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# BIO-ECONOMY AND THE SUSTAINABILITY OF THE AGRICULTURE AND FOOD SYSTEM: OPPORTUNITIES AND POLICY CHALLENGES

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# *Executive Summary*

This report analyses the opportunities and policy challenges facing the bio-economy in transitioning towards a more sustainable agro-food system. It provides an overview of official national bio-economy-related strategies, based primarily on a literature review and information provided by governments in response to a questionnaire.

## Key findings

Worldwide, due to its promising potential, the bio-economy – "an economic sector" based primarily on biogenic instead of fossil resources – is becoming mainstream in policy making. Across the globe, at least 49 countries, including most OECD countries have bio-economy-related strategies or visions in place. These recognise the opportunity that the bio-economy can provide to address overarching societal challenges, such as food security, climate change, limited natural resources (including fossil fuels), economic growth and increasing demand for food and raw materials.

The agro-food system is a major part of the bio-economy policy agenda. The key findings in terms of the potential contribution of bio-economy to economic growth, its impact on the environment and how policies may impact or support its development are the following:

- There are high expectations that the bio-economy can provide an important contribution to sustainable development of the agro-food system through the creation of new business and innovation opportunities and jobs; the increase in the efficiency and productivity of natural resources; and its help to agriculture to adapt to climate change. The bio-economy can increase the value generated from biomass and stimulate value chains by diligent application of the "cascading use" of biomass and the reuse of waste materials.
- National bio-economy strategies tend to highlight food security (the "food-first-principle") and environmental sustainability as key goals.
- The development of the bio-economy is not intrinsically sustainable. Economic, social and environmental trade-offs and risks are unavoidable. Determining the most cost-efficient use of biological and other resources to meet food, feed, fuel and fibre needs is a major challenge for both private and public policy decision-makers.
- While the reduction of GHG emissions has been a key driver in fostering the development of a bio-economy, there are concerns about the overall GHG savings that will result from feedstock production, land-use changes and bioenergy conversion.
- Concrete empirical evidence of the net overall economic, environmental and social impacts of the bio-economy on the agro-food system is lacking. Better monitoring and assessment is needed.
- The most widespread policy initiatives adopted by governments are those focussing on research, knowledge development and more practical forms of engagement with stakeholders.

- A mix of technology-push and market-pull policy measures are used to expand demand for bio-economy products, such as the development of labels, standards and certification for new bio-based products; and the use of green public procurement to promote bio-economy products. Creating consumers' awareness of the bio-economy products is at the top of national agendas.
- Initiatives to increase the sharing of knowledge through industrial clusters and partnerships related to the bio-economy are increasingly extensive (e.g. co-location of existing and related industries, the provision of shared demonstration facilities and infrastructure). Establishing centres of excellence and databases, promotion of networks (e.g. through innovation clusters), promotion of new business models such as public-private partnerships (PPPs), training and education measures, building pilot and demonstration plants for bio-refining and strengthening international collaboration are common in most bio-economy strategies.
- While the importance of coherence is highlighted in most strategies, this review shows that they, in general, remain relatively vague, while recognising that the development of the bio-economy requires a coherent policy approach that enhance synergies. Coherence needs to be sought in particular across agriculture, food, rural development, environment, forestry, energy, research and innovation, waste and climate change policies that are perceived to foster the development of the bio-economy of the agriculture and food system.
- Although most bio-economy related strategies highlight the need to create bio-economy-friendly framework conditions, only a few countries emphasise the importance of reviewing and harmonising the regulatory framework.
- Besides competing for land use, other challenges and obstacles in developing the bio-economy of the agriculture and food system faced by policy makers include: lack of public awareness and enhancing public acceptance and availability; understanding financing and risks; regulatory restrictions; addressing educational and skills requirements; tackling transport logistics; facilitating market opportunities; enhancing public acceptance and availability; and developing a framework and indicators to monitor and evaluate performance.
- It should be stressed that achieving successful implementation of bio-economy strategies depends on holistic cross-cutting policy approaches to facilitate market development and build consumer trust.

## Policy recommendations

### *Definition and scope of the bio-economy need more clarity*

The concept of the bio-economy is evolving. There is a general recognition that it encompasses more than biotechnology or biofuels. While earlier bio-economy strategies were driven mainly by the search for renewable resources as a substitute feedstock for fossil fuels, more recent strategies also focus on the enhancement of the value (valorisation) of bio-resources, including in the agro-food system. In general, these national bio-economy strategies seek to help achieve the UN Sustainable Development Goals (SDGs), with green growth – a path of economic growth that uses natural resources sustainably – as a key goal.

Nevertheless, a commonly accepted definition is still lacking, while the bio-economy concept is often used interchangeably with other related concepts, such as the "bio-based"

or as part of the "circular economy". A clear understanding of the bio-economy concept would help to better identify the underlying drivers, define objectives, illustrate the value added of bio-economy strategies compared to other sustainable economic approaches and strategies such as green growth, outline the role of bio-economy plays in the agro-food system, and determine the monitoring and assessment requirements.

### *There is a need to ensure that bio-economy leads to sustainability*

Given the dependence of agriculture on biological resources, agro-food systems are prominent in most bio-economy strategies. The agricultural sector plays a central role in the bio-economy in that it is a major provider of biomass for the food and other bio-based industries, such as energy, materials (wood, plastics and clothing), bio-chemicals and bio-pharmaceutical products.

The bio-economy is not intrinsically sustainable. A major risk in developing the bio-economy lies in the increased competition between food supply and non-food biomass production. An important dilemma associated with the bio-economy is that the expansion of the production of industrial products on farms will divert farmland from food production to other uses, and thus the bio-economy will accentuate the "food versus fuel" concerns currently associated with biofuels.

It is essential to identify and implement mechanisms for the sustainable production of biomass. Policy incentives to adopt sustainable agriculture methods that help maintain soil cover and health, increase water-use efficiency and reduce soil erosion are critical. Furthermore, research focussing on ecosystem services, together with technological developments, which help to provide the necessary information and means to make appropriate land-management decisions, and improve the biomass-to-biofuels conversion efficiency, are also required.

### *Policy actions need more coherence and more targeting*

Policy and institutional coherence are prerequisites to reaching the full potential of the bio-economy. This requires ensuring sufficient co-ordination across bio-economy sub-sectors of agriculture, food, forestry, marine, waste and energy. Policies offering incentives for different economic uses of biomass – such as food, feed, bio-based products and bio-energy – in the context of the strategic goals for the bio-economy should be aligned and evaluated. Regulatory frameworks may also need to be assessed and revised, which is often needed to increase the value generated from biomass and to stimulate the creation of value chains.

Several national bio-economy strategies aim at fostering coherence across policy levels and areas by: investing in research, innovation and skills; promoting a participatory governance structure; facilitating informed public dialogue; monitoring progress; and strengthening co-operation at the international, national and regional levels. In this respect, several countries have established inter-ministerial working groups and policy advisory bodies. Some countries have also established dedicated bio-economy councils or panels, which include various stakeholders, to advise on the implementation process. These strategies are encouraging and recommend that they should be disseminated so that other countries can learn from them.

The bio-economy is complex and entails inter-disciplinary knowledge. Developing a skilled workforce for the emerging bio-economy is a major challenge and development of expertise is one of the main concerns of almost all bio-economy-related policy strategies.

The promotion in several strategies of education and training, funding and communication is an encouraging sign for advancing the sustainable implementation of the bio-economy.

### *Diffusion and adoption of innovations are critical*

The review of national strategies reveals many commonalities, in particular the emphasis on research, innovation and technology – which are at the centre of all bio-economy strategies – and the encouragement of public-private partnerships.

Besides biotechnology, the opportunities stemming from a wide range of other novel technologies, such as in bio-engineering, and the development and wider adoption of technologies for energy- and water-saving, are highlighted in most national strategies. Some strategies also mention the possibility to enhance food and nutritional quality while reducing waste, as well as enhancing big data techniques and the Internet of Things. Transferring the latest research results and best practice approaches, including advances in biotechnologies to the farming community, is key to advancing agricultural productivity in a sustainable way.

### *Countries should monitor progress*

There is no internationally agreed methodology today to measure the size of the bio-economy so it is difficult to monitor its development and assess the impacts of bio-economy strategies within and across countries. Most countries only measure the direct contribution to GDP, turnover, employment, exports of the bio-economy sectors – including agriculture and food – the number of firms and businesses operating in bio-economy sectors and the contribution of bio-economy in the energy matrix of the countries. Such indicators provide only a partial and static picture of the bio-economy in the agro-food system and do not inform its development and impact on environmental sustainability.

Monitoring of progress and outcomes is thus a priority as an integral part of policy implementation. Several approaches may be used to measure the bio-economy, but each needs to be scrutinised in regard to what is being measured and how, and trade-offs need to be made transparent. There is no one-size-fits-all approach for measurement given the complexities due to externalities, uncertainties of opportunities, changing preferences and the effect of its development driven by a diverse set of policy measures.

One possible approach is to adopt and adapt the conceptual framework and indicators developed by OECD to monitor progress towards green growth, which focuses on natural resource efficiency and productivity, the environmental performance of production and consumption, on the innovations adopted and policy instruments implemented.

## Policy recommendations for a bio-economy that contributes towards a sustainable agriculture and food system

| Main findings | Key recommendations |
|---|---|
| **Scaling-up the bio-economy** | |
| Absence of an international consensus on the definition of the concept, objectives, and strategy for the bio-economy | Clearly articulate the purpose and aims of developing a bio-economy strategy.<br>Develop a consensus on a definition of the bio-economy concept as the basis for taking forward a shared policy agenda, which can then be compared and contrasted across countries. |
| Weak public awareness of the nature and implications of the bio-economy, and engagement with stakeholders | Explore ways to enhance greater awareness of the bio-economy, its products and technologies: through knowledge transfer of best practices; harnessing advisory services; developing sustainable business models; strengthening public procurement; using consumer awareness campaigns; and implementing product labelling initiatives.<br>Provide the general public with knowledge-based information regarding: key objectives; costs and benefits; and the challenges, opportunities and trade-offs in advancing the bio-economy to contribute to the sustainability of the agro-food system.<br>Include the full range of stakeholders from industry, government, research institutions and civil society in the discussion, dialogue and development of a bio-economy strategy, through the establishment of social dialogue platforms. |
| **Enhancing sustainability performance** | |
| Potential conflicts among sustainability objectives to achieve food security and other demands on natural resources | Identify drivers and barriers that influence the sustainable development of the bio-economy.<br>Outline the priorities and trade-offs for enhancing the sustainable performance of the bio-economy, throughout the agro-food supply chain.<br>Undertake studies to establish the extent and location of critical pressures on land use, at local, national and international levels.<br>Mitigate pressures and potential conflicts on land-use between food production and production of renewable raw materials for energy and industrial materials by adopting approaches that increase production efficiently and sustainably; improve the efficiency of their use; and boost the use of residual products and non-edible food by-products.<br>Address potential conflicts between goals such as “food security versus biomass for fuel”, and competition for land use, through engagement with different actors in the bio-economy, by expanding international research and technological co-operation, and ensuring that any externalities are fully taken into account in assessing social values. |
| Insufficient information and data on market potential and business practices along agro-food supply chains to enhance sustainable performance of the bio-economy | Establish an inventory of initiatives, indicators and case studies on the costs and benefits of the sustainability performance of bio-economy.<br>Tap market growth potential in high-value food and feed sectors by fostering research on renewable raw materials such as economically efficient biomass-use as an energy source and the production of second-generation fuels, as well as by fostering innovations in the agro-food system.<br>Where possible, apply the cascading use of biomass whereby higher value existing or new applications are preferentially derived from biological resources (e.g. food, bio-based materials and chemicals) prior to their use in energy and fuel generation. The by-products emerging, as renewable resources should be utilised as fully as possible in high-value uses, while simultaneously reducing waste. |
| Negative environmental impacts from increasing demand for biomass not sufficiently taken into account | Enhance understanding of the ecological boundaries, the capacity of the environment to replenish itself, and the overall impact on the environment and trade-offs of the bio-economy on the environment through acquiring knowledge of the limits of sustainable biomass supply at the local, regional and global level.<br>Undertake forward looking and cross-sectoral assessments of sustainable biomass supply and demand, including through life cycle analysis. |
| **Enabling policy framework** | |
| Insufficient coherence and targeting of policy measures addressing the bio-economy | Review existing domestic and trade policies and regulations at regional, national and international level which impact on the bio-economy and explore various innovative approaches such as the establishment of inter-Ministerial working groups and stakeholder engagement in order to develop a coherent policy framework for a sustainable bio-economy.<br>Make greater efforts to ensure policy coherence in the design and implementation of a bio-economy strategy as well as among sectoral strategies that impact on the bio-economy.<br>Remove fossil fuel subsidies, phase out biofuel subsidies, apply the polluter pay and provider gets principles to address the negative and positive environmental impacts. |

| Main findings | Key recommendations |
|---|---|
| | Facilitate voluntary agreements (e.g. between actors along the agro-food supply chain); targeted information and advisory services, awareness-raising campaigns (e.g. among consumers, producers and local authorities on ways to reduce food waste). |
| Weak market uptake and consumer confidence | Use a range of policy instruments, including provision of information on the environmental footprint of bio-economy products, public procurement, development of standards, and product labelling.<br>Ensure that bio-economy policies are clear and implemented for the long-term so that businesses have certainty in making investment decisions, and consumers are confident as to the products they buy. |
| The emergence of the bio-economy blurs the distinction between agricultural, environmental, and energy policies | Assess the costs and benefits of implementing bio-economy and related policies in an integrated and joined-up manner, including through reform of institutional and governance structures.<br>Adopt holistic and transparent crosscutting approaches and policies for consumer trust-building. |
| Inadequate diffusion, transparency and adoption of research and innovation | Increase efforts to increase agricultural productivity through investing in innovative R&D such as plant and livestock breeding for precision farming, soil research and measures to adapt to climate change.<br>Encourage deployment of research and innovation through promoting collaboration between research institutions (academia) and industry (e.g. through pilot schemes, demonstrations and benchmarking) in a transparent way.<br>Encourage the development of measures to promote targeted research and knowledge exchange to significantly widen understanding of emerging aspects of the bio-economy, in particular through new and novel technologies.<br>Establish a long-term research and innovation agenda to support the development of new, eco-friendly processes, products and services. |
| New requirements for education and skills for stakeholders | Build up and expand the expertise necessary for a bio-economy by integrating dedicated curricula and training programmes in the higher education and vocational training systems. |
| **Monitoring progress** | |
| Monitoring performance is insufficiently addressed | Develop a list of key indicators of the bio-economy related to the agro-food system.<br>Establish a multilateral platform to discuss – with the aim of reaching consensus - on the design and implementation of a monitoring system, including governance and institutional arrangements, to track the progress towards a sustainable bio-economy to facilitate cross-country comparisons. The OECD conceptual framework to monitor progress towards green growth – which focuses on natural resource efficiency and productivity, the environmental performance of production and consumption, and on the drivers of green growth, such as policy instruments and innovation activity – could provide a useful tool or blueprint in building such a system. |
| Lack of empirical evidence of the economic, environmental and social impacts of bio-economy policies | Identify the economic, social and environmental impacts and trade-offs of bio-economy policies at sectoral and economy-wide levels using quantitative approaches such as partial and general equilibrium modelling and life-cycle analysis.<br>Establish inventories of life cycle case studies prioritising agro-food products most relevant for the bio-economy; and carbon accounting to provide evidence on the contribution of agro-food bio-based products to GHG emissions across the agro-food system. |

# 1. The Bio-economy is gaining prominence on the policy agenda

## 1.1. Setting the scene

1. The food and agriculture sector faces multiple challenges this century: globally, the demand for food and agricultural products is projected to increase substantially due to population and income growth and to associated dietary changes; additional demands are likely to be placed on the sector for the supply of biomass for energy and industrial raw materials; and the need to adapt to climate change.

2. Meeting these demands will place increased pressure on the agro-food sector to supply food and raw materials from scarce natural resources, while ensuring environmental quality. Meeting these challenges in a sustainable way would require developments that can lead to new products and innovative improvements of existing technologies and practices, while also mitigating climate change.

3. The vision of a bio-economy – an economy based primarily on biogenic instead of fossil resources – has gained prominence in the policy debate in recent years as technical progress in microbiology provides new opportunities for using natural resources sustainably. It is frequently argued that the bio-economy can be a key part of the solution to multiple societal challenges, and several visions and strategies have been developed at international, national and regional levels.

4. G***overnments are developing bio-economy strategies with the aim of generating a range of economic and environmental benefits, while also ensuring food security and securing a supply of biomass for other industries*** (FAO, 2016[1]***;*** Von Braun, 2013[2]***;*** El-Chichakli et al., 2016[3])**.** More and more countries are developing holistic national bio-economy strategies – rather than those just related to specific policy areas – as a new development vision to decouple economic growth from dependence on fossil fuel, and as a pathway towards supporting the achievement of some of the UN Sustainable Development Goals (SDGs) and the commitments under the Paris Climate Agreement.

5. The key objective of this report is to provide an overview of the implications for the sustainability of the agriculture and food system that arise from official national bio-economy-related strategies, based primarily on literature and material provided by governments in response to a short questionnaire sent to governments (see Annex A).

6. There are high expectations that the bio-economy can provide a substantial contribution to sustainable development (OECD, 2018[6]; El-Chichakli et al., 2016[3]; OECD, 2009[4]). Some analysts consider the bio-economy as the pathway for achieving key UN SDGs related to food security and nutrition; health and well-being; and clean water and sanitation (Von Braun, 2013[2]). Indeed, the more recent bio-economy policy strategies are aligned with meeting some of the UN SDGs, pursuing increased domestic economic growth, competitiveness and employment, while protecting the environment and fostering social inclusion (Biookonomierat, 2018[5]).

7. Currently, the G7 industrialised countries – and at least 42 others – either have a dedicated bio-economy strategy in place (or related policies) and accord them prominence in their policy agendas, including for the agriculture and food system (OECD, 2018[6];

Biookonomierat, 2018[5]; Biookonomierat, 2015[7]; Staffas, Gustavsson and McCormick, 2013[8]; Priefer, Jörissen and Frör, 2017[9]).

8. The core idea of the bio-economy is the gradual replacement of non-renewable fossil resources used in industrial production and energy supply by renewable biogenic feedstock. This replacement could pave the way for a more sustainable, resource efficient economy and offer opportunities to support growth and jobs, or address climate change, food security and resource depletion (OECD, 2009[4]; OECD, 2013[10]; FAO, 2016[1]; Hansen and Bjørkhaug, 2017[11]; Priefer, Jörissen and Frör, 2017[9]).

9. Food and agriculture is a central part of the bio-economy. Broadly speaking, the term bio-economy means the use of biological feed stocks to generate economic outputs through the production and use of renewable biological resources (biomass) for conversion into commercial products, ranging from food and feed to materials and energy (OECD, 2018[6]; Allen et al., 2015[12]).

10. One of the important developments of the bio-economy that has attracted considerable attention is the use of advanced tools of modern biology to transform established economic sectors, such as agriculture, food, chemical industries, pharmaceuticals and construction industries, while also improving the environment. The bio-economy therefore is not a "new" sector *per se*, but rather a cluster of intersecting value chains in different sectors encompassing agriculture, forestry, fisheries, food processing, and parts of the energy, chemicals and biotechnology sectors.

11. Although some parts of the bio-economy are already long established, the bio-economy has received much attention in recent years due to new technological opportunities as well as efforts to reduce dependency on oil and fossil fuels, often reflecting changing consumer preferences.

12. Although the original use of the concept primarily referred to the use of biotechnologies for economic growth, the bio-economy has now moved beyond biotechnology and is being supported by a wide range of multiple scientific areas (such as life sciences and agronomy), a wide range of technologies (including biotechnology, nanotechnology and communication) and anticipates continuous knowledge transfer. The bio-economy is embedded in the far-reaching transitions that are taking place in energy, transport and industrial production (OECD, 2018[6]).

13. The concept of the bio-economy has been associated with visions of green growth. Developing a bio-economy is seen by some as critical because of its potential role to address three main issues: i) the need for sustainability of resource use; ii) the growing demand for both food and energy; and iii) the need to decouple economic growth from environmental degradation.

14. The bio-economy concept is built on two premises, namely that: i) biomass is currently being underexploited as many waste streams are not used in an optimal way and more materials and energy could be extracted; and ii) the biomass potential can be upgraded by increasing current yields, increasing the amount of productive land, introducing new or improved species that may or may not be generated by various biotechnological advances and introducing new and improved extraction and processing technologies.

15. Estimations point at the potentially significant impacts of bio-economy on growth, competitiveness and job creation along the entire biomass value chain. According to the (OECD, 2009[4]) report, a "business-as-usual" estimate is that bio-economy could contribute up to approximately 2.7% of GDP (of which 39% of industry, 36% of agriculture

and 25% of health applications) in the OECD area by 2030. The OECD report suggests that the key factors in shaping the benefits flowing from the bio-economy will be the "quality" of governance and the economic competitiveness of biotechnology.

16. The actual contribution of the bio-economy to national economies varies from one country to another, but all countries consider that the bio-economy is likely to increasingly contribute to national economies in the future. It is one of the main reasons motivating the development of bio-economy strategies. Some national strategies (**Finland** and **Italy**) set economic targets (in terms of job creation, and output or turnover) for the development of their bio-economy, reflecting the high expectations put on bio-economy development.

17. The **European Union**'s (EU), *Europe 2020 Strategy* calls for a bio-economy as a key element for green growth maintaining competitiveness and creating jobs, which presents opportunities for the agriculture- and food-based sectors (European Commission, 2017[13]; SCAR, 2015[14]), while the *2012 EU Bio-economy Strategy* identifies five objectives to which the strategy and its action plan contribute: i) ensuring food security; ii) managing natural resources sustainably; iii) reducing dependence on non-renewable resources; iv) mitigating and adapting to climate change; and v) creating jobs and maintaining EU competitiveness. The bio-economy is viewed as a potential major contributor to achieving several SDG goals: zero hunger; good health and well-being; clean water; affordable and clean energy; decent work and economic growth (in rural areas); industry and innovation infrastructure; sustainable cities and communities; responsible consumption and production; climate action; and life on land and below water.

18. In the **United States**, the *Billion Ton Bio-economy* strategy suggests that the bio-economy presents significant opportunities for biomass to make positive economic and environmental contributions to the country (US Department of Energy, 2016[15]). It found that a billion dry tonnes of sustainable biomass has the potential, *inter alia*, to produce 1.1 million direct jobs, 25% displacement of transportation fuels with biofuels and 400 million tonnes of $CO_{2e}$ reductions per year. Success, however, is contingent upon developing feed stock supplies, lowering producing costs and enhancing the value of bio-economy products.

19. In general, there is great optimism about the potential benefits and opportunities for the agriculture and food system associated with a growing bio-economy. However, development of the bio-economy is complex as it includes a variety of diverse sectors and stakeholders, and is related to far-reaching changes in production systems and consumption patterns. Essential to the growth of the bio-economy are technologies (e.g. systems to reduce emissions), organisations (e.g. changes in institutional organisation and behaviour), social aspects (e.g. job creation) and policy innovations (El-Chichakli et al., 2016[3]).

20. Achieving sustainable development in the bio-economy poses many challenges, such as addressing climate change and managing natural resources in a sustainable way, and competition between the different uses of biomass, while ensuring social inclusiveness. Sustainable production of renewable resources will be needed, with the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy.

21. Changes in the production of biomass, which a transition to the bio-economy entails, put the agriculture and food sector in the spotlight. As agricultural, trade and environmental policies influence primary production methods, markets and the quality and quantity of products, policies – including agricultural policies – can become a critical tool for facilitating or hindering such transition.

22. Trade-offs and synergies are likely to occur in the transition to bio-economy, not only for production, supply and transport of biomass, but also for skilled labour, land use, new waste streams, market niches or national funds. For example, a study on the prospects of the bio-economy in Europe shows that, whichever scenario is considered, there are no "all wins" options (Philippidis, M'barek and Ferrari, 2016[19]).

23. While the development of bio-economy is in principle consistent with sustainability policy (e.g. green growth), it is necessary to avoid the over-exploitation of natural bio-resources. The growth of the bio-economy calls for an integrated, coherent approach consisting of close co-operation and co-ordination between business, policy makers, civil society and scientists (Philp and Winickoff, 2017[20]). It is therefore important and timely to analyse how coherent and integrated policy approaches might evolve to arrive at more sustainable outcomes for the agriculture and food system.

**Box 1.1. Defining the bio-economy in the report**

The OECD defines the bio-economy as "transforming life science knowledge into new, sustainable, eco-efficient and competitive products" (OECD, 2009[4]). In a similar vein, the first Global Bio-economy Summit held in Berlin 2015 notes that an understanding of "bio-economy as knowledge-based production and utilisation of biological resources, biological processes and principles to sustainably provide goods and services across all economic sectors" is shared by many (Global Bioeconomy Summit, 2015[23]).

The bio-economy encompasses three major elements (OECD, 2009[4]):

- The use of *renewable biomass* and efficient bio-processes to stimulate sustainable production;
- *Enabling and converging technologies*: Beyond biotechnology, a key development is the combination of digitalisation (precision agriculture) and "biologisation";
- *The integration of biotechnology knowledge and applications across sectors*: Integration concerns primary production (i.e. all living natural resources), health (i.e. pharmaceuticals and medical devices), and industry (i.e. chemicals, plastics, enzymes, pulp and paper, bioenergy).

For the purposes of this present report, the "bio-economy" is defined as the production and use of biological resources (aquatic and terrestrial biomass) to produce energy, intermediate and final products. It comprises two groups: i) sectors upstream in the value chain, namely the primary sector (as the supplier of biomass) and other inputs, including technologies sector (R&D), which provides inputs to production; and ii) sectors downstream in the value chain, namely the users of biomass including food and feed, materials (textile and clothing, wood, paper and pulp), chemical, energy and building sectors.

## 1.2. What does the bio-economy encompasses in country strategies?

24. Worldwide, in recent years there has been an increasing of policy development around the bio-economy. Countries and regions are adopting comprehensive strategies and initiatives fostering the advancement of the bio-economy, albeit with some differences that mainly reflect national and regional priorities (Table 1.1). Currently, 49 countries have developed policy strategies related to bio-economy development, 15 of which have a dedicated bio-economy policy strategy in place (Biookonomierat, 2018[5]). In Northern Europe, the Nordic Countries (**Denmark**, **Finland**, **Norway**, **Sweden**, the Faroe Islands, Greenland and **Iceland**) are developing a common Nordic bio-economy

programmes/strategy with 15 action points to boost the transition towards a sustainable bio-economy.

25. Strategies vary considerably in their scope and focus. Some countries, such as in **Germany** and **Finland** take a broad view, encompassing the whole bio-economy within a single strategy at the national level. Others have placed more emphasis on promoting certain aspects of the bio-economy deploying dedicated policies with a thematic focus, such as the **Netherlands** and **Sweden**, while others, such as **Belgium**, adopt a regional approach without an overarching national framework.[1]

26. The **United States** (and South-Africa), for example, focus on the health, agricultural and industry sectors, while in other countries bio-economy strategies cover a wider range of sectors, such as food, forestry and marine bio-economy. For example, in **Germany** and **Norway** the bio-economy encompasses all sectors and related services, which produce, process or use biological resources in whatever form.

**Table 1.1. Bio-economy strategies in selected countries**

| Country/region | Name of the strategy | Level of Strategy | Date | Sectors of interest | Main focus/key funding areas |
|---|---|---|---|---|---|
| **Countries with holistic (across the board) bio-economy strategies** | | | | | |
| Belgium (Flanders) | Bio-economy in Flanders: The vision and strategy of the Government of Flanders for a sustainable and competitive bio-economy in 2030 | Regional | 2014 | Bioenergy, bio-based products | |
| Canada | A Forest Bio-economy Framework for Canada | National | 2017 | Forestry and bio-based industries | Regional development, supply chain and sustainability; support innovation, productivity and competitiveness |
| European Union | Innovating for Sustainable Growth: A Bio-economy for Europe | International | 2012 | Agriculture and forestry, aquaculture and fisheries, bio-based industries, food chain | Research and innovation; Public-Private-Partnerships |
| Finland | The Finnish bio-economy strategy | National | 2014 | Forestry, bioenergy, chemical industry, bio-based products, water bodies and the sea, and fresh water | Mostly focussed on important renewable resources as the biomass in the forests, soil, fields, water bodies |
| France | A bio-economy strategy for France | National | 2017 | Agriculture, forestry, fisheries and aquaculture, bio-based industries, bioenergy, green chemicals | Bioenergy; green chemicals; clusters; circular economy |
| Germany | National policy strategy on bio-economy | National | 2013 | Industrial biotechnology; bio-based products and bioenergy; food and feed | R&D on food security, sustainable agriculture, healthy nutrition, industrial processes, bio-energy |
| Italy | Bio-economy in Italy | National | 2016 | Agriculture, food industry, forestry, marine bio-economy, bio-based industry | |

[1]. The Flemish government, for example established a vision and strategy for a sustainable and competitive bio-economy in 2030.

| | | | | | |
|---|---|---|---|---|---|
| Ireland | The Irish Bio-economy: Definition, Structure, and Situational Analysis | Interim | 2017 | Agriculture, food, forestry, marine resources, bioenergy | |
| Japan | Basic Plan of Biomass Utilisation | National | 2010; 2016 | Agriculture, forestry and fish | Research and innovation, circular economy; regional development |
| Norway | Familiar resources, undreamt of possibilities: the government bio-economy strategy | National | 2016 | Forestry, fisheries and aquaculture | Integrated approach to bio-economy and climate, green shift, circular economy, resource effectivity, low carbon society |
| Nordic Council of Ministers | Future opportunities for bio-economy in the West Nordic Countries | International | 2014 | Fishing industry | |
| Spain | The Spanish bio-economy strategy 2030 horizon | National | 2015 | Food and agriculture, forestry, conditioned by water availability; industrial bio-products and bioenergy | The Strategy is based on the sustainable and efficient production and use of biological resources |
| The Netherlands | Framework Memorandum for a bio-based economy | Policy paper | 2012 | | |
| Sweden | Swedish Research and Innovation Strategy for a Bio-based Economy | National | 2012 | Primary production (forestry, agriculture, aquaculture), bio-based industries, bioenergy | |
| United States | National Bio-economy Blueprint; Billion Ton Strategy | National National | 2012 2016 | Health, agriculture and industry | Life Sciences (Biomedicine) and agriculture (multiple areas) |
| Argentina | Bioeconomia Argentina; Programme on Promoting the Bio-economy | National | 2017 | Agriculture; food; agro-industry; bio-energy | Sustainable energy supply from biomass; innovation (precision agriculture; circular economy.) |
| South-Africa | The bio-economy strategy | National | 2013 | Health, agriculture and industry | The strategy seeks to improve the bio-economy innovation capacity in south Africa. |
| **Countries with bio-economy-related strategies** | | | | | |
| Australia | Research and Innovation | | | Primary industry | Renewable energy technologies; bio-science |
| Austria | Bio-economy Policy Paper | Policy paper | 2013 | Agro-industry, chemicals, timber industry, health care | |
| United Kingdom | Evidencing the bio-economy (2016); Agri-Tech Strategy (2014) | Consultant report ; National | 2016 2014 | Agro-industry; bio-energy; forestry; marine | Bioenergy; agri-science and technology |

27. There are many definitions and descriptions of what constitutes a 'bio-economy', and it is not the purpose of this report to produce a definitive definition. Nevertheless, it is of interest to see how countries defined "bio-economy" in their strategies in order to have a better understanding of their perception of the concept, implications and the role of the agro-food system.

28. Across national bio-economy related-strategies, the bio-economy is mainly defined as a set of sectors or economic activities relating to the invention, development, production and use of biological products and processes. But, as there is no internationally agreed definition of the term "bio-economy", national bio-economy strategies cover and emphasise different sectors; moreover the definition is evolving over time in a given country.

29. Where definitions of the bio-economy exist they are concerned for the most part with the feedstocks that form the component parts of the bio-economy, almost exclusively those of biological origin, and their ultimate end use. Similarly, the term "renewable", features in most of the definitions stressing the sustainability of the bio-economy in the long term compared to a finite fossil fuel alternative.

30. In general, countries with bio-economy strategies could be classified as those with: i) an abundance of renewable biological resources, but a lack of downstream processing industries; ii) both high feedstock potential and advanced processing industries; and iii) low feedstock potential, but advanced processing industries (Bracco et al., 2018[24]).

31. Overall, the bio-economy encompasses the traditional bio-economy sectors, such as agriculture, forestry, fisheries and aquaculture, as well as related processing and service industries, such as food, paper, textiles, building and construction, chemistry and bio-pharma. Key enabling and converging technologies, such as bio-, nano- and information technologies, are vitally important.

32. Even if the scope and content of the bio-economy vision varies, most strategies focus on the production and utilisation of biological resources to generate high-value bio-based products. Generally, national strategies are aimed at growth, new economic opportunities and job creation, but make little reference to production issues and access to biomass. Some refer to the bio-economy in sustainable development issues (e.g. Finland), while others do not (Staffas, Gustavsson and McCormick, 2013[8]).

33. In some countries, bio-economy is seen as an opportunity to develop science-based, high-value industries and emphasise the application of biotechnology in different sectors of activity (e.g. **Australia**, the **United Kingdom**, the **United States**). Existing agricultural strategies have been supplemented by research-focused strategies that target development of industrial biotechnology in the agriculture (and health) sector in particular. Countries with strong industrial structures such as **Germany**, **France**, **Japan** and **Italy** bio-economy strategies emphasise the innovative potential offered by the bio-economy and point to the potential of the bio-economy to reinvigorate specific sectors, including agro-food.

**Box 1.2. Defining bio-economy in national strategies**

**Belgium** (Flanders) (2014): All activities associated with the production of biomass and the various ways in which this biomass and its residual streams are subsequently used.

**European Commission** (2012): The production of renewable biological resources and the conversion of these resources and waste streams into value-added products, such as food, feed, bio-based products and bioenergy. It includes agriculture, forestry, fisheries, food and pulp and paper production, as well as parts of chemical, biotechnological and energy industries.

**Finland** (2014): An economy that relies on renewable natural resources to produce food, energy, products and services.

**France** (2017): The whole range of activities linked to the production, use and processing of bio-resources". The strategy further highlights the circular economy component of the bio-economy. In this respect, the focus is on closing the loop (i.e. by reusing and recycling bio-based resources).

**German Bio-economy Council Communiqué** (2015): The knowledge-based production and utilisation of biological resources, innovative biological processes and principles to sustainably provide goods and services across all economic sectors.

**Italy** (2017): The integration of "the sustainable production of renewable biological resources

and the conversion of these resources and waste streams into value-added products such as food, feed, bio-based products and bioenergy.

**Latvia** (2017): The sustainable utilisation of renewable natural resources (including plants, animals, micro-organisms, etc.) for producing food, feed, industrial products and energy.

**New Zealand** (2017): The set of economic activities relating to the invention, development, production and use of biological products and processes.

**Norway** (2016): The sustainable, effective and profitable production, extraction and use of renewable, biological resources for food and feed, health products, energy, industrial materials, chemicals, paper, textiles and numerous other products.

**Spain** (2015): The set of economic activities based on products and services, generating economic value, making efficient and sustainable use of resources of biological origin as fundamental elements.

**Sweden** (2012): A bio-based economy (bio-economy) is an economy based on sustainable production of biomass and increased added value for biomass materials.

**United Kingdom** (2015): The economic activity derived from utilizing biological resources or bio-processes for the production of value added products such as food, feed, materials, fuels, chemicals, bio-based products (products that are wholly or partly derived from materials of biological origin) and bioenergy.

**United States** (2016): The global industrial transition of sustainably utilising renewable aquatic and terrestrial biomass resources in energy, intermediate and final products for economic, environmental, social and national security benefits (The Federal Activities Report).

**United States** (2016): The sustainable use of domestically produced renewable biomass for fuels, products and power (The Strategic Plan for a Thriving and Sustainable Bio-economy).

**United States** (2012): An economy based on the use of research and innovation in the biological sciences to create economic activity and public benefit.

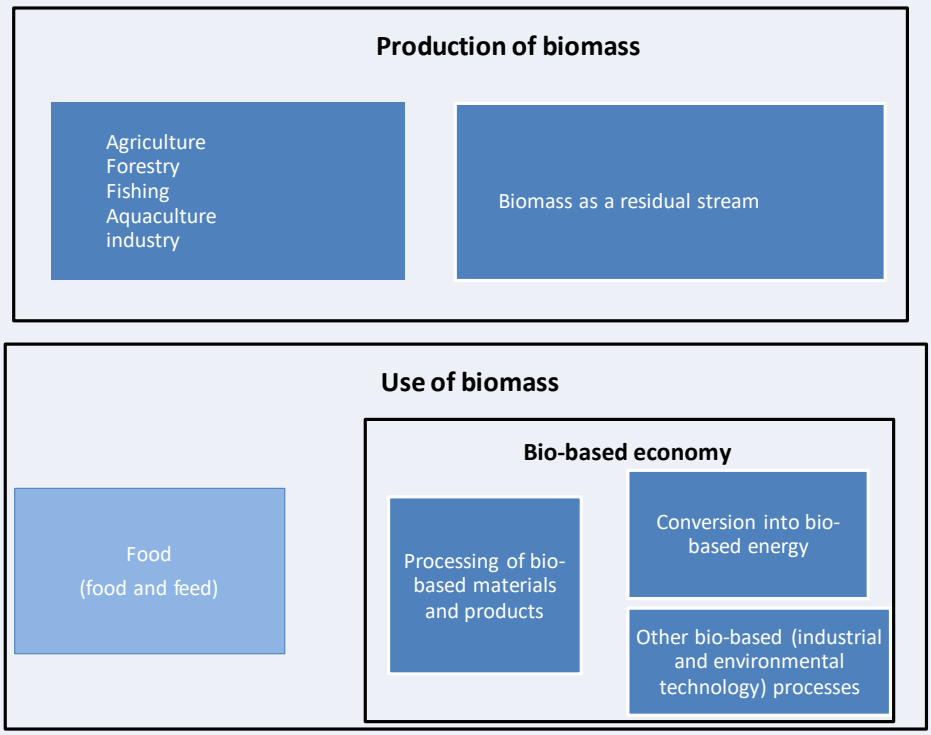
**South Africa** (2013): Activities that make use of bio-innovations, based on biological sources, materials and processes to generate sustainable economic, social and environmental development. (2013): Activities that make use of bio-innovations, based on biological sources, materials and processes to generate sustainable economic, social and environmental development.

34. Many of the bio-economy strategies, particularly in **European Union** Member States, highlight the close relationship of the bio-economy with the bio-based economy (e.g. **Sweden**) and circular economy (e.g. **Ireland**, **Italy**).[2] For example, in Sweden, the term bio-economy is considered equivalent to the bio-based economy based on the sustainable production of biomass and the creation of added value for biomass material (Swedish Research Council (Formas), 2012[25]). In the **Netherlands**, the government has set up the "Bio-based Economy" initiative. However, there are important differences between the two concepts (Box 1.2).

[2] The existing synonyms (i.e. bio-based economy or knowledge-based bio-economy), are often used interchangeably (McCormick and Kautto, 2013[26]).

**Box 1.3. Distinction between the bio-economy and the bio-based economy**

The bio-based economy refers only to the production (including residual stream) and use of biomass for non-food applications (materials, chemicals and other bio-based processes). On the other hand, the bio-economy includes both bio-based economy and the production and use of food and feed. Bio-based products may range from high-value added (usually low volume) fine chemicals such as pharmaceuticals, cosmetics, food/feed additives to high volume materials such as biopolymers, biofuels, fibres, etc. They may include existing bio-based products, such as paper and pulp, detergents, lubricants, construction materials, or new ones, such as vaccines made from plants or second-generation bio-fuels.




*Source*: Vlamse overhead, 2013 in turn adapted from MINA-raad & SALV, 2012, as reported in Allen et al., 2015[12].

### *Agriculture and food are prominent in most bio-economy strategies*

35. The agricultural and food sector plays a key role in the development of the bio-economy as it is a major producer of biomass for food, feed, and also energy. Sustainable agro-food systems have to meet the challenge of producing growing quantities of biomass, while reducing the negative impact on the environment. Hence, while the agriculture and food sectors are included in almost all bio-economy strategies, the emphasis and the way they are covered in the bio-economy strategies also differ (Table 1.2).

36. Countries rich in biomass (Argentina, Brazil, **Finland**, **New Zealand** and **Norway**) concentrate on developing higher added value from primary industries (agriculture, forestry and fisheries). Other countries such as **Australia**, **France**, **Germany** the **Netherlands** and the **United Kingdom** seek to develop high-tech sectors and to stimulate emerging industries. The strategies put forward by **Canada** and the **United States** seek to leverage

their huge areas of forest, coastline and arable land and increase the value of the agricultural and forestry sectors while promoting rural development. In **Belgium** (Flanders) the bio-economy includes the traditional and also the more technology-oriented sectors, in addition to the consumer and logistics sectors.

37. In **Chile**, bio-economy related initiatives are aimed at reducing food-waste, valorising re-use, promoting bio-energy generation (mainly from forestry and pulp waste, and livestock manure) and the development of bio-based agricultural inputs. In addition, there is an increasing interest from both the private and public sectors to promote the production and use of bio-based products, in particular bio-pesticides and bio-fertilisers, and food-ingredients extracted from food waste (e.g. natural colorants and enzymes).

38. Agriculture and the manufacture of food (beverage and tobacco) are dominant sectors of the European bio-economy, thus bio-economy strategies in the **European Union** tend to put a strong emphasis on these two sectors. For the same reason, the **United States** (and South-Africa) bio-economy strategy extensively covers the agricultural sector. The **Finnish**, **Norwegian** and **Swedish** strategies, on another hand, focus more on forestry (the use of wood biomass) and marine resources, which are abundant in Scandinavia.

**Table 1.2. Integration of the agriculture and food system in bio-economy strategies**

| Focus on agriculture | Focus on the food industry | Focus on the food system as a whole |
|---|---|---|
| Australia | Australia | European Union |
| European Union | European Union | Germany |
| Estonia | Finland | Ireland |
| France | France | Italy |
| Germany | Germany | Norway |
| Italy | Italy | Spain |
| Japan | Netherlands | United Kingdom |
| Latvia | New Zealand | |
| Lithuania | Norway | |
| Norway | Spain | |
| Spain | United States | |
| Sweden | | |
| United States | | |
| South Africa | | |

39. The **European Union** bio-economy strategy states with regard to agriculture that its aim is to provide knowledge and tools for productive, resource-efficient and resilient systems for food, feed and bio-based raw materials, in conjunction with policies that support rural livelihoods, without comprising ecosystem services. The **Spanish** strategy seeks to foster positive spillover effects from the primary sector to bio-innovation in other industrial sectors. In the **United States**, the focus of the bio-economy policy has changed in recent years: from a more holistic view of bio- and high-tech innovation across all economic sectors as portrayed in the 2012 Bio-economy Blueprint, towards a more agricultural and bio-resources-based vision (Biookonomierat, 2018[5]).

40. Among identified bio-economy strategies some only cover one of the two sectors. In particular, the **United States** and **Swedish** strategies only cover the bio-economy's contribution of agriculture. The **Finnish** strategy, on the other hand, only covers bio-economy's contribution to the food industry, and does not directly refer to its contribution to agriculture. Remaining strategies cover both the agricultural and food sectors. In addition, a few countries (**Germany**, **Italy** and **Spain**) consider the bio-economy's

contribution to the agro-food system as a whole by developing the idea of bio-economy "value chains".

41. In some OECD countries, the agro-food industry is seen as playing a key role in bio-economy related policy strategies, while in others, such as **Australia**, **France**, the **Netherlands**, **New Zealand** and the **United States** seek to further increase the competitiveness and innovativeness of their food industry. The Italian strategy – in line with the EU – considers as the top priority the sustainability and competitiveness of the agro-food sector.

42. Finally, in several OECD countries, such as **Estonia**, **Ireland**, **Latvia** and **Lithuania**, the bio-economy is often driven more by ministries responsible for agriculture, forestry, fisheries, rural development or economics and less by ministries for industry and innovation (Biookonomierat, 2018[5]).

# Annex 1.A. Questionnaire

For the purposes of this study, the "bio-economy" is defined as the production and use of biological resources (aquatic and terrestrial biomass) to produce energy, intermediate and final products. It comprises two groups: i) sectors upstream in the value chain, namely the primary sector (as the supplier of biomass) and the technologies sector (R&D) which provides inputs to production; and ii) sectors downstream in the value chain, namely the users of biomass including food and feed, materials (textile and clothing, wood, paper and pulp), chemical, energy and building sectors.

1. Which **bio-economy strategies/initiatives** related to the agriculture and food system are being undertaken in your country (at the national or regional level)?

| **Bio-economy strategy / initiative** (for example, these might include knowledge generation; knowledge transfer; generation of value chains; public awareness; and partnerships? | What is the **aim** of the strategy / initiative? | What are the expected **outcomes** of the strategy/ initiative (for example, environmental, societal, including the effects on innovation) | What **policies** have been in place to support these strategies/initiatives, in order to achieve the expected outcomes? | How is progress being **monitored** (such as indicators of take-up, share of value-added and employment, and environmental impacts)? |
|---|---|---|---|---|

2. What do you think are the main **opportunities** that can help achieve the sustainable development of the bio-economy of the agro-food system?

| **Opportunities** for example, the policy and regulatory environment; technological, infrastructural, and institutional structures; training, educational/skills; and consumer acceptance/resistance). | How are the opportunities being **used**? (for example, this might include stakeholder engagement). |
|---|---|

3. What do you think are the main **obstacles / challenges** to the sustainable development of the bio-economy of the agro-food system?

| **Challenges/ obstacles** (for example, this might include the policy and regulatory environment; technological, infrastructural, and institutional structures; training, educational/skills; and consumer resistance). | How are the challenges / obstacles being **addressed**? (for example, this might include stakeholder engagement) |
|---|---|

4. Is there any information or study being undertaken to assess the **current and potential supply and demand for various biomass types** (agricultural, forest-based, and marine sources)?

Please provide details if possible.

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# 2. The bio-economy - an opportunity to foster the sustainability of the agro-food system

## 2.1. Opportunities and challenges

***Widespread benefits are expected ….***

43. The development of a bio-economy is seen as important policy opportunities and challenges for addressing interconnected challenges. The increasing demand for a sustainable supply of food, raw materials and fuels, combined with recent scientific advances, are the major economic driving forces behind the growing prominence of the bio-economy in policy agenda. All bio-economy strategies point out population dynamics, climate change, food insecurity, resource depletion, new technological opportunities and changed preferences as the main factors favouring a transition to a bio-economy.[3]

44. In parallel, there is a growing focus on increasing overall resource efficiency and making better use of wastes, with varying degrees of emphasis between countries. In some countries reducing reliance on industrial raw materials is also seen as a contribution to the bio-economy in terms of reducing the environmental footprint, fostering the circular economy and limiting transport impacts. All these are drivers contributing to the move towards a bio-economy (OECD, 2018[1]).

45. The literature on the bio-economy vision has been evolving and has been clustered under three major perspectives: i) the biotechnology vision, which emphasises innovations and the utilisation of biotechnology at a commercial scale; ii) the bio-resource vision, which emphasises the improvement of value chains in the production of biomass; and iii) the bio-ecology vision, which emphasises the positive impacts of energy and resource optimisation on ecosystem health (Bugge, Hansen and Klitkou, 2016[2]; Bracco et al., 2018[3]). These perspectives underline the potential of the bio-economy to create opportunities, such as low-carbon economic growth, preservation of natural resources, restoration of environmental and ecosystem health, and development of rural areas.

46. Governments highlight a number of contributions of the bio-economy to more productive and sustainable agro-food systems. Without exception, all bio-economy strategies – supported by much of the academic literature – emphasise the bio-economy's economic contribution. In particular, bio-economy strategies refer to its potential to boost economy growth, create jobs, enhance competitiveness of industries, increase value-added and generate new products and businesses through appropriate cascading use of biomass and reuse of waste materials.

47. The strategies (and academic literature) also point to several other potential advantages and opportunities for the agro-food sector of a transition to a bio-economy, including: i) utilising natural resources more efficiently by replacing conventional fossil energy-based sectors with more cost-effective and less polluting bio-based sectors, and by

3. In the European Union, for example, the launching of its Bio-economy Strategy was triggered by the need to respond to grand societal challenges such as food security, sustainable production, mitigating climate change and contributing to global sustainable development.

developing novel bio-based production systems; ii) developing new integrated research structures through knowledge and technology transfer; and iii) reducing of $CO_2$ emissions.

48. The bio-economy is associated with transition from non-renewables to renewables (biofuel, green chemistry) and improvement of husbandry systems (better breeding and raising). Processing agricultural products into renewable materials and energy offers countries an opportunity to increase the value-generation potential of their food system and to enhance their economic development, while improving food security and nutrition (von Braun, 2017[16]). Moreover, the bio-economy could have the potential to reduce GHG emissions (via transition to renewable biofuels and improved crop productivity) and could accelerate adaptation to climate change by allowing the development of new cropping systems in response to varying conditions (Zilberman et al., 2013[17]).

49. Some argue that the bio-economy could also be considered as an overarching framework to assess the sustainability of production chains, adding value to food and agriculture supply chains, integration of digital technologies and management of natural capital (Bellon-Maureel, 2017[18]).

50. In addition, the development of a bio-economy is often seen as a stimulus to rural development as biomass production is usually located in rural areas. Development of bio-economy, for example, is expected to generate new activities and businesses based on the transformation of biological resources (production of bioenergy or bio-based products based on agriculture or forestry biomass/residues), create new jobs, and diversify sources of rural income (Box 2.1).

51. Bio-economy strategies, such as those in Canada, Finland, France, Germany, Italy, Japan, Spain and the United States, emphasise the potential of the bio-economy in creating rural diversification and revitalisation, creating employment opportunities and improving the regional innovation system.

52. In the **European Union**, the CAP Communication published in November 2017 on *The Future of Food and Farming* and the Cork 2.0 Declaration 2016 highlights that harnessing the potential of the bio-economy and the circular economy should be considered as a means to address sustainability in rural areas through establishing sustainable rural value chains and business models. Moreover, in the new delivery model of the post-2020 CAP the national strategic plans have to contain specific actions with regard to bio-economy.

**Box 2.1. Bio-economy – an opportunity for rural regions?**

The transition to a bio-economy might stimulate new business opportunities in rural areas, for example, around the development of bio-refinery facilities (i.e. the processing of biomass into a spectrum of bio-economy products: food, feed, chemicals, materials and bioenergy, biofuels, power and heat). Because it might be more expensive to transport low-value raw materials, rural areas could have a potential comparative advantage in large elements of the bio-economy, which can to some extent counter any economies of scale associated with the centralisation of higher value-added ends of the chain.

However, as with renewable energy – that is also mainly produced in rural regions – there is no guarantee that the development of the bio-economy will boost rural development. Many barriers to the bio-economy development exist. These include: incompatible regulations and standards around bio-wastes; conflicting policy objectives of different ministries and departments; uncertainty over environmental impacts; "one-size-fits all" policies; and simply an absence of consideration to rural development issues or objectives. Moreover, in countries and regions where fossil-fuel economies are well developed, there are significant path dependencies caused by sunk-investments and interest groups, which bio-economy interests have to address. Evidence collected in 16 regional case studies – across 10 countries – demonstrates that the territorial development impacts of renewable energy developments and related policies have been largely over-estimated.

*Source:* OECD (2012), *Linking Renewable Energy to Rural Development*, OECD Publishing, Paris, https://doi.org/10.1787/9789264180444-en

### *…. but there are obstacles to the development of the bio-economy*

53. While the benefits of the bio-economy are increasingly becoming recognised, there remains a range of obstacles to its development, including: weaknesses in policy coherence at different levels (e.g. bioenergy and waste policies); public perceptions; and lack of consumer awareness, which poses major barrier to increasing the market uptake of bio-based products.

54. One study, (Burns, Higson and Hodgson, 2016[4]), identified public perception as a major barrier to the development of the **United Kingdom**'s bio-economy innovation system. Several recommendations for gaining public acceptance of bio-based products are made, including: i) clearer benefits communicated to customers, to put risk and benefit in perspective; ii) stronger regulations to improve public trust and ethical application of new technology; and iii) greater transparency and more genuine public engagement.

55. The EC Expert Group for Bio-based Products (Expert Group's Lead Market Initiative LMI) also identifies lack of awareness and knowledge as a major obstacle to increasing market uptake of bio-based products and recommends the following: i) create conditions for informed consumer behaviour, using meaningful labels and information campaigns; ii) communicate the benefits of bio-based products across the value chain participants including producers, distributors, users and consumers, public authorities and NGOs; and iii) develop trusted business-to-business guidelines and comprehensible labels.

56. Overall, bio-economy is seen to provide major opportunities in multiple sectors and on various levels to create highly skilled jobs and foster competiveness, while opening new markets and developing bio-economy products.

**Box 2.2. EU public consultation results**

In the preparation of its bio-economy strategy in 2011, the European Commission conducted a public consultation on the bio-economy in Europe, which received over 200 submissions from organisations and individuals across most Member States of the European Union. The consultation drew a number of conclusions. The majority of respondents offered an optimistic outlook on the bio-economy, with more than 60% believing that potential benefits could be achieved by 2020 or 2030. The majority of respondents also believed that there are a number of risks associated with the bio-economy, including the potential over-exploitation of natural resources and negative impacts on food security.

A lack of public information and understanding of the bio-economy were also considered important issues, especially regarding benefits and risks, as well as ethical issues and the question of sustainable patterns of consumption and production. In this perspective, more than 70% of the respondents called for actions related to communication and dissemination of information on the bio-economy. Other key themes that emerged in the public consultation included fostering effective governance, promoting collaboration across disciplines and sectors, investing in interdisciplinary education and training, and ensuring robust linkages between research, innovation and implementation.

*Source*: European Commission (EC) (2011), Bio-based economy for Europe: state of play and future potential - Part1 - Report on the European Commission's Public on-line consultation, https://ec.europa.eu/research/consultations/bioeconomy/bio-based-economy-for-europe-part1.pdf

## 2.2. The bio-economy's contribution to primary production

*Optimism about the potential benefits …*

57. A majority of the bio-economy strategies consider that the development of a bio-economy can bring a significant contribution to the agricultural sector or to primary production in general (agriculture and forestry). The bio-economy strategies highlight the bio-economy's potential in fostering more productive and sustainable production systems. Some strategies also refer to more "resilient" and "resource-efficient" production systems (**European Union** and **France**), or to a "sustainable intensification" of biomass production (**Sweden, Norway** and **Spain**).

58. Agriculture has the potential to be at the centre to the bio-economy, providing raw materials for liquid fuels and value-added products (chemicals and materials), while providing healthy and safe food and feed, which, however, may result in trade-offs in terms of choices across the various products produced

59. The bio-economy has many potential applications in agriculture, including: water-use efficiency – producing crops that consume less water; nitrogen-use efficiency – fertiliser-use efficiency; crops that are more resistant to disease; and planting varieties of crops (especially rice) that increase yield and produce less $CO_2$. The move towards developing the bio-economy is seen as potentially bringing with it many opportunities for the agriculture sector. These include:

- New income streams and jobs by utilising new resources and opening up new markets.
- Diversifying farm practices and establishing links to new sectors and businesses.

- Reducing exposure to risk from commodity prices or changes in policy, by transitioning to more resource-efficient business models.
- Lowering costs, through more efficient use of resources and optimising the use of waste resources.

60. New, technologies could support improved productivity, efficiency and resilience, while reducing the environmental footprint. New plant varieties, along with improved methods of management, would allow for crops that are better adapted to growing conditions and improved yields, while irrigation needs, soil erosion, and salinisation could be reduced.

61. Concerning climate change, country strategies see a great opportunity in the bio-economy to minimise GHGs from agriculture. New sources of energy would replace fossil fuel-based products, and the sustainable intensification of agriculture and forestry would help to protect carbon stocks in soils and forests.

62. Regarding food security, the development of the bio-economy is expected to bring about a greater range of useful co-products that could reduce the pressure on food and feed markets in the future (Von Braun, 2013[5]). However, the impacts of bio-economy depends on how some of the key bio-economy value chains are actually evolving, both in terms of market development and in terms of technological progress (e.g. biofuels).

63. Agricultural production provides the basic input for the food-processing sector, but also recycles many by-products, not only from this sector but also from other sectors in the form of animal feed or nutrients applied to the soil. These inputs and their by-products are also important inputs for other, non-food industries to produce bioenergy, chemicals and materials.

64. The strategy in **Spain** seeks to foster positive spillover effects from the primary sector to bio-innovation in other industrial sectors – for example, by supporting bio-refining projects and using residues and by-products from agriculture and the food industry, in order to develop a range of new biomaterials and bio-products (including bio-lubricants, bioplastics, food additives, cosmetics, solvents, chemicals, etc.).

### *… but the potential risks should not be underestimated*

65. In general, while there is great optimism about the benefits and opportunities for the agricultural sector associated with the growing bio-economy, potential risks could arise, particularly if policies are developed and implemented in a partial and non-integrated way. There are also significant risks and trade-offs in the development of a large-scale increase in biomass utilisation.

66. As in conventional agriculture, a major risk in fostering a bio-economy lies in the increased competition between food supply and non-food biomass production. An important dilemma associated with the bio-economy is that the expansion of the production of industrial products on farms will divert farmland from food production to other uses, and thus the bio-economy will accentuate the “food versus fuel” concerns currently associated with biofuels.

67. Moreover, if the transition to a bio-economy is intended to provide cheap biomass for a growing bio-based industry, without giving adequate priority to the use of biomass as food, the transition may generate pressures on food prices. Increased demand for biomass for bio-economy products could undermine food security and can have a significant impact in terms of price levels and price volatility (as has been experienced in the past).

68. Bio-economy strategies often acknowledge such risk and point out the competition between food and fuel as an important challenge (Dietz et al., 2018[1]). A serious concern also relates to the sustainability of biofuels for transport, which are an integral part of the bio-economy.

69. Excessive emphasis on alternative uses of biomass would shift the focus away from food production, but also from the conservation and management of cultural landscapes. Biomass production and use should adhere to sustainability and biodiversity protection objectives. The transition to the bio-economy has to be viewed through the perspective of its overall impact on the environment, on which life cycle analysis can throw light. Such assessments may reveal that certain renewable production processes are inefficient and costly.[4] It should be noted that even after the transition from non-renewable to bio-economy systems, some non-renewable inputs are likely to be needed and used in food production (e.g. phosphorus).

70. The full potential of the bio-economy to contribute to sustainability needs clear policy and governance priorities (Lewandowski, 2015[6]).[5] The transition to systems that rely solely on renewable inputs requires innovations that will lead to better management systems in terms of the precision in the use of inputs, (recycling, crop rotation and nutrient cycling) and their introduction will take time. It may also require different seed varieties (e.g. crops able to fix nitrogen). However, development of such technologies and their adoption will need to be supported by policies to encourage R&D as well as prices that will make adoption worthwhile.

71. The increased use of agricultural (and forest) waste streams for bio-economy e-materials could also have negative effects on the level of organic matter in soil and soil biodiversity, with additional negative impacts on soil fertility and soil productivity. The need to increase crop productivity could lead to the increased use of fertilisers and pesticides, with additional problems related to water and soil pollution. The bio-economy could also aggravate water scarcity in some areas of the world, because it puts additional pressure on water demand. Additional demand for land for food and non-food crops could result in more mono-cultures, negative environmental impacts and increased pressure on natural habitats and biodiversity.

72. While the reduction of GHG emissions has been a key driver in fostering the development of a bio-economy, there are several concerns in relation to the overall GHG savings from feedstock production, land-use changes and bioenergy conversion steps.

73. The growing demand for agricultural biomass associated with the development of the bio-economy has to be met within the context of limited arable land, and declining utilised agricultural areas in many regions/countries, as emphasised in **Germany**'s and the **United States**' strategies. Moreover, as the updated bio-economy strategy of the **EU** points out, it is crucial to ensure that biological resources are used within their sustainability thresholds and that ecosystems are not pushed beyond safe boundaries (e.g. through exceeding the capacity of specific provisioning ecosystem services). Therefore, the

4. For example, life cycle studies found instances where the transition from fossil fuel to biofuels may increase overall GHG emissions (Zilberman et al., 2013[4])

5. See, for example, Menrad, K., Eberle, U., Schmid, O., Vanhemelrijk, J. and Viaggi, D. (2011), Assessment of the Impacts of a European Bio-Based Economy, Report of the External Expert Group on Social, Economic and Environmental Implications of a Bio-Based Economy. Expert report for DG Research, EU Commission Brussels.

necessary increase in biomass production will have to rely on productivity gains and increased resource-efficiency.

74. Two major priorities need to be met as the bio-economy is developed. First, improving agricultural total factor productivity, and second, reducing waste and increasing the efficiency of use of agricultural and other products. There is a great potential to increase agricultural productivity even with the existing technologies – and new technologies that are part of the bio-economy suggest a much larger potential for increasing the productivity of land and water, while preserving biodiversity (Nin-Pratt and Magalhaes, 2018[7]). Mitigating these risks would also require coherent and integrated policies to ensure the long-term economic and environmental sustainability of bio-economy.

75. In **Denmark**, it was found that it would be possible to produce an additional 10 million tonnes of biomass by 2020 within the framework of the existing agriculture and forestry in the country without any adverse impacts on food and animal feed production (Gylling, et al., 2016[8]). It would also be possible to significantly reduce the environmental impact from agriculture and increase biodiversity. Additional biomass can be generated by 15% increase in the recovery of straw, changing to cereal varieties with more straw and by adopting new cropping systems. The first two initiatives could be implemented within a five-year period, while a large-scale transition to new cropping systems is unlikely to be implemented before 2020.

76. A number of strategies promote the principle of *food first*, suggesting that the increase in agricultural biomass production has to be first directed towards meeting the world's food and nutritional needs before supplying raw materials for energy or industrial purposes. This reduces the room for food versus fuel competition, one of the biggest challenges brought about by development of the bio-economy.

77. The sustainability of the large-scale use of biomass for energy production has been questioned (OECD, 2009[9]). Although the bio-economy is concerned with the uses and conversions of biomass, a striking feature in bio-economy strategies is how seldom the sustainability aspect of the use of biomass is mentioned as a driving force.

78. The amounts of biomass available are not sufficient to simultaneously cover large shares of today's energy demands for power generation, industry, construction and transportation. For example, a study by the Thünen-Institute found that, notwithstanding the fact that more than 10% of the agricultural area in **Germany** is currently dedicated to the production of raw materials for energy and material uses, the potential for the generation of energy from residual and waste materials is estimated to be small.[6] Similar results are found in the case of **Japan** (see Chapter 4).

79. It is essential to identify and implement mechanisms for the sustainable production of biomass. Policy incentives to adopt sustainable agriculture methods that help maintain soil cover, increase the overall water-use efficiency at the basin level and reduce soil erosion are critical. Furthermore, research focussing on ecosystem services that help to provide the necessary information to make appropriate land-management decisions is also required. Second, technological developments are needed in order to improve the biomass-to-biofuels conversion efficiency.

6. https://literatur.thuenen.de/digbib_extern/dn053498.pdf

### *… and the bio-economy cannot be considered as inherently sustainable*

80. The bio-economy's contribution to environmental protection and sustainability in general is highlighted in all bio-economy strategies. However, in the scientific literature, there is no consensus on the future impact of the bio-economy on sustainability. (Pfau et al., 2014[10]) reviewed 87 journal articles from different academic disciplines, dealing with the link between the bio-economy and sustainability. It appeared that visions about the relationship between the bio-economy and sustainability differ substantially among the articles reviewed. The more recurrent vision is the one of "conditional benefits", meaning that the bio-economy can contribute to sustainability, but only under certain conditions such as: sustainable biomass production, assessment of production chains and impact, assessment of sustainability, and efficient use of biomass resources.

81. Overall, the main concerns regarding the impact of the bio-economy on sustainability are the following: over-exploitation of renewable natural resources, over-use of soil and water resources, competition between food and fuel, the impact of new crop varieties on soil fertility, unsustainability of bioenergy production.

82. The over-exploitation of biomass has severe consequences that could even result in worsening climate change – deforestation, soil damage and destruction, imperilled water security. In addition, the amount of biomass that can be grown and harvested sustainably – the biomass potential – is not known. Current estimates of how much biomass can be sustainably produced in the future vary widely (OECD, 2018[1]).

## 2.3. The contribution of bio-economy to the food industry

83. The bio-economy is expected to bring a significant contribution to the food industry as well. Even though the contribution of the bio-economy to the food industry has received less attention than its contribution to primary sectors, it is still emphasised in a number of bio-economy strategies.

### *Improved food safety and healthier diets*

84. A key area of focus for the food sector in the evolving bio-economy is on improving food safety. In the livestock sector, for example, the control of animal diseases will continue to remain a priority. Advances in biomedical sciences in the developing bio-economy could have strong links to this sector. In other areas of the food system, the detection and treatment of problems with mycotoxins, E. coli, and other health threats to grains, vegetables, fruits and other products – either in their primary or processed form – will continue to demand greater applications of detection, tracking and treatment capacity from national food safety systems.

85. The **European Union**, **Spanish** and **Italian** strategies cover the potential contribution of the bio-economy in enhancing food safety and promoting consumer health and healthy diets. First, in light of the important increase in food safety incidents, which have increased consumer concern worldwide, the underlying strategies emphasise the need to further invest in research and innovation (R&I) and develop innovative approaches to strengthening food safety, from production to consumption.

86. In a number of countries, including Argentina, **France**, **Italy**, **Latvia**, **New Zealand**, **Norway**, **Spain** and the **United States**, innovations in the agro-food bio-economy are considered increasingly important for improving human health. Innovations in the agro-food sector, for example, should ensure the nutritional quality of foods and food

safety, while promoting long-term benefits for human health. In this context, R&D for functional foods (that is foods that have a potentially positive effect on health beyond basic nutrition) and healthy diets is emphasised. Alternative food resources, such as insects and algae, are also considered promising in countries such as **France** and **Italy**, in order to meet the future demands of protein supply (Biookonomierat, 2018[11]). Finally, with the development of a bio-economy, the food industry might exploit alternative food sources such as insects and algae, which can be used as protein sources in the food and feed industries. The **Finnish** Ministry of Agriculture and Forestry has recently announced that the cultivation and sale of insects as food is now permitted.

87. The **Italian** strategy highlights the need to develop fast on-line detection tools for food and feed safety (to deal with pathogens, allergens, toxins, chemical residues, nanomaterials, etc.) and integrates such tools in risk analysis. The development of innovative ICT tools, devices, and apps for smart food utilisation and domestic food management is also expected to enhance food safety. Moreover, greater integration and communication throughout the supply chain is considered essential.

88. The **European Union** and **Italian** strategies also emphasise the need to raise consumer awareness of the link between food and health, and to create incentives for informed food choices. Beside information and re-formulation policies, some innovative solutions might contribute to more adequate nutrition and dietary choices. The Italian strategy, for instance, proposes the development of smart nutrition solutions (e.g. with improved nutrient bio-availability) to establish how food production technologies, new delivery methods and ICT approaches might be used to provide tailored nutrition solutions and health care. Tailored and targeted nutrition responses to address obesity and ageing populations will have an important market potential according to the **Irish** strategy. The **Germany** strategy also highlights a new market potential for "highly-refined food with a high level of value-added, produced in conformity with the requirements of sustainable agricultural production".

### *New business and markets opportunities in the food industry*

89. According to the **Finnish** and the **Italian** strategies, the development of the bio-economy will bring new business opportunities to the food industry in both traditional and novel food sectors. First, exploiting the opportunities offered by closed systems, bio-refineries, domestic animal production side streams and field biomasses could generate completely new businesses.[7] By-products and streams and waste from the food industry can be converted into added-value food ingredients and bioactive products, bio-chemicals, biomaterials (packaging) and biofuels.

### *Increased resource-efficiency in the food-chain*

90. The development of a bio-economy is also expected to increase resource-efficiency in the food chain. According to the **European Union**, **Italian** and **Spanish** strategies, important reductions in water and energy use and also of waste, could be achieved through improvement of existing processes, the adoption of new technologies and processing methods, and increased circularity and recycling along the food chain (in processing, transport and distribution). Increased resource-efficiency and waste reduction would

[7] See, for example, Appleyard, D. (2014), "Biomass Outlook 2014: Is Biomass About To Go Bang?", Renewable Energy Outlook, February, 2014.

increase the food industry's competitiveness by reducing costs, while providing a positive impact for the environment.

### *New packaging materials for the food industry*

91. A number of strategies also highlight the various advantages of developing biodegradable food packaging (**European Commission**, **Sweden**, **Spain**, **Italy** and **Ireland**). These "new, biodegradable, thinner and/or lighter packaging materials that can be fully re-used, recycled or recovered as energy sources" (EC, 2012[12]) are expected to reduce the environmental footprint of the food industry, contribute to enhanced food safety and shelf-life, preserve taste, and boost the competitiveness of the food and packaging industries.

92. The **Spanish** strategy stresses the contribution of "new processing, wrapping, packing, conservation and cold chain technologies which preserve for a longer period the organoleptic and nutritional qualities" in promoting consumer health and guaranteeing food safety. The **Italian** strategy identifies a number of innovative biodegrable materials that could benefit the food and agricultural sectors, such as for carrier bags and waste bags, bags and gloves for fruits and vegetables, and mulching film. In addition to biodegradable and compostable packaging materials, the **Irish** bio-economy strategy also promotes innovative ideas such as the development of clean labels from fruits and vegetable waste, and packaging for agricultural produce derived from agricultural waste sources using upcycled wheat straw, tomato plant waste, or olive tree residues, for instance (O 'Reilly, 2017[13]).

**Box 2.3. Integrating primary production into the bio-economy value chain – The Matrica complex in Italy**

The Matrica complex in Sardinia, established in 2016, is a third-generation biorefinery, functioning as a green chemistry plant for the development of bioplastics in Italy. The plant utilises local thistle weeds – common weeds that grow throughout the year on poor Sardinian farmland where wheat is no longer profitable – as the main input in bio-lubricants, bio-fillers and bio-plastics. The project was initiated in 2011, when one of the region's most polluting petrochemical plants (which once produced petroleum-based polymers) was shut down and the decision was made to transform it into one of the most innovative green chemistry complexes in the world. Providing economic, social and environmental benefits for the local community, at full capacity the plant will produce up to 70 000 tonnes of bio-products annually, employing almost 700 people and drawing on local raw materials.

*Source*: Bioplastics News (2015), "Turning thistles into Plastics – The Matrica Complex", 20 July 2015, https://bioplasticsnews.com/2015/07/20/turning-thistles-into-plastics-the-matrica-complex/.

### *Bio-economy contribution to the agro-food chain*

93. In addition to its contribution to the agricultural sector and the food industry, the bio-economy is also expected to positively impact the agro-food chain as a whole, mainly through increased resource-efficiency. In this regard, the concept of bio-economy is closely related to the circular economy, as the bio-economy promotes the idea of waste reduction, and recycling and reuse all along the value-chain. The overall aim of developing of a bio-economy is to strengthen existing value-chains and create new ones.

*Increased resource-efficiency in the agro-food chain*

94. As emphasised earlier, the development of the bio-economy entails the more efficient use of all types of resources. The **European Union** and **Italian** strategies mainly emphasise the need to improve resource-efficiency in the "food supply chain'' and "food making value chain". In this regard, both strategies agree on the need to reduce water consumption and energy use, as well as minimise raw material losses and waste production, and to maximise recycling from food processing, through to transport and distribution. This is expected to result from increased resource-efficiency along the food chain by efficiency improvements of existing processes and the adoption of new technologies (water- and energy-saving technologies in particular) and processing methods.

**Box 2.4. Selected flagship projects for agro-food waste and increasing the value of by-products in the European Union**

***So.Fi.A*** (Sustainability of Agrifood supply chain) is an **Italian** project providing innovative technological solutions for the improvement of the sustainability of the national agro-food sector at every level of the supply chain, through climate change adaptation, scrap recovery and waste reduction. Examples of current incentives are the following: valorisation of dairy by-products, especially residues of ricotta cheese and cheese whey, for recuperation of their bio-molecules; strategies for the re-utilisation and valorisation on beef processing by-products and wastes; and new solutions for increasing the efficiency of processing fresh-cut vegetables.

***Agrimax*** is an EU-funded project that is developing and demonstrating the production of multiple, high-value products from crop and food-processing waste. The project aims at maximising the EU's sustainability, while providing new bio-based compounds for the food, packaging and farming sectors. Agrimax will develop two pilot processing plants, one in **Italy** and one in **Spain**, to demonstrate the technical and commercial feasibility of extracting high-value compounds from agricultural and food processing waste. By applying them sequentially, Agrimax will produce a cascade of bio-based compounds with high-value applications, such as: packaging (bio-polymers, bio-composites, bio-based coatings, active packaging, stabilising agents), food (additives, ingredients, natural flavourings, edible coatings, microbial growth media) and agricultural materials (biodegradable pots, mulching films, bio-fertilisers).

***Agrocycle***, an EU Horizon 2020 research and innovation project, addresses the recycling and valorisation of waste from the agro-food sector. The project takes an holistic approach to understanding and addressing how to make best use of the full range of waste streams associated with the agro-food industry. It will deliver the AgroCycle Protocol, a blueprint for achieving sustainable agro-food waste valorisation.

***AgriBioMéthane*** is a **French** project using manure from four cattle farms – as well as by-products and waste from local agro-food enterprises – to produce biogas, which is refined into biomethane. The biomethane is then injected into the gas network of the town of Mortagne-sur-Sèvre and used as fuel for school buses.

*Source*: http://www.clusteragrifood.it/images/progetti/Poster%20-20SOFIA%20- %20ENG.pdf; http://agrimax-project.eu/#overview; http://www.agrocycle.eu/; http://www.agribiomethane.fr/.

95. The **Spanish** and **German** strategies go one step further, by considering the need to improve resource-efficiency in the food system as a whole and along the agro-food chain: starting from production and via transport, storage, processing and marketing, through to

consumption. These strategies mainly highlight the importance of cutting residues and minimising losses and fostering the recovery of all waste and by-products as raw material for other productive processes. In this regard, the development of technologies for facilitating the recycling and recuperation of raw materials will be essential.

*Strengthening existing value chains and developing new ones*

96. It is characteristic of the bio-economy that the value chains of its products in the various business sectors become increasingly interlinked, and that by-products and residual materials are used in such a way as to achieve the highest possible value. In many instances, synergies exist between various paths of biomass use. For example, feed products are generated as by-products when plant oil is made, or the production of cereals generates straw, which can be used as a material or as an energy source.

97. Within the general realm of the bio-economy there are many examples of how materials from one value chain can feed into the development of a new value-added chain. The EU ***AgroCycle*** project, for example, outlines some of these possible pathways (Box 2.4).

98. A number of bio-economy strategies (**European Union**, **Germany**, **Spain** and **Flanders**) promote the principle of the *cascading use of biomass* and waste streams. This refers to the idea that biomass from primary production as well as from residual and waste streams must provide sources of: firstly, food and animal feed (guaranteed to meet food safety standards); then raw materials; and subsequently energy (OECD, 2018[1]; Government of Ireland, 2018[14]). The cascading use principle gives priority to higher value uses that allow the reuse and recycling of products and raw materials and promotes energy use only when other options are starting to run out.

99. The cascading use of biomass is seen as a way to increase the productivity and efficient use of scarce and valuable raw materials. The basic idea is that, along the chains, the biomass must be kept in the production chain for as long as possible in its various forms through reuse, being split into different fractions and by utilising residual streams. In this way, economic and societal value can be generated several times from the same biomass. However, proper implementation of the biomass cascading should take into consideration the regional and local economic and technological circumstances, the maintenance of the necessary carbon stock in the soil and the quality of soil and ecosystems.

100. Future development of the bio-economy may also bring about a radical redesign of products and processes and create a demand for new skills and open new markets for the agro-food sector. At the same time, it may make some of the old products, processes and skills obsolete (SCAR, 2015[15]). The net effect will depend on the way bio-economic strategies are implemented. A bio-economy based on large-scale industrial plants may result in a concentration and intensification of international trade, with an uneven geographical and social distribution of costs and benefits and a net loss of jobs. Focusing on bulk biomass production may generate low-skilled and low-paid jobs, while focusing on high-added value would generate demand for skilled jobs.

101. Overall, increased knowledge and better understanding of biological systems, their functioning and their interactions, is expected to foster new production methods. The **Italian** strategy highlights the need to "explore the sustainability potential" of different models of agricultural production, such as: climate-smart agriculture, precision farming, ecological intensification, agro-ecology and regenerative agriculture. The **French** strategy

also emphasises the need to adopt "balanced and diversified production systems more integrated into natural systems", such as agro-ecology and organic farming.

**Box 2.5. The principle of cascading use of natural resources**

The principle of the cascading use of natural resources has risen to prominence in recent years and it has become a commonly recurring concept within the European Union in policy discussions about renewable energy, the bio-economy economy and the "circular" economy.

Cascading can be useful as a descriptive framework for how to increase natural resource efficiency, but its implementation is complex and needs to address questions such as: which specific objective should be achieved through cascading? How to determine the value of a specific use (e.g. the actual "value" of a specific use of biomass strongly depends on the local needs and the specific infrastructure)? And which economic, environmental and social aspects should be taken into account?

Assuming that cascading is always sustainable can be misleading. Implementation of the cascading principle to promote the highest economic added value must also consider its environmental and social impacts. For example, its implementation should optimise synergies between the cascading use of biomass and its externalities in each particular case (e.g. in terms of emissions, social impacts, environmental damage, loss of biodiversity or other impacts).

### *Towards circular agro-food chains*

102. The concept of bio-economy is in certain ways related to the circular economy (Box 2.6). The main objective of the bio-economy is the production and use of biomass, while the circular economy is focused on the use and reuse of products and on closing the loop within major cycles. The circular economy strives to meet these objectives via reuse, recycling and closing loops, while the bio-economy focuses on renewable raw materials (D'Amato et al., 2017[16]).

103. In bio-economy strategies, the use of biological resources has been increasingly linked to this circular economy concept. For example, in December 2015 the **European Union** adopted a circular economy strategy to promote resource efficiency across industries and member states.[8] Practically all of the European bio-economy-related strategies published since 2015 highlight the compatibility of the concepts and the contribution of the bio-economy to circular economy approaches (including those of **Finland**, **France**, **Italy**, **Latvia**, **Norway**, **Spain** and the **United Kingdom**). The Italian bio-economy strategy even introduces the term "circular bio-economy".[9] In Argentina and **Canada**, the circular economy concept has also received considerable attention within bio-economy-related policy strategies.

8. https://ec.europa.eu/commission/priorities/jobs-growth-and-investment/towards-circular-economy_en.

9. The European Union also uses this term in its present roadmap for preparing an update of the bio-economy strategy and action plan of 2012.

**Box 2.6. The circular economy and its implications for the food system**

The circular economy can be defined as the transition from the existing linear economy (harvesting, producing, waste), with final resources to an economy in which raw materials and products remain in a closed cycle. The circular approach embraces a system view and considers the efficiency of the system as a whole by combining all production chains rather than the single production chain itself.

Current agro-food systems largely take the form of the linear production chain: a commodity is converted into food, and waste is generated along the process. Some recycling of production waste is performed, but it is not complete circularity, which is an integrated system and means zero waste.

Increased circularity in food production systems offers ways to increase food production without increasing biomass production, through waste reduction and re-use. The main idea is to make full use of all the biomass generated. This can be achieved by the adoption of an integrated approach of crop and livestock production within a circular production system, which maximises the overall production of nutritious food for human consumption, while minimising the environmental impact, and enhancing carbon sequestration in the soil. It mainly implies adding value to *multipurpose cropping* and of *animal manure.*

Adding value to *multipurpose cropping* entails the production of biomass for food, feed and non-food purposes from the same crop, by exploiting crop biomass to the fullest extent (increasing synergies between food and feed, and food and non-food products). First, smart food processing can make it possible to extract all the biomass that can be converted into human food. Then, the remaining biomass (that can be digested by animals, but not by humans) can be converted into feed. Finally, any resulting waste that has nutritional value can be composted, and insects (or fungi mushrooms) can be grown on the compost. Insects can, in turn, be used as a source of protein for food and feed. Finally, ecological intensification of grassland areas can also contribute to producing more food. Adding value to *animal manure* is achieved by "loading up" the soil with organic matter to increase carbon sequestration.

Circular crop and livestock systems would lead to reductions of GHG emission due to: lower product emission intensity, as more products are produced out of the same crop; increased carbon sequestration (due to manure organic matter); and better management of livestock production.

*Note*: For more information see the workshop on the Circular Approach and the Sustainability of the Agro-food System: - Closing Resource Loops to Improve Sustainability organised by the OECD and the Dutch Ministry of Agriculture, Nature and Food Quality (https://oe.cd/casafs).

104. The **German** and **Italian** strategies both highlight the potential of urban agriculture in fostering a more circular economy. For example, residual materials and waste materials generated locally and exploitable for energy purposes can be used in "urban farming", as can waste heat. In turn, small industries and agriculture can increase production if side streams from urban and peri-urban and local food production are utilised for nutrient recycling and local bioenergy production.

105. Both concepts promote the idea of increased resource-efficiency through generating less waste and increasing waste recycling. There is an important degree of scope for reducing waste and losses along the agro-food chain. New cultivation and harvesting

technologies, for instance, can help by reducing biomass waste from the beginning of the chain. Post-harvest losses and storage losses could also be reduced, as well as waste generated by processing, trade and consumption. Further reducing waste along the agro-food chain will require increased integration between sectors and better communication and co-ordination along the value-chain.

106. Thus, most bio-economy strategies include some reference to waste, either by the identification of genuine waste streams, or through promoting the use of industrial side-streams, such as agricultural or forestry residues and paper pulp. Such strategies highlight the importance of reducing waste and residues and recovering remaining waste and by-products as raw material for other productive processes or the creation of new value-added products. Bio-economy strategies point out that bio-waste, including agro-food waste, are currently under-used and under-valued, with possible negative consequences on the environment.

**Box 2.7. Efficient energy recycling using biomass – the biogas plant in Hokkaido (Japan)**

A centralised biomass treatment facility (biogas plant and composting plant) collects and treats manure from livestock farming (mainly dairy farming) which is a key industry in the area. A key objective of the plant is to improve the local environment by reducing the odour from cattle waste and lowering nitrogen leaching. It aims to produce high-quality compost derived from waste biomass, establishing systematised technologies to utilise biomass by using biogas energy. In the case of the biogas plant in Shikaoi Town, Hokkaido the power generated from biogas is primarily used in the facility and the rest of the power is sold to the Hokkaido Electric Power Corporation. Liquid derived from the biogas plant is used as fertiliser in farmland and thus promotes at local level the recycling-based society. Greenhouse cultivation of agricultural products and aquaculture is also conducted by using the heat generated by the biogas plant. The plant generates a daily total of roughly 6 200kWh, which is equivalent to the amount of electric power used by 490 Japanese households every day. The power generated by the plant will be used in the facility, and the surplus electricity will be sold to pay for the facility's operating costs.

107. The strategies therefore focus on promoting R&D on new and improved bio-based products. Many countries consider bio-refinery development as important for converting bio-based resources into innovative products. It is equally important to develop new resource alternatives for industrial use, such as organic waste and residues and by-products from agriculture, forestry and fisheries (Biookonomierat, 2018[11]).

108. The **Italian** strategy gives a number of possible ways of recovering and valorising agro-food waste. The strategy considers that, by adopting innovative processes, by- and side-products and waste from agro-food processing industries can be exploited and placed on the market as new foods or fodders, ingredients or bioactive compounds with a high nutritional value, or transformed into biodegradable food packaging. It also highlights the importance of using agro-food waste for composting, which contributes to reduce the depletion of soil organic matter (when used as fertiliser).

## 2.4. Innovating for growth of sustainable agriculture and food

109. Historically, technological advances have contributed significantly to the development of the agro-food sector, and research and innovation are essential to the development of the bio-economy. Some of the applications envisaged in the bio-economy are innovative and require additional R&D. The production and use of the necessary biomass also require innovative approaches. Moreover, systemic approaches focused on the bio-economy as a whole and its economic, environmental and social impacts also need to be underpinned by research (Gouvernement Francais, 2018[17]; Zilberman et al., 2018[1]).

110. The 2009 OECD report (OECD, 2009[9]) proposed boosting agricultural and industrial research through increased research funding from the public sector, reduced regulatory constraints and encouragement of public–private partnerships in these sectors. This is because 75% of the future economic contribution to the bio-economy is likely to come from agricultural and industrial applications. It also proposed the use of biotechnology to address global environmental issues by supporting international agreements to create and sustain markets for environmentally sustainable biotechnology products.

111. All bio-economy strategies agree that a positive contribution to the agro-food sector will be brought about mainly through increases in research and innovation, and the development and adoption of new methods, techniques and technologies. A prime example of what can be achieved in the bio-economy through research and innovation is the success of Glanbia in Ireland in transforming whey protein, a side-stream product of the dairy industry with limited value, into a critical ingredient in the global human nutrition market (Box 2.8).

**Box 2.8. Transforming low value by-products to high-value bio-commodities: the case of Glanbia-led AgriChemWhey project in Ireland**

Based on a new bio-economy campus, this innovative research project aims to convert low-value by-products from the dairy industry into a series of high value-added bio-based products, including biodegradable plastics. This flagship plant represents Ireland's first major industrial venture to convert residues from food processing, as second-generation feedstocks, to value-added bio-based products.

AgriChemWhey will build a state-of-the art, industrial-scale bio-refinery with integrated symbiotic industrial and agricultural value chains that will valorise more than 25 000 tonnes (100% dry matter) per annum of excess whey permeate and delactosed whey permeate to several added-value products, including biodegradable plastics, bio-based fertiliser and minerals for human nutrition.

The plant will investigate the techno-economic viability of the innovative bio-refinery technology and will establish a new value chain for industrial symbiosis with other local companies for the production of high-value sustainable food and feed products from other side-streams. It offers the opportunity for greater resource efficiency (less food waste, more products from raw milk, and the integration of food and non-food material production) and for harnessing the potential of by-products from the dairy processing stream, both of which are important elements in creating a circular bio-economy for the dairy industry. The AgriChemWhey will also strengthen the environmental sustainability of the sector, while offering new opportunities for rural employment and development.

AgriChemWhey is based on groundbreaking technology developed and patented by

Glanbia Ireland, in collaboration with University College Dublin and Trinity College Dublin. The overall cost of the project is EUR 30 million, of which EUR 22 million is EU funding from the Bio-Based Industries Joint Undertaking (BBI JU) under the European Union's Horizon 2020 research and innovation programme. If successful, the project will serve as a flagship for Europe's growing bio-economy, with potential for replication in other regions across Europe. The project runs until end-2021.

112. Research and innovation are at the centre of all bio-economy strategies. In particular, the bio-economy is seen as closely related to ongoing key technology trends in industry (such as in the fields of synthetic biology, big data techniques, additive manufacturing and the Internet of Things (IoT),[10] nanomaterials, and artificial intelligence).

113. Technology features as a key, defining component in the bio-economy in many strategies, including in the **United States**; as a central part in **Italy** with reference to the bio-refinery concept; with reference to the knowledge-based use of biological materials in **Germany**; and explicitly, as a necessary enabling tool, in the **Flanders**'s vision.

114. The **United States** strategy is strongly focused on research and innovation in the biological sciences. The **Swedish** strategy (which focus on research and innovation) defines the main priorities for the development of a bio-based economy, while the **Netherlands** places the emphasis on biomass production, innovation, sustainability and coherent policy. **Germany** has established a national Bio-economy Council, which focuses on the economy, innovation, education and policy. Overall, most bio-economy strategies include a research and innovation agenda and support the development of an innovation-driven and knowledge-based bio-economy. In the **United Kingdom**, the use of technology in the development of the bio-economy is made explicit in the House of Lord's report on waste.

115. Countries rich in bio-resources such as Argentina, Brazil, **Canada**, **France**, **Italy**, **Latvia**, **New Zealand**, **Norway**, **Spain** and the **United States** promote innovations in their primary industries, including agriculture, forestry, fisheries and aquaculture, to ensure sustainable development. Consequently, R&D in sustainable intensification, climate-smart agriculture and forestry, precision agriculture and livestock farming are considered promising.

116. The purpose of the **Swedish** strategy – which was published by the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning in collaboration with the Swedish Energy Agency and the Swedish Innovation Agency – is to form a basis for a research and innovation bill from the government. In the **United Kingdom**, the use of technology in the development of new aspects of the bio-economy is made explicitly. In the **European Union**, bio-economy related research and innovation (R&I) is a priority for most EU countries and regions in 2014-20, and an "agro-food" focus is most common within bio-economy related research and innovation.

117. The bio-economy entails the use of biotechnology on a large scale. The OECD has estimated that by 2030 biotechnology could contribute up to 50% of primary production, 80% of pharmaceutical production and 35% of industrial production in sectors where

[10] IoT refers to an ecosystem in which applications and services are driven by data collected from devices that sense and interface with the physical world. In the IoT, devices and objects have communication connectivity, either a direct connection to the internet or mediated through local or wide area networks. Important IoT application domains span almost all major economic sectors, such as health, education, agriculture, transportation, manufacturing and electric grids.

biotechnology has potential applications (OECD, 2009[9]).[11] Advances in biotechnology are considered as the basis for addressing the main challenges impacting the agricultural sector in the context of the bio-economy. The majority of bio-economy strategies that address this point recognise the importance of bio-technology in achieving a more productive and sustainable agricultural sector.

118. Against the backdrop of the debate on trade-offs between food security and renewable energy, priority is increasingly being given to R&D on non-food feedstock and on biotech innovations enabling 2nd- and 3rd-generation biofuels (e.g. **Japan**, **Denmark**, **United States**).

### *Opportunities for plants and animal breeding*

119. In the context of the bio-economy, advances in breeding techniques are seen as a way of developing plants and animals with "desirable traits" (Zilberman et al., 2018[1]). Bio-economy strategies highlight the potential of breeding techniques in: i) increasing the adaptive capacity of plants and animals by a changing environment (e.g. improving the heat-resistance and drought-tolerance of crops); ii) addressing biotic and abiotic stresses (mainly linked to the need to adapt to climate change); iii) enhancing disease resistance; iv) increasing production, yields, efficiency; v) creating opportunities for alternative animal feeds;[12] vi) reducing the need for external inputs (fertilisers, insecticides, water); and vii) increasing nutritional value.[13]

120. Policy strategies in Argentina, Brazil, China, **France**, **Latvia**, **New Zealand**, **Norway**, **Spain** and the **United States** highlight the potential of genetic improvements to increase yields and the quality of crops, while the **Italian** and French strategies also include enhancing the photosynthetic capacity of plants (Biookonomierat, 2018[11]).

### *Opportunities for managing plant and animal diseases*

121. Alternative technologies and practices such as integrated pest management or the use of robotics for weed control are gaining ground. Scientific advances are also providing new opportunities for managing livestock disease, both in terms of new diagnostic methods, as well as new vaccines. Advances in plant breeding that allow plants to photosynthesize more efficiently and capture more carbon dioxide could positively affect climate change mitigation, yields and nutrition, while reducing pressure on land.

122. The **European Union**'s strategy, for instance, emphasises the need for further progress on bioremediation – a biotechnology application used to clean up polluted soils and water by removing toxic compounds. The **United States**' bio-economy strategies

11. The OECD defines biotechnology as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services" (OECD, 2009[3]).

12. Estimates show that 58% of the world's biomass was used for animal feed in 2011, but with potentially competing uses of biomass with the growth of a bio-economy, this may not be sustainable.

13. The OECD Conference on Genome Editing: Applications in Agriculture – Implications for Health, Environment and Regulation held from 28-29 June 2018 explored the safety and regulatory considerations raised by genome edited products, including the regulatory questions associated with genome editing applications in agriculture (see http://www.oecd.org/environment/genome-editing-agriculture/).

highlight the role of biotechnology institutions in developing vaccines and diagnostic kits to mitigate the risk of potentially devastating outbreaks of livestock diseases.

### *Opportunities from engineering technologies*

123. Precision agriculture and related technologies such as digital technologies (sensors, digital platforms, robots, internet applications, drones, etc.) hold the promise of achieving more resilient, productive and sustainable agriculture and food systems. They can also provide an opportunity for governments to improve the efficiency and effectiveness of existing policies (OECD, 2016[18]; Bellon-Maureel, 2017[19]; Tripoli and Schmidhuber, 2018[20]; OECD, 2018[21]).

124. **Italy**, **France**, **Germany, Norway** and **Spain** all refer to the potential of ***precision farming*** in increasing agricultural sustainability, mainly though the more efficient use of fertilisers and plant-protection products. Further research into precision farming is therefore considered a priority.

125. Argentina, Brazil, **France**, **Italy**, **Latvia**, **New Zealand**, **Norway**, **Spain**, the **United Kingdom** and the **United States** mention the importance of converging technologies, such as biotechnology, nanotechnology, the "omics" technologies and ICT, to facilitate the development of innovative bio-based processes, products and services.

126. Only a few countries link bio-economy development directly to *digitisation*. Brazil, Republic of China, **New Zealand**, the **Spanish** region of Extremadura and the **United Kingdom** highlight the potential arising from combining both digital and biological technologies for modernising existing industries and businesses and for developing completely new sustainable industries and business models.

### *Increased research into biodiversity and ecosystem services*

127. As a prerequisite for the sustainable production of any bio-resources, most strategies support R&D for the purpose of ecosystem conservation, recovery and restoration. Several strategies emphasise the need to improve resource management and increase soil, water and air quality by using modern technologies, such as bio-technology.[14] Agro-ecological and organic farming management approaches are also considered important in Brazil, **France**, **Italy**, **Latvia**, and **Spain**, while the newer concepts of urban greening and urban farming receive special attention in the **Canadian** and the **Italian** bio-economy strategy.

128. Aside from the need to further advance on research and innovation, most bio-economy strategies also acknowledge the need for "better knowledge of how plant nutrients and water circulate and are released or fixed by the ecosystem". Additional research and innovation in those underlying areas is supposed to foster more productive and sustainable production systems by transforming resource management and agricultural practices.

129. Bio-economy strategies agree on the need to foster *sustainable soil management* in agriculture. The **European Union** strategy highlights the potential of research in promoting the sustainable management of soil and exploiting advances in conservation agriculture.

14. Examples include: i) the use of bioremediation – using micro-organisms to remove toxic compounds from soil, water or air; ii) improved crop varieties that require less tillage (reducing soil erosion and compaction) or fewer pesticides and fertilisers (reducing water pollution); iii) and industrial biotechnology applications that reduce GHG emissions from chemical production (e.g. biotechnological processes to produce chemicals and plastics) (OECD, 2016[2]).

**Germany**'s strategy emphasises the contribution of progressive farming methods, maintaining and improving soil quality, to enhance productivity without damaging the environment.[15] Finally, **Italy** stresses the importance of investment to ensure that agricultural practices and farming systems that improve the fertility and quality of soils, and their various ecosystem functions are researched and implemented by farmers.

130. Better *management of soil nutrients* is also considered essential for the development of a sustainable bio-economy. **Sweden**, **Germany** and **Spain** emphasise the need for the more efficient use of fertilisers and plant-protection products. **Italy**'s strategy stresses the need to reduce nitrogen and phosphate utilisation in order to lower agriculture's GHG emissions. **Ireland**'s strategy stresses the positive contribution that new fertiliser technologies and an increasing awareness of soil nutrient management have had on improving yields, while **Norway** promotes the increased use of organic fertilisers.

131. Efficiency *improvement in the use of water* in agriculture is also considered as a priority, especially in the context of climate change. The **German** strategy refers to the growing importance of irrigation and the more effective use of water, necessitating the introduction and wider adoption of water-saving technologies. Water-saving technologies can also contribute to reduce energy consumption. The **Italian** strategy emphasises the need to improve water use and management in agriculture, particularly through innovative tools and strategies (such as sensors, networks, DSS) that help to rationalise water use.

132. The development of a bio-economy is also expected to foster *climate change mitigation*. New plant varieties that require less fertilisers and plant-protection products, combined with increased plant carbon sequestration, are expected to contribute to lower GHG emissions. Modern animal breeding techniques and better management of livestock would also help to reduce the harmful environmental impacts of animal production. In addition, a number of countries agree on the need to adopt more sustainable production methods, such as climate-smart agriculture, precision farming, ecological intensification, agro-ecology and regenerative agriculture. Increased integration of information and communication technology (ICT) would also support resilience to climate change, as well as model-based adaptation and mitigation and connectivity along the product chain.

133. Bio-economy strategies stress the need to develop adaptation measures in order to cope with climate change, and limit negative effects on both crops and livestock. Bio-economy strategies highlight the importance of increasing the resilience and adaptive capacity of plants, crops and livestock to rapidly changing climate conditions and environments.

134. In the context of climate change, there is also a need to promote the more efficient use of water in agriculture. Bio-economy strategies support the introduction and wider adoption of water-saving technologies. The further development of irrigation measures in regions with increasing dry periods and the fostering of optimal management practices for irrigation and water recycling will also be essential. **Italy's** strategy emphasises the importance of developing nature-based solutions to cope with climate change and hydrological risks in the Mediterranean area, which is already characterised by high levels of hydric stress.

15. See, for example, German national research programme aiming at strengthening soil research: "Soil as a sustainable resource for the bio-economy" https://www.ptj.de/lw_resource/datapool/_items/item_4725/bonares_bekanntmachung_e.pdf.

**Box 2.9. Seaweed supplements that aim to reduce GHGs from livestock**

Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), in collaboration with James Cook University and Meat and Livestock Australia, has developed a cost-effective seaweed feed additive called FutureFeed, which uses a variety of Australian seaweed that significantly reduces methane emissions from livestock and has the potential to increase livestock productivity. FutureFeed has been found to reduce the production of enteric methane by more than 99% at addition rates of below 1% by weight in diets, with the reduction being dependent on addition rate and seaweed quality. CSIRO estimates that if just 10% of global ruminant producers adopted FutureFeed as an additive to their livestock feed, it would have the same impact on the climate as removing 50 million cars from the world's roads, and would improve the feed efficiency of livestock production in feedlots and dairies.

# Annex 2.A.

**Annex Table 2.A.1. Synopsis of priority areas, opportunities and barriers to the bio-economy**

| Country | Priority areas | | | Opportunities | | | Barriers | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Agriculture and food | Forestry | Bioenergy | Economic | Environmental | Social | Market scale | Lack of strategy | Regulatory framework | Skills | Public awareness | Policy coherence/co-ordination |
| Australia | | | | X | X | | X | | | | X | |
| Belgium | | | | | | | | | | | | |
| Canada | | X | X | X | X | X | | X | | | X | |
| Chile | | | | X | X | | | X | | | | X |
| Denmark | | | | | | | | | | | | |
| Estonia | | | | | | | | | | | | |
| European Union | X | X | | X | X | X | X | | | X | X | X |
| Finland | | X | | X | X | X | | | | | | |
| France | X | | X | X | X | X | | | | | X | |
| Germany | X | X | X | X | X | X | | | | | | |
| Ireland | X | | X | X | X | X | X | | X | X | X | X |
| Italy | X | | X | X | X | X | X | | | X | X | X |
| Japan | X | | X | X | X | X | X | | X | X | | |
| Korea | X | | X | X | X | X | | | | | | |
| Latvia | X | X | X | X | X | | X | | X | X | | |
| Lithuania | X | X | X | X | X | | X | | X | X | | |
| Netherlands | X | | X | X | X | | X | | | | X | X |
| New Zealand | X | X | X | X | X | | | | | | | |
| Norway | X | X | X | X | X | X | | | | | | |
| Portugal | X | | X | X | X | X | X | | X | X | X | X |
| Spain | X | X | X | X | X | | X | | X | X | X | X |
| Sweden | X | X | X | X | X | | | | | | | X |
| United Kingdom | X | | X | X | X | | | | | | | |
| United States | X | | X | X | X | | | | | | | |

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# 3. Policy approaches to develop the bio-economy of the agro-food system

## 3.1. Policy instruments

135. Seizing the opportunities and mitigating potential risks of the bio-economy depends heavily on how policies and regulations are employed in governing the transition process. But, due to its crosscutting nature, the design of policies for the development of the bio-economy is especially challenging. As acknowledged in some bio-economy strategies, multiple policy instruments from a wide spectrum of policy spheres influence the development of the bio-economy across different levels of government.

136. Bio-economy strategies all stress the need to adopt a mix of technology-push and market-pull measures. Social dialogue, policy coherence and collaboration at all levels (national, regional and international) are also considered essential. Box 3.1 summarises policy approaches and tools recommended by the OECD in the 2009 report on the bio-economy.

137. Overall, the most widespread initiatives are those focussing on research, knowledge development and more practical forms of exchange. Initiatives to increase the sharing of knowledge through industrial clusters and partnerships related to the bio-economy are increasingly extensive (e.g. co-location of existing and related industries, the provision of shared demonstration facilities and infrastructure, etc.). Box 3.2 presents selected examples of measures promoting bio-economy innovations related to the agriculture and food sectors.

**Box 3.1. Policy approaches and tools for the emerging bio-economy**

*Research subsidies*: Uses public resources to generate knowledge inputs such as private and public sector research and development and human resources through the education of researchers, scientists, technicians, etc. This could include both mission-oriented research to support a specific technology and multidisciplinary research.

*Market creation*: Puts in place an incentive structure that could include, among other things, procurement guidelines, production subsidies, pricing incentives, trade barriers (either their establishment or removal), and competition policies.

*Regulations/standards*: Mandates actions concerning safety, product registration, advertising, environmental mandates (e.g. tradable carbon markets, life cycle assessment), etc. This can also be a tool for market creation.

*Infrastructure investment*: Creates the underlying framework for systems such as for public healthcare, collaborative science, databases, transportation, energy production and distribution, etc.

*Institutional changes*: Modifies the rules for collaboration, trade, knowledge market transactions, etc.

*Foresight research*: Maps the links between evolving research programmes (including targeted and multidisciplinary research), regulatory frameworks, policy initiatives, and the development of new technologies.

*Public forums*: Engenders public discussion, debate, and education in areas such as ethics,

benefits and risks, and the utility of biotechnology.

*Development commitments*: Applies financial and other support (technology transfer, collaboration between universities, etc.) to developing countries. This includes initiatives like the United Nations' Millennium Development Goals.

*Source*: OECD (2009), *The Bio-economy to 2030: Designing a Policy Agenda*.

### *Technology-push measures*

138. Bio-economy strategies mainly focus on the following areas of action: increase public and private funding for bio-economy research, technology and innovation (R&D/I) enhance research collaboration and reduce regulatory barriers to innovation. All bio-economy strategies agree on the need to increase investment and funding for bio-economy R&D/I programmes in order to encourage the generation of knowledge, and its application to the development of innovation.

139. In order to foster innovation in bio-economy-related areas, basic and applied research on key enabling technologies, as well as strengthening links between science and business through interdisciplinary co-operation between universities, research institutes and business is encouraged by almost all bio-economy-related strategies.

140. Establishing centres of excellence and databases, promotion of networks (e.g. through innovation clusters), promotion of new business models such as public-private partnerships (PPPs), training and education measures, building pilot and demonstration plants for bio-refining and strengthening international collaboration is common in most bio-economy strategies.

141. The **European Union** overall bio-economy strategy aims to support better alignment of EU funding in research and innovation with the priorities of the bio-economy. Under its Horizon 2020 Research and Innovation programme – that seeks to leverage national research and innovation strategies and to foster international research co-operation – almost EUR 6 billion will be dedicated to research for energy efficiency, clean and low carbon technologies and smart cities and communities. In addition, between 2014 and 2020, EUR 23 billion will be available under the European Structural and Investment Funds for its Thematic Objective "Shift to low-carbon economy".

142. In the **Netherlands**, the government supports research in a variety of ways, such as reduction of income tax and national insurance contributions, investment subsidies and financial support for research programmes. In 2016, companies in the bio-based economy invested over EUR 200 million in research and development.

143. Public R&D funding is widely considered a key policy measure for enhancing the innovation ecosystem for the bio-economy. In this respect, recent policy strategies specifically highlight the importance of promoting links between basic and applied research and supporting multidisciplinary research alliances. Other proposed measures include tax incentives, business support and access to research capacities.

**Table 3.1. Measures promoting bio-economy innovations related to agriculture and food – selected examples**

| Country | Public R&D | Stimulating private sector R&D | Social innovations | Research networks, consortia |
|---|---|---|---|---|
| Australia | Advance Queensland Initiative: grants to research organisation | | | |
| Austria | | | | |
| Canada | Growing Forward 2 Programme (funding programmes agricultural research projects, particularly cluster projects. | | | Canadian Biomass Innovation Network |
| European Union | Horizon 2020 (funding projects in universities and research organisations) | | | |
| France | Establishing inter-disciplinary INRA meta-programmes in the area of food, ecology and agriculture; European Centre for Biotechnology and Bio-economy (CEBB) | | Agro-ecology Farm 112 | |
| Germany | Plant breeding (IPAS); Federal Organic Farming programme. | | | Bio-economy International (international collaboration on R&D projects with non-EU countries) |
| Italy | National Smart Specialisation Strategy; EU Cohesion Policy Funds; Horizon 2020 (PRIMA initiative) | | | |
| New Zealand | Primary Growth partnership | PPPs | Citizen science projects | Global Research Alliance |
| Norway | Action plan between the most important public actors | | | BIONAER (Research Programme on Sustainable Innovation in Food and Bio-based Industries); Programme on Bio-economy |
| Spain | Horizon 2020; | PPPs | | |
| United Kingdom | Innovative technologies and bio-refineries; UK Global Food Security Programme; Centres for Agricultural Innovation to promote sustainable intensification (Agri-tech Strategy 2014-18) | | | |
| United States | Transportation Energy Resources from Renewable Agriculture (TERRA) Program; Biomass Research and Development Initiatives; Agricultural and Food Research Initiative; research into organic farming and special crops. | PPPs (Foundation for Food and Agriculture Research) | | Industry-led consortia |

*Note*: PPPs = Public-private partnerships.
*Source*: Based on the reports of the German Bio-economy Council.

144. Several strategies also underline the importance of encouraging more private investment in bio-economy research, development and innovation (R&D/I) through active collaboration between stakeholders. The establishment of research networks and centres of excellence, which aim to ensure continuous stakeholder co-operation and dialogue, is also noted (Biookonomierat, 2018[1]). In **Spain**, the strategy points out the need to "promote knowledge of the bio-economy among private financial institutions and risk-capital companies" in order to boost private investment in bio-economy. In **Ireland** the *Food for Health Ireland* initiative links researchers with industry partners to collaboratively develop, manufacture and market functional food ingredients (Devaney and Henchion, 2017[2]).

145. In **Chile**, various policies on research, development and innovation have supported the development of bio-economy initiatives, particularly research on microorganisms as agricultural inputs, such as bio-pesticides and bio-fertilisers.

146. Industry-driven initiatives are increasing in the bio-economy policy. For example, the **Japanese** Bio-industry Association (JBA) has developed a Vision Document for the Japanese bio-based industry. The Japanese bio-industry comprises agriculture, fisheries, food processing, health and medical sector and environmental technologies. Key innovations are expected from advances in genome editing and synthetic biology. The JBA estimates that the future bio-economy will contribute JPY 20 trillion (around USD 190 million) to the GDP in 2030 (Japan Bio-industry Association, 2016[1]).

147. The promotion of PPPs is also considered essential in almost all the countries analysed to ensure jointly funded innovation projects. In **France**, for example, innovation partnerships between stakeholders in the primary sector and the chemical industry are encouraged. In the **United States**, it is argued that successful PPP with shared risk, defined responsibilities, and deliverables to achieve mutual benefit and grow the bio-economy need to be identified and supported (The White House, 2012[4]). The **Spanish** strategy emphasises the need to analyse successful public-private collaboration models in generating business innovation based on public research (e.g. Bioaster, Novo Nordisk, Wageningen) and to encourage their introduction as part of the focal points for innovation in the field of the bio-economy.

**Box 3.2. Bio-based Industries Joint Undertaking in the European Union (BBI JU)**

Established in June 2014 – as part of the Innovation Investment Package and as a key action of the European Bio-economy Strategy – BBI JU is a PPP between the EU and the Bio-based Industries Consortium that invest in research and innovation projects, including integrated bio-refineries and the acceleration of innovative bio-based chemicals and products such as polymers, packaging and fertilisers. Its budget for the 2014-20 period is EUR 3.7 billion, with 25% of the funding provided by the European Union from Horizon 2020 and the remaining 75% by the business sector. Project outcomes are monitored through key performance indicators.

Up to date, 65 projects have been funded consisting of 20 demonstration projects and 6 flagship projects, which correspond to a total of 729 beneficiaries from 30 countries for a total amount of EUR 414 million. The first flagship "First2Run" aims at setting up a commercial scale bio-refinery in Sardinia (Italy) for converting low input oil crops grown in arid or marginal lands, to produce added value chemicals, feed products and energy. It represents a total investment of EUR 58 million (of which 70% from industry).

*Source*: (European Commission, 2017[5]).

### *Building human capital*

148. The development of the bio-economy depends heavily on a highly qualified workforce as a wide range of knowledge and technological expertise is needed for different bio-economy related activities. It will require well-trained workers with specific qualification and competences, and capable to adapt to innovation and structural changes. There will be, for example, an increasing need for high-skilled individuals with expertise in biological sciences, natural resources, agronomy, biotechnology, bioengineering as well as strong entrepreneurial skills and innovation culture, including cross-disciplinary education and training programmes.

149. A number of bio-economy strategies (e.g. the **European Union** and the **United States**) have all identified an information and knowledge transfer gap that exists between

innovators, researchers, biotechnologists and the farming community. In the **United States**, for example, current education and training programmes are deemed inadequate to meet the *Billion Ton Bio-economy Strategy* and the Bioenergy Technologies Office BETO will co-ordinate with USDA to promote new generation of farmer workforce development. The **European Union** strategy also puts a particular emphasis on reinforcing informed dialogue between bio-economy research and policy making to ensure that public research results provide a sound scientific basis for responsible policy decisions.

150. To enhance innovation adoption, several programmes focus on the transfer of knowledge and technology to farmers. Such measures aim to bridge gaps between research and practice and mitigate persisting concerns regarding the absorptive capacity of farmers with regard to technology adoption.

151. Schmid, Padel and Levidow (2012[6]), on the other hand, highlight the importance of fully recognising the potential of farmers and small- and medium-sized enterprises (SMEs) to contribute to development and diffusion of bio-innovation, and of enhancing local knowledge and capabilities. According to the authors, there is a need to move from a knowledge transfer to a *knowledge exchanges* perspective by building a knowledge-based involving a wide range of stakeholders (farmers, foresters, fisherfolk, advisory services, all industries involved in the supply chain, consumers and society at large). The EU SCAR Working Group on Agricultural Knowledge and Innovation Systems (AKIS) also recommends building on models of joint knowledge-production, spanning the boundary between knowledge generators and users (SCAR, 2015[7]).

152. Several countries have already established bio-economy-related education and capacity building programmes (European Commission, 2017[5]). The support for education and human capacity building measures, for example, is deeply rooted in several national bio-economy-related strategies, including **Argentina**, **Canada**, **France**, **Italy**, **Latvia**, **New Zealand**, **Spain**, the **United Kingdom** and the **United States**. Measures for promoting capacity development include publicly-funded training courses for professionals in entrepreneurship, innovation management, technology transfer and IP rights; new training programmes that relate to the needs of the private sector; and promoting the career path of graduates by connecting them with industry and business.

153. In general, the strategies mainly prioritise the establishment of inter-disciplinary academic bio-economy courses (including master's and doctoral programmes) to improve both technical and soft skills, life-long learning opportunities and education programmes for policy-makers at all levels of government, although these efforts are frequently only in their infancy.

154. While **Finland**, **France** and the **United States** foster training of experts, others, including **Austria** and **Germany** also promote stakeholder platforms and cross-sectoral alliances as the basis for interdisciplinary exchange. In **France** and the **United States** specific measures for the improvement of education in schools and universities are part of bio-economy-related strategies. Specific educational programmes have also been developed in **Belgium** (Flanders) and **Germany**.

155. In the **United States**, the 2016 *Billion Ton Bio-economy Strategy* underlines the need to mobilise and develop a qualified workforce for the bio-economy. It focuses on training programmes for professionals and technical students and pledges support for career path information for high school students.

156. In **France**, educating and training the workforce for the future bio-economy is considered a priority. In its strategy, inter-disciplinary education and capacity building,

including technical and vocational training as well as life-long learning opportunities are highlighted. In 2015, the European Centre for Biotechnology and Bio-economy was established. Its mission is to promote multi-disciplinary research for the sustainable production of biological resources, to foster bio-refinery development and the agro-food industry. In June 2017, the public research institutes INRA and Irstea hosted a European workshop on bio-economy which was attended by more than 300 European and international bio-economy experts.[16] As a result of the event, recommendations on bio-economy-related research and development were published. They focus, *inter alia*, on promoting multi-disciplinary and multi-sectoral co-operation, modelling the externalities of the bio-economy and implementing bio-economy-related policies.

157. In **Italy**, the range of measures proposed encompasses new technical programmes for schools, academic bio-economy courses and post-graduate education in the bio-economy. In 2017, the first European masters programme in "Bio-economy in the Circular Economy" was launched through a PPP between four Italian universities, three industrial partners and an Italian banking group.

158. In order to enhance access to bio-economy knowledge the **Spanish** strategy proposes the creation of tools and materials for self-training and professional recycling through "online" platforms, allowing access to study in the various fields of the bio-economy.

159. In **Estonia**, the University of Life Sciences aims to become an internationally recognised university in the field of bio-economy and defined their development plan for 2016-25 through a bio-economy value chain approach.

160. In **Latvia**, the Institute of Energy Systems and Environment (IESE) in Riga Technical University (RTU) is working to increase knowledge about the bio-economy through activities at different levels – higher and social education, research and innovation. RTU IESE is oriented towards a trans-disciplinary approach in addressing bio-economy-related issues, including technological, environmental, climate, and economic and socio-economic aspects.

161. The Lodz Declaration on a European Bio-economy Education Platform was announced within the **Poland** Congress on Bio-economy in November 2017. The platform is intended to foster exchange between multi-disciplinary bio-economy education programmes to build a skilled working force for the new generation (Biookonomierat, 2018[1]).

### *Promoting and creating markets*

162. Bio-economy development is expected to potentially create entirely new markets or enter markets dominated by fossil-based products. National bio-economy strategies include advocating a number of market-pull measures to expand demand for bio-economy products. Proposed measures mainly consist in: increasing consumers' awareness of bio-products; the development of labels, standards and certification for new bio-based products; and the use of green public procurement to promote bio-economy products.

163. Creating *consumers' awareness* of the bio-economy is at the top of national agendas as reflected in the recently published **French** Action Plan, for example. While national bio-economy strategies agree on the need to organise conferences and forums open

16. http://institut.inra.fr/en/Events/INRA-Irstea-Workshop-on-Bioeconomy-2017.

to the general public in order to increase awareness and promote bio-economy products among society, most of the strategies remain vague with regard to the promotion of concrete measures (Biookonomierat, 2018[1]).

164. Social attitudes to bio-economy products and technologies have important implications and a number of bio-economy strategies highlight the contribution of *social dialogue* with the public as a crucial requirement in stimulating the demand for bio-economy products.

165. The ethical views of citizens can influence the bio-economy through its impact on regulations and other laws that affect research (what is permitted and the level of public support for research), markets (what people will buy and at what price) and business models (what business strategies are legally permitted). Enhancing social dialogue and other initiatives supporting public understanding of the technologies underpinning the bio-economy could be achieved through appropriate incentives. The involvement of scientists, and research and innovation community in such as process is essential as well.

166. In **Germany**, measures for addressing consumer behaviour by providing information on sustainable consumption and food waste are an example of enhancing the dialogue. In **Sweden** and **Finland** measures to communicate the benefits of the bio-economy and bio-based products to society in order to shift consumption away from fossil-based products are also highlighted.

167. *Public forums* and *conferences* can increase awareness of bio-economy alternatives and provide end-users, and citizens in general, with more information about bio-products. In particular, consistent information can be provided on the characteristics of bio-products, with regard to production methods, environmental sustainability or nutritional benefits for instance. Clear information about bio-products and the impacts of consumption patterns and lifestyle (for instance on the issue of waste), would enable more responsible and informed consumer choices.

168. While most strategies mention public forums and conferences as the main platforms for social dialogue, in recent years *online platforms* have become established as a useful communication tool on the bio-economy. In **Finland**, **Germany** and **Spain**, for example, exclusive websites on the bio-economy have been launched to provide information about recent developments, to publicise upcoming events and outline national and international policies. The **European Commission** launched the Bio-economy Knowledge Center in July 2017. The website provides data and relevant publications on bio-economy in member states to ensure better knowledge sharing.[17]

169. Even if bio-economy strategies underline the need for consumer information and communication, concrete measures are seldom foreseen to communicate the benefits of bio-economy products and services to customers or to address the role of the media. The SCAR group confirmed that there is a clear need to develop and implement a coherent communication strategy to raise consumer awareness around the bio-economy and the opportunities for and barriers to its development (SCAR, 2015[7]). It recommends that this should be done in the context of the big challenges facing future generations such as climate change, resource efficiency, energy and food security. Among its recommendations is the dissemination of more case studies, and establishing a European Bio-economy Week.

17. https://biobs.jrc.ec.europa.eu.

170. The introduction *public procurement* as a way to enhance awareness and for stimulating demand for bio-economy products and services is seen as promising by most countries, including **Australia**, **Canada**, **France**, **Italy**, **Latvia**, **Norway**, **Spain** and the **United States**. Proposed measures range from introducing standards for bio-economy public procurement to reviewing the present regulatory framework on public procurement.

171. The rationale for using public procurement to accelerate the development of bio-economy markets is that it allows the public sector to act as a "launching pad", early adopter, or first buyer. The public sector also acts as a market development facilitator by establishing a buyers group for the market with critical mass that triggers industry to scale up its production chain to bring products on to the market with the desired quality/price ratio within a specific time.

172. Overall, bio-economy strategies consider that public procurement should contribute to "the reduction of environmentally degrading effects and an advancement of climate friendly solutions" and provide incentives for the replacement of non-renewable natural resources by renewable ones. Public procurement of bio-based products is also expected to promote innovation, as well as create jobs and open new markets in rural areas, as being the main location for biomass production and manufacturing (Box 3.3; The White House, 2012[4]).

**Box 3.3. The US BioPreferred® Program**

Created by the 2002 Farm Bill and re-authorised and expanded by the 2018 Farm Bill, the USDA BioPreferred® programme aims to increase the purchase and use of bio-based products. The two major parts of the programme are: i) mandatory purchasing requirements for federal agencies and their contractors; and ii) a voluntary labelling initiative for bio-based products. Products that meet the minimum bio-based content criteria may display the USDA Certified Biobased Product label. To date, USDA has identified 97 categories (e.g. cleaners, carpet, lubricants, paints) (that include approximately 14 200 products of bio-based products on the market today for which agencies and their contractors have purchasing requirements. For purposes of the BioPreferred® program, bio-based products do not include food, animal feed or fuel. The 2018 Farm Bill authorised mandatory funding of USD 3 million for each of FY2019-23 for bio-based products testing and labelling, similar to the 2014 Farm Bill. The 2014 Farm Bill authorised discretionary funding of USD 2 million annually, although from FY2013-18 no discretionary funding was appropriated.[18] The 2018 Farm Bill increased the authorisation for discretionary funding to USD 3 million annually from FY2019-23.

173. Developing *standard, labels and certification* for bio-economy products appear as the main instrument to facilitate product identification, provide consumers with guarantees regarding products quality, safety, as well as the source and processes used (origin of biological resources and products), and "elucidate the various advantages of bio-based products". In particular, bio-economy strategies agree on the need to develop clear and unambiguous standards for bio-based products and to ensure their consistency across sectors. Bio-economy strategies mainly discuss the importance of determining comparable criteria for bio-based products sustainability. Standards for bio-economy products deal with bio-based content, biodegradability, sustainability and functionalities of products.

[18] For more information on the programme, see the section on the United States in Chapter 4.

174. Standards are also central for the *development of labels* for bio-based products. Labelling can play an important role for the commercialisation of bio-based products as it can provide consumers with information on the environmental performance of the products and guide purchasing behaviour towards sustainable choices. Labels can also be critical for the uptake of bio-based products by green public procurement.

175. As part of these efforts, standards and certifications for bio-economy products have been discussed in **Norway**. In **Japan –** in addition to a uniform feed-in tariff for renewable energies (including biomass) set up in 2012 – state departments are also required to purchase environmentally-friendly products and various labels to identify environmentally-friendly and bio-based products for consumers have been introduced. In **France**, in order to attract greater attention to bio-based products and services the building codes and standards have been updated to increase the share of hemp in construction.

176. Market development and expansion of the bio-economy also requires improvement and investment in *transport* and *storage infrastructure* as well as the development of the necessary logistics for the "cascading use of biomass" at the national and regional levels. **Denmark** and **New Zealand** also specify measures targeting international marketing and market development.

177. Finally, bio-economy strategies also highlight the importance of investing in and providing access to *demonstration and pilot plants* to foster the commercialisation of bio-economy products and technologies, and to contribute towards better linkages between researchers and industry.

### *Reviewing, updating and simplifying regulations*

178. Bio-economy strategies stress the need to reduce regulatory barriers to technology development and research-based innovation in order to foster the development of the bio-economy. Regulations play a central role in reducing safety and security risks as a result of new technologies and products. However, due to the rapid evolution of technologies, and its associated products and services, some regulations could have become inadequate or unnecessarily restrictive (The White House, 2012[4]).

179. Therefore, there is a need to carefully review regulatory frameworks impacting bio-economy technologies and products in order to identify possible negative effects of compliance on innovation. There could be a need for new, appropriate and efficient regulatory processes and the reform of some regulations. In particular, the **United States** and **European** strategies emphasise the need to reduce the cost of compliance with regulation, and increase predictability and timeliness of regulatory processes in order to achieve the promise of the future bio-economy more rapidly and safely. Clear, predictable, and efficient regulations are powerful drivers of R&D investments in all sectors.

180. Although most bio-economy related strategies highlight the need to create bio-economy-friendly framework conditions, only few countries emphasise the importance of reviewing and harmonising the regulatory framework. While countries including Argentina, **New Zealand** and the **United States** focus more on reviewing regulations governing new biotechnologies, **Italy**, **Norway**, **Spain** and the **United Kingdom** focus on reviewing circular economy regulations (especially regarding the use of waste and residues for higher value applications). **New Zealand** also highlights the need to review the policy framework for intellectual property rights. Interestingly, only a few countries (**Canada**, **New Zealand** and **Norway**) mention carbon taxing and global data policies.

## 3.2. The imperative to develop a coherent policy framework for the bio-economy

181. Due to its broad scope, the development of the bio-economy is particularly complex from a policy perspective. In principle, developing a bio-economy strategy is an essential first step towards policy coherence and co-ordination at national level. Due to its nature, the bio-economy encompasses a wide range of sectors and its advancement depends on efforts across a wide spectrum of policy spheres. Policies offering incentives for different economic uses of biomass – including food, feed, bio-based products and bio-energy need to be aligned with strategic goals for the bio-economy.

182. The development of the bio-economy demands a coherent policy approach that enhance synergies. Coherence needs to be sought in particular across agriculture, food, rural development, environment, forestry, energy, research and innovation, waste and climate change policies that are perceived as very important to foster the development of the bio-economy of the agriculture and food system.

183. Overall, governments suggest reinforcing policy interaction and stakeholder engagement, and increasing dialogue between the different actors in the bio-economy. The creation of bio-economy dedicated bodies or working groups in charge of ensuring policy coherence and monitoring is also proposed by several strategies. All bio-economy strategies also stress the importance of improving policy coherence and co-ordination at the international level.

184. While the importance of coherence issue is highlighted in most strategies, this review shows that they, in general, remain relatively vague. In the **European Union**, for example, it is explicitly stated that the bio-economy strategy will seek synergies with the EU Common Agricultural Policy (CAP). Yet, notwithstanding recent initiatives, there is little direct alignment between the current CAP and the bio-economy vision. A public consultation by the European Commission in 2011 (predating the Strategy and White paper) further identified lack of policy coherence as a barrier to developing a bio-economy. However, Moreover, the new European Commission's proposal for the post-2020 CAP (running from 2021 to 2027) provides EU Member States with enough flexibility to link their CAP national strategic plans to national Bio-economy Strategies.

185. National strategies also agree on the fact that policy coherence could be heightened through enhanced communication and co-ordination between stakeholders, in particular private sector, science and civil society. Organising discussions or co-ordination platforms, as well as open public debates involving a wide range of stakeholders is seen as a way to foster knowledge exchange and information flow between related policy areas, sectors and disciplines.

186. Institutional issues are also important and dedicated bio-economy advisory bodies or working groups have been created in a number of countries. Inter-governmental and federal-state co-operation is considered critical for bio-economy policy, specifically in terms of policy coherence and effectiveness (e.g. **Australia**, **Denmark**, **Germany**, **Ireland**, the **Netherlands**, **Italy**, **Norway**, **Spain** and the **United States)**.

187. An increasing number of countries are also addressing the issue of accountability by establishing dedicated *bio-economy advisory councils*. Most often, they represent public, private and civil society stakeholders, including research institutions and provide advisory services for bio-economy policy development. Such panels have been nominated in **Germany**, **Denmark**, the **European Union**, **Nordic** countries, the **Netherlands** and the **Czech Republic**.

188. In the **European Union**, two platforms have been created at the European level: the Bio-economy Stakeholder Panel and the Bio-economy Knowledge Center (replacing the Bio-economy Observatory) (Box 3.4). The European strategy also encourages member states to create similar bio-economy bodies in order to enhance policy coordination and coherence at the national and European levels.

**Box 3.4. European bio-economy platforms**

*Bio-economy Stakeholder Panel*: Set by the EU's Bio-economy Strategy, the Panel seeks to support synergies and coherence between different policy areas, to provide a discussion platform and framework to support the implementation of the strategy, to propose European joint actions and monitor and evaluate progress made (European Commission, 2017[5])

Originally set up in 2013, the membership of the Panel was renewed in 2016 to strengthen the diversity in stakeholders' representation. The Panel has 29 members, representing different groups: business and primary producers, policy-makers and public administrations, scientists and researchers and civil society organisations. The members of the Stakeholders Panel, in its new configuration, have been appointed for a two-year period, from 2016 to 2018 with a possibility of renewal.

*Bio-economy Knowledge Centre*: In July 2017, the European Commission launched the new Bio-economy Knowledge Centre to better support EU and national policy makers and stakeholders with science-based evidence in this field. Its objective is to gather data and indicators to assess the progress of bio-economy markets and socio-economic, scientific, technological, market and the impact of legislation impact. It will produce foresights and forecasts on bio-economy, scenario analyses for aiming at supporting policies and derive research and innovation directions. The Knowledge Centre is being created by the Commission's in-house science service, the Joint Research Centre, in co-operation with Directorate-General for Research and Innovation.

*Source*: https://ec.europa.eu/research/bio-economy/.

189. In **Denmark**, the Ministry of Environment and Food set up a Bio-economy Council in 2017. Its members represent bio-economy-related expertise from academia, business, associations and clusters. Also in 2017, a "Bio-economy Federation" was formed in the **Netherlands**. While developing a strategic bio-economy agenda, it seeks to connect bio-economy stakeholders, strengthen international co-operation and showcase successful bio-economy stories. More than 70 members from companies, research organisations and NGOs have already joined the Federation. So far, the work of the organisation has been financed on a crowd-funding basis. The Federation foresees the creation of a Scientific Council, a Council for Sustainability Issues and a student platform as the next steps.

190. In **Ireland**, an inter-ministerial working group was established in late 2016. It is chaired by the Department of the Prime Minister and aims primarily at reconciling bio-economy-related activities and identifying opportunities for a national policy strategy. In **Austria**, a sub-working group on bio-economy has evolved as part of the inter-ministerial working group on climate change and resource scarcity.

191. In **Germany** an inter-ministerial working group has been established in 2013 to address inter-ministerial collaboration and coherence. In addition, the German Bio-economy Council plays a central role in advising the Federal Government on the implementation of the bio-economy strategy with the overall goal of creating optimum economic and political framework conditions for a bio-economy (BMEL, 2014[8]).

192. **Spain** and **Italy** also plan to create similar bio-economy bodies or working groups. The **Spanish** strategy sets out the creation of a "Spanish Bio-economy Observatory" with two components: a "monitoring group" responsible for tracking the strategy, co-ordinating the introduction of new measures in the field and promoting co-operation between the different administrations; and a "management committee" whose objective will be to foster implementation of the measures established as part of this strategy and the annual action plans (State Secretariat for Research Development and Innovation, 2016[9]).

193. The **Italian** strategy plans the establishment of a permanent working group on the bio-economy composed of representatives of ministries, other public administration and national technological clusters involved in the bio-economy domain, in order to define a proper and coherent legislative framework and minimising duplication and fragmentation. Their main responsibilities will be to: collect and share data and information, guarantee the policy coordination among public authorities, and monitor the implementation of the bio-economy strategy (Italian Government,(n.d.)[10]).

194. In **Japan**, in line with the policy direction of the *Basic Plan for Promotion of Biomass Utilisation*, regional biomass industrialisation networks are being promoted. The purpose of these networks is to implement the concept of biomass industrial cities, to create bio-based, environmentally friendly and disaster-resistant communities (Box 3.5). Furthermore, a liaison conference on biomass utilisation has been set up to co-ordinate between the departments with the aim of ensuring comprehensive and effective promotion of biomass utilisation. The liaison conference office is housed within the Ministry for Agriculture, Forestry and Fisheries (MAFF).

**Box 3.5. Biomass Industrial Cities – the case of Japan**

The *Biomass Industrial City Concept* centres on the biomass industry taking advantage of the characteristics of the area, and aiming for environmentally friendly, disaster-resilient communities. As of November 2018, relevant Ministries have selected 84 municipalities as Biomass Industrial Cities. These Cities are expected to develop regional value chains from material production, collection and transportation to use of biomass-derived products and energy. Local stakeholders will make partnerships and form a consensus for realising the projects under the municipalities' initiative. The government will periodically request the Biomass Industrial Cities to report on the progress of each project.

195. Policy coherence related to the bio-economy in the **United States** includes increased inter-agency collaboration to fully leverage governmental expertise (Box 3.6). In this respect, for example, it highlights a Bio-economy Federal Strategy Workshop, which was organised by the Biomass R&D Board and was aimed at sharing information on existing agency programs and activities, identifying processes for working together and building a national federal government coalition to coordinate agency efforts.

**Box 3.6. Inter-agency collaboration in the United States: Founding partnerships, breaking barriers**

In the United states, the Department of Agriculture (USDA), the Department of Energy (DOE) and the Environmental Protection Agency (EPA) jointly released a progress report on the Biogas Opportunities Roadmap of 2014. The Roadmap identifies voluntary actions that can be taken to reduce methane emissions through the use of biogas systems. It outlines strategies to overcome barriers limiting further expansion and development of a robust biogas industry in the United States.

*Source:* Federal Activities Report on the Bio-economy (2016), www.energy.gov/sites/prod/files/2016/02/f30/farb_2_18_16.pdf

## 3.3. Monitoring progress

196. Currently, there is no an internationally agreed methodology today to measure its size and monitor progress in attaining the targets set in the bio-economy strategies and visions (Bracco et al., 2018[11]; OECD, 2018[12]; Vandermeulen et al., 2011[13]). The bio-economy targets set up in the strategies often reflect the country's priorities and comparative advantages. However, comprehensive approaches to measure the size of the bio-economy as well as to monitor its development and assessing its impacts are still lacking (Staffas, Gustavsson and McCormick, 2013[14]).

197. The difficulty of measuring progress can be a consequence of the lack of a clear definition of what constitutes a bio-economy and the fact that most bio-economy strategies do not set out concrete goals. It is essential, however, that measurements for progress are defined and applied. This is also one of the key findings of the 2017 EU Bio-economy Strategy Review, which emphasises that better monitoring and assessment frameworks are needed (e.g. indicators of biomass supply and demand).

198. Measuring the performance of the bio-economy through indicators is complex because the bio-economy comprises a wide range of different products, commodities, intermediate goods and technologies. Moreover, a large part will emerge from markets and transformation and from new markets creation, for which statistical data and indicators are currently not available.

199. Most countries only measure the contribution to gross domestic product (GDP), turnover, employment, exports of the bio-economy sectors – including agriculture and food – and the number of firms and businesses operating in bio-economy sectors (Bracco et al., 2018[11]; Box 3.7). Such indicators, however, may provide only a partial picture of the size and impacts of the bio-economy of the agriculture and food system and underestimate the contribution of bio-economy to society as sustainability impacts are overlooked (Wesseler and von Braun, 2017[2]).

200. Measuring and monitoring the implementation of strategies for the bio-economy need to address the impact of the development of the bio-economy on environmental, social and economic outcomes (the three dimensions of sustainability) (OECD, 2018[12]; Fritsche and Iriarte, 2014[23]). Only the updated **EU** bio-economy strategy, and the indicators identified in the **Italian** and **Finnish** strategies, are currently proposed to measure and monitor the sustainability of their bio-economies.

**Box 3.7. What is the direct economic impact of the bio-economy?**

In the **European Union**, it is estimated that – with an annual turnover of around two trillion euros (of which 18% are contributing by agriculture and 46% by food) and contributing to approximately 9% of the workforce (55% agriculture, 20% food) and 80% of land use – the bio-economy is already one of the biggest and most important components of the EU economy. In addition, as in other sectors, each euro invested in EU-funded bio-economy research and innovation is estimated to generate EUR 10 of value-added in bio-economy sectors by 2025. Significant growth is expected to arise from sustainable primary production, food processing and industrial biotechnology and bio-refineries. The food and agriculture sectors are the ones contributing the most to the EU-28 bio-economy, both in terms of employment and turnover. While more people are employed in the agricultural sector, the food sector generates a higher turnover. The same situation applies for France, Ireland, and Italy. In Belgium, Finland, and Germany, the food sector is making the biggest contribution both in terms of employment and turnover.

In **Germany**, it is estimated that about five million employees, representing 10% of all employees and EUR 140 billion, representing 6% of GDP have been identified in the bio-economy in 2010 (Efken et al., 2016[15]).

In **Ireland**, agriculture, food (and beverages), fisheries and forestry are the main sectors that contribute to the country's bio-economy.

In **Italy**, it has been estimated that the whole bio-economy sector in 2013 (which includes agriculture, forestry, fisheries, food and beverages production, paper, wood and biochemistry) accounted for around EUR 244 billion, ranking third in turnover after Germany and France, with around 1.5 million employees. According to these estimates, the food industries and agriculture contributed to more than half of the total bio-economy's turnover (Intesa San Paolo, 2015[16]). Italy's bio-economy overarching goal is to increase turnover from EUR 250 billion (2015) to EUR 300 billion by 2030 and the entire bio-economy sector should account for more than 2 million jobs by 2030.

In the **Netherlands**, the bio-economy contributed 7.7% to national GDP (of which 26% from agriculture, forestry and fisheries, and 60% food and feed), 4.9% to national value added (of which 37% from agriculture, forestry and fisheries, and 47% food and feed) and national employment (of which 47% from agriculture, forestry and fisheries, and 38% food and feed) in 2013, with the contribution of the primary, food and feed sectors was dominant (Van Meijl et al., 2016[17]).

In **New Zealand**, the "traditional" bio-economy (the primary sector and the food industry) contributes to more than two thirds of exports and is a key pillar in the economy.

In **Norway**, the bio-economy accounts for 6% of the economy (of which 46% is due to agriculture and food). Moreover, more than a three-fold increase in total GDP is estimated in 2050 (from EUR 33 billion to EUR 110 billion), with agriculture and food sector's contribution estimated to rise from EUR 15 billion to EUR 27 billion (Bardalen, 2016[18]). The bio-economy sector in Norway with the largest value added is the food and drink industry, and with NOK 37 billion in 2014 it was nearly three times as high in terms of value added as the second largest, agriculture, at NOK 13 billion.

In **Spain**, the bio-economy accounts for an estimated 6.5% of the GDP (with agriculture accounting for 2.5% and the food industry 2.7%) and employs around 9% of the working population. Overall, the food and agriculture sector, with more than 900 000 farms and 30 000 companies, was responsible of more than 17% of all Spanish exports in 2014 (State Secretariat for Research Development and Innovation, 2016[9]).

In the **United States**, the bio-based economy (excluding food, feed, livestock, pharmaceuticals

and energy) generated about 4.2 million jobs and about USD 393 billion in 2014, including direct, indirect and induced effects (Golden et al., 2018[19]). Moreover, the World Economic Forum estimates that the revenue potential for new business opportunities in biomass value chains could amount to approximately USD 295 billion globally, by 2020 (World Economic Forum, 2010[20])These revenues generated at the different stages of new biomass value chains include the manufacturing of agricultural inputs, biomass production and trading, bio-refining inputs (e.g. biomass pre-treatment methods), the actual biomass conversion in the bio-refineries and the sale of end products.

201. Bio-economy strategies that report indicators on its size include the **European Union**, **Finland**, **Spain**, **France** and **Italy**. Some of the bio-economy-related strategies, including **Australia**, **Italy**, **Latvia** and the **United Kingdom** also provide concrete quantitative targets for bio-economy development. These targets range from increasing the bio-industry share of GDP or annual sales of biotech products, to raising the general bio-economy turnover and creating more bio-economy-related jobs. The **Latvian** Bio-economy strategy, for example, defines a range of quantitative targets for bio-economy development: employment in the bio-economy should increase by 128 000 employees by 2030; the added value of bio-based products should increase up to at least EUR 3.8 billion (around USD 4.7 billion) by 2030; and the value of bio-economy-related exports should be boosted to at least EUR 9 billion (around USD 11 billion) by 2030. Nevertheless, most countries only define qualitative targets. Only **Spain** provides concrete budget targets within their bio-economy policy strategies by listing funding opportunities.

202. With a view to accountability of bio-economy development, an increasing number of governments, including **Australia**, **Canada**, **France**, **Italy**, **Latvia**, **New Zealand**, **Spain**, the **United Kingdom** and the **United States** are promoting measuring activities to measure the bio-economy in order to monitor new technologies (particularly new biotechnologies), biomass supply and demand, as well as bio-based products and services and their economic, ecological and social impacts (Biookonomierat, 2018[1]). In the **United States**, for example, trends in the bio-based economy are analysed using various indicators, including indicators for agriculture (Golden et al., 2018[19]).[19]

203. Other countries are promoting the evaluation of policy programmes. For example, with regard to monitoring the implementation of the **German** bio-economy policy strategy, the Ministry of Food and Agriculture (BMEL) released a progress report in late 2016, with first results expected by 2019.

204. Furthermore, work is in progress at the **European Union** level to establish indicators to monitor the development of bio-economy. The European Commission, for example, has funded several activities to monitor bio-economy development in Europe under the "Bio-economy Observatory" project led by its Joint Research Center (JRC). The results have been published in its *Bio-economy Policy Report in 2016* (Ronzon et al., 2017[21]).[20]

[19] For agriculture, the indicators take into account: i) the various organic inputs into bio-fuels, renewable chemicals and bio-based products; ii) crop production; iii) crop consumption for bio-fuels (i.e. maize for ethanol and soybeans for bio-diesel); and iv) the relative prices of each crop.

[20] Efforts are also underway at the EU level to increase the statistical information available on the bio-economy, taking into account the work done by the JRC and in some research institutions (e.g. Nova Institute).

205. In **Japan**, various surveys provide information on the supply of and demand for biomass (e.g. survey on discharge and disposal of industrial waste; survey on disposal of general waste; status survey on recycling of circulating food resources; and woody bioenergy usage trend survey).

206. In **Canada**, biomass inventory work is carried out regularly to monitor the state of forest resources. In the case of agriculture, annual crop maps are prepared and satellite imagery is being increasingly used to improve the resolution. Fallow land and marginal lands are identified as areas that could potentially be available for additional crop production. The publicly available, Biomass Inventory Mapping and Analysis Tool (BIMAT) identifies the crop residue available across the country based on the crop production of the past thirty years.

207. In the **Netherlands**, since 2012 data are compiled to provide a quantitative and qualitative overview of solid and liquid biomass import flows and assess, to extent possible, whether biomass is produced sustainably (van Lieshout Marit and Scholten Thijs, 2017[22]).

208. In **Italy**, the monitoring indicators proposed deal with five sustainability objectives of the bio-economy: ensuring food security, managing natural resources sustainably, reducing dependence on non-renewable resources, coping with climate change and enhancing economic growth.[21]

209. In **Finland**, among the range of indicators proposed to monitor implementation of the bio-economy strategy, the aim is to measure its environmental benefits, as well as its sustainability. Environmental indicators deal with raw material inputs used and reduced GHG emissions, whilst sustainability indicators concern the use of natural resources and waste. In addition, the strategy aims to develop a range of sustainability indicators for ecosystem services, environmental and resource-efficiency as well as environmental assets.

### *The use of life cycle assessment*

210. The bio-economy is a highly complex system with many interconnections and impacts. In order to improve sustainability, it is imperative that the bio-economy is developed in a way that helps reduce environmental pressures, values biodiversity and contributes to enhance the provision of all ecosystem services. To ensure that the bio-economy operates within planetary boundaries, a robust sustainability assessment of the amounts, types, qualities and impacts of the sustainable production and use of biomass from all sources is needed. Impacts include the implications of different land uses (and changes) on biodiversity, as well as on the local, regional and sometimes global socio-economic systems.

211. The updated bio-economy strategy of the **European Union** – in addition to the actions to enhance understanding of the ecological boundaries of the bio-economy, such as collecting data and information on biomass and biomass change – advocates the building of an EU-wide internationally coherent monitoring system to track economic, environmental and social progress towards a sustainable bio-economy.

212. Some bio-economy strategies highlight the importance of environmental impact assessments for the development of a sustainable bio-economy (e.g. Box 3.8). The **French**

21. The indicators are based on the results of Sat-BE consortium, "Systems Analysis Tools Framework for the EU Bio-Based Economy Strategy" (https://www.wur.nl/en/project/satbbe.htm) developed by Wageningen University of Research.

bio-economy strategy, for example, emphasises the fact that the bio-based content of a product does not provide a guarantee of its sustainability or its quality *per se* and suggests taking into consideration the following:

- Greenhouse gas balances;
- Resource-efficiency (direct and indirect energy and water consumption, phosphorus, land use, biomass use);
- Maintenance of ecosystem services (biological dimension) and landscape (cultural dimension); and
- Waste and by-products management, recyclability of end products.

213. The transition to a bio-economy has to be viewed through the perspective of its overall impact on the environment, for which life cycle analysis can make a contribution. Because of the interdependencies between processes involved in growing, harvesting, manufacturing, distributing and disposing of a product, sustainability requires such a life cycle analysis encompasses the whole supply chain. This includes the production of biomass (e.g. land use, consumption of water, energy, pesticides and fertilisers), the processing of biomass, and the production and use of final products. Such assessments may reveal that certain renewable production processes may be inefficient and costly in terms of their requirements for market and non-market inputs.

214. Several bio-economy strategies also highlight the contribution of Life Cycle Assessment (LCA) in measuring the environmental performance of the bio-economy's products and processes (OECD, 2018[12]). In particular, bio-economy strategies stress the LCA contribution to the development of methodological standards for bio-based products. LCAs can also contribute to determine the most efficient use for biomass and bio-waste.

**Box 3.8. France: database for environmental impact assessment of agricultural products**

In France, l'Ademe (the French Environmental Agency) is co-ordinating the programme "Agribalyse", in partnership with l'INRA, agricultural technical institutes, the CIRAD, co-operatives, and the Ministry of Environment with the aim of developing a database allowing the assessment of environmental impacts of agricultural products. The programme aims at developing a harmonised methodology, adapted to French production, as well as indicators calculated according to the international framework of LCA. Since the publication of the first version of the database in 2013, these data are providing an important contribution to a number projects linked to the environmental assessment of sectors, food practices as well as projects providing environmental information to consumers. Data and methodologies are regularly updated and improved. This tool also contributes to the environmental assessment of agricultural bio-economy's products.

*Source*: The French Government, 2017.

215. In **Spain** the strategy emphasises the use of LCA for comparing the environmental footprint of primary production systems (farming, livestock, forestry and aquaculture) and products (food products, bio industry by-products) depending on the technology used. In this case, LCA enables an assessment of the change in the environmental footprint of production systems and products brought by the incorporation of new technologies. Overall, LCAs is expected to contribute to improving the sustainability of products and processes. The **German** strategy considers that the further development of norms,

standards and life-cycle analyses can support the implementation of sustainability initiatives by the business community in the area of use of biomass.

An important limitation of the vast majority of methods pointed out in the literature is their inability to aggregate the different sustainability issues in a consistent way. Aggregation requires making complicated trade-offs between sustainability aspects with different dimensions. In order to address this limitation some suggest the Total Factor Productivity (TFP) approach (Cremaschi, 2016[24]). TFP reflects the rate of transformation of inputs (capital, labour, materials, energy and services) into outputs (biomass stock), where negative social and ecological externalities associated with different sustainability issues are included in terms of "bad" outputs.[22]

216. Another approach is to measure the share of renewable bio-based content embedded in the products and services in the economy. However, this approach overlooks sustainability issues, for example, on the origins of resources and how their production and utilisation relate to sustainability. On the other hand, approaches based on outcome indicators such as reduced carbon emissions and sustainability of water, soil and biodiversity improvements are more promising, although most demanding in terms of data and methodological challenges (Wesseler and von Braun, 2017[2]).

## 3.4. International collaboration

217. As the bio-economy has an international scope, policy co-ordination and coherence needs to be achieved at the international level. International policy dialogue on bio-economy is essential to ensure the harmonisation between different policy objectives and requirements, as well as coherence in legislation and regulation at international level. Additionally, enhanced co-operation at the international level is essential to ensure that bio-economy-related global challenges – such as the supply of sustainable biomass – are well addressed at the appropriate level, and to develop common standards, coherent surveillance and regulations that do not impede trade.

218. International collaboration is mentioned as important in most policy strategies, but it broadly lacks implementation beyond bilateral research co-operation. Even if the need for bi- and multi-lateral co-operation is often mentioned (e.g. to promote R&D), substantially less importance is attached to issues relating to the discussions on how to harmonise international trade and policy frameworks, promote capacity building, knowledge sharing and technology transfer between countries and foster international monitoring activities. The global inter-connectedness of the bio-economy with respect to trade in biomass resources, to global industrial value chains and transfer of technologies has hardly been addressed in policy strategies so far. According to the **European Union** strategy, little transnational collaboration and co-ordination between national public R&D programmes is one of the causes for sub-optimal returns from R&D spending.

219. *The International Bio-economy Forum* (IBF) is a platform for multilateral R&D collaboration in areas of common interest launched in 2016. The IBF is currently made up of seven members – **European Commission, New Zealand**, South Africa, India, China, Argentina, **Canada** and the **United States**. It aims to foster co-operation in the bio-

[22] See for example, the discussions of the meeting of the OECD TFP and the Environment Network www.oecd.org/tad/sustainable-agriculture/oecdnetworkonagriculturaltotalfactorproductivityandtheenvironment.htm and the Summary record [COM/TAD/CA/ENV/EPOC(2017)15].

economy through policy dialogue and scientific co-operation between the partners. The work of the IBF is undertaken in organised *ad-hoc* working groups. Established working groups include microbiome and ICT in Precision Food Systems. New IBF Working Groups are currently being proposed (e.g. Plant Health, Bio-economy Indicators).

220. The *Global Alliance for Climate-smart Agriculture* (GACSA) is a partnership of countries and international organisations committed to mitigating GHGs in agricultural systems. Partners currently include 23 countries and 7 United Nations organisations, with Brazil and Italy as co-chairs. The GACSA focuses on providing support for research and monitoring, data standardization and outreach activities.

221. The *Nordic Council of Ministers* developed a bio-economy strategy in 2014 for the west Nordic countries. Given the importance of fisheries in the economies of these countries, the strategy focuses on the fishing industry for creating value added. Within the agricultural sector, the strategy highlights opportunities for value creation by means of expanded research on soil conservation, grazing pressure and new crop varieties. To address harsh climatic conditions in the region, the strategy recommends establishing a research centre to support efforts for adapting crops to the unique environment. An advisory body - the Nordic Bio-economy Panel - was established in 2015 to identify key issues and opportunities for the region-related bio-economy.

222. Finally, the *Central-Eastern European Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bio-economy* is promoting a strategic vision for bio-economy development in Eastern Europe, including the **Czech Republic**, **Estonia**, **Hungary**, **Poland** and the **Slovak Republic**, as well as in South East European countries, Bulgaria, Romania, Slovenia and Croatia.

**Box 3.9. Increasing value creation in Norwegian aquaculture and agriculture – the case of *Foods of Norway***

*Foods of Norway* is a Centre for Research-based Innovation (CRI) at the Norwegian University of Life Sciences, funded by The Research Council of Norway and the Centre`s industry partners (www.foodsofnorway.net/). *Foods of Norway* uses new technology to increase value creation in the Norwegian aquaculture, meat and dairy industries. It targets three key research areas: Biomass, feed efficiency and product quality. A key research area is the use of novel biotechnology to develop sustainable feed resources from blue and green biomass (trees, seaweed and animal-co-products). New feed products will be developed from forestry, agriculture, and marine resources through industrial exploitation of cutting-edge research on processing and (bio)technology. *Foods of Norway* consists of a multidisciplinary research team with academic partners from Europe, Australia and the United States, as well as 19 industry and innovation partners.

# Annex 3.A.

**Annex Table 3.A.1. Synopsis of policy approaches, governance and monitoring**

| Country | Policy approaches | | | | | Governance | | | Monitoring | |
|---|---|---|---|---|---|---|---|---|---|---|
| | R&D&I | PPPs | Human capacity building | Labelling and certifications | Regulations, public procurements | Inter-ministerial co-operation | Bio-economy advisory council/action plan | Social dialogue | Quantitative targets | Indicators |
| Australia | X | X | X | X | X | X | | | X | |
| Belgium | X | | X | X | X | | | | | |
| Canada | X | X | X | X | X | X | | | | |
| Chile | X | X | | | | | | | | |
| Denmark | X | | | | | | X | | | |
| Estonia | | | | | | | | | | |
| European Union | X | X | X | X | X | X | | X | | X |
| Finland | X | X | X | X | X | X | X | X | | X |
| France | X | X | X | X | X | | X | X | | X |
| Germany | X | X | X | X | X | X | X | X | | |
| Ireland | X | X | X | X | X | X | X | X | | |
| Italy | X | X | X | X | X | X | | X | X | X |
| Japan | X | X | X | X | X | X | X | X | X | X |
| Korea | X | X | X | X | X | X | | | | |
| Latvia | X | | X | | | | | | X | |
| Lithuania | X | | X | | | | | | | |
| Netherlands | X | X | X | | | | | | | |
| New Zealand | X | X | | | | | | | | |
| Norway | X | X | | | X | X | | | | |
| Portugal | X | X | X | | X | X | X | | | |
| Spain | X | X | | | X | X | | | X | X |
| Sweden | X | X | X | | | | | | | |
| United Kingdom | X | X | X | | X | | | | X | |
| United States | X | X | X | | X | X | | | | |

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# 4. Bio-economy policies and practices by country

## Australia

223. Australia does not currently have an overarching bio-economy strategy in place at the national level. However, there are a number of initiatives underway (outlined below) that promote the principles of the bio-economy and aim to address similar challenges (e.g. sustainability of the food and agriculture system, resource scarcity, climate change and productivity growth).[23] Most bio-economy-related policies could be characterised as R&D strategies. The agriculture-related R&D priorities are food, soil and water and environmental change.[24]

224. Expected outcomes from these bio-economy-related initiatives include improved agricultural productivity and sustainability, reduced costs for agricultural businesses, reduced GHG emissions, and less waste going to landfill. Furthermore, investment in innovation around clean energy technologies and using waste to generate electricity may lead to improved resource efficiency and further environmental benefits in the future.

225. In terms of opportunities, the bio-economy has an important role to play in helping to deal with emerging challenges, including those arising from climate change, pressure on global food supplies and the management of pests and diseases. The bio-economy, such as biotechnologies, can benefit the environment, through reduced chemical use, and consumers, through the development of products with greater health benefits. Further opportunities for governments to better unlock the incentives for the private sector to engage with the bio-economy include continued improvement and coherence of the policy and regulatory environment to attract and encourage investment.

226. Key challenges and obstacle in developing the bio-economy of the agriculture and food system include: a potential lack of awareness of the opportunities that exist and the potential savings to be made; and that farmers and others are not always willing to risk taking on more debt through upgrading infrastructure and changing to new practices.

227. The *Australian Government's Emissions Reduction Fund* (ERF) provides incentives for businesses and landholders to reduce GHG emissions.[25] Some of the activities under the ERF include opportunities for more sustainable use of agricultural and food waste. These cover: using animal waste from piggeries and dairies to generate electricity through the combustion of methane; separating organic material from waste at

[23] Interestingly, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), which is the national science agency in Australia, has created a web portal on the bio-economy, where it lists the national research flagships that deal with bio-economy-related areas such as biosecurity, climate adaptation, sustainable agriculture and water issues.

[24] The 2008 report entitled *Biotechnology and Australian Agriculture: Toward the Development of a Vision and Strategy for the Application of Biotechnology to Australian Agriculture,* commissioned by Biotechnology Australia and the Department of Agriculture, Fisheries and Forestry, recognises the emerging concept of the bio-economy and deals with biotechnology applications in the agricultural sector. It also emphasises the importance of consumer trust for the technologies in question.

[25] www.environment.gov.au/climate-change/government/emissions-reduction-fund/methods.

the point of generation and diverting it away from landfill to be treated by eligible alternative treatments (such as composting and bio-digestion); and using compost and other organic fertilisers to increase plant productivity leading to increases in soil organic carbon.

228. The *Clean Energy Finance Corporation* (CEFC) is a statutory authority established by the Australian Government under the Clean Energy Finance Corporation Act 2012. The CEFC is investing in clean energy for agribusiness, including provision of asset finance for energy efficient equipment and renewable energy improvements, green loan lending for energy efficient and low emissions assets.[26] An Australian Bioenergy Fund finances technologies, including energy from agriculture waste projects and biofuel production.

229. The *Australian Renewable Energy Agency* (ARENA) provides support to projects that advance energy technologies along the innovation chain.[27] This includes support to bioenergy projects, which use waste from agricultural products, forestry products, municipal and other waste to generate energy.

230. Besides national innovation strategies, bio-economy development in Australia is very much characterised by regional approaches. For example, South Australia has issued a regional bio-economy strategy "Building a Bio-economy in South Australia 2011-15", which focuses on the development opportunities arising from biosciences. The strategy seeks to leverage expert expertise in the biosciences to foster innovation in several key sectors of the region, in particular for agriculture, wine and renewable energy.

231. In 2015, a major initiative was launched by the Federal State of Queensland with AUD 1 billion (around USD 780 million) for the "Queensland Biofutures 10-Year-Roadmap and Action Plan" (2016) for the industrial biotechnology and bio-based products sector. The initiative particularly seeks to foster knowledge and technology transfer by promoting collaboration among entrepreneurs and researchers from universities and public organisations. Investment in these high-value and knowledge-intensive industries is expected to increase economic growth and create new jobs, particularly in rural areas and regional centres.

232. The Australian Government's National Innovation and Science Agenda (NISA) (December 2015) sets out a new vision for Australia's entire innovation and science system. The agenda provides AUS 1 billion of investment aimed at supporting innovation and an entrepreneurial culture across all sectors of the economy. The agenda focuses on encouraging individual enterprises and complements existing efforts to build an innovative rural sector.

233. Australia also has a globally unique rural research and development system that operates as a partnership between industry and government. Central to the rural innovation system are Australia's 15 rural research and development corporations (RDCs), jointly funded by industry and government. The government provides over AUS 250 million annually to the RDCs, mainly by matching industry levies. Ongoing agricultural research is undertaken by other government-funded agencies, including Cooperative Research Centres, the Australian Research Council, universities, CSIRO, and the Food Innovation Australia Limited (FIAL) Industry Growth Centre. In 2011, the *Rural Industries Research and Development Corporation* (RIRDC) published a Bioenergy R&D Strategy focused on

[26] For more information see: www.cefc.com.au/where-we-invest/agribusiness/; www.cefc.com.au/case-studies/cefc-program-unlocks-bioenergy-potential.aspx.

[27] https://arena.gov.au/projects/?technology=bioenergy&project-value-start=0&project-value-end=500000000.

establishing value chains from sustainable biomass feedstock supply to bioenergy. It identified three priority areas for innovation: feedstock identification and availability; supply logistics; and sustainability. In 2015, the strategy was scaled back to a working group.

234. CSIRO's *Food & Agribusiness Roadmap*, released in July 2017 and developed with widespread industry consultation and analysis, identified a number of growth opportunities and enablers. Five key enablers for these opportunities are explored in the roadmap: traceability and provenance; food safety and biosecurity; market intelligence and access; collaboration and knowledge sharing; and skills. Sustained growth in the sector will require proactive investment and translation of enabling science and technology, involving transdisciplinary teams and trans-partisan relationships.

## Belgium

235. In Belgium, bio-economy policies vary according to region. The Walloon region places the bio-economy within the wider context of the green economy. The Flemish government published (in 2014) its vision for putting in place a long-term bio-economy strategy by 2030, with the bio-economy seen as a contribution to green growth, job creation and the further development of a circular economy. The strategy focuses mainly on promoting bio-economy related innovations.[28]

## Canada

236. In Canada, development of the bio-economy is focused on regional approaches. The first federal policy approach was launched in 2017 with the adoption of a strategy paper "A Forest Bio-economy Framework for Canada".

237. In 2006, the Government of Canada launched a four-pronged Renewable Fuels Strategy to encourage the development of a strong, domestic renewable fuels industry, including over CAN 2 billion in incentives and programming to encourage farmer participation in the biofuels industry. The strategy also included a regulation to require renewable content of 5% in gasoline and 2% in diesel fuel and heating oil. It led to the development of the first generation biofuels industry in Canada. Five provinces (British Columbia, Alberta, Saskatchewan, Manitoba and Ontario) have also implemented renewable fuels regulations, mandates and incentives that in some cases exceed the federal mandate requirements.

238. Although Canada does not have an official national bio-economy strategy for the agri-food sector, Agriculture and Agri-Food Canada (AAFC) has supported the development of the bio-economy through research, development and technology transfer and other initiatives. The federal government has provided support to the sector in previous agricultural programming in the CAN 125 million budget allocated to the Agricultural Bio-products Innovation Program and the funding for Growing Forward 1 and 2 science programming.

239. The *Industrial Bio-products Value Chain Committee* was established by AAFC as an industry-led forum tasked with enhancing Canadian competitiveness and profitability within the industrial bio-products sector. To ensure alignment between federal departments to better position Canada's agriculture and forestry sectors within the global bio-economy,

28. https://www.vlaanderen.be/nl/publicaties/detail/bio-economy-in-flanders.

*a Bio-economy Interdepartmental Working Group* was established by AAFC and Natural Resources Canada with a mandate to explore possible options for the development of a national framework and vision for the bio-economy.

240. Canada signed the Paris Agreement in 2015 and pledged to cut its GHG emissions by 30% below 2005 levels before 2030. The federal government in Canada is developing a Clean Fuel Standard (CFS) with lower carbon intensity requirements. The CFS is considered quite innovative and designs the regulation scope, regulated parties, carbon intensity approach, timing, and potential compliance options such as credit trading.

241. A key action under the CFS aims to reduce GHG emissions by 30 megatonnes per year by 2030 with measures to lower the carbon intensity of fuels used in transportation, buildings, and industry. The approach will be designed to incentivise the use of a broad range of lower carbon fuels, energy sources, and technologies. Ethanol and biodiesel produced from agricultural biomass are the main sources of renewable fuel in Canadian transportation fuels.

242. The CFS presents potential opportunities for the agriculture sector as providers of agricultural biomass for use in the manufacture of low-carbon fuels. The scope of these opportunities will depend on key design features of the CFS which is still under development.

243. Several provinces have policies that support the development of biogas from agriculture. In the past these policies have provided premium for biogas-generated electricity. Today, two provinces have implemented renewable gas policies that would support biogas-upgrading projects.

244. It is hoped that fostering the development of the bio-economy in agriculture would: increase revenue for agricultural producers and processors; generate new manufacturing lines; create new jobs requiring new skills; foster economic development in rural areas; and reduce landfilling of organic wastes and greenhouse gas (through displacement of fossil fuel based products by bio-products).

245. The main obstacle is uptake at a commercial scale. While in the literature, bio-products appear to offer a great potential for new economic development, in general, Canadian producers have not been convinced of their added value.

## Chile

246. Whilst Chile has not, as yet, adopted a specific bio-economy strategy related to agriculture and food systems, there are related initiatives. These initiatives are aimed at limiting food-waste, valorising re-use, promoting bio-energy generation (mainly from forestry and pulp waste, and livestock manure) and the development of bio-based agricultural inputs. In addition, there is an increasing interest from both the private and public sectors to promote the production and use of bio-based products, in particular bio-pesticides and bio-fertilisers, and food-ingredients extracted from food waste (e.g. natural colorants and enzymes).

247. In the absence of a specific bio-economy strategy, the expected outcomes relate to each individual initiative. Initiatives such as the development of bio-based agricultural inputs aim to reduce the environmental footprint of agricultural production, as well as minimise hazards to human health. Overall, it is hoped that increased resource efficiency and better use of waste will be achieved, especially through clean production policy.

248. Basically, two kinds of policies have been put in place to support bio-economy initiatives. On the one hand, different incentives have been established to generate and utilise non-conventional renewable energies, promoting the use of forestry and pulp waste and livestock manure to generate energy. On the other hand, different policies on R&D and innovation have supported the development of bio-economy initiatives, particularly research on micro-organisms, in order to develop agricultural inputs, such as bio-pesticides and bio-fertilisers.

249. These initiatives are monitored through the regular monitoring system used by the Chilean government, but there is no way to specifically monitor bio-economy initiatives.

250. The main opportunities for achieving the sustainable development through bio-economy initiatives in the agriculture and food system in Chile have been identified as follows: awareness of the private sector regarding the development of bio-economy in conjunction with the support provided by the public sector; development of bio-technological innovative products using local resources (i.e. local micro-organisms for bio-pesticides); the existence of strong R&D and innovations local infrastructure; and the availability of highly-skilled human capital.

251. On the other hand, the main obstacles have been identified as: the absence of a dedicated bio-economy policy and a lack of specific regulations. For example, agricultural bio-inputs have to follow the same bureaucratic path in order to obtain permits for commercialisation as agrochemicals. There are also gaps in the implementation of coherent agricultural, energy and environmental policies needed to ensure the coherence of bio-economy initiatives with other policies, such as those to foster the circular economy.

## Denmark

252. Denmark does not have a dedicated national bio-economy strategy, but numerous strategies and initiatives are being implemented to promote the sustainable development of the bio-economy. The government's commitment to a bio-economy is mainly reflected in the Growth Plan for Foods and the Growth Plan for Water, Bio and Environmental Solutions, published in 2013. In December 2015, the Danish Government re-confirmed its acknowledgment of sustainable bio-economy as an important agenda for sustainable growth.

253. A bio-economy panel has existed in Denmark since 2013, and was revised and re-established in 2017 with fewer members and a more dedicated marked-oriented focus. The first recommendations from the re-launched panel were announced in June 2018, regarding new protein value chains.[29] The Panel is now focused on bio-based products, and new recommendations are expected to be announced by April 2019.

254. Within the Growth Plan for Foods, the bio-economy mainly refers to sustainable and resource-efficient food production. The Growth Plan for Water, highlights, *inter alia*, the potential of country's agricultural sector concerning the production of biomass. At the regional level, several regions include bio-economy in their strategic approach. One example is the Central Denmark Region's bio-economy development programme.[30]

[29] http://mfvm.dk/fileadmin/user_upload/MFVM/Miljoe/Cirkulaer_oekonomi/Anbefalinger_om_proteiner_fra_Det_Nationale_Biooekonomipanel.pdf

[30] www.rm.dk/om-os/aktuelt/nyheder/nyheder-2017/maj-17/21-mio.-til-gronnere-gras-skaber-job-i-midtjylland/.

255. The Innovation Network for Biomass is a networking facility.[31] At the research and business level, there is the strategic platform for innovation and research on value-added products from biomass - BioValue SPIR.[32]

256. The recommendations from the National Bio-economy Panel are intended to help the government improve the framework conditions necessary for promoting the development of a sustainable bio-economy. The government will provide its reactions to the panel no later than three months after the recommendations have been made public.

## Estonia

257. Estonia does not have a bio-economy strategy but different strategic documents published by the government support the development of bio-economy related to agriculture, food and fisheries. Those of most relevance to the agri-food sector are: the 2014-20 Rural Development Plan; the National Development Plan of the Energy Sector until 2030; the Agriculture and Fisheries strategy 2030; and the General Principles of Climate Policy until 2050.

258. Several studies have been conducted – some of which are still ongoing – which generate new knowledge in the area of the bio-economy. The three-year bio-economy research project, *Maximising added value and efficient use of raw materials in bio-economy sectors*, started in March 2018 and prepared in co-operation with the Ministry of Rural Affairs, the Ministry of Economy and Communications, the Ministry of Environment and the Estonian Research Council, will examine the state of Estonia's bio-economy (including the supply and demand of resources) in the context of six bio-economic value chains: i) food and feed; ii) cellulose, paper and wood products and wooden buildings; iii) textiles and clothing; iv) fuels and energy; v) biomaterials, chemicals, pharmaceutical and plastic products; and vi) other ecosystem services related to the bio-economy.

## European Union

259. The European Union (EU) is a key player in promoting bio-economy, having declared a strong emphasis on the "knowledge-based bio-economy" in fields such as agriculture, bioenergy, new materials and bio-refineries. In the context of the Europe 2020 Strategy – which considers the bio-economy to be a key element for the sustainable, smart and green economic growth of Europe, while comprehensively addressing societal challenges – the 2012 Bio-economy Strategy (*Innovating for Sustainable Growth: A Bio-economy for Europe)* and an action plan were developed.[33] A key component of the strategy is the production of food, feed, bio-based products and bioenergy and the sustainable use of renewable sources.

260. The strategy encompasses all areas and sectors involved in the production or use of bio-resources. It was co-sponsored by the Commissioners for Research and Innovation,

31. http://www.inbiom.dk/en

32. https://biovalue.dk/

33. Two documents provide the policy and technical foundation: Communication, which set the scene, and a Working Document, presenting the action plan in detail, including some scenarios and policy interaction that arises from the strategy document.

Agriculture, Enterprise & Industry (now Internal Market, Industry, Entrepreneurship and SMEs), Environment, and Maritime Affairs & Fisheries.

261. Key actions proposed are: strategic research and innovation to support transition to the bio-economy; education and training to ensure a skilled workforce; the strengthening of bio-based sectors; creation of new markets and value chains; exploitation of opportunities at local level; the protection and restoration of natural resources; and the monitoring of progress.

262. The bio-economy is expected to be a driver of rural and coastal development. The EU vision builds on the understanding that the bio-economy rests on integrated systems and networks that use biological resources, maximise value-added and, ideally, work in closed loops with regard to raw materials, water, nutrient, by-products and energy (i.e. the "bio-economy web").

263. The main expectations with respect to managing natural resources sustainably are: smart, sustainable production of biomass; reduction and reversal of environmental degradation, loss of ecosystem services and biodiversity; implementation of an ecosystem-based management approach; and of smart, sustainable farming, fisheries and aquaculture.

264. The bio-economy strategy is in many ways a natural consequence of the EU 2020 climate-related goals, established in 2008 and the EU 2020 Strategy for Smart, Sustainable and Inclusive Growth. Linked to these is the resource efficiency platform. The strategy builds upon the EU's Renewable Energy Directive, which calls for Member States to derive 20% of their energy needs from renewable sources by 2020, and the biomass action plan, which encourages the use of biomass for heating, cooling, and transportation fuel, and promotes research projects. Under the EU 7th Framework Programme on Research and Innovation, approximately EUR 387 million has been directed towards the bio-economy (European Commission 7th Framework Programme).

265. The Strategy identifies five objectives: i) food security; ii) sustainable management of natural resources; iii) reduction of dependence on non-renewable resources; iv) mitigation and adaption to climate change; and v) the creation of jobs and preservation of EU competitiveness. These five objectives were addressed via the Strategy's action plan that focused on three areas with a total of twelve actions, sub-divided into 54 sub-actions (European Commission, 2012[1]). However, there is no a monitoring framework with regard to specific indicators and targets, thus making it difficult to carry out a quantitative assessment of the impact of the Strategy and of the Action Plan.

266. Concerning agriculture, the objective is to provide knowledge and tools for productive, resource-efficient and resilient systems for food, feed and bio-based raw materials, without comprising ecosystem services and in conjunction with policies that support rural livelihoods.

267. The Strategy is structured around three pillars for action: i) investments in research, innovation and skills; ii) reinforced policy interaction and stakeholder engagement; and iii) enhancement of market developments and competitiveness of the bio-economy sector.

268. The research and innovation pillar specifically focuses on co-funded investments. Support is provided by two EU research and innovation funding programmes: Horizon 2020, and the Bio-based Industries Joint Undertaking (BBI JU). The former receives support of EUR 3.8 billion – a doubling of the funding allocated to research and innovation dedicated to the bio-economy as compared to the previous period 2007-13 – and the latter is a EUR 3.7 billion public-private partnership (nearly EUR 1 billion of EU

funding and EUR 2.7 billion of private investment), which focuses on transforming biological resources, as well as residues and wastes, into greener products through the development, demonstration and large-scale deployment of innovative technologies and bio-refineries (European Commission, 2017[2]).

269. The European Commission also launched a Circular Bio-economy Investment Platform in November 2017 through the Horizon 2020 SC-2 funding programme to be managed by the European Investment Bank. It is proposed that this public fund of EUR 100 million will leverage private capital to fund technological validation and scale-up industrial bio-refinery development. It has been estimated that the direct research funding associated with the strategy under Horizon 2020 could help generate 130 000 additional jobs and EUR 45 billion in added value by 2025.

270. In the second pillar, in order to enhance policy coherence in the European Union, the bio-economy panel was created in 2013 to support interactions between different policy areas, sectors and stakeholders in the bio-economy (e.g. business and primary producers, policy-makers, researchers and civil society organisations). The panel was reorganised in 2016 to improve its representativeness of all the bio-economy-relevant sectors and stakeholders, and a stakeholders' manifesto was published in 2017, which lays down guiding principles and identifies actions that stakeholders and policy makers could take to develop the bio-economy along a shared societal agenda.

271. The Bio-economy Observatory (BISO) was also set up in 2013 to assess the progress and impact of the bio-economy and to develop forward-looking and modelling tools. However, the need to provide a more systemic and dynamic approach to support the Bio-economy Strategy (i.e. cross-sectoral and cross-policy) and related policies has led to a new entity that integrated BISO as of July 2017, namely, the Bio-economy Knowledge Centre (BKC). The BKC is expected to act as a knowledge hub on the bio-economy, as well as identifying critical knowledge gaps.

272. The third pillar encompasses activities concerning the development of methods of measurement and standards for different bio-based products, as well as for labels for the communication of product characteristics to the consumer (e.g. the European Innovation Partnership for Agriculture).

273. The strategy was reviewed in November 2017 and it was found that, while it had been successful in mobilising funding for research and innovation purposes, further investment is necessary for scaling-up and rolling-out new products and technologies (European Commission, 2017[3]; European Commission, 2017[2]). In turn, this would require a more stable regulatory environment to diminish uncertainties around investment funding.

274. In addition, the review found that while efforts have been deployed to reinforce the development of human capital for the bio-economy, the level of ambition of the Strategy and of the actions implemented have remained limited (e.g. vocational training is largely absent). Similarly, whilst technologies are being researched and developed, it remains difficult to predict whether (and when) they will reach the market.

275. The review also found that as the bio-economy impinges on many different policy areas – such as the impacts of increased biomass use on water, soil, ecosystem services and biodiversity – a greater level of policy coherence and appreciation of synergies is necessary.

276. The EU Bio-economy stakeholders' panel – a group representing industry, public administration, researchers and civil society – reinforced some of these points in calling for

a stable legal framework, to reduce regulatory uncertainty, and for greater co-operation between sectors and actors along the value-chains associated with the bio-economy.[34]

277. In October 2018, the European Commission unveiled its updated bio-economy strategy and new three-tiered action plan (https://ec.europa.eu/commission/news/new-bioeconomy-strategy-sustainable-europe-2018-oct-11-0_en):

- scaling up and strengthening bio-based sectors (e.g. promoting and developing standards, labelling and market uptake of bio-based products, such as the EU Ecolabel or green public procurement);
- deploying local-bio-economies across Europe (e.g. a strategic deployment agenda for sustainable food and farming systems, forestry and bio-based products); and
- a better understanding of the ecological boundaries of the bio-economy (e.g. implementing an EU-wide monitoring system to track progress towards a sustainable and circular bio-economy).

## Finland

278. Finland possesses large areas of forest, which represent an important resource for the development of a bio-economy. It has also carried out research and innovation in the field of bio-refining and bio-based industries.

279. The Finnish bio-economy strategy, *Sustainable Growth from Bio-economy*, published in 2014, was prepared in close collaboration with stakeholders.[35] Although it focuses on the forest sector, the strategy underlies the importance of water as a prerequisite for a successful bio-economy and highlights the need for improved technologies for water efficiency and water recycling. The sustainable use of water and aquatic natural resources is also the core aim of the *National Development Programme for Blue bio-economy 2025* adopted by the government in 2018.

280. Its central objective is to generate economic growth and create jobs by promoting business related to the bio-economy and from developing high value-added products and services, while respecting ecosystem services. The objective of the Bio-economy Strategy is to push the output of the bio-economy up to EUR 100 billion by 2025 and to create 100 000 new jobs.[36]

281. The strategy also addresses the issue of consumption patterns. Three focus areas are: i) the boosting of investments, particularly in bio-refineries; ii) regulation (e.g. regulatory survey on "Bio-economy bottlenecks and boosters"; open access to biomass data (Biomass Atlas); and iii) promotion of exports of bio-based products and technologies.

34. On 20-21 September 2018, the European Commission organised a workshop on Best practices in integrating primary producers (farmers and forestry owners) in the bio-economy value chains and boosting the development of the bio-economy in rural areas. The focus of the workshop was to reflect on best practices and identify different possible business models in the bio-economy. The workshop also presented best practices regarding national/regional polices in this area.

35. www.bio-economy.fi/facts-and-contacts/finnish-bio-economy-strategy/.

36. http://biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

282. Concerning initiatives related to the agriculture and food system, the government has started a key project for a circular economy, which includes the second phase of the *Making use of Agricultural Nutrients* project. With regard to pollution of the Baltic Sea and other water systems, the project aims at bringing at least 50% of the manure and municipal sewage sludge in the areas involved under advanced processing by 2025. Finland's ambition is to become a model country in terms of efficient recycling of agricultural nutrients in order to improve the health of the water systems, reinforce food security and create new business opportunities.[37]

283. Another agriculture-related initiative is the *Climate Programme for Finnish Agriculture – Steps towards Climate-Friendly* Food.[38] The Programme consists of 76 measures to facilitate the adaptation of food production and consumption to climate change and/ or mitigate the change.

284. Financial support for the development of bio-economy in agriculture is mainly provided through the measures in the EU Rural Development Programme 2014-20.

## France

285. France has a long tradition in bio-economy development and policy support.[39] It is host to one of the world's largest bio-refineries and is responsible for establishing the "Industries & Agro-Ressources" (IAR) Competitiveness Cluster.

286. A dedicated national bio-economy strategy, *A Bio-economy Strategy for France* was published in January 2017[40] and an Action Plan was published in February 2018.[41] Some regions are also building local bio-economy strategies and are working on regional bio-economy roadmaps.

287. The primary goal of the strategy is to promote sustainable economic growth in France. There are four main challenges: i) producing more bio-resources sustainably and using them; ii) making bio-economy products a market reality; iii) supporting innovations; and iv) sharing bio-economy results with stakeholders.

288. It is hoped that the development of bio-economy would result in: improving food security; providing new jobs for farmers and forestry workers; creating economic value; reducing the country's dependence on imports of fossil products; contributing to the reduction of GHG emissions; and enhancing carbon sequestration in agricultural soils.

289. The strategy focuses on innovations in primary industries, which are intended to contribute to the sustainable production and utilisation of bio-resources. This includes, for example, promoting sustainable resource management practices (such as precision farming) and adopting innovative crop-production systems (e.g. organic farming, agro-ecology and agroforestry). The strategy also prioritises the utilisation of waste resources and residues from primary industries.

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37. https://mmm.fi/en/recyclenutrients.

38. https://mmm.fi/en/climatefriendlyfood.

39. See, for example, Economic, Social and Environmental Council (CESE) (2017), *Vers une bioéconomie durable*, http://www.lecese.fr/travaux-publies/vers-une-bioeconomie-durable.

40. http://agriculture.gouv.fr/telecharger/88386?token=d7ce1762548787efcf4c17968b81895e.

41. http://agriculture.gouv.fr/une-strategiebioeconomie-pour-la-france-plan-daction-2018-2020.

290. The bio-economy strategy is consistent with the other national strategies relating to the production of bio-resources, their mobilisation, use and the environmental goals and issues involved: the plant protein plan, the agro-ecology project, the national low-carbon strategy, the national biomass mobilisation strategy and regional biomass schemes, the roadmap for a circular economy, the national biodiversity strategy, the multiyear energy programme, the "*4 per 1000*" programme unveiled at the Paris Climate Change Summit, the national forest and wood programme, the convention on biological diversity and the national strategy for the sea and coastal areas.

291. Another characteristic of the strategy is the importance of the role of society in the design and implementation of the strategy, which is seen as a prerequisite for the successful transformation into a bio-economy. The strategy also stresses the need to strengthen the demand side of the bio-economy (i.e. by raising awareness of bio-based products through standards, certifications and labels (e.g. a dedicated label for bio-based products).

292. In order to create bio-economy-friendly framework conditions, the strategy proposes, *inter alia*, regulations supporting the use of biobased innovation in the construction sector (e.g. using hemp-based materials in construction).

293. The Action Plan – a result of a stakeholder consultation process – puts forward measures for promoting bio-economy development in the period from 2018 to 2020. The Action Plan addresses five areas of action, including: the improvement of knowledge; the raising of public awareness of bio-economy and bio-based products; the promotion of both the demand and supply sides; and the sustainable production and utilisation of bio-based resources as well as new financing mechanisms.[42] The Action Plan also highlights the development of new value chains (e.g. based on animal by-products). However, the strategy does not set out a concrete budget for implementing the measures proposed.

294. Opportunities to foster the sustainable development of bio-economy for the agriculture and food system include: identifying bio-based products through explanatory labelling; conducting communication campaigns to showcase bio-economy products, databases listing bio-based products and holding open days in companies active in the bio-economy; implementing agricultural policies (CAP 2020) to support intercropping; public procurement; public funding to facilitate investment in methanisation of bio-based products; training to disseminate the bio-economy concept and continuous training courses and school programmes.

295. On the other hand, key impediments include: lack of public awareness about the bio-economy; reluctance to use bio-resources to produce anything other than food; investment in bio-economy linked to the price of fuel oil; and the heterogeneity of bio-resources.

296. The government is also developing a national biomass mobilisation strategy aimed at sustainable biomass production and utilisation. This strategy provides a national framework for assessing the current and potential supply and demand for various biomass types (agricultural, forest-based and marine sources). A national biomass resources observatory has also been developed and has become a major source of data for regional authorities that make use of bio-resources.

42. The Action Plan highlights the building of a bio-based Olympic village for the Olympic Games in 2024, which could show case bio-based materials used in construction (e.g. wood, hemp, flax fibre).

## Germany

297. Germany represents one of the frontrunners in the development of its national bio-economy strategies: a Bio-economy Policy Strategy was adopted in 2013 (a Progress Report was published in 2016) and a national research strategy, *National Research Strategy Bio-economy 2030: Our Route Towards a Bio-based Economy*, was published in 2010.

298. The strategy for a bio-economy pursues a comprehensive approach to fostering bio-economy development and has a strong focus on research and innovation. It targets economic growth as well as global responsibility and addresses global nutrition, sustainable agriculture, food safety, renewable resources for industry and biomass-based energy, as well as cross-section activities.

299. The expected outcomes of the National Bio-economy Strategy are a strengthening of Germany's bio-economy, particularly its innovative power and its international competitiveness in business and research; an increase in the sustainable use of renewable resources while conserving biodiversity and soil fertility; protection of the climate; creation of employment and value-added, particularly in rural areas; encouragement of sustainable consumption, as a part of the bio-economy's value chain; and contribution to global food security.

300. The German bio-economy strategy is national, but within the context of a global outlook. It is built on several pillars and covers numerous sectors, the impetus being in the field of biotechnology. The main topics for action are: securing improvement in global nutrition; ensuring sustainable agricultural production; producing healthy and safe foods; using renewable resources for industry; and developing bio-based energy carriers.

301. The aforementioned fields are specified in more detail and examples are given within each field of research needs, ongoing funding and goals, as well as measures on how to reach these goals. The description of each field includes specifications of which guidelines will be followed for the implementation of the measures described.

302. The strategy also includes cross-sectoral activities, such as transdisciplinary research, facilitating implementation of new innovations and technologies through the actions of many parties (academia, small- and medium-sized enterprises, and industry), exploiting international collaboration and knowledge sharing, and intensifying the dialogue with society.

303. With a bio-economy geared to sustainability and resource efficiency, the aim is to shift from the era of fossil fuels and technologies, to make a contribution to securing the long-term and sustainable supply of energy and raw materials, and to tackle key social challenges in the process through:

- Securing and create economic prosperity and jobs;
- Finding resource alternatives in view of the finite nature of fossil resources;
- Taking global responsibility in counteracting climate change;
- Protecting natural resources and using renewable resources in a sustainable way; and
- Ensuring the supply of food and the right to development of all parts of a growing world population.

304. The policy strategy (Progress Report 2016) pursues the following core goals:

- Securing the supply of high-quality food for the German population and – to the extent possible - contributing to the food supply for a growing world population;
- Assuring a food supply with sustainably produced renewable resources;
- Assuring the research excellence in Germany; and
- Protecting biodiversity, long-term soil fertility and the climate, when producing and using renewable resources.

305. A Bio-economy Council was established in 2009, which is an independent advisory committee to the government for all matters regarding the bio-economy. It consists of experts from academia, from public sector research and from research departments of the federal government. The Council has published a number of recommendations for actions on which the national strategy is based.

306. Several policy documents relating to the bio-economy of the agriculture and food system have been issued, and include: German National Action Plan Bioenergy (2009); the Federal Government's action plan for the industrial use of renewable resources (2009); National research strategy bio-economy 2030 (2010) – which highlights social dialogue between the industry and the social actors, as an integral part of building a bio-based economy; Biorefineries Roadmap (2012); National Policy Strategy Bio-economy (2013) and Progress Report 2016 ; the cornerstones of North Rhine-Westphalia's Bio-economy Strategy; and German Sustainability Strategy.

307. In terms of initiatives, they include: the German Bio-economy Council[43] (*public awareness*); Bio-economy Council Bavaria[44] (*public awareness*); Charter for Wood[45] (*partnership*); funding via Programme "Renewable Raw materials" of the Federal Ministry of Food and Agriculture (BMEL) managed by the Agency for Renewable Resources (FNR)[46] (*knowledge generation*); Research Program Bio-economy Baden-Württemberg[47] (*knowledge generation*); BMEL communication campaign "Neue Produkte: aus Natur gemacht"[48] (*public awareness*); and the Bio-economy Cluster.[49]

308. Major issues in the bio-economy debate in Germany include: the ethical debate about consumerism and the commercialisation of nature; waste of food; safety and quality of agricultural products as well as agricultural production; use of (bio) technologies and the associated – possibly negative – consequences; origin of bio-based raw materials and the global impact of resource use (e.g. palm oil and the impact on biodiversity).

309. A comprehensive monitoring approach is currently being developed in a joint inter-ministerial undertaking of the BMEL, the Federal Ministry of Economic Affairs and

43. http://biooekonomierat.de/.

44. http://www.biooekonomierat-bayern.de/.

45. https://www.bmel.de/DE/Wald-Fischerei/03_Holz/_texte/ChartaHolz2017.html.

46. https://www.bmel.de/SharedDocs/Downloads/Landwirtschaft/Bioenergie-NachwachsendeRohstoffe/FPNR-Foerderschwerpunkte.html.

47. https://biooekonomie-bw.uni-hohenheim.de/en/researchprogram.

48. http://www.bmelv.de/SharedDocs/Downloads/Broschueren/NeueProdukteNaWaRoImAlltag.pdf?__blob=publicationFile.

49. http://www.bio-economy.de/.

Energy (BMWi) and the Federal Ministry of Education and Research (BMBF), including the following elements: monitoring of biomass flows;[50] identification of economic key performance indicators to monitor the bio-economy;[51] systemic effects of bio-economy.[52]

310. The biomass potentials of residual and waste materials in Germany are recorded by a Working Group headed by the German Biomass Research Centre (DBFZ). It is an ongoing project supported by BMEL/FNR on the basis of the Renewable Resources Programme.

311. The cultivation and processing of renewable raw materials and energy crops are being monitored. Data are collected and analysed for the agriculture, forestry and fisheries sectors as well as the downstream production chains. The following work packages being pursued in the project cover: the concept of cross-sector material flow analysis; material flow analysis for agriculture, wood and fish; framework concept for sustainability balance sheets of a bio-economy; and the concept for sustainability accounting of the bio-economy. However, the extent to which actual data will be made available on a large scale is currently not foreseeable. The current focus is on the design of both data collection and sustainability assessment.

## Ireland

312. The *National Policy Statement* released in February 2018 – the outcome of extensive consultation – sets out a vision, the strategic policy objectives for developing the bio-economy, and identifies guiding principles to implement the vision. It also outlines the major challenges such as promoting greater coherence across all areas impinging on the bio-economy; developing an appropriate regulatory regime for the bio-economy that would encourage private investment; stimulating market demand for bio-economy products; and accessing funding available at EU level (Government of Ireland, 2018[4]).

313. The Government recognises that the bio-economy is crucial for sustainability while also providing an impetus to rural development and employment. The strategic policy objectives aim to increase GHG mitigation, decarbonisation and sustainable economic development and increased rural employment.

314. The Government has mandated an implementation Group – jointly chaired by the Departments of Agriculture, Food and Marine and Communications, Climate Action and Environment – to take forward a number of major actions, in close collaboration with bio-economy industries and other partners, and report back to Government by the end of 2018. The main areas to be explored include: knowledge generation; knowledge transfer; generation of value chains; public awareness; and partnerships. The remit covers agriculture, food and marine as well as waste. In the medium term, the focus is to strengthen the commercial prospects for the bio-economy. It is expected that the bio-economy will develop in line with principles of: sustainability; food first; the precautionary principle and cascading use of biomaterials. The circular economy concept is also encouraged.

315. In the medium term, the Group will seek to: i) increase sectoral coherence between government departments and agencies; ii) increase bio-economy network activity and

50. https://www.thuenen.de/de/institutsuebergreifende-projekte/biooekonomie-monitoring/.

51. https://www.atb-potsdam.de/forschungsprogramme/projekt/portrait/wiebke-jander.html?xq=422.

52. https://www.uni-kassel.de/einrichtungen/cesr/forschung/projekte/aktuell/symobio.html.

raising of awareness with key stakeholders; iii) translate R&I into industrial application; and iv) examine waste legislation for re-designation of residual waste flows to be successfully managed for use in the bio-economy management; and v) evaluate the key value chain propositions identified in the *Bio-Eire* project in terms of technical viability, economic, viability and sustainability (see below and Box 4.1).

316. Supporting policies in the strategy include: Innovation 2020 – Government Science, Technology & Innovation Strategy; National Research Prioritisation update 2018; FoodWise 2025 – a ten-year plan for the agri-food sector; Action Plan for Jobs; Action Plan for Rural Development; and National Bio-economy Policy Statement (2018).

317. Project Ireland 2040 - the *National Planning Framework* also highlights the potential of the bio-economy in promoting more efficient use of renewable resources while supporting economic development and employment in rural Ireland.

**Box 4.1. The BioEire project**

The BioÉire project, which was concluded in 2017, aimed to identify the most promising value chain opportunities for development in the Irish bio-economy. This project has played a significant role in raising awareness of the bio-economy concept and value chain opportunities amongst public and private sector stakeholders. The project identified the need in the short/medium term to focus on agricultural, marine and forestry resources through the valorisation of waste and side streams and the production of bio-based materials, bio-based chemicals and bio-energy. Value chains with significant short-term potential were identified as the use of dairy side streams for new food products and the use of agricultural and food waste for bio-energy production.

The project also highlighted a number of concerns in the bio-economy for further consideration, namely the issues of: policy coherence, sufficient scale, international competition, economic and technological feasibility, market availability, consumer acceptance, legislation and regulation impediments, environmental sustainability, and the prevalence of robust supply chains, industry fragmentation and competition with food production.

The ultimate aim of the project was to identify up to eight value chains that will be evaluated in terms of technical viability, economic viability, and sustainability thus informing development of integrated measures to overcome barriers and facilitate exploitation of commercial opportunities for the expansion of the Irish bio-economy.

318. Another development includes the establishment of the *Science Foundation Ireland of the Bio-economy Research Centre* in September 2017, which brings together relevant stakeholders from industry, academia and policy leaders. Its purpose is to enable the transition to the bio-economy through scientific research that will develop new products and technologies and stimulate rural development.

319. The *National Research Strategy* highlights research priorities in bio-economy-related areas such as functional foods, sustainable food production and processing, marine renewable energy, processing technologies and novel materials.

320. The Action Plan for Rural Development (2017) establishes baseline assessment of the current bio-economy activity and opportunities across the various sectors in Ireland and underlines how the bio-economy can contribute to decarbonisation, sustainable growth and job creation in the agricultural, industrial and technological sectors in rural areas, where 80% of the agri-food sector is based.

321. Over the past several years, the Department of Agriculture, Food and the Marine has funded a number of collaborative, academic-led bio-economy related research projects including the *BioÉire* research project, led by Teagasc, focused on identifying and prioritising interlinking cross-sectoral value chains in the bio-economy.

322. The government, through Science Foundation Ireland funded EUR 14.2 million for the Bio-economy Research Centre (Beacon) in 2017, which will explore how to convert marine resources and the residues produced during food production into higher value products. The government also funded a pilot bio-refinery facility in 2017 to be operational in 2019.

323. The main opportunities for the development of the bio-economy of the agri-food system are being harnessed through: commercial application; improved networks; improved innovation ecosystem; regional and local level bio-economy development; development of a bio-economy pipeline and innovation platform; waste as a feedstock (e.g. wastewater, MSW, sewage sludge); a comprehensive policy framework to address bio-economy development; and bio-refineries and small-scale bio-economy opportunities for the agriculture sector.

324. Obstacles that impede the sustainable development of the bio-economy of the agri-food system that need to be further addressed include: mapping of resources and clustering; integration of bio-economy development with natural capital accounting; mobilisation of biomass; lack of indicators to monitor and evaluate performance; sectoral coherence; regulatory challenges; alignment of pull (demand) measures and push (supply) and pull measures; education and skills needs; improving the necessary level of primary producer, public and consumer awareness; implementation of circular economy principles to ensure that valorisation of resources is built on unavoidable wastes; how to enhance applicability of bio-economy for the primary producer; and planning, including alignment of energy, agri-food, circular economy and bio-economy implementation.

## Italy

325. Within the EU-28, Italy has been identified among those countries with a "bio-economy geared toward the agro-food industry and bio-based chemical industries" (Ronzon et al., 2015). Thus the bio-economy is centred on increasing value-added from the primary production sectors (Biookonomierat, 2018[5]).

326. In April 2017, the Italian government officially adopted the strategy document entitled *Bio-economy in Italy: A unique opportunity to reconnect economy, society and environment*. The Italian Presidency of the Council of Ministers promoted the strategy and all main administrations, both central and regional, have been involved in the preparation, including the Ministry of Agriculture, Food and Forestry Policies. The private sector also contributed and a broader involvement of civil society in policy design and implementation emerged as a major objective of the strategy. The strategy was put for public consultation from November to December 2016.

327. The National Bio-economy Strategy considers agriculture, forestry and the agri-food sector as well as the marine bio-economy and bio-based industries as the core sectors of "an integrated Italian bio-economy ecosystem". Its main objectives are to improve the productivity of the bio-economy sectors sustainably by creating networks among them and their value chains, by increasing the efficiency and sustainability of bio-based value chains and by creating new value chains, while preventing biodiversity loss and protecting ecosystems.

328. The strategy also seeks to create: i) a wider and more coherent political commitment; ii) more investment in R&I, spin off/start-up, education, training and communication; iii) better co-ordination between EU national and regional policies and stakeholders; iv) better engagement of a public dialogue; and v) tailored market development actions. Particular emphasis is given to research and innovation places a strong emphasis on sustainability and the circular approach to the bio-economy, and provides a system of indicators to monitor progress. The strategy sets a quantitative objective, such as achieving the sustainable increase – of about 20% – in the Italian Bio-economy turnover and employment by 2030.

329. With regard to the agricultural sector, the following priorities have been identified: the improvement of: i) resource management and efficiency; ii) multiple functions and benefits of land, rural and abandoned areas; and iii) human and social capital and innovation.

330. The Bio-economy Strategy includes some accompanying measures in order to: boost demand-side innovation policy tools such as standardisation, labelling, and public procurement; boost demand for bio-economy products and services and create a bio-economy marketplace, to match demand and supply of biomasses, technologies, and services; promote education and professional training for bio-economy specialists, including with partnerships with private and/or industrial actors; support corporate social responsibility by proposing a methodological framework to enterprises to highlight the bio-based contents and features of bio-economy processes and products.

331. The National Strategy highlights the need for better co-ordination between regional, national and EU policies and initiatives. It also emphasises the importance of regional approaches, which are critical for implementing circular economy activities and for improving environmental resilience and adaptation to climate change. In this respect, the promotion of key enabling technologies, such as industrial and environmental biotechnologies, 'omics' and big data, digitisation and precision farming, is considered vitally important. The strategy underlines the social dimension of the bio-economy and the importance of education, training and societal participation

332. The strategy aims to implement a number of measures to support both horizontal and vertical policy co-ordination as well as monitoring and review. In particular, it highlights the need for co-ordination in the implementation of European waste-related legislation. The strategy defines a set of indicators for monitoring the implementation process. These indicators are based on the EU key performance indicators and the sustainability indicators proposed by the *EU initiative29*.

## Japan

333. Japan does not, as yet, have an overarching bio-economy strategy, although plans are underway to formulate one, which will include the agri-food sector. Moreover, there are some strategies and initiatives to promote the bio-economy of the agriculture and food system.

334. The *New Basic Plan for the Promotion of Biomass Utilisation*, which was initially decided by the government in 2010, and subsequently revised in 2016, aims at the efficient utilisation of the available biomass along the entire value chain. It sets the directions of policy, including targets for utilisation of different types of biomass up to 2025 and the development of technologies for efficient biomass utilisation at national, prefectural and district level. Quantitative targets – including the food sector – are being introduced in order

to improve biomass supplies and the circular economy. Recycled food waste is primarily used for producing animal fodder, 40% of which is targeted to come from domestic production by 2025.

335. Under the *New Basic Plan*, the government in promoting: i) increased use of biomass in order to create more value added; ii) multiple-stage application of biomass to ensure the thorough use of limited resources; and iii) biomass utilisation for heat. The *New Basic Plan* is expected to contribute to the revitalisation of agriculture, forestry and fisheries and local communities, the creation of new industries to supply biomass products, and the prevention of global warming (i.e. reduction of fossil fuel use and thus a decrease in GHG emissions).

336. The main thrust of the *Biomass Commercialisation Strategy* – which was developed in 2012 by the Ministry of Agriculture, Forestry and Fisheries (MAFF), along with six other ministries – is the development of renewable energy systems in rural regions (currently accounting for less than 10% of total energy consumption) and the development of industrial conversion technologies (e.g. methane fermentation and combustion) as well as new products. The main policies targeted at achieving these objectives include: i) technological development; ii) incentives to stimulate market demand (e.g. the feed-in tariff scheme, carbon credit system and tax reductions); iii) procurement of raw materials (the establishment of agricultural and forest management systems to supply biomass resources to manufacturers in a stable manner; development of highly-productive energy crops and plants; full utilisation of waste-related biomass, such as food, and animal and human waste); iv) specific measures concerning the targeted biomass (biofuel, woody biomass, food waste, sewage sludge and animal waste); v) establishment of *biomass industrial communities*; and the development of technologies and business models related to biomass overseas, particularly in Asia.

337. The main obstacles to the sustainable development of the bio-economy relate to biomass market barriers to entry, such as lack of local market knowledge; difficulties in securing stable feedstock supply; problems in adapting the technology to local feedstocks; and the necessity for regulatory approvals. Government actions for addressing barriers through regulatory reform, commercialisation of biomass, taxes and other incentives to promote biomass generation are considered of critical importance.

338. Japan implements the various policy strategies by means of targets, action plans and measurable indicators. A national target of average utilisation ratio is set for each type of biomass, to promote the thorough utilisation of each variety processed and to clarify the necessary measures to be taken at the national level (see Table 4.1). Guidelines for achieving these targets are set out, along with a technical "road map" to identify key technologies and biomass resources and a list of priorities, ranging from raw material procurement to the securing of markets. An estimate of annual energy potential from biomass by 2025 is also included.

339. Table 4.1 indicates the current utilisation rate of each biomass type and the target set for 2025, some of which vary significantly compared to current utilisation rates. The economic efficiency of biomass utilisation in general needs to be improved, since most biomass is distributed widely, but thinly across the region. Crop potential for biomass usage in Japan is limited due to the disparity of climate between northern and southern Japan (Pambudi et al., 2017[7]). The key points for turning the challenges into opportunities are: i) ensuring the efficient collection of raw materials and the establishment of an adapted transportation system; ii) securing sales and distribution routes for biomass products;

iii) promoting a wide range of application (creation of high-added value); and iv) reducing the cost of production and application technology.

**Table 4.1.Targets for biomass utilisation by type**

| | Type | Resources | Utilisation rate | | Measures for achieving the targets |
|---|---|---|---|---|---|
| | | ('000 tons) | Current | Target | |
| Waste | Livestock | 81 000 | 87% | 90% | In addition to its use in compost, promoting advanced energy use, such as carbonisation, methane fermentation, etc. |
| | Sewage sludge | 80 000 | 63% | 85% | Expanding its use in construction materials and fertiliser to methane fermentation and the production of solid fuel. |
| | Black liquor | 13 000 | 100% | 100% | Maintaining its use as a fuel at paper and pulp plants |
| | Paper | 27 000 | 81% | 85% | Promoting the use of recyclable paper |
| | Food | 17 000 | 24% | 40% | Promoting its use as fertiliser and feed |
| | Timber, off-cuts from sawmills, etc. | 6 400 | 97% | 97% | Maintaining its use in the form of wood board and raw materials for paper manufacturing |
| | Wood chips generated by construction | 5 000 | 94% | 95% | Maintaining its use as raw materials for wood boards and livestock litter |
| Unused | Non-food parts of agricultural production | 13 000 | 32% | 45% | Converting from ploughing it in at farmland and promoting its use as feed and fertiliser; promoting its use as fuel. |
| | Timber off-cuts from forest | 8 000 | 9% | 30% | Promoting its thermal use |

*Notes*: Current resources and utilisation rates refer to data collected as of March 2016.
*Source*: Ministry of Agriculture, Forestry and Fisheries (MAFF) (2016), Basic Plan for the Promotion of Biomass Utilisation, September 2016, www.maff.go.jp/e/policies/env/attach/pdf/index-4.pdf; https://www.asiabiomass.jp/english/topics/1608_01.html.

## Korea

340. Korea's commitment to bio-economy is reflected in its nation-wide Basic Plans to promote R&D in biotechnology. With the third *Biotechnology Promotion Basic Plan, namely, Bio-economy Innovative Strategy* 2025 (*2017-26*) established in 2017, Korea put in place nine objectives, based on three strategies including bio-R&D innovation, the creation of a bio-economy and preserving ecosystems for the bio-economy. The plans are jointly undertaken by seven government agencies, including the Ministry of Agriculture, Food and Rural Affairs (MAFRA), with the Ministry of Science and ICT as the lead agency.

341. The expected outcome of biotechnology-related strategies in agriculture is to strengthen agricultural competitiveness through the development and application of core agricultural biotechnologies through R&D. Over KRW 200 billion is invested by MAFRA in projects relating to agri-bio industry technology development, high value-added food technology development and "golden" seed projects for the development and application of bio-technology using bio-resources. Major achievements so far include the development of core agri-bio technologies/infrastructure, genome sequencing/utilisation of major agri-bio resources and promotion of high value-added product development using agri-bio technology.

342. Progress of bio-related R&D is being monitored quantitatively by indicators such as research papers, royalties, patent registration and technology application, and revenues of companies that introduce R&D results into the market. The economic and social effects

(employment, added-value, production) of R&D and commercialisation of the results are also monitored.

343. In addition to the R&D sector, there are "mid-to-long term measures for energy recovery from livestock manure", aimed at producing bio-energy with livestock manure, amounting to KRW 27.3 billion (EUR 21 billion) over the 2015-17 period. The size and supply channels of each type of biomass used in the domestic bio-industry have been estimated in the report, *Status and Challenges of the Agricultural Biomaterial Industry,* published by the Korea Rural Economic Institute (KREI) in 2017.

## Latvia

344. Latvia adopted a national bio-economy strategy (*Latvian Bio-economy Strategy 2030*) in 2017, which is strongly aligned with the European Union's bio-economy strategy. Its development was led by the Ministry of Agriculture and is characterised by broad stakeholder involvement.

345. The strategy specifically targets businesses in the primary industries (including agriculture, forestry and fisheries) and in manufacturing, including the food and feed industry. It highlights, for example, the promotion of innovative plant and animal breeding technologies, sustainable resource management practices and improved land-use efficiency.

346. Excellence of research and effective knowledge transfer in bio-economy sectors are defined as preconditions for reaching the strategic goals of the Strategy. Therefore one of the five main action areas of the Strategy is knowledge and innovation development. Other actions include promotion of co-operation between small producers, as well as promotion of bio-economy and public involvement.

347. In order to promote innovation, the Strategy stresses the need for increased public R&D investment in environmental protection (particularly with respect to soil fertility, water and air quality), climate-resistant crops and tree species, organic farming and animal health and welfare.

348. The strategy also highlights the promotion of measures related to capacity building and education, including interdisciplinary and multidisciplinary training and education programmes, as well as higher education and life-long learning opportunities.

349. The EU CAP instruments are the main support instruments for the implementation of the Strategy. Progress will be monitored for the three strategic targets of the Strategy (employment, value-added and export).

350. Among the measures mentioned for ensuring bio-economy-friendly framework conditions are regulations for sustainable agriculture and forestry (e.g. land-use policies based on functional land-use principles).

351. Given the country's favourable agro-climatic conditions for biomass production, Latvia has significant potential for the development of the bio-economy. Insufficient funding for R&D, lack of cross-sector co-operation, short-term planning in business and policies, and climate-related risks are the main obstacles to the sustainable development of the bio-economy of the agri-food sector.

## Lithuania

352. Lithuania's approach to the bio-economy is outlined in the *Smart Specialisation Strategy* adopted in 2014. The strategy encourages excellence driven by both technological and non-technological drivers. Lithuania has set up six priorities for R&D and innovation development, one of which relates to sustainable agro-biological resources and safer food.

353. The development of the bio-economy in agriculture is mainly supported through sectoral policies, particularly through the EU Rural Development Programme 2014-20 (RDP). The Ministry of Agriculture is also an active partner and has implemented the *Bio-economy - Agriculture, Forestry and Fisheries* policy area of the *Macro Regional Strategy - EU Strategy for the Baltic Sea Region*. In particular, the Ministry of Agriculture is co-ordinating the activities of rural development in relation to the bio-economy.

354. The legal environment in Lithuania is generally favourable to the development of a bio-economy. Structural rigidities in labour market, migration from Lithuania, ageing of the population, taxation, high input costs, the existence of the shadow economy and climate change are the main obstacles in developing the bio-economy in the agri-food sector.

## The Netherlands

355. In the Netherlands, existing sustainability agreements between agriculture, food, transport and chemical sectors within the scope of the government's 2011 Innovation Strategy *Top Sector Approach* are the foundations for the sustainable development of the bio-economy. Examples of this include the "Green Deals", within which agreements have been made concerning the production of bio-based chemicals, biofuels and electricity. In this regard, attention is being paid to the development of sustainable chains, with a particular focus on the development of business models and removing legislative obstacles.

356. Ten action points have been formulated based on existing policy and goals achieved that can be classified into two groups:

- *Substantive lines of action:* i) optimal value creation involving biomass and residual flows to realise circular, bio-based products; ii) closing the loop with regard to nutrient cycles and maintaining soil quality; iii) reducing food waste; iv) expanding the supply of sustainably produced biomass; v) the protein transition; and vi) boosting sustainability (i.e. "greening" of megacities).
- *Pre-conditional lines of action:* i) reward soil carbon sequestration and carbon sequestration in products; ii) boost the investment climate for new production capacity; iii) clearer and simplifier waste regulations; iv) promote the Circular Economy Programme in all policies.

357. The "*Top Sector Approach*" identified the bio-economy as a common theme across nine sectors (including agro-food, horticulture and seed stock, high tech; energy; logistics; creative industries; life sciences; chemicals; and water). The core of the approach is collaboration among researchers, entrepreneurs and government (the "golden triangle"). Top-sector Agro-Food focuses on further sustainable food supply chains where there is a continuous challenge of improving resource efficiency.

358. Within the Top Sectors, the theme of the circular economy is highlighted focusing on closing loops in key cycles, limiting losses and value creation involving residual flows from the agri-food sector. This involves the entire chain from primary production to end products and their end-of-life processes.

359. The key objectives of the Circular Economy Programme 2050 are the following:

- "Closing the loop" as the core concept.
- All raw materials and residual flows must be kept within the loop for as long as possible while keeping their quality as high as possible.
- Cascading and multifaceted value creation are key ambitions.
- Reduction and replacement of critical non-renewable raw materials with biomass.
- Identifying new methods of production and consumption.
- Bringing production and consumption back within planetary boundaries and capacity.
- For biomass and food, the key principle is to maintain soil balance, with a key focus on maintaining and boosting soil health as a key factor in sustainable production.
- Social sustainability.

360. The long-term goal to 2030 is to only use biomass for the non-food and feed sectors when other renewable alternatives are not available or are scarce: chemicals and materials; aviation and shipping; heavy long-distance road transport; and high-temperature industrial heating. In the short term, the use of biomass is considered vital in order to realise the goals in the country's Energy Agreement and the Climate Policy Agreement.

361. In addition a Framework Memorandum on the Bio-based Economy in 2012, stresses the opportunities offered by a bio-based economy to address big societal challenges. Efficient use of biomass is prioritised, emphasising the concept of "co-production", linked to bio-refineries as a key technology for ensuring optimal use of biomass for food.

362. The objective of the Energy Agenda is to reduce $CO_2$ emissions by 80-95% by 2050. Consultations have been held with civic organisations, the business sector and government bodies in order to determine what can and must be done in order to achieve this goal. Two key pillars of the Energy Agenda are the Climate Act, which establishes the key aspects of the climate and energy policy, and the Climate Agreement.

## New Zealand

363. Although New Zealand does not have a specific bio-economy strategy, there are a number of bio-economy related initiatives for the agri-food sector such as the "Primary Growth Partnership". The main goals of such initiatives are twofold: improving the primary sector's competitiveness and sustainability; and developing high-value food industrial biological applications, including bioenergy. The development of innovative processed food products, such as plant-based proteins and synthetic foods aimed at producing alternative meat products, is considered important.

364. The Ministry for Primary Industries published the bio-economy research strategy *Primary Sector Science Roadmap - Te Ao Turoa* in 2017. The Roadmap provides a 10 to 20-year outlook for future science needs and opportunities for further developing the bio-economy of the primary sector. The application of new technologies, such as digitalisation, advanced engineering, nanotechnology and sensor technology is considered vital for increasing efficiency in production and processing while also reducing negative

environmental effects. Implementation of the research strategy is through the Global Research Alliance and the Primary Growth Partnership.

## Norway

365. Norway has access to a rich source of renewable biological recourses from both terrestrial and aquatic areas. It is also in a strong position due to its well-developed research environment on fundamental areas of importance for the bio-economy such as life science, technology and industrial processing, research within agriculture, forestry and marine sector, and research on environmental impacts. Norway has a long tradition of private-public co-operation, and many public instruments are in place to support innovation and business development.

366. In 2016, the Norwegian Government published the national strategy on bio-economy, *Familiar recourses, undreamt of possibilities* (Norwegian Ministries, 2018[8]; Bardalen, 2016[9]). This was a broad cross-sectoral strategy, developed by eight ministries, including the Norwegian Ministry of Agriculture and Food. National institutions such as Innovation Norway, The Research Council of Norway and the Norwegian Environmental Agency were especially important advisers in the process. The strategy covers a 10-year period and is subject to mid-term evaluation.

367. The strategy points out three overarching objectives – increased value creation, reduction in climate gas emissions, increased resource efficiency and sustainability – and four focus areas: co-operation across sectors, industries and thematic areas; markets for renewable bio-based products; efficient use and profitable processing of renewable biological resources; and sustainable production and extraction of renewable biological resources.

368. The strategy aims to provide a common understanding of the opportunities and challenges associated with the development of the bio-economy in the country. The strategy specifically addresses goal conflicts and opportunities to minimise them, for example by minimising waste and optimising efficiency of use. In this respect, bio-refinery development in the food, feed and wood industry is considered a promising route in Norway.

369. One of the key challenges for the development of the bio-economy is to improve the resource efficiency in the whole value chain. The Strategy underlines the need for innovation to develop new products, markets and businesses.

370. The partnership between three of the most central public actors the Reseach Council of Norway, Innovation Norway and Siva has been strengthened, and a common Action Plan for the implementation of the recommendations and instructions in the strategy has been drawn up.

371. With a view to promoting innovation, the strategy supports public R&D and encourages innovation projects along the bio-economy value chain. Innovations in agriculture, forestry and fisheries/aquaculture are considered necessary to achieve climate-resistant plants and improvements in soil fertility/quality. In particular, the strategy emphasises the promotion of key enabling technologies (including biotechnology, nanotechnology, precision farming and ICT) to facilitate the development of new bio-based processes, products and services, such as the microbial production of food and feed ingredients and the anaerobic fermentation of biogas, as well as sustainable farm practices.

372. Several policy instruments have been introduced to support industrial and commercial development. Given Norway's experience in environmental taxation, the government proposes several regulatory improvements to create a level playing field for bio-based products, for example taxes or quotas for fossil-based products to account for negative environmental and climate effects. In addition, a revision of fertiliser regulations and an increase in the use of organic fertilisers/sludge, including regulations for deposing, storage and spreading, are on the agenda (Norwegian Ministries, 2018[8]).

373. The strategy highlights increased collaboration within and between value chains. However, the structure of industry within the production of primary resources is characterised by many small industries and SMEs. This can be a challenge for effective production and advanced technology development and emphasises the need to bring together the many research and innovation communities across sectors.

374. Several studies have been undertaken on forest-based supplies. In general, the studies point out that there is a large surplus of biomass from forestry in Norway, which can be made available if it is profitable in terms of market price. As for agricultural sources, a 2016 study from the Norwegian research centre NOFIMA provided an overview of the amounts of agri-food residues resulting from Norwegian industrial processing of cereals, livestock, oil plants, fruits and berries, and vegetables and potatoes. The study found that the industries processing raw material, including agricultural sectors, produce 415 000 tonnes annually of agri-food residues.

## Portugal

375. Portugal has not yet developed an holistic approach to the bio-economy. The concept is emerging, together with the objectives for the circular economy, and bio-economy is embedded in several national and regional strategies (agro-food, forests and oceans). Those most directly linked to the agriculture and food sector are:

- Smart Specialization Strategies;[53]
- Commitment to Green Growth;[54]
- Agri-food and Forestry R&I Strategy 2014-20;[55]
- National Strategy and Action Plan to Combat Food Waste;[56] and
- National Strategy for Effluents from Livestock Farming and Agro-industries.[57]

376. In 2017, the National Plan for the Promotion of Bio-refineries[58] was approved, which aims at the valorisation of biomass (based on residual biomass that does not compete with the animal or human food value chain). In addition, a national waste policy is in place,

53. https://www.fct.pt/esp_inteligente/index.phtml.en

54. http://www.crescimentoverde.gov.pt/

55. http://www.iniav.pt/fotos/editor2/estrategia_mam_livro.pdf

56. https://dre.pt/application/file/a/115191363

57. https://dre.pt/application/file/a/106581232

58. https://dre.pt/application/file/a/114133785

based on a National Waste Management Plan[59] and on several sector-specific management and prevention waste plans.

377. In 2016, the Ministry of Science, Technology and Higher Education, through a multi-stakeholder approach, defined the *Commitment to Knowledge and Science: the Commitment to the Future*. Two of the 14 thematic strategic research and innovation agendas are being developed in the following thematic areas: agro-food; forest and biodiversity; and the circular economy.

378. Portugal is also promoting the bio-economy at national level, through the launch of several international initiatives at ministerial level (such as the Agri-Innovation Summit in 2017). There are also some networks, platforms, associations, clusters encouraging and facilitating the development of the bio-economy and the bio-based industrial sector. Furthermore, in 2017 Portugal launched an Action Plan on the Circular Economy, jointly developed by the Ministries of Environment, Agriculture, Forestry and Rural Development, Science Technology and Higher Education and Economy, in which the contribution of the EU, Bio-economy Strategy to the Circular Economy, was assessed.[60]

379. Concerning barriers hindering the development of the bio-economy within the agri-food sector, an obstacle to overcome is the small scale of the majority of producers and their locations, scattered across the country. Another challenge is the absence of dedicated public policies supporting a wider uptake of bio-economy actions and the lack of public awareness on the potential and the benefits of the circular economy.

## Spain

380. Spain launched its national strategy on boosting the bio-economy in January 2016 based on the sustainable and efficient production and use of biological resources (State Secretariat for Research Development and Innovation, 2016[10]; Lainez et al., 2018[11]). At the regional level, the governments of Andalucía,[61] Castilla-León, Comunidad Valenciana and Extremadura[62] are promoting bio-economy developments.

381. The national strategy highlights global societal challenges related to agricultural and biotechnological sciences in Spain and the dynamism of the private sectors involved, particularly the agri-food, biotech and biomass sectors. Its main focus is the use of biological resources to produce food and feed. An important pillar in the strategy is the promotion of public-private sector collaboration in order to enhance existing value chains and to create new ones.

382. Targeted sectors are food and agriculture, as well as forestry, limited by increasing restrictions on the availability of water. Industrial bio-products and bioenergy obtained from other sources of biomass are also included. Furthermore, adequate water management and re-use, along with rural and coastal development, through several uses and services linked to ecosystems, are considered fundamental to the development of bio-economy. The bio-economy is also viewed as contributing to stronger territorial cohesion.

59. https://dre.pt/application/file/a/66763017

60. http://eco.nomia.pt/

61. http://www.juntadeandalucia.es/organismos/agriculturapescaydesarrollorural/areas/politica-agraria-comun/desarrollorural/paginas/the-andalusia-bio-economy-strategy.html

62. http://extremadura2030.com/wpcontent/uploads/2017/03/marco_070617_v.f_sin-nexos.pdf

383. The strategic, long-term objectives of the national bio-economy strategy are based on three main principles:

- Enhancing competitiveness and internationalisation of Spanish companies operating in the area of biological resources, and creating new economic activities and new jobs by generating knowledge which in turn leads to new scientific and technological developments;
- Maintaining the bio-economy as an essential part of Spanish economic activity, and;
- Developing the potential of the bio-economy with a 15-year horizon, based on technological, organisational and managerial innovation as tools for resolving problems and maximising market opportunities.

384. The national bio-economy strategy explicitly emphasises that the transition to a sustainable bio-economy will be driven by innovations in the areas of biosciences and digitalisation. In the agri-food sector, development of the bio-economy is expected to produce technologies and innovations, including "omics" technologies as well as precision farming tools, which will improve the efficiency of the sector's productive, organisational and logistic processes. New processing, packing, conservation and cold chain technologies should help to reduce waste throughout the supply chain, while also improving the nutritional quality of traditional and new functional food products. Collaboration throughout the supply chain will be intensified, to adapt to the various market niches and will use specific technologies in addition to those related to information technologies.

385. The Spanish bio-economy strategy also seeks to foster good governance in the bio-economy, notably by forming a Spanish Bio-economy Observatory, which includes a Bio-economy Strategy Monitoring Group, composed of representatives from ministries and autonomous communities.

386. Knowledge generation, innovation and private investment in the bio-economy are supported by European, national and regional policies. At the European level, the generally applied policy is Horizon 2020 for science and technology, and the Common Agricultural Policy (CAP), Pillar 2, for innovation in agro-food systems. At regional level, each Autonomous Region has adapted the application of the European Regional Development Funds and the Rural Development Programme.

## Sweden

387. A strategy for research and innovation for a bio-based economy was published in 2012 (Swedish Research Council (Formas), 2012[12]). The Strategy – developed by the Swedish Research Council (Formas), in co-operation with the Swedish Government Agency for Innovation Systems (Vinnova) and the Swedish Energy Agency – aims to create a sustainable society, based on the use of raw materials and products from biomass.

388. The strategy deals with many aspects of a shift to a bio-based economy, including new value chains, the central role of ecosystem services, sustainable consumption and recycling. The roles of different funding bodies, co-operation between academic institutions and industry, and the need for co-ordination between research funding bodies, researchers and commerce are highlighted. Innovation incentives for both short-term and long-term investments and several initiatives for further development are proposed.

389. The strategy identifies research gaps and the prerequisites for the sustainable development of the bio-economy in Sweden. In particular, four strategic areas were identified: i) replacement of fossil fuels by means of increased biomass production (e.g. nutrient and fertiliser optimisation systems, adaption of crops and production systems to climate change); ii) creation of smarter products by making more efficient use of by-products and waste products; iii) focusing research on changes in consumption patterns and attitudes; and iv) making research more responsive to the environmental and socio-economic consequences of increased biomass production.

390. Several measures are proposed to foster Sweden's transition to a bio-economy. These include promoting cross-industry collaboration on R&D, and supporting small- and medium-sized companies with business development. Universities and research institutes have a central role to play in supporting appropriate research activities. It is also pointed out that much of the implementation of the strategy will be carried out within the limits of existing resources.

391. In June 2016, the Government launched five innovation partnership programmes to help in meeting a range of societal challenges, such as digitalisation, life sciences and environmental and climate technology.[63] These programmes involve new ways of travelling, residing, doing business, living, communicating, and using and preserving the world's resources and ecosystems.

392. The aim of the partnership programme "Circular and Bio-based Economy" is to jointly mobilise innovation initiatives to ensure the growth of the bio-based economy through the promotion of circular solutions. The programme has resulted in, for example, Treesearch, which is a platform for new materials and speciality chemicals from forest raw material;[64] Grogrund, which is a competence centre for plant breeding, focusing on climate change;[65] and the creation of a Council for a circular and bio-based economy. The Council will gather all relevant stakeholders to identify and prioritise issues with the aim of speeding up the transition.

## United Kingdom

393. In December 2018, the government announced a national *Bio-economy Strategy* for 2018 through 2030, as part of a wider policy landscape where the main priorities are energy, the environment, waste and resources, and clean growth (HM Government, 2018[1]). In October 2017, the United Kingdom adopted a *Clean Growth Strategy* that targets investments of GBP 2.5 billion to support low carbon innovation from 2015 to 2021. In November 2017, the United Kingdom also adopted an *Industrial Strategy* based on ideas (innovation is central to the economy), people (maintaining workers jobs and incomes), upgrading infrastructure, and a favourable environment in which to start and grow business. In January 2018, the United Kingdom released a 25 Year Environment Plan, which focuses principally on: using and managing land sustainably, increasing resource efficiency and reducing pollution and waste, and protecting and improving the global environment.

63. https://www.government.se/articles/2016/07/innovation-partnership-programmes--mobilising-new-ways-to-meet-societal-challenges/.

64. http://www.treesearch.se/en/home/.

65. https://www.slu.se/centrumbildningar-och-projekt/grogrund/.

394. The *Bio-economy Strategy's* main goal is to remove reliance on finite fossil resources whilst increasing productivity across the country. Under the British vision, the bio-economy represents the economic potential of harnessing the power of bioscience using renewable biological resources to replace fossil resources in innovative products, processes and services. The bio-economy is considered as an opportunity for the country to become a global leader in developing, manufacturing, using and exporting bio-based solutions, strengthening the country's economy and moving towards a low carbon future. The strategy will also aim to make the most of the feed stocks available.

395. The *Bio-economy Strategy* – which is a collective approach from government, industry and the research community – is based on an ambitious forecast in the bio-economy growth from 2017 to 2022, when the global bio-refineries market is set to grow from GBP 350 billion to GBP 550 billion, the global market for bioplastics is expected to grow from GBP 13 billion to GBP 33 billion, and the global market for agricultural biotechnology is set to grow from GBP 22 billion to GBP 40 billion.

## The United States

396. In the United States, the government has encouraged bio-economy development for several decades and a more comprehensive vision was adopted in 2016 (Biomass Research and Development Board, 2016[13]). The *National Bio-economy Blueprint* released in 2012, which covers the entire bio-economy portfolio including explicitly the health sector, promotes the growth of the US bio-economy through biological research, education, regulatory reform and public-private partnerships.

397. The United States employs a suite of programmes aimed at fostering bio-economy development in the agri-food sector (Table 4.2). For example, although the Agricultural Improvement Act of 2018 (2018 Farm Bill) does not specifically relate to the bio-economy, several programmes are in place to encourage the cultivation of sustainable biomass and for renewable energy policies related to agriculture and food. These programmes offer technical and financial assistance (grants, guaranteed loans and payments) to help agricultural producers, co-operatives, and other businesses improve the effectiveness of their operations, produce energy as a new cash crop, and process raw agricultural and forestry raw materials into value-added, bio-based products.

398. The 2015 *Strategy for American Innovation*[66] particularly highlights the need for investing in new technologies to develop future US industries, such as the bio-economy.

399. The *Strategic Plan for a Thriving and Sustainable Bio-economy* (2016)[67] follows the newer direction of US bio-economy development and reflects a vision of a future clean energy economy rather than one of a holistic bio-economy (Biookonomierat, 2018[5]).

400. In 2016, the government adopted the *Billion Ton Strategy* which provides a framework for biomass-derived product development in the United States (U.S. Department of Energy, 2016[14]; Gylling et al., 2016[15]). The strategy builds on a series of reports that provide an inter-agency vision to sustainably produce one billion tons of biomass by 2030 (Biomass Research and Development Board, 2016[13]). The strategy is

66. https://obamawhitehouse.archives.gov/sites/default/files/strategy_for_american_innovation_october_2015.pdf.

67. https://www.energy.gov/sites/prod/files/2016/12/f34/beto_strategic_plan_december_2016_0.pdf.

oriented towards sustainable development goals, specifically job creation, rural development, optimal land use, energy security and the reduction of GHG emissions.

401. The Strategy seeks to leverage domestically produced biological resources for new industrial applications and renewable energy. The strategy highlights the importance of respecting the three pillars of sustainability. Its goal is to develop and implement innovative approaches to remove barriers to using the country's biomass resources in a sustainable manner, while maximising economic, social, and environmental outcomes. The sustainable use of domestically produced renewable biomass for fuels, products, and power can help achieve the country's national energy and economic goals without competing with food and animal feed. It is argued that when combining all potentially available biogenic resources, such as agricultural and forestry resources, municipal and solid waste and algae production, more than one billion dry tons of biomass will be available by 2040 – tripling the size of today's bio-economy.

402. In terms of content, there is a gradual shift from a strong emphasis on using biomass for energy purposes towards non-energy applications (see adaptation of the Biorefinery, Renewable Chemical, and Bio-based Product Manufacturing Assistance Program to bio-based materials below). Increasingly, more attention is paid towards bio-based consumer goods for sports, leisure time, health care, ecosmetics, etc.

403. The United States has made significant investments in bioproduct and biofuel R&D driven by energy security and rural development objectives. For example, the Department of Energy (DOE) and the United States Department of Agriculture (USDA) have heavily invested in research efforts to develop domestic biomass crops as alternative energy and fuel sources.

404. The *Federal Activities Report on Bio-economy* (2016) lists all relevant and existing agency programmes that promote bio-economy development, including standards and certification schemes (Biomass Research and Development Board, 2016[13]). Funding, *inter alia*, for targeted research and technology development, public-private partnerships to develop new market opportunities for bio-based products and support for building state-of-the art digital infrastructure are highlighted.

405. There is general agreement in the United States that expanding the bio-economy would offer significant benefits; however, some major hurdles still exist. They include: i) a lack of available, cost-competitive, biomass-derived products as compared to fossil resource (petroleum, natural gas, coal) products; ii) concerns over environmental issues associated with growing biomass and mitigating/reducing negative impacts; iii) reducing risks to warrant investment in biomass production systems, conversion facilities, and end-use infrastructure; iv) limited availability of land and resources (e.g. water, fertiliser, labour, etc.) to produce one billion tonnes of biomass; v) current inability to transport and dispense larger quantities of fuels; and vi) the need for large capital expenditures in a risk-averse financial environment. These challenges need to be considered and mitigated for the goals of the Vision to be accomplished.

406. The Bioenergy Technologies Office, in collaboration with USDA, will analyse the impacts of a growing bio-economy on rural communities.

407. The *2014-18 Farm Bill* includes a broad spectrum of incentive measures fostering the bio-economy, especially in the area of *Renewable Energies and Energy Efficiency*. Noteworthy in this context is the *Bio-refinery Assistance Program*, which promotes the production of biofuels and other bio-based materials. Plant research, in particular for energy production continues to be heavily supported.

408. The *Biomass Crop Assistance Program* (BCAP) is intended to assist the bioenergy industry (cellulosic biofuels industry) to overcome the hurdle of constant supply of available biomass - viewed as a critical deterrent to private sector investment in the cellulosic biofuels industry. To meet these objectives, BCAP provides financial assistance to owners and operators of agricultural land and non-industrial private forest land who wish to establish, produce and deliver biomass feed stocks. Two categories of financial assistance are provided: i) payments that share in the cost of establishing and annually maintaining production of eligible biomass crops; and ii) matching payments that share in the collection, harvest, storage and transportation (CHST) of biomass to an eligible biomass conversion facility. BCAP assistance is available within designated geographic areas.

409. Initially BCAP's CHST matching payments raised questions and concerns about feedstock eligibility, sustainability and the slow development of cellulosic biofuels. An enduring issue is the continued slow development of a commercial-scale cellulosic biofuels industry despite BCAP's support. Commercial scale production of cellulosic biofuels has not yet been achieved. There are also sustainability issues. For example, the BCAP incentives for biomass removal is counterproductive as many conservation programmes provide financial assistance for practices that increase crop residue retention on the land, because of the environmental benefits. The benefits to bioenergy should not outweigh the potential soil and environmental concerns associated with the removal of crop residue and caution against removing too much residue in sensitive areas (Mcminimy, 2015[16]).

410. While the 2014 Farm Bill provided mandatory funding of USD 25 million per year, no mandatory funding is provided in the 2018 Farm Bill. Instead, the 2018 Farm Bill authorises the programme to be appropriated USD 25 million annually through FY2023. Of that amount, USDA must use between 10% and 50% for CHST payments. The remaining funds are used to make project payments to producers and to provide technical assistance.

411. The *BioPreferred® Program* promotes mandatory bio-based product purchasing requirements for federal government agencies as well as voluntary bio-product certification and labelling (see also **Box 3.3** in Chapter 3). The part of the programme relating to public procurement of bio-based products was extended to include forestry products. Together with the Department for Agriculture, the Energy and Defence Departments also play a significant role in promoting and even creating new markets for biofuels. For example, in 2014 more than USD 200 million of funding was allocated for building three bio-refineries in association with the "Farm to Fleet" biofuel procurement programme for the US Navy. Although biofuels will be purchased via regular public tenders this measure intends to ensure sufficient production capacity for cost-competitive biofuels for military use by 2018.

412. Other relevant main programmes in the 2018 Farm Bill include: the newly created Carbon Utilization Education Program, which extends competitive funding for eligible entities to provide education to the public and biogas producers about the benefits of carbon utilization and sequestration and the opportunities to aggregate multiple sources of organic waste into a single biogas system; the *Bioenergy Program for Advanced Biofuels*, which provides payments to producers in order to support and expand production of advanced biofuels refined from sources other than corn kernel starch; and the *Rural Energy for America Program*, which provides assistance to agricultural producers and rural small businesses to complete a variety of projects, including renewable energy systems, energy efficiency improvements, renewable energy development assistance, and energy audits.

413. The *National Institute of Food and Agriculture* (NIFA) provides funding for programmes that advance agriculture-related sciences. NIFA seeks to facilitate the

development of regional biomass systems for the sustainable production of biofuels and bio-based products. NIFA programmes support the entire Bio-economy supply chain at the regional scale. Co-ordinated agricultural projects that consist of partnerships between government, industry, non-government organisations and universities, including 1 890 land-grant universities, tribal nation colleges, and Hispanic serving institutions, address the integration of the supply chain (https://nifa.usda.gov/sites/default/files/resources/Bio-economy-Bioenergy-Bioproduct%20Portfolio%20Strategic%20Plan.pdf).

**Table 4.2. Key measures for promoting the bio-economy in agriculture and food**

| | Policy measure | Concrete implementation | Budget (USD million) | Timetable | Sources |
|---|---|---|---|---|---|
| Promoting innovation | Public research | Biomass Research and Development Initiative (USDA-DOE) | 112 | 2014-18 | 2014 Farm Bill |
| | | Agricultural and Food Research Initiative (National Institute of Food and Agriculture) | 136 | Since 2011 | Bio-economy Blueprint |
| | | Transportation Energy Resources from renewable Agriculture (TERRA) Program | | | |
| | | Research into organic farming | 100 | 2014-18 | 2014 Farm Bill |
| | | Research into specialty crops | 400 | 2014-18 | 2014 Farm Bill |
| | Public-Private Partnerships | Foundation for food and Agriculture Research (private sector funding of research) | 200 | 2014-18 | 2014 Farm Bill |
| Supporting infrastructure and capacity building | Vocational training and further education | Courses available at the Community Colleges, business partnerships (e.g. via the TAACCCT program) | | | Bio-economy Blueprint |
| | | Beginning Farmer and Rancher training | 100 | 2014-18 | 2014 Farm Bill |
| | Rural development | Biomass Crop assistance Program (grants for bio-refineries to develop value chains with agricultural and forestry businesses) | 125 | 2014-18 | 2014 Farm Bill |
| Commercialisation | Lab-to-Market plans | Investor consortium (USDA Agricultural Technology partnership Innovation Foundation (ATIP) | | Since 2011 | ATIP Foundation |
| | Innovation capital | Biorefinery, Renewable Chemicals and Bio-based Product Manufacturing Assistance Program | 200 | 2014-18 | 2014 Farm Bill |
| | | Advanced Biofuel Payment Program | 175 | 2014-18 | 2014 Farm Bill |
| Demand-side instruments | Public procurement: mandatory bio-based product purchasing requirements for federal government agencies | Biopreferred Program (Procurement guideline for the preferential treatment of bio-based products at the federal level) | 25 | 2014-18 | 2014 Farm Bill |
| | Labels: voluntary bio-product certification and labelling | Biopreferred Program (USDA certified bio-based product) | | 2014-18 | 2014 Farm Bill |
| | Use of bio-energy | Repowering Assistance Program (bio-refineries should use biomass for energy and heating purpose) | 75 | 2014-18 | 2014 Farm Bill |
| | | Rural Energy for America Program (investment in energy efficiency and renewable energies) | 350 | 2014-18 | 2014 Farm Bill |

| | Policy measure | Concrete implementation | Budget (USD million) | Timetable | Sources |
|---|---|---|---|---|---|
| | Sustainability requirements for biomass feedstocks | Communication strategy | | | |
| | Establishments of a stakeholder network that organises conferences and workshops on bio-economy | Communication strategy | | | |
| | Increasing public awareness for bio-refineries, biofuels and bio-products | Communication strategy | | | |
| Enabling regulatory framework | Reviewing the regulatory framework (Legislation and approval of new technologies) | New principles for the regulation of new technologies ; Federal Co-ordinated Framework for the Regulation of Bio-technology; National regulations on waste management (e.g. Resource Conservation and Recovery Act) | 2 014 | Bio-economy Blueprint | |
| | USDA reforms concerning risk assessment and regulations, pilot projects for improving the approval process for genetically modified organisms | | | | |
| Promoting good governance | Intra- and Inter-agency collaboration | Bio-economy Federal Strategy Workshop | | | |
| Monitoring and Evaluation | Monitoring and measuring activities | Developing sustainability indicators; developing standard for feedstock valuation; Air, Climate and Energy Research Program | | | |
| | Impact analysis of bio-economy policies | | | | |
| International collaboration | International monitoring | Global alliance for Climate-smart Agriculture; Global bioenergy initiative | | | |

*Source*: Based on German Bio-economy Council (2018), *Bio-economy Policy (Part III) – Update Report on National Strategies around the World*, https://gbs2018.com/fileadmin/gbs2018/Downloads/GBS_2018_Bio-economy-Strategies-around-the_World_Part-III.pdf and Congressional Research Service (2019), The 2018 Farm Bill (P.L. 115-334): Summary and Side-by-Side Comparison.

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