



Review

Spanish strategy on bioeconomy: Towards a knowledge based sustainable innovation

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ABSTRACT

Spain launched its own strategy on bioeconomy in January 2016 aiming at boosting a bioeconomy based on the sustainable and efficient production and use of biological resources. It highlights global societal challenges related with agricultural and biotechnological sciences in Spain and the great dynamism of the private sectors involved, particularly the agri-food, biotech and biomass sectors.

The targeted sectors are food, agriculture and forestry, conditioned by water availability. It also includes the production of those industrial bioproducts and bioenergy obtained from the use and valorisation of wastes and residues and other non-conventional sources of biomass, in a circular economy. The strategy also puts a focus on rural and coastal development through several uses and services linked to ecosystems.

The capacity to generate know-how in this area and the promotion of public and private collaboration are important pillars in order to enhance existing value chains and to create new ones. The strategy is led by R&I and Agriculture, Food and Environment policy managers and largely supported at regional level too. The strategic objective is the maintenance of the bioeconomy as an essential part of Spanish economy to contribute to the economic growth by creating new jobs and fostering investments.

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Introduction

Bioeconomy has been identified as a tool to address a wide range of societal challenges in the coming years: food security, climate change, sustainable resource management, private companies' competitiveness, job creation and the high dependence on non-renewable resources [2–6].

Spain launched its own strategy on bioeconomy in January 2016, with its first year Action Plan, in order to boost a bioeconomy based on the sustainable production and use of biological resources. Spain is one of the 40 countries that have shown a huge interest in promoting this field, which could make an important contribution to economic growth [1,7].

This article analyses the reasons behind the decision taken in 2014 to prepare a specific bioeconomy strategy. The strategy highlights the global societal challenges related to the bioeconomy, namely the importance of agricultural and biotechnological sciences in Spain and the current behaviour of private sectors involved, in particular the dynamism of the agri-food, biotech and biomass sectors, even during the current Spanish economic crisis. The preparatory work has taken full account of the research and innovation policy framework at European, National and Regional levels, not only for science and technology, but also as regards economic growth and the enhancement of rural development based on innovation.

The bioeconomy is considered a strategic area for Spain, focusing attention on the business-led initiatives and on public-private partnerships with innovation from both public and private actors. This objective explains the strong presence of the private sector and its participation throughout the preparation of the working plan as well as the active involvement of researchers.

The promotion of current value chains and the creation of new ones provides a promising opportunity for the bioeconomy in Spain in the coming years, especially when the use and valorisation of wastes and residues from agri-food production systems is taken into consideration. There is also a major opportunity to involve society at large, because it has the right to understand and participate in the dialogue on science and technology developed by

managers and policy makers. The benefits of the kind of bioproducts which are sought will reach the market in the coming years, enhancing the advantages that our society will obtain through the implementation of the new 'green economy' or bioeconomy. Nevertheless, some concerns may arise in society in relation to the sustainable use of natural resources. Thus, it will be critical to emphasise in any dialogue with representatives of civil society that sustainability is a general and basic principle of the strategy. Only in this way will the strategy be able to create trust and avoid potential concerns.

Methodology

A task force was set up in 2013 by the Spanish Secretary of State for Research, Development and Innovation, whose main goal was to evaluate the opportunity to develop a bioeconomy strategy for Spain. The updated OECD documents [8] and the different national (Germany [9], USA [10], Ireland [11], and The Netherlands [12]) and EU strategies [13] were analysed and served as background documents [14]. The same approach was followed with the different positions and documents of working groups and committees, in particular the Standing Committee on Agricultural Research of the European Commission, (SCAR) [15]. Different aspects were analysed, for example the Spanish scientific contribution to biological and biotechnological sciences, or the Spanish participation in public, competitive calls related to the Food, Agriculture and Fisheries, and Biotechnology Cooperation Theme under the 7th Framework Programme for Research and Innovation. The strength of economic sectors behind the bioeconomy concept, the involvement of society, and the challenges faced in our 2013–2016 National Plan for Scientific and Technological Research and Innovation [16] were taken into consideration. The overall conclusion was that the bioeconomy is deserving of a concrete strategy in Spain, taking into consideration its own characteristics.

The preparatory work of the bioeconomy strategy has been led by research and innovation policy managers, as in the EU and other European countries [17]. Open and fluid communication channels

Table 1
Time schedule for the strategy elaboration process.

Time	Action	Goal
2013	Internal task force. Spanish Secretary of State for Research, Development and Innovation.	Evaluate the opportunity to prepare a Bioeconomy strategy in Spain.
First quarter 2014	Political support: agreement between Ministries.	Ministries of Economy and Competitiveness (SEIDI); Agriculture, Food and Environment (MAGRAMA); and Energy, Industry and Tourism.
Second quarter 2014	Working group creation ^(a)	Prepare the basis and scope to implement the design of the strategy.
First quarter 2015	Draft the first working document on Bioeconomy strategy and distribute it together with a survey to selected stakeholders ^(b)	Learn from expectations, initiatives needed to promote Bioeconomy development, operational objectives of the strategy and case studies of corporate or social success.
November 2015	Final draft strategy was delivered.	Adopted by policy makers.
January 2016	Spanish Bioeconomy strategy – 2030 Horizon	Strategy publicly available and distributed nationally and internationally.

^a Working group was chaired by the Secretary of State for Research, Development and Innovation (SEIDI) and made up of experts belonging to Ministries of Economy and Competitiveness (SEIDI and CDTI), Agriculture, Food and Environment (MAGRAMA) and Industry, Energy and Tourism (MINETUR), Spanish food and beverages Federation (FIAB), Spanish Bioindustry Association (ASEBIO), Spanish Confederation of Business Organizations (CEOE), Spanish Biotechnology Society (SEBIOT), and research institutes in the fields of agri-food (INIA), energy and environment (CIEMAT) and general sciences (CSIC), and an external advisor from the European Federation of Biotechnology.

^b 240 selected people representing: national, regional and local administrations involved in science, innovation and biological resources (49); private companies that had received innovation grants in the two previous years in Bioeconomy fields (162); Bioeconomy-related technological platforms (11); and societal organizations such as NGO, trade unions, and farmers and consumer's associations (18).

have been established with different stakeholders (social representatives, industry, academia, national, regional and local administrations, etc.). These have made valuable comments which have enriched successive drafts of the strategy. Furthermore, a draft document was submitted to a public consultation, prior to approval by the drafting group.

Table 1 shows the timing and process followed to prepare the final document, based on the collaboration between representatives of the Ministries involved (Research and Innovation (SEIDI)),¹ Agriculture, Food and Environment (MAGRAMA),² Industry, Tourism and Energy (MINETUR)³ and representatives from the private sector (food sector, biotech companies, and technological platforms) and researchers.

The strategy: drivers and reasons

The efficient and sustainable use of biological resources is possible nowadays because of advances taking place in the fields of agricultural and food sciences, biotechnology and chemistry, along with the advances which are expected to be achieved in coming years [18]. These will be facilitated by technological and innovative support from other areas such as engineering, organisation and logistics, which may in turn enhance the competitive position of productive sectors. Nevertheless, beyond this general statement there are certain specific reasons which justify a bioeconomy strategy in Spain, the most important of which are described below.

Bioeconomy as a societal challenge

All the social challenges that the bioeconomy can face, as identified in the Introduction above, apply to the Spanish situation. In open, globalised markets, the requirement for nutrition and consumer goods in an increasingly populated and urbanised world must be met [19]. Spanish food and agricultural activities contribute to providing food, services and consumer goods worldwide. This new global context strongly conditions the nature of the demand for food, shifting it towards more secure, higher quality, more manufactured products, with specific nutritional profiles defined to promote consumer health, and with differentiated added values. At the same time, given the conditions which underlie this production, and which are affected by climate change (extreme temperatures, rainfall, draught, salinity, soil erosion, soil quality, etc.), there is a clear need for a better and more sustainable use of natural resources (land, water, emissions, biodiversity, ecosystems) [20,21].

Spanish agri-food companies must continue to hold the competitive position they have attained in recent years and will need to innovate, making the most of the available scientific know-how to adjust their food production models, to enlarge and differentiate the products reaching the market, and incorporate new production, conservation and transformation systems. They also need to improve efficiency while reducing food losses and wastes and, last but not least, they must respond to social expectations by making use of innovative business models to promote rural and coastal development [22,23].

Agroforestry systems are at the core of the Spanish strategy on bioeconomy: the production and transformation of timber, cork,

resin, production of pulp and paper and other industrial products; the extraction of energy and other bioproducts; and the uses and services linked to ecosystems, ranging from harvesting activities to tourism and leisure. All of these will be influenced by climate change and the need to apply criteria of maximum efficiency and sustainability in their respective management processes [24].

Bioeconomy offers unique opportunities which deserve our full attention. The efficient use of biological resources requires the identification, utilisation and further valorisation of waste, residues and by-products from crop and animal production systems, from the production, harvesting, transformation, transport and commercialisation of food, feed and bio-based products. Other biomass sources such as industrial and municipal solid waste from human activities are also within the scope of the Spanish bioeconomy strategy, as well as other non-conventional sources which must be taken into account in order to create new jobs and introduce new ranges of bio-based products into the market. An opportunity also exists to offer an alternative to those fossil-based products already established in the market and which could be partially and gradually replaced by bio-based products, with better performance in terms of sustainability and environmental indicators [25].

Another non-conventional and promising source of biomass comes from the cultivation of algae and microorganisms. These approaches must be taken into consideration given the potential for the creation of new jobs, the introduction of new ranges of bioproducts into the market (biolubricants, bioplastics, food additives, pharmaceutical and cosmetic products, chemical building blocks, varnishes, solvents, etc.), and bioenergy (advanced biofuels, thermal or electrical energy, etc.), thus reducing dependence on fossil resources. The marine environment also offers a vast reserve of unexploited natural resources of great genetic diversity, and may also be used to generate new value chains. Moreover, the potential of marine biotechnology to deliver solutions to the main societal challenges (healthcare, food, power energy supply, etc.), is unquestionable [11].

Economic sectors associated with the bioeconomy in Spain

The involvement of different economic sectors within the bioeconomy is quite significant in Spain, accounting for an estimated 6.5% of the Gross Domestic Product (GDP) and employing around 9% of the working population, with more than 900,000 farms and more than 30,000 companies. 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.

The importance of food production to the Spanish economy is clear: the farming sector generated Gross Value Added (GVA) of €21.707 billion, 2.5% of national GDP, pursuing its activity in 890,000 operations and employing 740,000 people [26]; GVA in the food industry sector was €28,448 billion in 2012, accounting for 2.7% of GDP, with a total of 28,762 companies and providing direct employment of 480,000 people [27].

The system which comprises the forestry sector plus the timber, cork and pulp and paper industry generated GVA of €5936 billion, 0.56% of national GDP. Of the total, €3307 billion came from the pulp and paper industry, €1867 billion from the timber and cork industry, and €762 million from the forestry sector [26].

The fisheries sector is also relevant, comprising offshore fishing as well as continental and marine aquaculture, and generating GVA of €1047 billion, with 5025 operations in all, 9871 vessels and 64,675 jobs contributing about 0.2% to GDP [28].

According to the National Statistics Institute, INE [29], the non-health biotechnology sector is made up of 2831 companies employing 172,939 staff of whom 9135 are engaged in R&D in

¹ Secretary of State for Research, Development and Innovation (SEIDI) within the Ministry of Economy and Competitiveness. From November 2016 onwards its name is Ministry of Economy, Industry and Competitiveness.

² From November 2016 onwards the new name is Ministry of Agriculture and Fisheries, Food and Environment.

³ From November 2016 onwards the new name is Ministry of Energy, Tourism and Digital Agenda.

biotechnology, and with 5148 researchers. As many as 530 companies are working in R&D: 196 in animal health and aquaculture, 314 in food, 206 in agriculture and forestry production, 182 in the environment and 159 in industry.

Last but not least, the sector producing and transforming biomass for energy generation and creating bioproducts comprises some 170 companies in Spain. According to the Association of Renewable Energy Companies (APPA) [30], the input to GDP from bioenergy, including biomass for the generation of electricity and thermal and biofuels for transport between 2007 and 2014 averaged €3562 billion each year. In that period, some 47,880 direct and indirect jobs were generated annually on average according to the same sources.

Knowledge generation capacity in the bioeconomy domain

Spain has a significant capacity to generate know-how in the area of the bioeconomy, either through public research bodies and universities, or public and private technological centres and companies. According to information provided by the Directorate-General for Scientific and Technological Research under the Secretary of State for Research, Development and Innovation (SEIDI), and by the National Institute for Agricultural and Food Research and Technology (INIA), at the end of 2014 as many as 2780 research projects were ongoing in bioeconomy related areas, with public funding from both divisions of the Spanish Public Administration. The distribution of these projects according to different scientific areas is shown in Table 2. Each research project is conducted by at least one research group. Groups specialising in food and agriculture were the most prevalent, but fundamental areas of biology and biochemical science and technology were also quite well represented.

There is an impressively large participation of Spanish entities in the Horizon 2020 Societal Challenge 2 “Bioeconomy”. According to data provided by Commission services and data from CORDA, Spain ranks second in the list of funding among EU participating countries in 2014–2015 projects, while Spain ranked fifth in the predecessor “Food, Agriculture and Fisheries, and Biotechnology” Cooperation Theme under the Seventh Framework Programme from 2007 to 2013. €61 million were allocated to Spanish entities in the competitive calls for proposals in 2014 and 2015, mainly to research centres, public research organisations, universities and enterprises. It is worth mentioning that the participation of Spanish enterprises, and particularly SMEs, is above average at European level. These results greatly exceed the initial expectations.

Public-private innovation experiences in the bioeconomy field

The number and expected impact of publicly funded projects targeted to innovation and led by private companies in different

Table 2
Spanish public funded research project distribution by scientific areas at the end of 2014.

Areas	No. of Projects
Food and Agriculture Resources and Technologies	1,150
Agriculture	451
Livestock farming	272
Aquaculture	83
Forestry	74
Food	270
Fundamental biology	577
Biotechnology	236
Environmental Sciences and Technologies	273
Chemical Sciences and Technologies (Bio)	439
Energy (Alt)	105

grand challenges provide a good indication of the strengths of Spain as regards innovation in the bioeconomy domain. According to the information supplied by SEIDI, CDTI and MAGRAMA, 339 projects were funded in 2013 by the Spanish Public Administration and by the EC. In all cases there was some kind of collaboration with research groups, mostly public ones. This figure represents 54% of public funds devoted to science and technology in the bioeconomy domain, and leads to the conclusion that public-private sector collaboration is quite well established in this area, although there is room to further strengthen this relationship. Fig. 1 demonstrates the importance in national programmes of public-private sector cooperation within the bioeconomy field (the so-called Challenge 2 in national programmes), in comparison with other sectors, not only with regard to innovation activities, but also in research activities. Research projects led by companies are always supported by applied research activities carried out in universities or research centres. Their achievements contribute to the objectives of the private sector while generating valuable knowledge.

The adopted science and innovation policies

Knowledge generation, innovation and private investment in bioeconomy are supported by European, national and regional policies [31–33]. At European level, the generally applied policy is Horizon 2020 for science and technology and the Common Agricultural Policy, pillar 2, for innovation in agro-food systems [18]. At national level, there is a 2013–2016 State Plan for Research, Innovation and Development [13], and a specific innovation measure in the National Rural Development Programme [34]. At regional level each Autonomous Region has adapted the application of the European Regional Development Funds and the Rural Development Programme to their territory.

Bioeconomy was present, as a priority, in every one of these programmes. Horizon 2020, as the EU Framework Programme for research and innovation, establishes three main pillars. One of them, the Societal Challenges Pillar, aims to mobilise the research and innovation critical mass to achieve the adopted policy goals. Within this Pillar, Societal Challenge 2 refers to “Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy”. Using different tools, the EC supports activities aimed at developing sustainable and productive agriculture, a competitive and sustainable agri-food sector for a healthy and safe diet, unlocking the potential of aquatic living resources and promoting marine and maritime research activities, fostering sustainable and competitive bio-based industries and promoting the development of the European bioeconomy. This policy was linked to the Common Agriculture Policy (CAP) through the European Innovation Partnership on Agricultural Productivity and Sustainability, a new tool targeted at promoting innovation through different measures and funded by the second pillar of the CAP.

The Spanish National Plan for Research, Innovation and Development was formulated, for the first time, in parallel to Horizon 2020 and followed a similar structure. One of the four main pillars of this plan is the National Programme for Research aimed at the challenges of society. The second challenge concerns the bioeconomy under the title “Food quality, safety and security; sustainable and productive agriculture; natural resource sustainability; marine and maritime, and inland water research”. Research groups and private companies can apply for financial support and loans to carry out research and innovation investment projects in that area [13]. At the same level, the National as well as most Regional Rural Development Programmes, have incorporated measures to promote innovation in those territories in different bioeconomy-related fields.

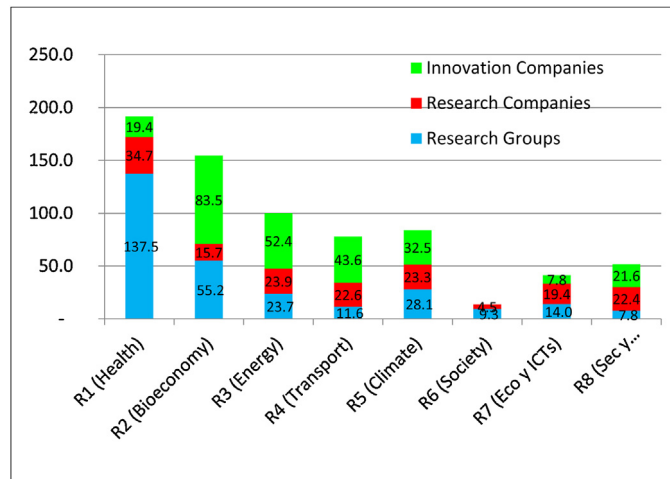


Fig. 1. Spanish research and innovation public funding, according to National Plan challenges in 2014 (million euros).

In order to increase the impact of the policy on growth and employment, the European Development Regional Fund invited EU regions to identify and prioritise the economic areas that could provide the different territories with comparative advantages, aligning their research and innovation capacities [35]. For this purpose, all Autonomous Regions have developed their own Research and Innovation Strategy for a Smart Specialization (RIS3), identifying up to four sectors in which to concentrate their investments. In accordance with this process, 16 out of 17 Autonomous Regions in Spain identified the agro-food sector as one of their main priorities: the biobased economy in 9 regions; the bioeconomy as a whole, as considered by Horizon 2020 in 6 regions; and marine and maritime activities in 7 regions. Table 2 summarises the results of this identification and prioritisation process at regional level (Table 3).

The opportunity for bioeconomy development in Spain

Spain maintains a strong position in the use of biological resources for purposes of human consumption, conditioned by long periods of water scarcity in most of the territory. Nevertheless, as has been pointed out in previous paragraphs, there is room for further uses of biological resources. The total volume of all organic residues and other biomass sources was quantified for the whole country in the 2011–2020 Renewable Energies Plan and in the PROBIOGAS project [36]. On the basis of both studies, the biomass

produced (including that derived from agricultural crops, forestry, the food industries, timber, pulp and paper and textile industries, animal waste and the organic fraction of municipal solid waste) can be estimated at 159 million tons/year.

The economy associated with resources of biological origin is benefiting from ongoing scientific and innovative advances, and will continue to do so to a greater extent in the future. New technologies must provide the tools to enhance the competitiveness and set apart those companies already operating in domestic and international markets while, at the same time, providing the basis for new economic activities.

The continuous development of the bioeconomy as an opportunity and a necessity both for society and for the Spanish industrial sectors remains at the heart of the bioeconomy strategy. It is needed in order to advance towards a society that must be much less dependent on non-renewable resources. At the same time, for a country like Spain, the bioeconomy must be a driving force in consolidating the process of economic growth.

The involvement of society

Spain, as a society, is on course towards the implementation of a circular economy in all daily activities. In order to be fully sustainable and efficient in the use of biological resources, society as a whole must be familiar with the objectives and guiding principles as well as the necessity to combine consolidated

Table 3 Final result in RIS3 methodology application in the Spanish regions, considering the economic sectors involved in Bioeconomy.

	Bioeconomy in general	Sustainable food systems	Blue Growth	Biobased industries
Andalucía		x	x	x
Aragón		x		
Canarias	x	x	x	x
Cantabria				x
Castilla-La Mancha	x	x		x
Castilla y León	x	x		x
Cataluña	x			
C. Valenciana		x		
Extremadura		x		x
Galicia		x	x	x
Illes Balears		x	x	
La Rioja		x		
Madrid	x	x		
Navarra		x		
País Vasco		x	x	
Principado de Asturias	x	x	x	x
Region de Murcia		x	x	x

technologies technology with other, recently developed technologies. For this reason, the different stakeholders that integrate civil society must be involved in a bioeconomy strategy as a tool to implement the circular economy [37,38]. Their opinion matters for the general objectives, the expected benefits derived from the efficient and sustainable use of bioresources and the commitments that must be adopted to achieve an optimal use and preservation of natural resources and ecosystems along with the technological advances developed and applied to expand the biobased industries [6].

The bioeconomy cannot be developed in Spain if it is not known, accepted, appreciated and promoted by all the actors that make up Spanish society [39]. For this reason, from the outset, it is considered essential that society is fully aware of the favourable impacts of bioeconomy as regards the environment, reducing dependence on fossil resources, once the technologies have been adequately evaluated. At the same time, society must be given the opportunity to observe its development during the implementation process. This would allow consumers to be more informed regarding the new range of products which will gradually become available and appear on the market. Development of a communication strategy, with the participation of all social and economic stakeholders, is essential for technology to be understood and accepted by society and, subsequently, used by companies to market new products or incorporate different added values [40].

Pillars of the Spanish bioeconomy strategy

The main focus of the bioeconomy in Spain is the use of biological resources to produce food and feed. There is a consensus that environmental sustainability is the only path to obtain renewable organic material. This particularly applies to the efficient use of natural resources, especially water and soil [41]. The necessity to consider knowledge generation as the first step towards achieving the desired bioeconomy sector in the long term has been established. Public and private sector collaboration in knowledge generation and application is considered essential to promote innovation, including the involvement of society throughout the development of the strategy.

These ideas are described through different statements in the Spanish bioeconomy strategy as follows:

- The use of renewable resources, obtained under special circumstances of climate change and destined fundamentally to meet the requirements of a growing world population, is considered an essential element of the strategy. The demand for biological renewable resources for food, bioproducts and bioenergy is expected to grow in coming decades. Therefore, an improved efficiency and sustainability of natural resources exploitation is a guarantee for environmental sustainability. This fact is strongly emphasised throughout the strategy due to the scenario of reduced water availability in Spain as well as the limited availability of land to satisfy the current needs for food production and the growing worldwide demand for energy.
- The strategy is based on the science – economy – society triangle: the knowledge generated in the scientific field must be used to develop productive activities which will allow us to continue to grow in those areas which society accepts and shares. Therefore, direct and indirect involvement of all stakeholders is required to strengthen the triangle:
 - Society, through consumers, organisations representing different social, economic and environmental groups, together with the media and all areas of public administration involved, which will play a key role as promoters, facilitators and catalysts of the strategy;

- Science, through scientists and researchers who are an integral part of the Spanish science and innovation system;
 - The Economy, through companies in the productive sectors forming part of the area of activity, either individually or organised around their associations and clusters.
- Another 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. Several value chains have been considered, namely: food and agriculture activities, including primary production and raw material transformation; the use of residues and wastes as a source of biomass for new activities, especially biorefineries; marine and maritime activities, including aquaculture for food or biomass production; sustainable forestry production and its contribution to the biomass pool as raw material for the biochemical industry and bioenergy. In the current situation in Spain, adequate water management and reuse, along with rural development were considered fundamental.

Scope and objectives

In the framework of the Spanish strategy, the bioeconomy can be considered as a set of economic activities through which products and services are obtained, thus generating economic value while making efficient and sustainable use of biological resources. The objective of the strategy is to produce and commercialise food, along with forestry products, bioproducts and bioenergy obtained by physical, chemical, biochemical or biological processing of organic matter not destined for human or animal consumption, and involving processes which are respectful of the environment, along with the development of rural and coastal areas.

The targeted sectors are food and agriculture, comprising crop production, livestock farming, fishing, aquaculture, food production and marketing, as well as the forestry, timber, cork and pulp and paper sector. It also includes those industrial bioproducts obtained with or without chemical, biochemical or biological processing of the organic matter generated by our society and not used for human and animal consumption, and the bioenergy obtained from different sources of biomass. Environmental services and rural development are also within the scope of the strategy. The base of all these activities is conditioned by the growing limitations on the availability of water and the need for sustainable management based on science and technology.

Two types of targets – strategic and operational – were established.

The **strategic, long term objectives** 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;
- The maintenance of the bioeconomy as an essential part of Spanish economic activity, and;
- Developing the potential of the bioeconomy on a 15-year horizon, based on technological, organisational and management innovation as a tool for resolving problems and making the most of market openings.

Regarding the **operational objectives**, ten main targets were identified which can be grouped into three blocks:

- The first regards the interaction between the public and private science and technology systems, both Spanish and international, the productive sectors and their companies, in permanent cooperation with the Spanish public administration.
- The second is related to the implementation of the bioeconomy: the identification of limitations to its expansion (social, regulatory barriers, financing, market barriers, etc.).
- The third refers to the connection with society through bioeconomy awareness-raising campaigns and training activities targeted at stakeholders applying to public, competitive calls.

Strategic measures

In order to achieve the above targets, it is deemed essential to promote research activities, led by either public or private actors, but oriented towards companies' innovation. The general view was that society needs to be involved in the technological progress geared to developing the bioeconomy, knowing and understanding the science behind the evolution of technology. Private companies will finance bioeconomy projects if they consider that their investments are going to be profitable. The entrepreneurs consulted in the preparation phase of the strategy identified technological, social, legal and market obstacles to be removed before their decision on investments can be made. All these issues must be addressed throughout the strategy, along with the participation and implication of Spanish regional authorities. Bearing these ideas in mind, actions included in the strategy have been grouped into five major areas considered major strategic lines:

- The first strategic measure is **“to promote public and private research and industrial investment in innovation in the area of the bioeconomy”**. This aims to encourage the generation of knowledge and its application to the development of innovation, using all the instruments available to the science and innovation

system whilst at the same time making the private financial sector aware of the potential of the bioeconomy.

- The participation of companies and researchers, especially through multidisciplinary alliances, in knowledge generation, research and innovation projects at European, National and Regional level, must be strongly encouraged. A training course was set up for this purpose.
- Specific actions are included: prioritisation mechanisms for access to funds devoted to promoting the bioeconomy; participation of the most suitable stakeholders for the operational groups in the European Innovation Partnership (EIP) in Rural Development Programmes; development of models to facilitate the funding of pilot projects and demonstration plants; and analysis of successful public-private sector collaboration models generating business innovation based on public research.
- The organisation of an annual conference on bioeconomy is also foreseen, as well as the setting up of a repository of public and private research projects.
- The second strategic measure is **“to reinforce the social, political and administrative context of the bioeconomy”** to organise the structure for support, promotion and cooperation in the development of the Spanish bioeconomy strategy. For this purpose, the creation of an observatory, as a strategic government tool has been established.
- The main objective of the observatory is to foster the implementation of the measures established as part of this strategy as well as the annual action plans. It comprises representatives of Ministries and Autonomous Regions, scientific and business associations, technological platforms and networks, and a specific group coming from civil society.
- There is also a programme for social dissemination and dialogue on the bioeconomy based on the exchange of opinions between

Table 4

The five major strategic lines to promote Bioeconomy in Spain.

Strategic lines	Measures
1. Promote public and private research and company investment in innovation	<ul style="list-style-type: none"> • Multidisciplinary alliances of researchers and companies to apply for European, National and Regional calls • Operational groups in the European Innovation Partnership (EIP) • Innovation in the framework of Regional Operating Programmes • Models to facilitate the funding of pilot projects • Analyse successful international public-private sector collaboration models • Annual Conference on Bioeconomy • Involvement of private financial institutions and risk- capital companies • Repository of raw data on Spanish public research projects
2. Reinforce social, political and administrative context	<ul style="list-style-type: none"> • Creation of Spanish Bioeconomy Observatory • Programme for social divulgation and dialogue on Bioeconomy • Group of parties interested in Bioeconomy matters in Spain • International cooperation and exchange • Promote training in the Bioeconomy field
3. Competitiveness and development of the market	<ul style="list-style-type: none"> • Develop the concept of social and environmental sustainability • Identify legal, administrative or other new product limitations • Exports and internationalisation • Development of chains of value intended to reappraise resources • Standardisation and certification processes • Alternatives to current productive and organisational models
4. Develop demand for new products	<ul style="list-style-type: none"> • Identification of obtainable products • Innovative public procurement • Labelling system for bioproducts
5. Expansion and promotion	<ul style="list-style-type: none"> • Successful business cases • Promote strategies in the Autonomous Regions and locally • Linking Spanish to other European Bioeconomy strategies

all the stakeholders. This will assess the current perception of society with regard to the bioeconomy.

- The third strategic measure is **“to promote the competitiveness and development of the market for new bio-based products”** taking into account all those elements that will be dictated by both supply and demand, along with the regulatory demands associated with this new market. It is necessary to define the concept of social and environmental sustainability, taking into consideration the different environmental footprints and the updated procedures to evaluate the sustainability of production models using objective, comparable indicators. At the same time, it is necessary to establish a channel to identify legal, administrative or other limitations preventing new products from being placed on the market, and to develop a specific working plan to help overcome such limitations. Additionally, the development of new value chains must be promoted to further valorise biological resources with still limited market. The standardisation and certification processes for products from biological sources, where applicable, is being considered at European level, and will be taken into consideration in the strategy.
- The fourth group of actions aims **“to develop demand for new bio-based products”** either by new consumers or by intermediaries for other productive activities. For this purpose, it is important to identify limitations based on technology, finance or demand and the possible public tools to overcome the difficulties, paying special attention to public procurement or labelling systems.
- The last strategic measure is **“to expand and promote the bioeconomy”** in both areas: private investment and public support. The strategy will compile and explain success cases in order to learn from experiences in different places, providing incentives for innovators and entrepreneurs. It will also encourage the development of specific strategies in the Autonomous Regions. It is worth mentioning that several Autonomous Regions are already working on their specific bioeconomy strategy. Several meetings have taken place with Regional Administrations to discuss the basis and scope of on-going regional initiatives. This is the case of Andalucía, Castilla-León, Comunidad Valenciana and Extremadura. At the same time, the work and initial experiences of the Spanish strategy on bioeconomy have been explained in many different Latin American countries like Colombia, Perú, Chile, Argentina, Uruguay and Costa Rica, as well as in the EU.

Table 4 summarises the different measures adopted in each strategic line described above.

Other aspects of the strategy

The strategy includes three additional sections. One describes the technical, economic and organisational resources for the start-up phase. This chapter estimates the funding possibilities for the 2016–2020 period, considering European, national and regional funds. Another section establishes the way in which the strategy is to be implemented, through Annual Action Plans. These Plans, promoted by the Spanish bioeconomy observatory, must be drafted after a thorough analysis of the general framework and the possibilities for financing and implementing each measure. This programming exercise must include specific activities for the following year specifying for each measure the actors responsible and the budget allocated. The last section of the document describes the indicators used to evaluate the implementation of the strategy. There are initially two groups of indicators:

- the first group will measure the related public and private investment and the number of activities;
- the second will analyse the evolution of the sectors linked to biomass use and the improvements with regard to the effectiveness of biological resource use.

Conclusions

The bioeconomy provides the means to ensure that the challenges facing our society will be met in accordance with guiding principles of sustainability, making the most of the economic opportunities afforded by an efficient use of biological resources in order to develop new biobased products which will reach the markets in the coming years. This is the framework within which Spain has launched its own strategy on the bioeconomy

The development of the Spanish strategy on bioeconomy has embraced ideas and proposals from different sectors of society, including the academic and economic sectors, as well as from public administration managers. From now on, policy makers must encourage the application of these measures, providing support to the activities of the observatory, especially through their annual plans. The scientific community should incorporate the development of the bioeconomy into their research objectives. Companies could contribute by innovating and developing technology to advance business projects, introducing products and services into the market with efficiency and sustainability as guiding principles. Society must be aware that bioeconomy, in the framework of the circular economy, implies the application of the sustainability and efficiency criteria and requires new technologies that should be accepted and integrated into purchasing decisions when products come onto the market.

In the meantime, the 2016 Action Plan for implementing this strategy has been launched. More than 250 people have been trained in the concept of bioeconomy and its funding opportunities. It has been brought to different areas of society, both at national and European level.

We face a huge challenge to address the future of our world, but at the same time the development of the bioeconomy presents enormous opportunities for the different countries, societies and companies involved to lead in the way in their respective fields.

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References

- [1] Spanish strategy on bioeconomy horizon 2030. State Secretariat for Research, Development and Innovation. <http://bioeconomia.agripa.org/download-doc/102159/> (Accessed 25.03.17.)
- [2] 2013/743/EU: Council Decision of 3 December 2013 establishing the specific programme implementing Horizon 2020 – the Framework Programme for Research and Innovation (2014–2020) and repealing Decisions.
- [3] EPSCO. The European bioeconomy in 2030: delivering sustainable growth by addressing the grand societal challenges. European Plant Science Organization; 2011. . (Accessed 15 July 2016) <http://www.europabio.org/EU%20Projects/bioeconomy-2030-becoteps-final-white-paper.pdf>.
- [4] McCormick K, Kautto N. The bioeconomy in europe: an overview. *Sustainability* 2013;5:2589–608.
- [5] Staffas L, Gustavsson M, McCormick K. Strategies and policies for the bioeconomy and bio-based economy: an analysis of official national approaches. *Sustainability* 2013;5:2751–69.
- [6] Ollikainen M. Forestry in bioeconomy – smart green growth for the humankind. *Scand J For Res* 2014;29(4):360–6.
- [7] 2016 Bioeconomy action plan, State Secretariat for Research, Development and Innovation. <http://bioeconomia.agripa.org/download-doc/102157/> (Accessed 25.03.17.)

- [8] OECD. *The bioeconomy to 2030: designing a policy agenda*. Paris, France: OECD International Futures Project. OECD; 2010.
- [9] Federal Ministry for Education and Research. *National research strategy bioeconomy 2030. Our route towards a biobased economy*. https://www.bmbf.de/pub/National_Research_Strategy_bioeconomy_2030.pdf. (Accessed 12 July 2016).
- [10] The White House. *National bioeconomy blueprint*. https://www.whitehouse.gov/sites/default/files/microsites/ostp/national_bioeconomy_blueprint_april_2012.pdf. (Accessed 15 July 2016).
- [11] Report of the high-level group on green enterprise. *Developing the green economy in Ireland*. <https://biobs.jrc.ec.europa.eu/policy/german-national-research-strategy-2030>. (Accessed 10 August 2013).
- [12] The Green Growth Group. *Gaan Voor Groene Groei*. <https://www.rijksoverheid.nl/onderwerpen/duurzame-economie/documenten/rapporten/2013/11/12/gaan-voor-groene-groei>. (Accessed 8 August 2016).
- [13] European Commission. *Innovating for sustainable growth: a bioeconomy for Europe, COM (2012) 60final*. Brussels: Communication from the Commission to the European Parliament, the Council, the Economic and Social Committee and the Committee of the Regions; 2012.
- [14] Bioökonomierat. *Bioeconomy policy synopsis and analysis of strategies in the G7*. <http://biooekonomierat.de/en/publications/>. (Accessed 12 September 2016).
- [15] European Commission. *Sustainable agriculture, forestry and fisheries in the bioeconomy – a challenge for Europe*. 4th SCAR foresight exercise. <https://ec.europa.eu/research/scar/index.cfm?pg=about>. (Accessed 15 July 2016).
- [16] Spanish government. *Ministry of Economy, Industry and Competitiveness, Spanish National Plan for scientific and technical research and innovation 2013–2016*. <http://www.idi.mineco.gob.es/stfls/MICINN/Investigacion/FICHEROS/Spanish_RDTI_Plan_2013-2016.pdf>. (Accessed 12 July 2016)
- [17] Socaciu C. *Bioeconomy and green economy: European strategies, action plans and impact on life quality*. *Bull UASVM Food Sci Technol* 2014;71(1).
- [18] D'Hondt K, Jiménez-Sánchez G, Philp J. *Reconciling food and industrial needs for an Asian bioeconomy: the enabling power of genomics and biotechnology*. *Asian Biotechnol Dev Rev* 2015;17(2):85–130.
- [19] Von Braun J. *Bioeconomy – science and technology policy for agricultural development and food security*. Paper presented at Festschrift seminar in honor of Per Pinstrup-Andersen on new directions in the fight against hunger and malnutrition. <http://ppafest.nutrition.cornell.edu/authors/vonBraundraft.pdf>. (Accessed 10 September 2016).
- [20] Pfau SF, Hagens JE, Dankbaar B, Smits AJM. *Visions of sustainability in bioeconomy research*. *Sustainability* 2014;6:1222–49.
- [21] Federal Ministry of Food and Agriculture. *Biobased business, sustainable agriculture and forestry*. http://www.bmel.de/SharedDocs/Downloads/EN/Publications/NatPolicyStrategybioeconomy.pdf?__blob=publicationFile. (Accessed 7 September 2016).
- [22] Schmid O, Padel S, Levidow L. *The bio-economy concept and knowledge base in a public goods and farmer perspective*. *Bio-Based Appl. Econ.* 2012;1(1):47–63.
- [23] Johnson TG. *Rural development opportunities in the bioeconomy*. *Biomass and Bioenergy* 2014. doi:<http://dx.doi.org/10.1016/j.biombioe.2014.01.028> Altman.
- [24] Graudal L, Nielsen UB, Schou E, Thorsen BJ, Hansen JK, et al. *Possibilities for sustainable increase of danish produced woody biomass 2010–2100*. http://static-curis.ku.dk/portal/files/161427469/Roos_A_et_al_20140227.pdf. (Accessed 8 September 2016).
- [25] Popp J, Lakner Z, Harangi-Rákos M, Fári M. *The effect of bioenergy expansion: food, energy, and environment*. *Renew Sustain Energy Rev* 2014;32:559–78.
- [26] MAGRAMA. *Main economic indicators for agricultural and food industry*. Ministry of Agriculture, Food and the Environment. Publication centre; 2013 http://www.mapama.gob.es/es/ministerio/servicios/analisis-y-prospectiva/Ayp_Indicadores_n12_JUL_2013_english_tcm7-291299.pdf. [accessed 12.07.16].
- [27] MAGRAMA. *Annual Report of the Spanish Food Industry period 2014–2015*. Ministry of Agriculture, Food and the Environment. Publication centre. http://www.mapama.gob.es/es/alimentacion/temas/industria-agroalimentaria/_informeanualindustriaalimentaria2014-2015_tcm7-421229.pdf (Accessed 08.08.16.)
- [28] MAGRAMA. *Estadísticas pesqueras 2014*. Ministerio de Agricultura, Alimentación y Medio Ambiente. Centro de Publicaciones; 2014 <http://publicacionesoficiales.boe.es/>. (Accessed 12 September 2016).
- [29] INE. *Statistics in biotechnology use*. http://www.ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736176808&menu=resultados&idp=1254735576669. (Accessed 8 September 2016).
- [30] BIOPLAT. *Implementation plan 2015 of Spanish bioenergy sector*, Spanish Biomass Technology Platform. http://www.bioplat.org/setup/upload/modules_en_docs/content_cont_URL_2854.pdf (Accessed 09.09.16.)
- [31] Aguilar A, Magnien E, Thomas D. *Thirty years of European biotechnology programmes: from biomolecular engineering to the bioeconomy*. *New Biotechnol* 2013;30:410–25.
- [32] de Besi M, McCormick K. *Towards a bioeconomy in Europe: national, regional and industrial strategies*. *Sustainability* 2015;7:10461–78.
- [33] European Commission. *Innovating for sustainable growth. COM (2012) 60 final*. Brussels: Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the Regions; 2012.
- [34] MAGRAMA. *Programa de Desarrollo Rural Nacional 2014–2020*. <http://www.mapama.gob.es/es/desarrollo-rural/temas/programas-ue/periodo-2014-2020/programas-de-desarrollo-rural/programa-nacional/>. (Accessed 8 July 2016).
- [35] Regulation (EU) No 1301/2013 of the European Parliament and of the Council of 17 December 2013 on the European Regional Development Fund and on specific provisions concerning the Investment for growth and jobs goal and repealing Regulation (EC) No 1080/2006.
- [36] PROBIOGAS. *Cuantificación de materias primas para producción de biogás. Desarrollo de sistemas sostenibles de producción y uso de biogás agroindustrial en España. Proyecto Singular y Estratégico*; 2010 <http://www.probiogas.es/>. (Accessed 8 September 2015).
- [37] European Commission. *Towards a circular economy: a zero waste programme for Europe; COM (2014) 398 final*. Communication from the commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the Regions; 2014.
- [38] Wield D. *Bioeconomy and the global economy: industrial policies and bio-innovation*. *Technol Anal Strat Manag* 2013;25(10):1209–21.
- [39] Wield D, Hanlin R, Mittra J, Smith J. *Twenty-first century bioeconomy: global challenges of biological knowledge for health and agriculture*. *Sci Public Policy* 2013;40(1):17–24.
- [40] Zilberman D, Kim E, Kirschner S, Kaplan S, Reeves J. *Technology and the future bioeconomy*. *Agric Econ* 2013;44(Suppl):95–102.
- [41] Rosegrant MW, Ringler C, Zhu T, Tokgoz S, Bhandary P. *Water and food in the bioeconomy ? challenges and opportunities for development*. International Association of Agricultural Economists (IAAE) triennial conference. .