head on. Bioeconomy is in a unique position to significantly contribute to climate change mitigation through the replacement of fossil fuels-based goods with low-carbon bioproducts. In that context, it is essential that bioeconomy plays a crucial role to achieve COP targets.

Criterion 2.3. Water quality and quantity are maintained, and, in as much as possible enhanced

Water is a crucial input at all stages of almost all bioeconomy value chains. At the same time, it is a scarce resource, both in quality and quantity, in several parts of the world. Moreover, pressure on water has recently been exacerbated due to the increasing competition between food/feed and energy, including bioenergy. Therefore, one should ensure that the development of bioeconomy does not further exacerbate the competition for water but rather guarantees its quality and supply for all.

Criterion 2.4. The degradation of land, soil, forests and marine environments is prevented, stopped or reversed

Land, soil, forests and marine environments are the main asset to produce biomass and preserving their quality is therefore key to a sustainable bioeconomy. At the same time, a significant proportion of these resources have already been degraded. Degraded natural resources should be restored and natural functions enhanced, bearing in mind that it should be balanced with the need to ensure economic viability and social acceptance of these actions.

PRINCIPLE 3. SUSTAINABLE BIOECONOMY SHOULD SUPPORT COMPETITIVE AND INCLUSIVE ECONOMIC GROWTH

Criterion 3.1. Economic development is fostered

A safe and healthy business environment to biomass producers and other bioeconomy investors is needed because biomass production and use is a complex, sometimes expensive and risky endeavor.

Criterion 3.2. Inclusive economic growth is strengthened

'Equality of opportunity' and 'participation in growth by all' with a special focus on the working poor and the unemployed should be promoted by bioeconomy to ensure that it 'leaves nobody behind'. Moreover, inclusive growth has deep interconnections with other important areas of sustainable bioeconomy, such as food, water and energy security, gender equality and public-private partnerships.

Criterion 3.3. Resilience of the rural and urban economy is enhanced

Economic crises, fluctuations in commodity prices and market/food prices have shown to increase insecurity in the rural economy and are obstacles to long-term investments. Resilience to economic insecurity of communities and livelihoods should be enhanced by capitalizing on the linkages between rural and urban areas. This can be achieved by diversifying the rural economy and by promoting regional and local production and processing of food. Rural and urban areas should be seen as a whole and not as competing with each other since they are linked by reciprocal exchanges of products and services that build upon a common infrastructure.

PRINCIPLE 4. SUSTAINABLE BIOECONOMY SHOULD MAKE COMMUNITIES HEALTHIER, MORE SUSTAINABLE, AND HARNESS SOCIAL AND ECOSYSTEM RESILIENCE.

Criterion 4.1. The sustainability of urban centers is enhanced

Cities and urban areas host half of the world's population. With a growing urbanization projected for the next decades, challenges such as fresh water supplies, food and energy resources availability, climate change and securing an

overall healthy environment, especially for the developing world, will be more pressing than ever. Bioeconomy has many sustainable solutions to offer and should consequently form a tool for urban planners, policy makers, politicians and other crucial stakeholders at the city level in collaboration with the research community, local, regional and national NGOs and the private sector.

Criterion 4.2. Resilience of biomass producers, rural communities and ecosystems is developed and/or strengthened

Bioeconomy that promotes technologies and practices that build or strengthen biomass producers, rural communities and ecosystems resilience to threats and increase adaptation to climate change is crucial to ensuring stable and good quality supply of biomass and the production of bio-based materials.

PRINCIPLE 5. SUSTAINABLE BIOECONOMY SHOULD RELY ON IMPROVED EFFICIENCY IN THE USE OF RESOURCES AND BIOMASS

Criterion 5.1. Resource efficiency, waste prevention and waste re-use along the whole bioeconomy value chain is improved

There is a general agreement that one should 'do more with less' in the production of goods in order to manage the balance between the needs of a growing population and environmental boundaries. Therefore, efficiency should be strengthened in the use of natural resources and inputs for the production of biomass and bioproducts.

Food loss and waste prevention as well as re-use and upgrade of waste should be an integral component of a sustainable bioeconomy. This would minimize environmental impact, mainstream a circular, inclusive, economy and tackle global challenges such as marine litter and plastic waste, and thus contribute to the recycling of raw materials and reduction of GHG emissions.

Criterion 5.2. Food loss and waste is minimized and, when unavoidable, its biomass is reused or recycled

Food waste and food loss, especially in the food chain, significantly contribute to resource use inefficiency, environmental pollution and GHG emissions. On the other hand, unavoidable food losses can be a source of biomass for bioeconomy.

PRINCIPLE 6. RESPONSIBLE AND EFFECTIVE GOVERNANCE MECHANISMS SHOULD UNDERPIN SUSTAINABLE BIOECONOMY

Criterion 6.1. Policies, regulations and institutional set up relevant to bioeconomy sectors are adequately harmonized

Regulatory and institutional harmonization is necessary due to the cross-sectoral nature of bioeconomy and potential ensuing conflicts of existing legislation and governance mechanisms related to sectoral areas on the bioeconomy and vice versa.

Criterion 6.2. Inclusive consultation processes and engagement of all relevant sectors of society are adequate and based on transparent sharing of information

The design and implementation of bioeconomy should be undertaken with society's agreement and engagement, linking top-down and bottom-up approaches. The transition to a sustainable bioeconomy should be transparent, supported by the application of international standards, and with the right balance between private, public and civic sector initiatives.

Criterion 6.3. Appropriate risk assessment and management, monitoring and accountability systems are put in place and implemented

Given its magnitude as well as multi-sectoral and multi-scale character, the implementation of bioeconomy requires cost-effective and inclusive monitoring and evaluation at all levels, as a basis for proper accountability and systemic 'learning'.

PRINCIPLE 7. SUSTAINABLE BIOECONOMY SHOULD MAKE GOOD USE OF EXISTING RELEVANT KNOWLEDGE AND PROVEN SOUND TECHNOLOGIES AND GOOD PRACTICES AND, WHERE APPROPRIATE, PROMOTE RESEARCH AND INNOVATION

Criterion 7.1. Existing knowledge is adequately valued and proven sound technologies are fostered

There is a significant amount of existing knowledge and sound proven technologies, for both food and non-food goods, to produce and use biomass in a sustainable way.

Criterion 7.2. Knowledge generation and innovation are promoted

Research and innovation should be supported in bioeconomy development, to complement existing sound knowledge and proven technologies.

PRINCIPLE 8. SUSTAINABLE BIOECONOMY SHOULD USE AND PROMOTE SUSTAINABLE TRADE AND MARKET PRACTICES

Criterion 8.1. Local economies are not hampered but rather harnessed by the trade of raw and processed biomass, and related technologies

The trade of biomass and bioproducts bears potential risks in relation to food security and the viability of the local and national economy in both exporting and importing countries.

PRINCIPLE 9. SUSTAINABLE BIOECONOMY SHOULD ADDRESS SOCIETAL NEEDS AND ENCOURAGE SUSTAINABLE CONSUMPTION

Criterion 9.1. Consumption patterns of bioeconomy goods match sustainable supply levels of biomass goods

A sustainable bioeconomy should contribute to a shift towards sustainable consumption and production. This would concern national and regional consumption in relation to globally and nationally fair and environmentally safe levels of supply, including minimization of problem shifts across regions and sectors.

Criterion 9.2. Demand- and supply-side market mechanisms and policy coherence between supply and demand of food and non-food goods are enhanced

The cross-sectoral nature of bioeconomy calls for market-guarantee mechanisms that are harmonized between the bioeconomy sectors, to ensure policy coherence in the production of food and non-food goods and the management of natural resources.

PRINCIPLE 10: SUSTAINABLE BIOECONOMY SHOULD PROMOTE COOPERATION, COLLABORATION AND SHARING BETWEEN INTERESTED AND CONCERNED STAKEHOLDERS IN ALL RELEVANT DOMAINS AND AT ALL RELEVANT LEVELS

Criterion 10.1. Cooperation, collaboration and sharing of resources, skills and technologies are enhanced when and where appropriate

There is currently an uneven distribution of resources, skills and technologies related to bioeconomy across the globe, including in the research and innovation domains. This hampers the realization of the global potential for the uptake of bioeconomy. Harnessing effective biomass production, transformation and utilization across the globe should be encouraged through mutually beneficial knowledge sharing.

ANNEX 2

COMMON OBJECTIVES TO IMPLEMENT THE BIOECONOMY AND STAKEHOLDERS INVOLVED IN THEIR ACHIEVEMENT

TABLE A1.

THE FIFTEEN IDENTIFIED COMMON OBJECTIVES, THE CASE STUDIES THAT HAVE SOUGHT TO ACHIEVE THEM, THE TYPE OF CASE STUDIES, AND THE LEADING STAKEHOLDERS AND THE BENEFICIARIES INVOLVED IN THE IMPLEMENTATION OF ACTIVITIES ON THE GROUND THAT HELP ACHIEVE THE OBJECTIVES IN EACH OF THE CASE STUDIES

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
1. TO SAFEGUARD FOOD SECURITY			
Biochar production and use (Ghana)	Development project and R&D&I activity	NGOs and small-scale farmers	Small-scale farmers, local communities and poor households
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers and manufacturing businesses	Consumers, local communities and society as a whole
Towards second-generation biofuels (India)	Private sector activity	National policy makers and manufacturing businesses	Society as a whole
Biofibre for clothing (Philippines)	Private sector activity	Start-up manufacturing businesses	Local communities
Alternatives to burning straw (China)	Government programme	National policy makers	Society as a whole
Blue bioeconomy development (Iceland)	Private sector activity	Hybrid organizations (clusters and innovation hubs)	Society as a whole
2. TO SUBSTITUTE FOSSIL-BASED OR UNSUSTAINABLY SOURCED PRODUCTS WITH SUSTAINABLE BIOPRODUCTS			
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers and policy makers	Society as a whole
Biofibre for clothing (Philippines)	Private sector activity	Start-up manufacturing businesses and certification bodies	Local communities and consumers
Agroforestry and conservation (Indonesia)	Private sector activity	National policy makers, certification bodies and large-scale manufacturing businesses	Local communities, society as a whole and consumers
Bio-based plastics from agave residues (Mexico)	Private sector activity	Large-scale manufacturing businesses	Society as a whole and consumers

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
From gas to bio-based plastic (United States of America)	Private sector activity	Start-up and large-scale manufacturing businesses	Consumers
Promoting bioproduct use (United States of America)	Government programme	National policy makers	National manufacturing businesses
The use of cardoon as biomass (EU and Italy)	R&D&I activity and private sector activity	Regional policy makers and manufacturing businesses	Society as a whole
Rubber from dandelions (Germany)	Private sector activity	Large-scale manufacturing company	Manufacturing businesses and society as a whole
3. TO INCENTIVIZE THE SUSTAINABLE AND EFFICIENT USE OF BIOLOGICAL RESOURCES WHILE PROTECTING BIODIVERSITY, WATER AND THE SOIL			
Biochar production and use (Ghana)	Development project and R&D&I activity	NGOs	Small- and medium-scale farmers and manufacturing businesses
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers and policy makers	Society as a whole
Seaweed value addition (United Republic of Tanzania)	Development project and private sector activity	NGOs and researchers	Small-scale women farmers
From Farmer to Pharma (South Africa)	Government programme	National policy makers	Local communities
National Biomass Strategy (Malaysia)	Government programme	National policy makers	Society as a whole and manufacturing businesses
Towards second-generation biofuels (India)	Private sector activity	National policy makers	Manufacturing businesses and service providers (logistics)
Agroforestry and conservation (Indonesia)	Private sector activity	Manufacturing businesses	Society as a whole
Mesa Sucroalcoholera (Argentina)	Government programme	National policy makers	Farmers and manufacturing businesses
Functional use of passion fruit (Brazil)	R&D&I activity activity and government programme	National policy makers and researchers	Local communities
Family Cattle Producers and Climate Change (Uruguay)	Government programme	National policy makers	Family farmers
Rubber from dandelions (Germany)	Private sector activity	Large-scale manufacturing company and researchers	Local, national and regional farmers
Blue bioeconomy development (Iceland)	Private sector activity	Hybrid organizations (clusters and innovation hubs)	Start-up and large-scale manufacturing businesses
Urban circular bioeconomy (United States of America)	Government programme	Municipal policy makers	Society as a whole, manufacturing businesses and service providers
4. TO MITIGATE AND ADAPT TO THE EFFECTS OF CLIMATE CHANGE AND REDUCE ENVIRONMENTAL POLLUTION			
Biochar production and use (Ghana)	Development project and R&D&I activity	NGOs, small- and medium-scale farmers and small- and medium-scale enterprises	Small-and medium-scale farmers and society as a whole
Seaweed value addition (United Republic of Tanzania)	Development project and private sector activity	Policy-makers, NGOs and hybrid organizations (clusters)	Small-scale women farmers
Alternatives to burning straw (China)	Government programme	National policy makers	Society as a whole
Family Cattle Producers and Climate Change (Uruguay)	Government programme	National policy makers	Family farmers and society as a whole
From gas to bio-based plastic (United States of America)	Private sector activity	Start-up and large-scale manufacturing businesses and researchers	Society as a whole
Urban circular bioeconomy (United States of America)	Government programme	Municipal policy makers	Society as a whole

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
5. TO INCREASE PROFITABILITY BY ADDING VALUE TO BIOMASS			
Integral use of oil palm (Ghana)	Private sector activity	Manufacturing businesses	Manufacturing businesses, small-scale farmers and local communities
Bio-industrial clusters to add value (Malaysia)	Government programme	Hybrid organizations (clusters) and financing institutions	Manufacturing businesses
Towards second-generation biofuels (India)	Private sector activity	Manufacturing businesses	Manufacturing businesses
Biofibre for clothing (Philippines)	Private sector activity	Start-up manufacturing businesses	Start-up manufacturing businesses, farmers and local communities
Agroforestry and conservation (Indonesia)	Private sector activity	Manufacturing businesses and farmers	Manufacturing businesses and farmers
Beekeeping dermocosmetics (Colombia)	Private sector activity	Manufacturing businesses	Manufacturing businesses
Bio-based plastics from agave residues (Mexico)	Private sector activity	Large-scale manufacturing businesses	Large-scale manufacturing businesses
Sunflower protein (Brazil)	R&D&I activity and private sector activity	Researchers and start-up, small- and medium-scale manufacturing businesses	Manufacturing businesses
From gas to bio-based plastic (United States of America)	Private sector activity	Start-up and large-scale manufacturing businesses	Start-up and large-scale manufacturing businesses
Rubber from dandelions (Germany)	Private sector activity	Large-scale manufacturing company	Large-scale manufacturing company
Blue bioeconomy development (Iceland)	Private sector activity	Start-up, medium- and large-scale manufacturing businesses	Start-up, medium- and large-scale manufacturing businesses
6. TO CREATE AND SECURE EMPLOYMENT THROUGH IN SITU VALUE ADDITION AND ENHANCE RURAL AND URBAN ECONOMIC RESILIENCE			
Integral use of oil palm (Ghana)	Private sector activity	Manufacturing businesses	Small-scale farmers
Seaweed value addition (United Republic of Tanzania)	Development project and private sector activity	Hybrid organizations (clusters) and NGOs	Small manufacturing businesses (women's associations)
Bio-industrial clusters to add value (Malaysia)	Government programme	Hybrid organizations (clusters) and national policy makers	Local farmers and manufacturing businesses
From biomass towns to industrial areas (Japan)	Government programme	Municipal policy makers	Local communities, manufacturing businesses and service providers
Mesa Sucroalcoholera (Argentina)	Government programme	National policy makers	Farmers and manufacturing businesses
Rubber from dandelions (Germany)	Private sector activity	Large-scale manufacturing company	Local farmers
Blue bioeconomy development (Iceland)	Private sector activity	Policy-makers	Hybrid organizations (clusters and innovation hubs) and start-up businesses
Forest bioeconomy cluster (Finland)	Government programme	National and regional governments	Local communities
7. TO PROMOTE ACTIONS THAT CONTRIBUTE TO THE REVITALIZATION AND DEVELOPMENT OF RURAL AREAS			
Integral use of oil palm (Ghana)	Private sector activity	Manufacturing businesses and extensionists	Small-scale farmers
Bioeconomy Community Development Programme (Malaysia)	Development project and government programme	National policy makers	Farmers and medium- and large-scale manufacturing businesses
From biomass towns to industrial areas (Japan)	Government programme	Municipal policy makers	Society as a whole and local communities
Biofibre for clothing (Philippines)	Private sector activity	Manufacturing businesses	Small- and medium-scale farmers
Alternatives to burning straw (China)	Government programme	Policy makers	Farmers, local communities and manufacturing businesses

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
Agroforestry and conservation (Indonesia)	Private sector activity	Manufacturing businesses	Farmers
Mesa Sucroalcoholera (Argentina)	Government programme	National policy makers	Farmers and manufacturing businesses
Family Cattle Producers and Climate Change (Uruguay)	Government programme	National policy makers	Small- and medium-scale farmers and producer associations
Urban circular bioeconomy (United States of America)	Government programme	Municipal policy makers and local cities	Local farmers
Forest bioeconomy cluster (Finland)	Government programme	Regional policy makers and hybrid organizations (clusters)	Local communities and society as a whole
8. TO SUPPORT VULNERABLE STAKEHOLDERS WHO ACT AS GUARDIANS OF NATURAL RESOURCES, INCLUDING LOW-INCOME COMMUNITIES, SMALLHOLDER AGRICULTURAL PRODUCERS AND INDIGENOUS PEOPLES			
Biochar production and use (Ghana)	Development project and R&D&I activity	Manufacturing businesses	Local communities
Integral use of oil palm (Ghana)	Private sector activity	NGOs	Small-scale farmers and small manufacturing businesses
Seaweed value addition (United Republic of Tanzania)	Development project and private sector activity	NGOs and hybrid organizations (clusters)	Small-scale women farmers and small-scale manufacturing businesses
From Farmer to Pharma (South Africa)	Government programme	National policy makers	Local communities and indigenous people
Bioeconomy Community Development Programme (Malaysia)	Development project and government programme	National policy makers and manufacturing businesses	Small- and medium-scale farmers and local communities
Agroforestry and conservation (Indonesia)	Private sector activity	Large-scale manufacturing businesses	Labourers and local communities
Beekeeping dermocosmetics (Colombia)	Private sector activity	Manufacturing businesses	Local communities
Family Cattle Producers and Climate Change (Uruguay)	Government programme	National policy makers	Rural organizations
9. TO MOVE TOWARDS A MORE CIRCULAR BIOECONOMY			
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers	Local communities, society as a whole and manufacturing businesses
From biomass towns to industrial areas (Japan)	Government programme	Municipal policy makers	Society as a whole, manufacturing businesses and service providers
Biofibre for clothing (Philippines)	Private sector activity	Start-up manufacturing businesses and certification bodies	Manufacturing businesses and consumers
Blue bioeconomy development (Iceland)	Private sector activity	Hybrid organizations (clusters and innovation hubs)	Start-up and large-scale manufacturing businesses
Urban circular bioeconomy (United States of America)	Government programme	Municipal policy makers	Society as a whole and manufacturing businesses and service providers
Forest bioeconomy cluster (Finland)	Government programme	Regional policy makers and hybrid organizations (clusters)	Manufacturing businesses and farmers
10. To promote synergies and reduce trade-offs between biomass uses while meeting the growing demand for food and non-food goods			
Biochar production and use (Ghana)	Development project and R&D&I activity	Farmers	Local communities
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers and manufacturing businesses	Society as a whole
National Biomass Strategy (Malaysia)	Government programme	National policy-makers, hybrid organizations (clusters) and financing institutions	Society as a whole, manufacturing businesses and farmers

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
Bio-industrial clusters to add value (Malaysia)	Government programme	Hybrid organizations (clusters) and financing institutions	Manufacturing businesses and local communities
Towards second-generation biofuels (India)	Private sector activity	National policy makers	Manufacturing businesses
Agroforestry and conservation (Indonesia)	Private sector activity	Large-scale manufacturing businesses	Small-scale farmers
Sunflower protein (Brazil)	R&D&I activity and private sector activity	Researchers	Manufacturing businesses
The use of cardoon as biomass (EU and Italy)	R&D&I activity and private sector activity	Regional policy makers and manufacturing businesses	Society as a whole
Forest bioeconomy cluster (Finland)	Government programme	Regional policy-makers and hybrid organizations (clusters)	Manufacturing businesses and farmers
11. TO ESTABLISH LOCAL FAIR AND EQUITABLE VALUE CHAINS OR WEBS BY INCREASING INCLUSIVENESS AND INFORMATION FLOWS			
Integral use of oil palm (Ghana)	Private sector activity	NGOs	Small-scale farmers
From Farmer to Pharma (South Africa)	Government programme	National policy makers	Local communities and indigenous people
Bioeconomy Community Development Programme (Malaysia)	Development project and government programme	National policy makers	Farmers and medium- and large-scale manufacturing businesses
Biofibre for clothing (Philippines)	Private sector activity	Manufacturing businesses and certification bodies	Farmer associations
Mesa Sucroalcoholera (Argentina)	Government programme	Manufacturing businesses and national policy makers	Farmers and manufacturing businesses
Functional use of passion fruit (Brazil)	R&D&I activity and government programme	Policy makers	Local communities
12. TO PROMOTE A TRANSPARENT MONITORING SYSTEM FOR BIOECONOMY DEVELOPMENT AND COMPLIANCE WITH NATIONAL AND/OR INTERNATIONAL SUSTAINABILITY TARGETS			
Bioeconomy Community Development Programme (Malaysia)	Development project and government programme	National policy makers	Farmers and medium- and large-scale manufacturing businesses
National Biomass Strategy (Malaysia)	Government programme	National policy makers	Society as a whole and manufacturing businesses
Agroforestry and conservation (Indonesia)	Private sector activity	Certification bodies and national and international policy makers	Farmers and society as a whole
Family Cattle Producers and Climate Change (Uruguay)	Government programme	National policy makers	Small- and medium-scale farmers
Promoting bioproduct use (United States of America)	Government programme	National policy makers and certification bodies	National manufacturing businesses and consumers
13. TO SUPPORT RESEARCH, DEVELOPMENT AND INNOVATION AND PUT IT INTO PRACTICE TO ACCELERATE THE DEPLOYMENT OF SUSTAINABLE BIOECONOMY			
From Farmer to Pharma (South Africa)	Government programme	National policy makers	National manufacturing businesses and researchers
Bioeconomy Community Development Programme (Malaysia)	Development project and governmental programme	National policy makers	Farmers and manufacturing businesses
National Biomass Strategy (Malaysia)	Government programme	National policy makers and financing institutions	Manufacturing businesses
Alternatives to burning straw (China)	Government programme	Policy makers	Manufacturing businesses
Bio-based plastics from agave residues (Mexico)	Private sector activity	Large-scale manufacturing businesses and research	Consumers

CASE STUDY NAME AND COUNTRY	TYPE OF CASE STUDY	LEADING STAKEHOLDER OF THE SPECIFIC ACTION	BENEFICIARIES OF THE SPECIFIC ACTION
Sunflower protein (Brazil)	R&D&I activity and private sector activity	Researchers	Start-up, small-and medium-scale manufacturing businesses
Functional use of passion fruit (Brazil)	R&D&I activity and government programme	Researchers	Society as a whole and manufacturing businesses
From gas to bio-based plastic (United States of America)	Private sector activity	Large-scale manufacturing businesses	Start-up manufacturing businesses
The use of cardoon as biomass (EU and Italy)	R&D&I and private sector activity	Large-scale manufacturing businesses	Society as a whole
Blue bioeconomy development (Iceland)	Private sector activity	Hybrid organizations (clusters/ innovation hubs) and policy makers	Manufacturing businesses and service providers
14. TO POSITION THE COUNTRY AS AN INTERNATIONAL LEADER IN THE BIOECONOMY AND IMPROVE ITS GLOBAL COMPETITIVENESS IN TRADE AND RESEARCH			
BiomassWeb (Sub-Saharan Africa)	Development project and R&D&I activity	Researchers	National policy makers and society as a whole
Seaweed value addition (United Republic of Tanzania)	Development project and private sector activity	National policy makers and hybrid organizations (clusters)	Farmers and society as a whole
From Farmer to Pharma (South Africa)	Government programme	National policy makers	National manufacturing businesses
Bioeconomy Community Development Programme (Malaysia)	Development project and governmental programme	National policy makers	Manufacturing businesses
National Biomass Strategy (Malaysia)	Government programme	National policy makers and financing institutions	Society as a whole and manufacturing businesses
Bio-industrial clusters to add value (Malaysia)	Government programme	Hybrid organizations (clusters) and national policy makers	Society as a whole and manufacturing businesses
Beekeeping dermocosmetics (Colombia)	Private sector activity	Manufacturing businesses and national policy makers	Local communities and manufacturing businesses
Functional use of passion fruit (Brazil)	R&D&I activity and government programme	National policy makers and researchers	Local communities
15. TO PROMOTE SUSTAINABLE CONSUMPTION AND RAISE THE AWARENESS AND ACCEPTANCE AMONG CONSUMERS AND MANUFACTURERS ABOUT THE GOODS AND SERVICES PROVIDED BY THE BIOECONOMY			
From Farmer to Pharma (South Africa)	Government programme	National policy makers	National manufacturing businesses
Biofibre for clothing (Philippines)	Private sector activity	Start-up manufacturing businesses	Manufacturing businesses and consumers
Alternatives to burning straw (China)	Government programme	Manufacturing businesses	Consumers
Sunflower protein (Brazil)	R&D&I and private sector activity	Researchers and national policy makers	Start-up, small-and medium-scale manufacturing businesses and financing institutions
Promoting bioproduct use (United States of America)	Government programme	National policy-makers	National manufacturing businesses and consumers
The use of cardoon as biomass (EU and Italy)	R&D&I and private sector activity	Large-scale manufacturing businesses and local policy makers	Consumers and financing institutions
Urban circular bioeconomy (United States of America)	Government programme	Municipal policy makers	Consumers and manufacturing businesses

Almost fifty countries have placed the promotion of the bioeconomy on their political agendas. However, bioeconomy activities are not necessarily sustainable, and sustainability issues are not often considered in the implementation of the bioeconomy.

In 2016, FAO published the study '*How sustainability is addressed in official bioeconomy strategies at international, national and regional levels. An overview*'. As a continuation, this report reviews how sustainability is addressed in 26 case studies from around the world and from a variety of different sectors.

The overall aim of the report is to provide examples of how sustainable bioeconomy looks like in practice and to draw lessons from them. By doing so, the case studies expand the general understanding of sustainability in the context of the bioeconomy, ranging from value addition through the processing of seaweed in the United Republic of Tanzania to a public procurement programme for bio-based products in the United States of America.

Each case study is presented in a factsheet, which provides a summarized description of it as well as insights on its strategic objectives and factors of success. The factsheets also show how each case study contributes to the Aspirational Principles and Criteria for Sustainable Bioeconomy and the Sustainable Development Goals.

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