Chapter

The Bioeconomy: An Opportunity for the Spanish Economy

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Abstract

The objective of this chapter will be to show the possibilities of the bioeconomy in Spain and how it can help to create new productive models that favor the sustainable economic development, taking into consideration the circular economy framework that the EU Commission has launched. For this, we will collect the current socioeconomic weight of the sectors that integrate the bioeconomy in Spain. We will then review the current policies and those that are predictably a short and medium term, at European level, and are going to affect the use of biological resources, as well as the evolution of the behavior of European Consumers. This will give us the chance to demonstrate the need and the opportunity to move forward different economic activities through the interaction between science, society, and companies, in order to increase efficiency and sustainability in the traditional value chains and, at the same time, to create new ones. Then we will briefly describe the Spanish strategy of bioeconomy: the process of elaboration, its essential elements, and observatory of bioeconomy, as the instrument that promotes its development. We will describe the Spanish Bioeconomy Observatory as a tool to move forward towards an ecosystem where science and technology, society, and the economy work together to overcome the challenges of our society.

Keywords: sustainability, resource efficiency, rural development

1. Introduction

The bioeconomy can be defined as being the result of all the economic activities related to the direct or indirect production, transformation, and utilization of resources of biological origin. However, technological advances mean that—in addition to the production of food, forest products, textiles, and energy—such resources can now be exploited to obtain extracts or active compounds for use in nutrition and pharmacology as well as diverse biocompounds, such as bioplastics and biofuels.

The European Union (EU) approved its bioeconomy Strategy in 2012, driven by the General Research Directorate of the European Commission. One of its objectives was to stimulate the development of a national strategy in each member state, adapting the objectives and lines of work to the particular conditions, singularities, and specifications of each country. In Spain, the Bioeconomy Strategy was launched at the start of 2016. This considers the use of science and knowledge as an essential element, while attempting to meet the challenges presented in each of the socioeconomic sectors related to the production and utilization of resources with a biological origin.

The Spanish Bioeconomy Strategy defines the bioeconomy as the whole of the economic activities that provide goods and services, and thus generate economic value, through the use, as fundamental elements, of resources of biological origin in an efficient and sustainable manner. As recognized in this Strategy, and in our context, the objective is the production and commercialization of foodstuffs, forest products, bioproducts, and bioenergy, obtained by means of physical, chemical, biochemical, or biological transformations of the organic materials not destined for human or animal consumption. It is implicit that this should involve processes that are respectful of both the environment and the development of rural communities.

In this chapter, we analyze the possibilities for the bioeconomy in Spain. We describe the sectors that currently form part of it and the challenges that, from our perspective, it must meet, as well as stressing the need to incorporate technology based on the generation of knowledge and innovation. Then, we focus on the Spanish Bioeconomy Strategy, describing its genesis and the elements essential to it, before finishing with an explanation of the activity of the Spanish Observatory of the Bioeconomy, an instrument vital to the development of the bioeconomy in Spain.

2. The bioeconomy in Spain

The development of the Spanish Bioeconomy Strategy involved the economic characterization of the sectors that constitute the bioeconomy. It was not an easy task due to the absence of the necessary series of statistical data. This led to the accumulation of data from diverse sources; in some cases, they were obtained directly from the different sectorial administrations and in others from the different economic sectors themselves. Based on this, the bioeconomy in Spain represented 6.5% of the gross domestic product (GDP) in 2015, employing around 9% of the economically active population [1].

The report on the bioeconomy in the EU presented by the Joint Research Center for the year 2016 [2] mentions the difficulty faced in collecting the statistics for the economic and employment data related to this activity in Europe. However, it includes information from the official statistics of the relevant sectors: agriculture, forestry, fishing and fish farming, food processing, drinks, tobacco, the production of textiles of biological origin, the production of wood products and furniture, the production and processing of paper and paper-derived materials, the synthesis of chemical compounds, pharmaceuticals, plastics and gums from biological resources, the production of liquid biofuels, and the generation of electricity.

Taken together, in 2015, these activities employ 18.6 million people in the EU and have an economic value of 2200 M€, which represents around 9% of the total economy of the EU. The agri-food sector accounts for around three-quarters of this employment and two-thirds of the economic value [3, 4]. Using the data from the report, in 2016, the Spanish bioeconomy represented 8.6% of the total economic value of this sector in the EU, and 7.1% of the jobs. Based on the statistical analyses of the Bioeconomy Knowledge Center [3], in 2017, the bioeconomy in Spain generated around 192 M€ and more than 1.3 M jobs. The data are presented in **Table 1**.

According to this same source, the agri-food sector is the most important sector of the Spanish bioeconomy. The agricultural sector comprises around 900,000 farms, representing 2.5% of the GDP; fishing involves more than 5000 companies and almost 9900 boats, representing 0.2% of the GDP, and the food and drink sector comprises almost 28,000 companies, representing 2.7% of the GDP. Forestry (wood, cork, and paper) represents 0.56% of the GDP. In addition, there are 540 companies involved in biotechnology (excluding healthcare) and 170 in the transformation of biomass into energy.

Sector	Value (M€)	%	Employment (no of people)	%
Agriculture	43.8	22.7	678,700	50.9
Fishing and fish farming	2.5	1.3	53,035	4
Foods, drinks, and tobacco	104.9	54.5	351,315	26.4
Biotextiles	8.2	4.2	70,153	5.2
Bioproducts	9.1	4.7	28,921	2.2
Bioelectricity	0	0	0	0
Biofuels	1.88	0.9	3781	0.2
Forestry	0.95	0.5	26,100	1.9
Paper and derivatives	12.5	6.5	40,826	3
Wood and furniture	8.5	4.4	78,778	6
Total	**192.4**		**1,331,609**	

Table 1.
The importance of the bioeconomy in Spain in 2015, by sector [3].

The Joint Research Center has recently published data concerning the biorefineries in the EU, distinguishing them according to their products and the raw materials used [5]. The same authors (Parisi y M'Barek, personal communication) have informed us that their database includes 29 such plants in Spain; of these, 25 produce "bio-based chemicals," 19 produce "liquid biofuels," and four produce "bio-based composites and/or fibers." In relation to the raw materials processed, most of these Spanish biorefineries use resources of agricultural origin. Thus, 10 use the organic fraction of residues, five use biological materials from forests, five use materials of marine origin, and one uses material from short-term pastures and catch-crops.

3. The challenges faced by the bioeconomy

The resources of biological origin have varied uses and are subject to changeable conditions of production and transformation, due to fluctuations in the agro-climatic, market, and political circumstances. In consequence, the bioeconomy faces a set of challenges, summarized in **Figure 1**. All of these were taken into account during the development of the Spanish strategy, as described below.

The most important usage of biological resources is the feeding of human beings. In the coming decades, the human population of the Earth will reach 9100 million. To feed this population, around 68% more food will be required [6]. In addition to the population rise, it must be borne in mind that economic growth will modify the demand of foodstuffs, with a particular rise in the consumption of products of animal origin [7]. Another factor to consider is the concentration of the population in cities and the consolidation of large conurbations [8].

In an ever more globalized world, the total worldwide demand will condition the production of foodstuffs, as well as the type of use of agricultural zones, the production systems, and their technologies. For this reason, the *first challenge* that the bioeconomy faces is to produce more food, in a more efficient manner since the availability of resources is limited. On a global scale, the soil available for agricultural purposes is limited. Before, the solution would have been to expand agricultural activities into land occupied by forests or jungles; but, this is no longer an option due to the effect that deforestation would have on the atmospheric concentrations of greenhouse gases. Another limiting resource is the availability

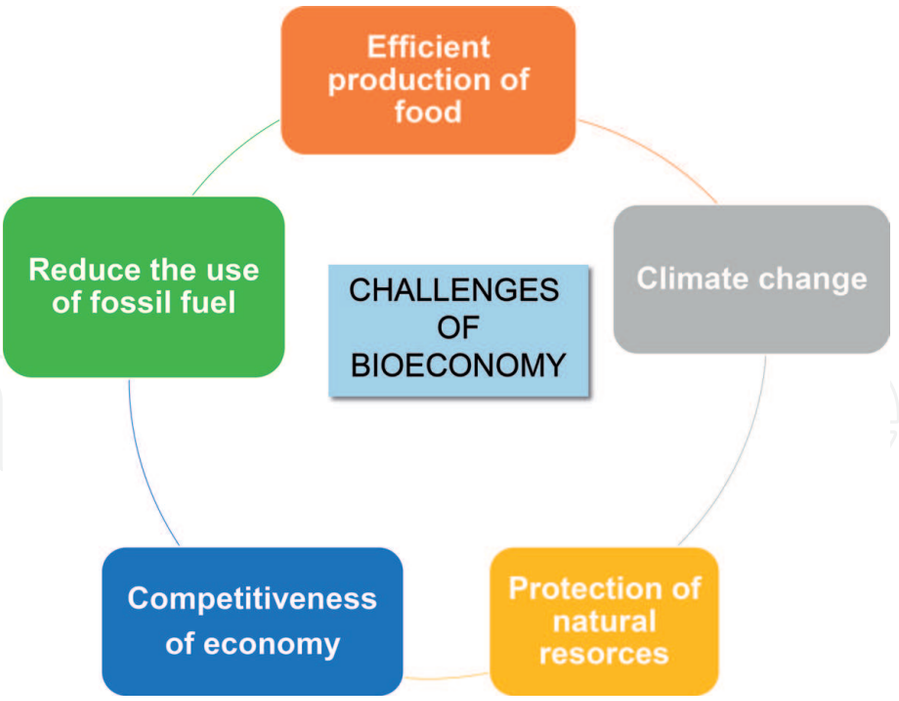

Figure 1.
The five challenges of bioeconomy (own elaboration).

of high-quality fresh water, for both agriculture and other human uses, especially in zones that currently have a water deficit. However, the efficiency of water use should increase—for instance, due to technological advances in irrigation and plant breeding.

The different groups of the Intergovernmental Panel on Climate Change (IPCC) concluded that there is increasing evidence showing the form and magnitude of the impact of climate change on agricultural production. The majority of the models that have been used to simulate the consequences of increases in the concentrations of greenhouse gases indicate the advancement of a process that combines an increase in mean temperatures, a decline in precipitation, and a greater frequency of extreme meteorological events, such as droughts and floods. These projections have started to become a fact in the Mediterranean Basin, where the mean temperatures have risen, on average, to 1.4°C since the pre-industrial era; this is 0.4°C more than the global mean [9]. According to these authors, under the most favorable scenario, a decrease around 10–30% in the precipitation means that irrigation requirements will rise by 4–22%.

The climate change is the *second major challenge* facing the bioeconomy. Its consequences, with respect to the resources of biological origin, are both physical and legal. The former are that climatic and agricultural systems will need to be adapted through the use of new varieties, modifications in soil and water management, monitoring and control of diseases and infestations, etc. The legal aspects are related to the obligation, enforced by governments, to reduce the emission of greenhouse gases: CO_2, CH_4, and N_2O. Thus far, the production of biological resources, especially in fish-farming, has been considered a diffuse source of these gases and has not been subjected to concrete and individualized regulation in order to reduce emissions. However, the policies being developed, particularly in the EU, may alter this situation, with concrete measures tailored to the individual activities.

The bioeconomy should allow the production systems within it to maintain their output levels under changing agro-climatic conditions, while reducing their emissions. The achievement of these two objectives will be possible only with the development and implementation of the necessary technology.

The *third challenge* is to protect the natural resources. For the systems that produce resources of biological origin, soil and water are essential elements. Also, their activities take place in natural surroundings, often in picturesque locations, that society and governing administrations insist should be protected, to maintain the biodiversity and ecosystems. The new and developing concepts governing the bioeconomy imply that it is necessary to go beyond protection and advance towards a circular economy and an integrated use of all resources.

Different authors have focused on these aspects. For example, [10] the need to reduce the environmental impact and, regarding human beings, the need to maintain global levels of food production and the types of diet that can sustain both, mankind and the planet were pointed out. Others [11] modeled the environmental consequences of a reduction of between 25 and 50% in the consumption of products of animal origin in Europe. Other authors [12] discussed a nutritional transition in developed countries, and among the middle class in developing countries, in which the trends in consumption are determined not only by income but also by considerations of health, the environment, and ethics (in relation to animal welfare). The loss of biodiversity is another important aspect pointed out by others [13], who put forward ideas of how to advance economically in parallel with an increase in biodiversity, while also raising food production.

This point of view has become widespread in society, especially in Europe, as it was demonstrated in a survey of 2783 consumers in Germany, the United Kingdom, Belgium, and the Netherlands [14]. Of the replies, in 62% of cases, the consumption of foodstuffs was influenced by sustainability; of these, in 31% of cases, the consumption was influenced also by health concerns. Currently, more than 22% of the food consumption is determined by health aspects.

To overcome this third challenge, it is vital to redesign the systems of production and the chain in which value is added to products. First and foremost, the inputs must be minimized, and the wastes converted into secondary products, so that the whole production and utilization process is sustainable and renewable. Again, this is dependent on the development of the necessary technology.

The *fourth challenge* for the bioeconomy is to guarantee the competitiveness of the economic activities related to biological resources. In free-market economies, companies must maintain their presence in the markets, both internal and external, in a continuous fashion. As a function of the demand, directly from the consumers or mediated by the distribution chains, the producers must control the arrival of their products in the market so that they are able to compete on price and/or novelty. In the case of the bioeconomy in general, in particular for foodstuffs, they must consider the nutritional and health-related properties of their products as well as the environmental sustainability. The completion of this task depends, once again, on technological advances in the systems of production, in relation to the efficient use and conservation of the resources.

The *fifth challenge* facing the bioeconomy is to facilitate the transition from a fossil fuel-based economy to one based on the use of renewable resources. The use of petroleum derivatives in economic activities leaves an important environmental footprint, in terms of CO_2. Resources of biological origin could form the basis for the synthesis of any of these derivatives. Currently, petroleum derivatives are more competitive in terms of price, due to differences in production costs. Notwithstanding, the development of the appropriate technology and the fragmentation of the market could allow bioproducts—biofuels or bioenergy—to compete with "nonrenewable" materials.

The Organization for Economic Cooperation and Development [15, 16] has, on numerous occasions, underlined the potential of the bioeconomy to overcome the challenges described here and to stimulate the development of new economic

activities in the countries where it is promoted. For this, it is imperative to strengthen the traditional series of activities that add value to biological resources, the most important being agri-food, followed by forest products. The appearance of new series of this kind would permit the commercialization of bioplastics, biocomposites, cosmetics, biofuels, bioenergy, and bioproducts related to nutrition and pharmacology.

The growth of all these areas requires, as described by the Standing Committee of Agricultural Research [17], the application of a series of principals essential to the development of the bioeconomy. These are described below:

1. Prioritize the use of biological resources for the production of foods, guaranteeing their worldwide availability for human consumption.

2. Include sustainability in the development of the bioeconomy, such that the amounts of the resources harvested or extracted, in any system or setting, never exceed the capacity for regeneration. This principle should be applied equally to the inputs.

3. Utilization in a cascade, guaranteeing that the biomass is used to obtain the product with the highest added value, while achieving its integral utilization.

4. Move towards a circular economy, by designing productive processes that minimize the output of wastes and maximize reutilization and recycling.

5. Diversification of the use of resources and the accompanying activities.

In the case of the member states of the EU, the challenges described above are reflected in the strategies that define the European policies related to the production and use of resources of biological origin. Below, their most important aspects are described:

- *Climate change policy.* This has been establishing objectives in the medium and long term. By 2020, the aim was to reduce greenhouse gases by 20% compared to 1990, increase renewable energies to 20%, increase the use of renewable biofuels to 10%, and increase energy efficiency by 20%. The successive summits since the United Nations Conferences on Climate Change (COP21 and COP24) have seen greater commitments of the European Commission in this area. For the year 2030, the objectives for these same indicators are 40, 27, and 27%, respectively, while for the year 2050, an 80–95% reduction of greenhouse gases is the aim. To achieve these objectives, reduction requirements are imposed on the emission sectors and neutral or negative technologies are promoted in their CO_2 balance. The diffuse sectors, such as agriculture, will have to assume a reduction of their emissions of 10% by 2020 and an additional 30% by 2030.

- *Environmental policy.* The objectives set at the European level are to achieve a "greener" economy through green growth in a framework of environmental sustainability, to protect nature, and to safeguard the health and quality of life of people, with special attention to water quality, air quality, and hazardous chemicals. In this context, the sustainable use of soil, land, biodiversity, and ecosystems is considered essential, as are ammonia emissions or the generation of dust that has recently become something to consider.

- *Circular economy policy.* This has also been defined recently, in a package that includes as objectives the recycling of 65% of urban solid waste and a reduction

of the burial of waste by up to 10% by the year 2030. The action plan recognizes the potential of the bioeconomy to improve the use of waste in current chains that add value and in the creation of new and innovative chains. As a specific example, the European Plastics Strategy states that by 2030, all plastic packaging marketed in the EU must be reusable or recycled cost-effectively [18].

- *Common agricultural policy* (CAP). The communication "The future of food and agriculture," written by the European Commission, was made public in November 2017. In this document, farmers are considered as the managers of the natural environment (responsible for the care of soil, water, air, and biodiversity) and the suppliers of food and other renewable products, while at the same time, agriculture is credited with the function of retaining carbon in the system as a whole. The aforementioned communication considers that the future CAP must lead the transition towards more sustainable European agriculture. In addition to its traditional objectives, this policy must take advantage of the potential of the circular economy and the bioeconomy to support the care of the environment and the fight against and adaptation to climate change [19].

- *Energy and biofuel policy.* This policy has promoted first generation biorefineries, although its objectives for the coming years have been modified, since the European Commission proposes to reduce the production of first generation biofuels by 7% by the year 2021, and by 3.8% by 2030. Individual countries can even set lower limits. Further, it states that the incorporation of 1.5% of renewable energy in transport in the year 2021 should be obligatory, reaching 6.8% in 2030. In addition, the generation of biofuels from further generation biorefineries must rise from 0.5% in 2021 to 3.6% in 2030.

4. The importance of science and technology in the bioeconomy

Overcoming the challenges we have described for the bioeconomy will be possible with the accumulation of knowledge in different scientific areas, and its transformation into innovations applied to each of the areas that comprise the bioeconomy.

The improvement in the efficiency of the processes that make up agri-food production will be one of the essential elements. Implementation of the eco-blueprint—rethinking all the productive, organizational, and logistic processes to reduce the quantity of inputs, which is proposed for the application of the circular economy [20], thereby achieving a balance between productivity and sustainability—will require the integration of knowledge from different areas:

- The areas of biology and biotechnology are essential for the development of new genetic materials for use in arable and livestock farming. The selection and crossing of materials will become much more precise and faster with the sequencing of complete genomes, the use of bioinformatics tools, or the editing of genes. This will allow responses to the joint challenges of productivity, resistance to drought, diseases, and pests, improved efficiency in the use of nutrients, and enrichment of food in certain components of interest. Knowledge of the microbiomes of the soil or the digestive tract of animals will improve the efficiency of the use of fertilizers, water, and feed ingredients, or improve the immune response of plants or animals. These same technologies, as well as nanotechnology, will also be applied to agri-food processing. The European Court of Justice issued a ruling in which it equates, for the EU, the techniques of gene editing with those of genetic modification. A

decision of this type, if it is not modified, could inhibit the scientific development in Europe in the coming years, making it difficult to advance in this field.

- The areas of engineering (mechanization, automation, robotization, avionics, and artificial intelligence) will revolutionize both the work itself and, above all, the precision in the handling and application of inputs, allowing progress in arable and livestock farming in the coming years. The use of the means of production at the correct moment and in the exact quantity that is extracted by plants or used by animals improves efficiency and, at the same time, reduces the use of natural resources, the impacts on the environment, and the final waste output of the productive processes. Some of the current objectives, such as reducing the use of fertilizers, phytosanitary products, or antimicrobials, will become a reality.

- The application of information and communication technologies in agri-food production processes will facilitate precision in the use of inputs. Decision support tools will be developed based on the capture and storage of data, or images, for both the productive systems and external ones. The sensors and cameras placed in/on plants, animals, buildings, production chains, vehicles, drones, or satellites will continuously inform about the real productive situation. The processing of this information, and its combination with other external information from consumers or markets, will allow us to leave behind the descriptive analysis of the events that have happened, and instead to predict what may happen and even to prescribe a certain decision.

The aforementioned technological development is fully applicable to the sector of the production and transformation of forest resources. In Spain, there is a tendency to consider that the exploitation of forest resources entails a loss of natural capital and associated environmental services. This vision of the conservation of the environment has manifested itself in the preparation of the Spanish Bioeconomy Strategy [21]. As a result of this, the Juntos por los bosques initiative has arisen [22] that tries to install in Spanish society the concept that where there is forest management with sustainability criteria, the biomass, and therefore the sequestration of carbon, increases, thereby maintaining an economic activity and the preservation of the forests. This group defends the use of forest-based biomass as a unique opportunity to reduce the fire risk, create jobs, mitigate climate change, and reduce the dependence on external energy.

Spain has almost 6000 km of coasts. If we leave tourism aside, the traditional use of the marine environment has focused on the extractive fishing industry. Aquaculture has developed slowly, and the extraction of algae for different purposes (to obtain active ingredients, animal feed, or human food) is incipient. The Blue Growth initiative [6, 23] identified other opportunities linked to marine biotechnology (understood as the exploration and exploitation of marine organisms in order to create new products), as well as other areas far from the bioeconomy such as ocean energy or the mineral exploitation of the seabed.

Paredes [24] grouped biomass conversion technologies into: biological (based on techniques of anaerobic digestion, fermentation, and enzymatic hydrolysis), mechanical (such as densification, extraction, and pressing), chemical (transesterification), and thermochemical (carbonization, combustion, gasification, and pyrolysis). However, this author pointed out that the main technological pathways for biomass research include: combustion, gasification, cogeneration, pyrolysis, transesterification, fermentation-hydrolysis, and anaerobic digestion. The foresight document of SCAR [17] also explored these issues.

5. The Spanish bioeconomy strategy

In 2014, the process of drafting the Spanish Bioeconomy Strategy began. It ended at the end of 2015, the strategy becoming public in early 2016. The essential milestones of this process, as it has been reported [1], were the following:

- Analysis of the opportunity to develop the Bioeconomy Strategy, within the framework of the National Ministry of Research, Development, and Innovation.
- Agreement to initiate the work by the ministries involved (economy and competitiveness; agriculture, food, and environment; and energy, industry, and tourism), and the start-up of a working group with representatives from the three ministries, the scientific and business worlds, and technological platforms.
- Preparation of a first draft of documents, and their distribution and discussion among economic sectors and representatives of society, research, and local, regional, and national administrations.
- Preparation and adoption of the final document, after submitting it to public consultation.

The definition of bioeconomy included in the document appears in the introduction to this chapter, as do its objectives. It is important to refer to some specificities of this strategy, which were widely discussed throughout the elaboration process, such as the scope, the bases, the particularities of Spain, and the essential elements.

The scope of the strategy is included in the definition: agri-food, forest production and marine resources, residual biomass, and bioproducts. The importance given to each of these areas is proportional to the specific weight that each currently has in the Spanish economy, with the proviso that the transformation of biomass into bioproducts and bioenergy should be an important objective since it was a field of activity that was still under development. From certain points of view, it was considered that agri-food should be excluded from both the concept and the scope, in the same way as in other European strategies that were being worked on. Subsequently, the same decision was made in some of the Spanish regional strategies. However, the agreement that it was necessary to address the production and transformation of all biological resources in an integral manner, from a rural and coastal development perspective, led to its integration.

The basis of this integration determined that foods were considered first, using productive methods based on efficiency and sustainability. Therefore, from the very beginning, the need to prioritize the use of agricultural and marine resources to provide food was considered, suggesting that the raw material for biorefineries should be the residual biomass of the agricultural industries. It was understood that the use of natural and biological resources is an economic decision of their owners. However, it was considered also that, as a principle, priority should be given to the alimentary use of agricultural products, as against the current European policy that promotes first-generation biofuels. Today, this policy has been changed, as a consequence of public opinion.

Another founding principle was the requirement to give efficiency and sustainability—economic, social, and environmental—the same level of importance. There were two reasons for this: the first was related to the social perception in Europe of the bioeconomy, meaning that the European strategy had been launched thinking especially about the efficiency of the use of biological resources. This had provoked a reaction of rejection in certain groups that believed that behind the strategy, there was an interest in depleting forest resources. The second was the assurance that the future

of the agri-food and forestry sector would be based on the guarantee of both its viability in a globalized market and the maintenance and recovery of the natural capital that sustains it, due to the use of more efficient and sustainable production processes.

The triangle of science, economy, and society must be present throughout the process of creating the bioeconomy, and it has been demonstrated that the basis for the development of the bioeconomy is the availability of technologies. The emergence of new technologies is only possible if it is supported by new scientific knowledge of the existing environment. The generation of basic knowledge comes from different areas, such as fundamental biology, genomics, biotechnology, ecology, physics, chemistry, physics, nanotechnology, transformation technologies, biochemistry, and thermochemistry, as well as information and communication, without forgetting the social sciences associated with the social economy and its organization. This knowledge should be aimed at solving specific problems of the different processes or areas. For this reason, it is necessary to invest in research that is both cutting-edge and oriented to face the challenges that, progressively, arise in our society, thereby achieving technological development.

In our opinion, society must be aware of the bioeconomy, its justification, its challenges, its objectives and interests, and the tools to make it possible. Only in this way will it be possible for the population to support public financing of research activities, accept the extension of knowledge in certain controversial areas, and have a broader vision when voicing its opinion in relation to the derived technologies, such as gene editing or genetic modification. In addition, when new bioproducts reach the market, competing with those derived from fossil resources, the members of the public will be able to make sound purchasing decisions based on their knowledge. For these reasons, from the first moment, we have had representatives of consumers, NGOs, and other collectives in our working groups.

The last component of the bioeconomy is the companies capable of interpreting the current and potential demand for these new products and of integrating emerging technologies in a productive process, obtaining an economic benefit. Basically, this refers to innovative companies, which require these technologies that are controversial or, at least, different from the conventional ones present in the market. The source of knowledge for these activities is in research centers and consortiums, where new information or processes can be produced to remove old limitations or make previous transformations more efficient. These entities must be in a close relationship with research projects, technological platforms, and places where scientific results are presented, and they must participate in projects aimed at the assimilation of knowledge. In short, they have to maintain a close collaboration with research as the only possible way to innovate in a pioneering way in these areas.

Spain has a great diversity of agro-climatic areas, but in 80% of its territory, the availability of water is limited. Here, the water supply is a primary constraint on agricultural yields and, therefore, on the production of resources of biological origin or on the processes that require a large input of water.

The approaches of the Spanish Bioeconomy Strategy are aimed at promoting the development of the bioeconomy through the following routes:

- Public and private research and the investment of companies in innovation in the areas of the bioeconomy. Here, one can highlight the promotion and facilitation of multidisciplinary alliances between researchers and companies that can participate in all calls for the funding of projects, from European to national or regional levels. Another aim is to publicize the European models of public-private collaboration for the development of the bioeconomy, the search for financing of pilot-scale installations (both public and private), and the interaction between technology platforms and campuses of excellence.

- The reinforcement of the social, political, and administrative environment of the bioeconomy, based on the creation of an observatory, the launching of a program of dissemination and social dialog, and the generation and training of a group of stakeholders focused on this discipline.

- The improvement of competitiveness and the development of the bioeconomy market, which could be achieved by developing the concept of sustainability (by means of precise indicators), identification of the limitations for its development (both technical and legal or administrative), the identification and promotion of new chains of value, or the standardization and certification of new bioproducts.

- The development of the demand for new products, through the identification of new products and the difficulties for their entry into the market, the development of innovative public sale campaigns applied to bioproducts, and the labeling of such products.

- Support for the expansion of the bioeconomy through the collection and presentation of success stories and cooperation and collaboration among stakeholders, so that specific strategies can be implemented at the regional level and connections can be made with international projects.

The strategy is promoted through annual action plans focused on developing the activities described in the five strategic areas. The promoter of this plan is the Observatory of the Spanish Bioeconomy Strategy, which we will describe in a specific section.

In the first 3 years of operation of the strategy, progress has been made in different areas, as discussed below:

- The bioeconomy has been included, in a comprehensive fashion, among the Spanish research and innovation objectives, within the framework of the revision of the State R & D Plan for the period 2017–2020. It is considered globally, integrating all the economic and social challenges associated with the agri-food, marine, and maritime sector and bioproducts, clearly establishing that the bioeconomy is a tool to advance towards the circular economy. In this context, the EU is moving in the same direction, in research and innovation, both in its work package within H2020 and in the ideas that are emerging for the 9th research program. In addition, the connection and interaction between the bioeconomy and the circular economy are considered, considering the former as a tool to develop the latter in the field of biological resources.

- A project has been carried out to determine the social perception of the bioeconomy in Spain, based on discussions with 20 focus groups, throughout the country, representing different age groups, professions, and levels of study. Particular emphasis was placed on knowing the opinion of the people active in social networks and environmental NGOs. The conclusions were varied; among them, one can highlight the scarce knowledge of what underpins the bioeconomy, the interest it provokes for the sectors linked to the production of biological resources, the doubts that its implementation raises in certain groups actively involved in the defense of the environment, and the need to improve information and communication, identifying the administrations related to science, technology, agriculture and food as the only ones that will have sufficient credibility to address the process.

- A coordinated strategy of training and communication has been developed, which has enabled 21 dissemination and training courses to be organized: eight by the central administration and the autonomous regional communities, in seven cases by universities, especially through their summer courses, and on six occasions by private entities. The scheme followed has always been based on a general presentation, explaining the concepts, objectives, elements, and strategic lines. From there, modules have been developed for different areas, with examples of bioeconomic activities in operation in the market. It has been quite common to explain the ways in which financing can be obtained for projects, both research and innovation.

- Two public-private collaboration forums have been organized—with the participation of researchers, administrations, and companies—to discuss the sustainability indicators applied in arable and livestock farming and forestry production. These agreed on the need to continue developing proposals and collaborating at the European level.

- At the international level, the Spanish bioeconomy has been represented in the SCAR working groups, in the stakeholder panel of the European Commission, and in the events organized by the Commission. It has also participated in the two Global Bioeconomy Summits, organized in Germany, and has established collaborations with the Latin American bioeconomy group through contacts within the framework of FONTAGRO and CEPAL.

- Several autonomous communities have started to develop their own initiatives in the area of the bioeconomy. Sixteen of the 17 Spanish regions featured the bioeconomy in their "smart" specialization strategies at the beginning of the current programming period; today, they all have it. In addition, eight communities have been working on their own strategies. At present, Andalusia has finalized and adopted the document of its regional strategy. Extremadura has included it in its green growth strategy. Aragón has included it in its circular economy strategy, but trying to promote rural development as an element of differentiation. Other Communities where work is being done, in different stages of progress, are Asturias, the Balearic Islands, Castilla León, the Region of Murcia, and the Valencian Community.

- There is an online platform available to the participants in which different documents can be presented, as well as showing examples of successful cases, for both the central administration and the Autonomous Communities that are working in this area. Training sessions have been organized to raise awareness of what constitutes the bioeconomy and the possibilities of financing its activities.

In 2018, work began to develop a Circular Economy Strategy in Spain. Since its implementation, the Bioeconomy Strategy has been present as such. The activities of the observatory, with its annual action plans, have become one of the measures of the Circular Economy Strategy itself, which shows the complementarity between the two strategies with regard to promotion of economic development and sustainability.

6. The Spanish observatory of the bioeconomy

An essential element for boosting the bioeconomy in Spain is the Spanish Observatory of the Bioeconomy. It is an instrument of support and cooperation for

the development of the Spanish Strategy of Bioeconomy, dealing with both administrations, central and regional, and with the different stakeholders of science, economy, and society as a whole.

Its functions are the following:

- Promotion of the Spanish Strategy of Bioeconomy and the measures stipulated therein.
- Adoption and promotion of the action plans.
- Collaboration in the analysis, diagnosis, evaluation, and monitoring of the activities defined within the framework of the Spanish Strategy of Bioeconomy.
- Monitoring of the development of the activities included in the action plans.
- Encouraging a strategy of public communication, education, sensitization, and participation of Spanish society in relation to the bioeconomy.
- Promote the inclusion of the bioeconomy in policies at the national level.

The Spanish Observatory of the Bioeconomy is made up of 38 members belonging to different administrations (central, regional, and local), to research facilities and companies within the structure of the bioeconomy, to universities, public research organizations, and technological platforms related to those same areas, and to social organizations that include sectoral representatives, trade unions, nongovernmental organizations, credit entities, etc.

Its structure, as shown in **Figure 2**, is as follows:

- *Monitoring group*: with representatives of the different administrations.

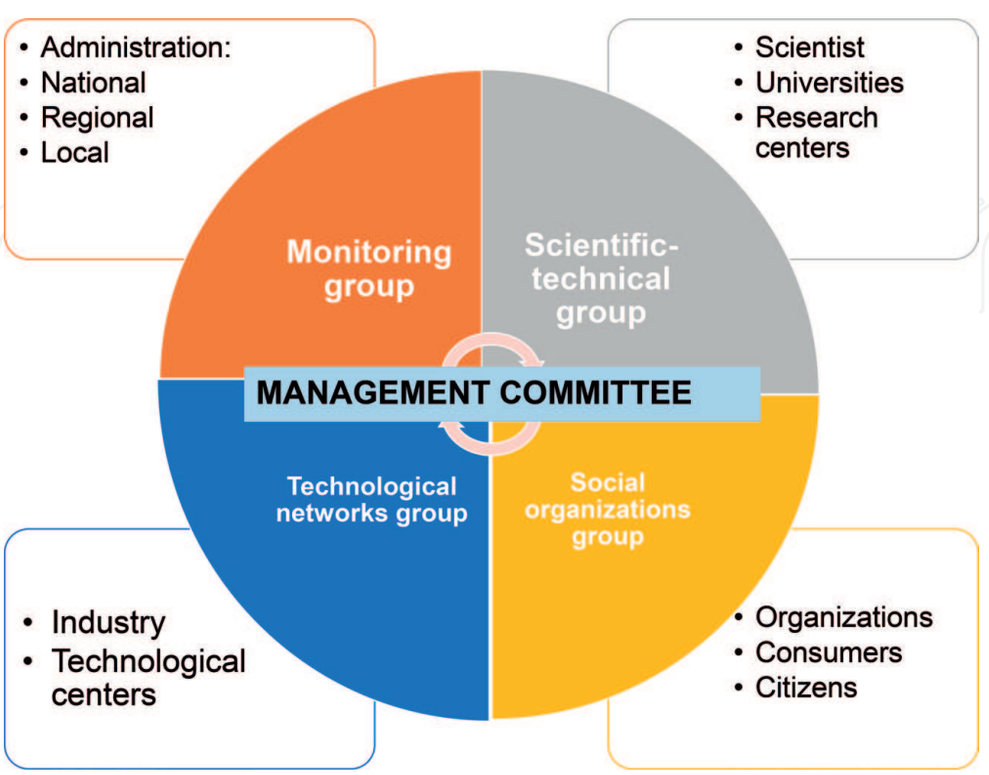

Figure 2.
Structure of the Spanish observatory of bioeconomy (own elaboration).

- *Scientific-technical group*: with a clear leadership role across the full gamut of possibilities in the bioeconomy and promoting innovation.
- *Technological network group*: this facilitates collaboration among the spheres of science, business, and innovation.
- *Social organization group*: this articulates the opinions within society as a whole.
- *Management committee*: this is formed by the two people who coordinate the work of each of the previous groups, together with a general coordinator. The coordinators mobilize and energize each of the previous groups, follow up on the general work, convene meetings, and summarize what was discussed in them.

7. Concluding remarks

The planet is facing a number of challenges that must be addressed in the coming decades, in relation to the use of natural resources to feed, in the medium and long term, all of humanity. Society has become aware of this reality and, at the international level, an agreement is being reached that obliges countries to modify their production and consumption practices in relation to goods and services. The sustainable bioeconomy, as a tool to develop the circular economy, can be an adequate instrument to overcome these challenges.

The bioeconomy groups together all activities related to the use of biological resources, providing a global and integrated view of their use in which the generation of knowledge and its application by companies, taking into consideration the opinion of society, will provide a response to political and social challenges with tools that guarantee the sustainable and efficient use of these resources.

In a country like Spain, in which biological resources represent 6.5% of GDP and provide employment for 9% of the active population, and which will be subject in the medium term to the pressure of changing agro-climatic conditions, the development of the bioeconomy—from the rural to the coastal environment and from the production of food to the commercialization of bioproducts—is a strategic area with a promising future.

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