STRATEGIC RESEARCH AND INNOVATION AGENDA

Biomass and Bioeconomy

Bioplat

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ACKNOWLEDGEMENTS

This Strategic Research and Innovation Agenda of the Spanish Biomass and Bioeconomy sector is the tenth edition that we have prepared and published in BIOPLAT. As with our previous reports, the effort, involvement, and desire of our members make BIOPLAT publications are a benchmark for all type of agents from public administrations to companies, universities, and both national and international research centres. It acts as a guideline for decision-making, a road map, and a tool for knowledge transfer.

This is the first time that a BIOPLAT strategic publication covers the entire Bioeconomy sector. Our previous publications mainly focused on bioenergy and biofuels (electricity and thermal generation, syngas, biogas, bioalcohols, biodiesel, biojetfuel, and other biofuels, such as biohydrogen, bio-oils, biopropane, etc.). However, this Strategic Research and Innovation Agenda of the Spanish Biomass and Bioeconomy sector covers both bioenergy and bioproducts (biomaterials such as biocomposites, biofibres, and bioplastics; chemical bioproducts such as biofertilisers, biocosmetics and biopharmaceuticals; food bio-additives and food bioproducts for animals, among others), integrating the biorefinery concept as a model.

BIOPLAT's Coordinating Group has provided an interdisciplinary view and has ensured a balance between every sub-sector, while the Working Group Coordinators led the preparation of the document. Our special thanks go to them all: INIA and URBASER (raw material coordinators), CIEMAT and ENSO Energy, Environment and Sustainability (Bioenergy coordinators), Fundación TECNALIA and the NATAC Group (Bioproduct coordinators), along with the Instituto Complutense de Estudios Internacionales (ICEI) and ACCIONA Energía (biomass and bioeconomy added value coordinators).

Additionally, our most heartfelt thanks to the Ministry of Science and Innovation and the State Research Agency, for supporting BIOPLAT's activities, along with IDAE, CDTI, and CIEMAT for supporting the development of the initiatives implemented in BIOPLAT.

We are convinced that the decade from 2020-2030 will prove key for the development and expansion of biomass valorisation, and therefore, the bioeconomy. The need to close productive cycles, to minimise waste and emissions, and to create sustainable production models, creating positive externalities and opportunities, both for society and the environment, will manage to push bioeconomy towards a very relevant position in every region in Spain. It won't be easy, effort and desire will be required on both sides, but it will definitely be hugely gratifying to be able to contribute to improving the world we live in from our sector.

Margarita de Gregorio.
BIOPLAT coordinator.

EXECUTIVE SUMMARY

The Strategic Research and Innovation Agenda of the Spanish Biomass and Bioeconomy sector was developed within the public-private collaboration space BIOPLAT provides, in which all the stakeholders involved in developing biomass and the bioeconomy in Spain work together in coordination. Since 2006, BIOPLAT has strived to achieve conditions that favour the development of biomass and the bioeconomy in every region of Spain. Understanding biomass and bioeconomy in its broadest sense, from organic material (waste, by-products, dedicated crops) that can be valorised, to transformation/ valorisation technologies and applications such as bioenergy (thermal energy and electricity generation, biofuels, biogas), and bioproducts. BIOPLAT tackles entire biomass value chains, placing value on the relevant positive externalities that they induce, as a contributing factor to achieving energy, sustainability, and environmental policy objectives. Therefore, a multi-perspective approach is adopted, integrating decarbonisation, industrialisation, fair and inclusive energy transition, sustainability, and regional structuring.

The Strategic Research and Innovation Agenda of the Spanish Biomass and Bioeconomy sector is divided into five major blocks. The first, as an introduction, analyses the value of biomass for the current society's major challenges regarding energy, the environment, and demographics. The next four blocks are presented below: Raw Materials, Bioenergy, Bioproducts, and Added Value, which will show what is required for development and the outlooks, with the lines of research and innovation described for each one.

Raw Materials

The extensive range of biomass that could be valorised are described (agricultural, forest, livestock, industrial, municipal, and aquatic). The sustainability and greenhouse gas emission reduction criteria in RED II for biofuels, bioliquids, and biomass fuels are described. The possibilities for using organic waste/by-products are analysed in accordance with the European Fertilising Products Regulation and bio-wastes and by-products are described. The following is defined as a priority area for research and innovation: **Optimising the identification, procurement, and mobilisation of biomass raw materials for different uses: bioenergy and bioproducts.** The following research, development and innovation challenges for that purpose are detailed:

- Identification, quantification, and geolocation of biomass.
- Biomass standardisation.
- Biomass mobilisation.
- Dedicated biomass crops.
- Biomass logistics.
- Biomass storage.
- The relationship between using forest biomass and fire prevention.
- Biomass value chain traceability.
- Activation of raw materials and bio-based monomers.

Bioenergy

The compulsory sustainability criteria for the biofuels used to fulfil the objectives set out in the European Renewable Energy Directive are defined. The available capacities for biomass to contribute to the challenges of empty Spain are analysed. The production of hydrogen from biomass and biofuels is approached. The following is defined as a priority area for research and innovation: **Extending and optimising the technical-economic and environmental response of the processes involved with bioenergy generation.** The following research and innovation challenges for that purpose are designed:

- To analyse the real possibilities of adapting old coal-fired power stations to biomass (even if the power output/capacity is lower).
- Hybridisations between biomass facilities and other renewable technologies.
- Optimising savings during the complete biomass cycle, particularly during the supply phase.
- Advanced pretreatments.
- Innovation in combustion processes to increase energy efficiency and control emissions.
- To foster lines of research that enable the integration of biomass as a fuel for industrial processes.
- To make use of the biodegradable fraction of municipal waste, sewage sludge, or liquid manure to produce biogas or biomethane.
- Research into streamlining the costs of upgrading biogas to obtain biomethane compatible with injection into the gas grid or for vehicle use.

- Analysis of biomass energy capacities in the electricity mix.
- Research and innovation into thermochemical, chemical, and biological technologies for producing advanced biofuels and bioliquids (thermal and electricity uses).
- The development of sustainable biofuel production technologies for aviation that represent progress with respect to the hydrogenation of vegetable oils, existing oils (forest/paper mills, textiles, agro-industrial, chemicals, mineral oil refineries, etc.) in biorefineries.
- The development of intermediate bioenergy vectors.
- The introduction of processes for integrating residual biomass flows (pyrolysis processes, hydrothermal liquefaction (HTL).
- Research and innovation into hydrogen production technologies from biomass.

Bioproducts

The value chains for bio-based industries are described and some key premises are established for the development of bioproducts. These are that the business model must ensure that the bioproducts are produced sustainably, both for the environment (ensuring its source, life cycle, etc.) and for the economy (enabling all value chain stakeholders to make a profit); using biomass sourced from waste or by-products from industrial products is essential when streamlining the cost of the raw materials, making the biorefinery and circular economy concepts converge. Drop-in bioproducts and dedicated bio-based chemicals are described. Additionally, the integrated production of bioproducts in the olive oil industry is analysed. The following is defined as a priority area for research and innovation: **Optimising the identification, procurement, and mobilisation of biomass raw materials for different uses: bioenergy and bioproducts.** Table 1 below lists the bioproducts that should be investigated and innovated in Spain to achieve production to a sufficient scale to enable their commercialisation.

BIOPRODUCTS	MARKET	Examples
Food additives (antioxidants, preservatives, etc.)	Human food, animal nutrition, cosmetics	Rosemary extract, grape seed extract, olive extract
Zootechnic additives	Animal nutrition	Plant extracts, essential oils, prebiotics
Food ingredients with healthy properties	Human food and the nutritional supplement sector	Standardised plant extracts, prebiotics
Pharmaceutical active ingredients	The pharmaceutical industry	Plant extracts and purified compounds, with European Pharmacopoeia quality
Cosmetic active ingredients	The cosmetics industry	Purified extracts and compounds
Biofertilisers, biostimulators	Agrochemical	
Natural bioproducts	Paper	Cellulose, hemicellulose, starch, sugars, chitin, plant fats and oils, lignin, natural rubber, terpenes
Biochar and activated carbon	Catalysis, absorption (chemical industry) Environment	Depolluting Catalysts
Biotechnology sourced bioplastics	Food	PHAs
Monomers	The chemical industry, paints,	Mono ethylene glycol, lactic acid, succinic acid, 1,4BDO (1,4 butanediol), 2,3BDO (2,3 butanediol), 1,3Propanediol, IBMC (isosorbide bis-methyl carbonate)), levulinic acid, 1,3 propanediol, xylitol
Polymers	The chemical industry, paints, adhesives, coverings,	Polyesters, polyolefins, polyurethanes, polyamides, epoxides
Solvents	The chemical industry	Ethanol, MEK (methyl ethyl ketone, lactate esters)

Table 1: Reference bioproducts for research and innovation in Spain.

Added Value

The biomass sector in Spain is generating significant economic, social, and environmental value in the regions. Biomass energy valorisation is a source of economic activity with a significant industrial component and a notable capacity for job creation, particularly in rural areas, where most biomass resources are found. This capacity for creating jobs represents a vector for a population settling in the region, enabling it to maintain its socio-economic activation and structure, while actively boosting the bioeconomy. Added value is created along the value chain from mobilising raw materials through to processes to generate bioenergy and bioproducts.

The added value generated by biomass valorisation with the framework of the circular economy is cross-sectional concerning the raw materials and bioenergy, biofuel, and bioproduct generation. This is why the focus isn't only placed on one main research and innovation area, rather than a series of domains are prioritised, which require action through auxiliary studies and sustainability, technical-economic, regulatory, and market penetration analyses, research and demonstration projects, educational and communication strategies, among others. These will contribute to increasing knowledge about sustainability and excellence during bioenergy and bioproduct production.

- A demonstration of the benefits and good practices of the biomass sector, to show them and raise awareness about the contribution of bioeconomy to the objectives of other strategic policies for Spain and its regions.
- The identification of the barriers to the development of the bioeconomy and its sub-sectors (bioenergy, biofuels, bioproducts).
- A life cycle analysis (LCA) of the bioeconomy value chains.
- An analysis of the social impact of the bioeconomy.
- A study of the role of biomass in the energy mix as a necessary technology to achieve the 2 °C (or 1.5 °C) scenario.
- The cascading use of biomass.
- To advance the fight against forest fires.
- To analyse potentially establishing forests on agricultural lands.
- The development of ecosystem services relating to forest biomass.
- To analyse the competition for land use.
- To promote formal education on the circular bioeconomy during primary and secondary education, as well as in universities and vocational training centres.
- To design communication strategies targeting society as a whole.

This Strategic Research and Innovation Agenda of the Spanish Biomass and Bioeconomy sector aspires to serve as a tool to facilitate the coordination of policies, strategies and funding for Research and Development and Innovation, to promote the development of projects based on biomass that can break through existing barriers and position Spanish companies and research centres at the forefront of the transition towards the bioeconomy, and the sustainable use of biomass in Europe. Making the most of the substantial added value that this sector can generate.

THE VALUE OF BIOMASS FOR THE MAIN CHALLENGES OF TODAY'S SOCIETY

Biomass[1] is a renewable source raw material used for different purposes, such as energy and fuel production, and to obtain biological-based products (bioproducts). It has the valuable capability of helping to increase renewable energy production and reduce the emission of CO_2 and greenhouse gases (GG) by replacing fossil fuels and fossil-derived components in materials. Biomass doesn't just provide energy, it can also be used in fertilisers and soil improvers, for manufacturing biomaterials, and in the food, chemical, biotechnology, and pharmaceutical industries[2]. In biological-based economy, these different uses complement each other and, when managed sustainably, contribute to promoting the circular bioeconomy. Consequently, the sustainable use and management of biomass play a key role when it comes to tackling the challenges faced by today's society.

1. GLOBAL CHALLENGES

In 2015, world leaders adopted the so-called Sustainable Development Goals[3] as part of the 2030 Agenda. This is a set of 17 global goals that aim to eradicate poverty, protect the planet, and guarantee everyone can prosper; as part of a new sustainable development agenda. Each goal has some specific targets that need to be met by 2030. Figure 1 shows the Sustainable Development Goals to which the biomass sector can actively contribute.

Besides, the pathway towards fulfilling the renewable energy goals for 2030 includes the use of biomass. As well as being a sustainable resource present in different forms in every region, it is a manageable and affordable resource, capable of reactivating local economies by actively inducing job creation, particularly in rural areas. Biomass can also represent a sustainable alternative to a range of fossil-derived materials.

Figure 1. Sustainable Development Goals to which the biomass sector actively contributes[3].

In 2016, the so-called Innovation Challenges (ICs) were agreed upon by the Mission Innovation group at the Conference of the Parties of the UN Framework Convention on Climate Change, held in Morocco (COP 22). This global initiative, fostered by 24 countries and the European Commission (EC), works to accelerate innovation in clean energy, based on public-private collaboration to tackle climate change, ensure clean energy is affordable for consumers, and create both green jobs and commercial opportunities[4].

The ICs[5] cover the entire spectrum of Research and Development and Innovation, from the evaluation of research needs in the early phases through to technological demonstration projects. These challenges are worldwide calls to action aimed at accelerating research, development, and demonstration in technological domains that could bring significant benefits for reducing GHG emissions, increasing energy security, and creating new opportunities for non-polluting economic growth. Each IC involves a worldwide network of people responsible for policies, science, and innovation work together towards an innovation goal.

[1] Biomass and Geothermal – Energy guide (IDAE, 2019)
[2] 2050 vision for 100% renewable heating and cooling in Europe (RHC Platform, 2019)
[3] Sustainable Development Goals (UN, 2019)
[4] Mission Innovation Overview (Mission Innovation, 2015)
[5] Innovation Challenges (Mission Innovation, 2016)

Of the 8 ICs defined by *Mission Innovation*, biomass research and innovation can contribute to at least 6 of them (Figure 2):

- **IC1:** Smart grids.
- **IC2:** Off-grid access to electricity.
- **IC3:** Carbon capture.
- **IC4:** Sustainable biofuels.
- **IC5:** Converting sunlight.
- **IC6:** Clean energy materials.
- **IC7:** Affordable heating and cooling of buildings.
- **IC8:** Renewable and clean hydrogen.

IC2:
Off-grid access to electricity
To develop systems that enable off-grid households and communities to access affordable and reliable renewable electricity.

IC3:
Carbon capture
To enable near-zero CO_2 emissions from power plants and carbon intensive industries.

IC4:
Sustainable biofuels
To develop ways to produce, at scale, widely affordable, advanced biofuels for transportation and industrial applications.

IC6:
Clean energy materials
To accelerate the exploration, discovery and use of new high-performance, low-cost clean energy materials.

IC7:
Affordable heating and cooling of buildings
To make low-carbon heating and cooling affordable for everyone.

IC8:
Renewable and clean hydrogen
To accelerate the development of a global hydrogen market by identifying and overcoming key technology barriers to the production, distribution, storage, and use of hydrogen at gigawatt scale.

Figure 2. The Innovation Challenges (IC) to which the biomass sector actively contributes (Source: Mission Innovation) [5].

MISSION INNOVATION

2. EUROPEAN AND NATIONAL CHALLENGES

The European Green Deal (Figure 3), the new European programme in favour of sustainable growth, will set out the EU's action plan[6] (Figure 3). In 2020, the Commission began to present a range of proposals in different areas, such as the Just Transition Mechanism, the Climate Law, the Industrial Strategy, the Circular Economy Action Plan, or the Biodiversity Strategy for 2030.

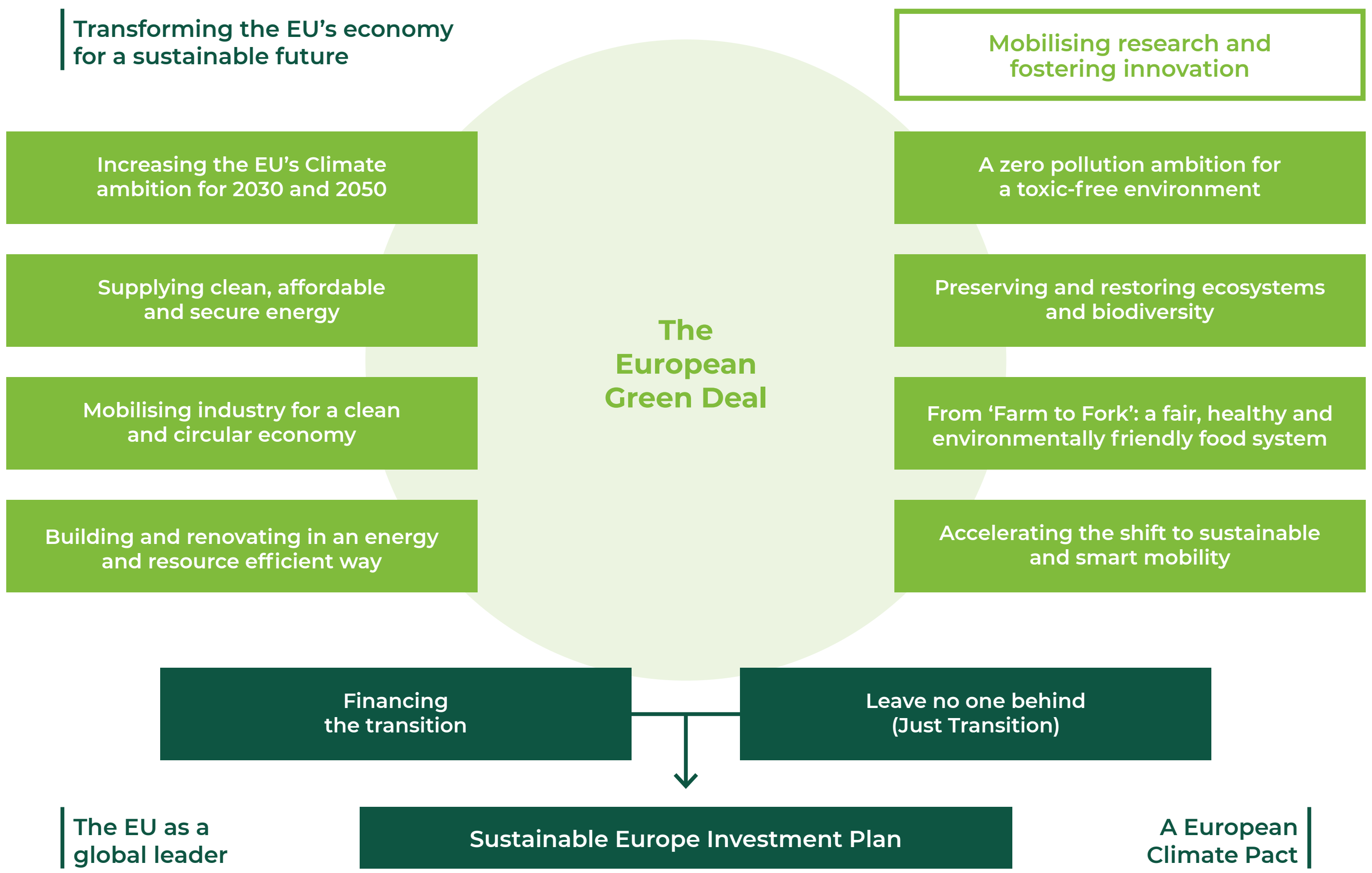


Figure 3. The European Green Deal plan[7].

Within the framework of the European Green Deal, the Commission proposes raising the objective of reducing emissions to at least 50% for 2030 and will evaluate the final versions of the Integrated National Energy and Climate Plans (NECPs) for each Member State, which will be in force from 2021, to ensure at least a 32% share of renewable energies and at least a 32.5% improvement in energy efficiency by 2030.

There will also be the presentation of 'farm to fork' strategies, offshore energy production, forests, and chemical products, along with the initiative to renovate buildings, a review of the non-financial reporting directive, and the proposal of the environmental action programme[7].

In the national domain, the government presented the Strategic Framework for Energy and Climate in 2019. This focuses on helping to modernise the economy towards a sustainable and competitive model that helps to slow down climate change[8]. This strategic framework comprises:

- A draft of the Climate Change Law.
- The Integrated National Energy and Climate Plan (Spanish NECP).
- Fair Transition Strategy.

These are three elements designed to provide Spain with a robust and stable framework for decarbonising its economy. The draft law aims to offer an efficient road map for the coming decades. The Integrated National Energy and Climate Plan 2021-2030, which will lead on from the Renewable Energies Plan 2011-2020, was designed in the context of the neutral emissions target in 2050. The fair transition and support strategy aims to ensure that people and regions make the most of the current energy transition opportunities, particularly in regions when conventional power stations are being decommissioned.

2.1. Biomass' contribution to the energy challenge

A major advantage of biomass is that it is a renewable resource, which can be used to generate electricity or thermal energy from native resources. Furthermore, the very nature of the resources means that they can be stored and moved for use whenever necessary, making biomass a 100% manageable energy source. In other words, there is no need to wait for the source to appear (as is the case with sun and wind). This manageability turns out to be particularly valuable for the Spanish electricity system, in which subsequent years are expected to see a massive influx of non-manageable (or intermittent) renewable energies.

Similarly, another of the main benefits of using biomass is that it enables the valorisation of wastes and by-products. These can be potentially hazardous in some cases (because they generate emissions, can leach and pollute aquifers, and can cause fires), so environmental problems are also being solved while generating renewable energy.

The third main benefit of biomass derives from the marked industrial nature of the sector, as it depends on a constant supply of raw materials (biomass resources). Biomass collection, management, and transportation to the valorisation facility generate and sustains a high number of jobs, as it requires a large workforce. A workforce that is mainly linked to the primary and secondary sectors, and in the rural domain in particular, where the need is great. This contributes to generating opportunities for empty Spain and providing a structure for the region, opportunities linked to a renewable and sustainable business model.

Additionally, biomass represents a renewable energy option for domains where other alternatives to the traditionally used fossil fuels don't exist (like transportation), representing the only pathway towards their decarbonisation. The aviation sector is a clear example, where different types of biojet (biokerosene) emerge as a preferred solution for reducing greenhouse gas emissions from fleets of aircraft.

• Biomass and Fair Transition

Coincidentally in Spain, many coal-fired and nuclear power stations are going to be decommissioned, but they are located in regions with a significant biomass resource of all types, which is also largely under used. Some locations have agricultural biomass, whereas others have more forest, livestock, industrial resources etc.

[6] A European Green Deal (EC, 2020)
[7] The challenges for Europe 2020 (El País, 2020)
[8] Fair Transition within the Strategic Framework for Energy and Climate (MITECO, 2019)

These biomass resources could be extracted, managed, and distributed to energy valorisation facilities or even biorefineries. Some of these facilities could even be developed on existing old facilities (not in terms of replacing one with another, but making use of existing energy infrastructures). Workers at coal-fired and nuclear power stations could be trained on the generating energy from biomass, in terms of the types of biofuels, transportation and logistics, pre-treatments, etc., as well as on the installation and operation of electricity and thermal generators (domestic, community, heat grids, and also boilers for industrial use, cogeneration etc.), biogas, and even biorefineries, meaning the biomass sector could absorb as many jobs as possible that are at risk of being lost due to the closure of coal-fired and nuclear power stations.

2.2. Biomass' contribution to the environmental challenge

2.2.1. The Circular Bioeconomy

In March 2020, the European Commission adopted a new Circular Economy Action Plan as one of the main elements of the European Green Deal, which includes measures throughout the life cycle of products. The new Action Plan aims to adapt the economy to an environmental future and to strengthen competitiveness while protecting the environment and conferring new rights to consumers. Based on the work undertaken since 2015, the new Plan focuses on design and production with a view to a circular economy, intending to ensure the resources used remain within the EU economy for as long as possible. The transition towards a circular economy is already under way, as there are companies, public bodies, and pioneering consumers in Europe that are welcoming this sustainable model.

The circular economy within the biomass domain is called the Circular Bioeconomy, which forms part of the circular economy that covers the domain of resources, by-products, and wastes with an organic component, meaning that **the bioeconomy is considered the renewable segment of the circular economy**. There is a European Bioeconomy Strategy,[9] published in October 2018, which focuses on 'closing the circle' in biological-based (or organic-based, but not fossil-derived) sectors (Figure 4), promoting public and private research and company investment into innovation in the bioeconomy sector, strengthening the social, political, and administrative environment for the bioeconomy, fostering competitiveness and the development of the bioeconomy-related market, and the development of demand for new products and to implement a plan to expand and promote the bioeconomy.

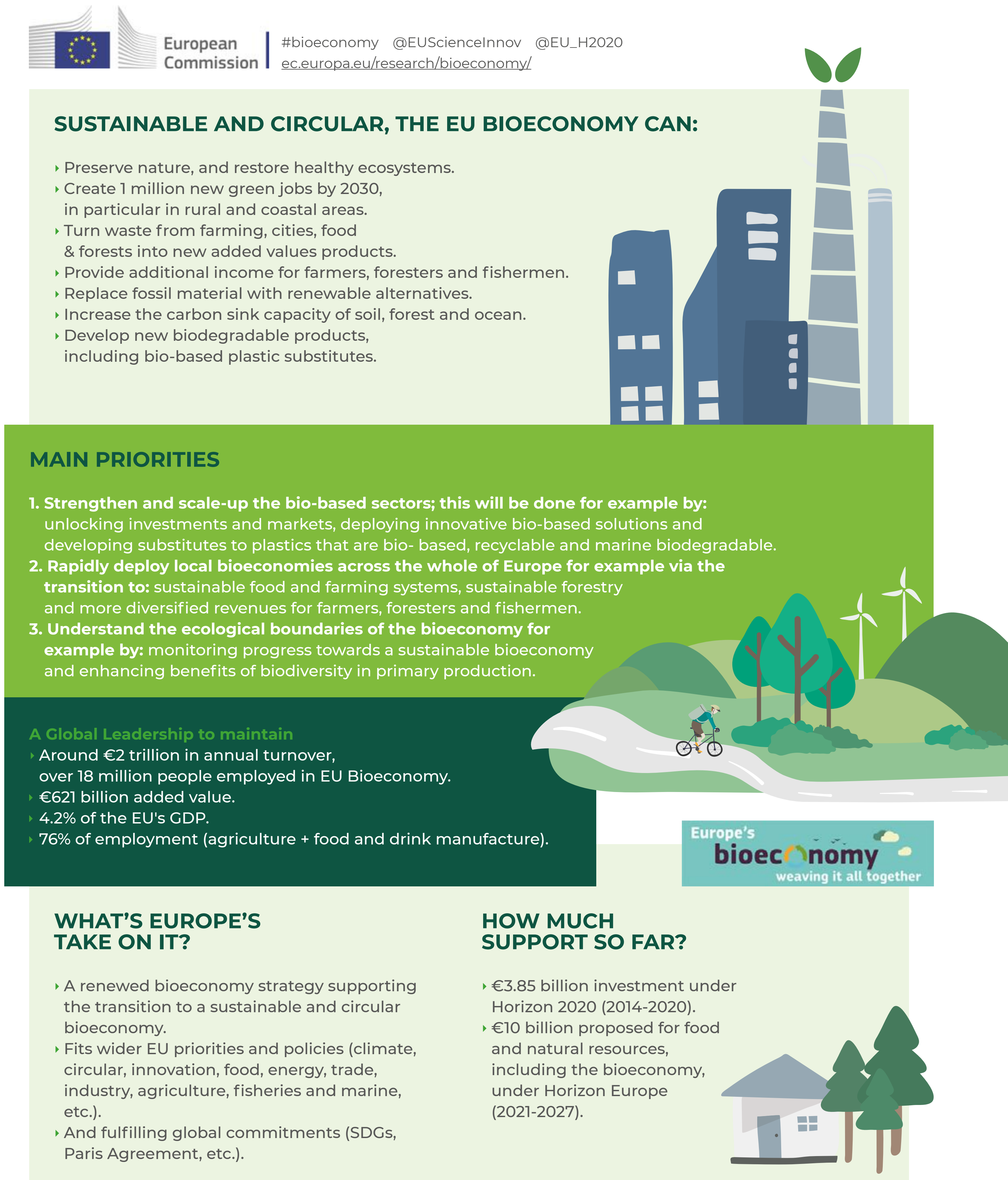


Figure 4. EC infographic on the European Bioeconomy Strategy (Source: EC)[10].

[9] A new bioeconomy strategy for a sustainable Europe (EC, 2018)

The wastes and by-products used in these sectors come from growing, manufacturing and processing food, from the forest, from livestock and fisheries, among others. These are potential raw materials for other processes to obtain bioproducts (biomaterials, food ingredients, cosmetics, etc.) and bioenergy (electricity, heat, biofuels). Their valorisation makes the most of using local resources to generate value, induces industrialisation, increases the number of jobs associated with a sustainable and difficult to relocate industrial model, providing a structure for regions for people to settle down. The decade from 2020-2030 will be key when it comes to implementing the bioeconomy in the EU and Spain. These primary and secondary sectors are expected to converge with the generation of bioenergy and bioproducts, which will end up being their intrinsic processes (Figure 5).

Global challenges, such as climate change and land and ecosystem degradation, coupled with growing demands for food and energy, force us to find new ways of producing and consuming.

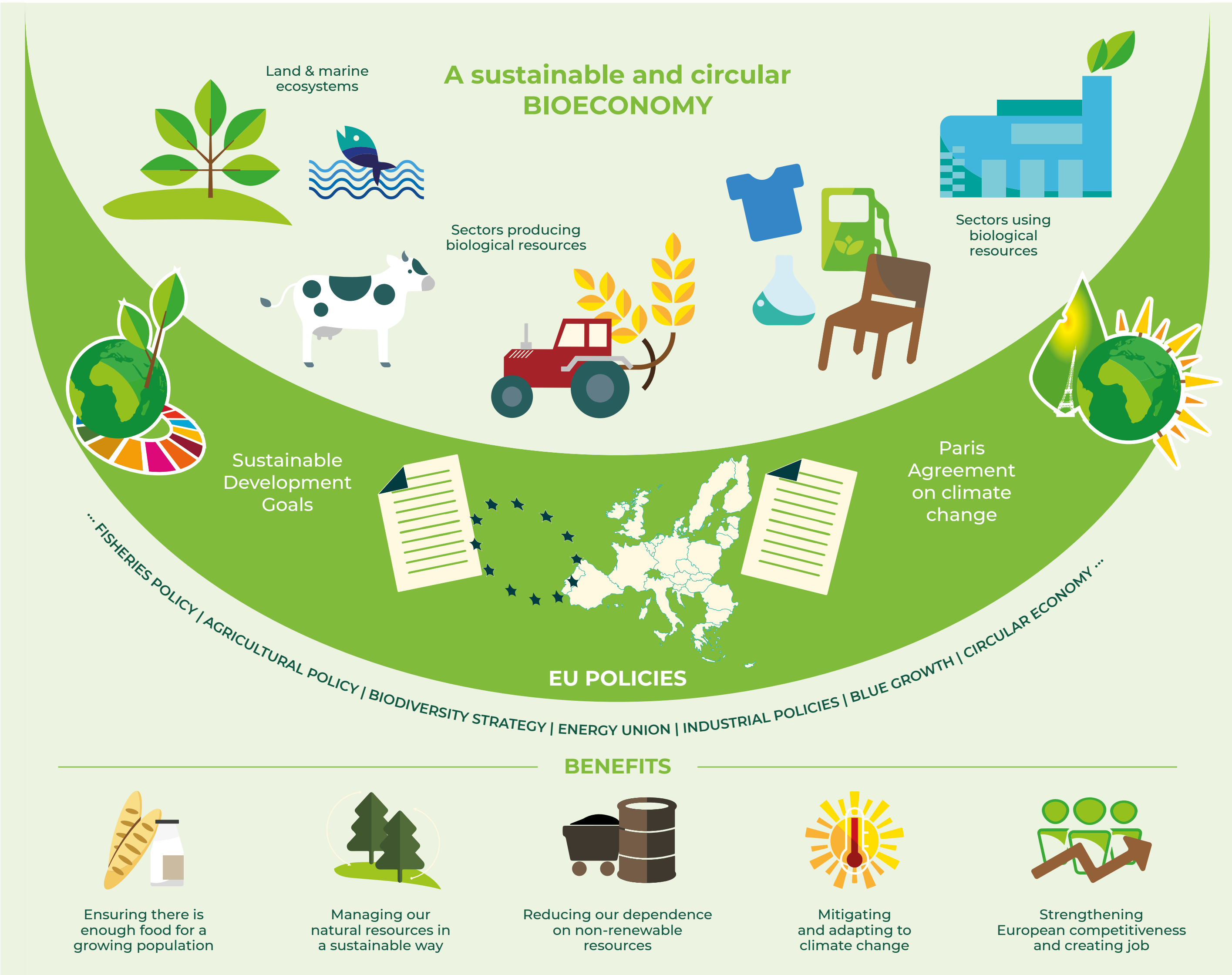


Figure 5. EC infographic on the bioeconomy sectors, policies, and benefits (Source: EC)[10].

2.2.2. Emissions

The Spanish biomass sector is aware of the huge importance of ensuring sustainability in every process to consolidate its future development. Despite biomass valorisation assumed to be CO_2 emission neutral by the international community (the carbon that accumulates throughout the life of the biomass resource is the carbon that is released when the valorisation process is undertaken), this is why valorisation process emissions should be minimised to be as sustainable and efficient as possible during both bioproduct and bioenergy/biofuel production compared to the fossil alternatives they are replacing.

When it comes to electricity generation facilities using biomass, they use well-developed gas extraction technologies, which are widely used in other industrial facilities. Additionally, it is increasingly more common to find public body emissions monitoring systems on plants, ensuring transparency and the ability to react.

When it comes to generating thermal energy from biomass, January 2020 saw the entry into force of European Regulation 2015/1189 about ecodesign requirements for solid fuel boilers[11], with a rated heat output ≤ 500 kW, with specifications on energy efficiency and the emission limits for the equipment. The European Commission will review this Regulation before January 1st, 2022, to include solid fuel boilers with a heat output < 1 MW. Meanwhile, medium combustion facilities, with a rated heat output ≥ 1 < 50 MW, are governed by Royal Decree 1042/2017, derived from the transposition of European Directive 2015/2193 on the limitation of emissions of certain pollutants into the air from medium combustion plants. This means that all types of biomass burners, from small (individual/domestic) to large (buildings/industries) have strict emission limits that they must fulfil to enable commercial use.

Air quality in urban areas is currently a critical point on the urban agenda, and different restrictive measures on public movement are being established. However, heating systems are also relevant as they are another point source of emissions. Biomass boilers are a suitable alternative for replacing the community coal or diesel boilers that remain in use in many cities. Therefore, heat grids fed by biomass that supply heat to several buildings are presented as a positive alternative given there is only one emission source, which would be easy to monitor in terms of its emissions, even limiting them as the regulations become increasingly more restrictive.

[10] A sustainable and Circular Economy (EC Knowledge Centre for Bioeconomy, 2018)
[11] European regulation of ecodesign (EU) 2015/1189 (EC, 2015)

On the other hand, the biodigestion of livestock and municipal wastes (which are point sources of diffuse GHG generation) is proposed as an alternative to the great tanks of animal defecation or the tipping of organic matter (biodegradable) into landfill. The biodigestion of this biomass can generate biogas that can be used directly to produce electricity and/or thermal energy or be transformed into biomethane for injection into the gas grid, or act as a basis for producing bioproducts. When it comes to biomethane, there is significant potential from biomass resources (municipal wastes, agro-industrial wastes, and sewage sludge) that can generate biogas, which once treated and concentrated using an upgrading process[12], can be exchanged with natural gas, representing direct decarbonisation, making use of existing gas infrastructures, or its use as a fuel for transport.

It should be considered that the major source of GHG emissions is the dumping of biodegradable waste because it naturally converts into methane, which is largely emitted straight into the atmosphere. This means prioritising the energy valorisation of the rejection compared to landfill is necessary, always keeping in mind the hierarchy of wastes (i.e. the valorisation of what's left after prevention, reuse, and recycling, instead of dumping it into landfill). The biodegradable fraction of municipal wastes is biomass and currently represents around 50% of the waste generated in urban areas. Only a very small proportion of this waste is being collected separately. This situation will continue over the medium-term until selective collection systems are widely implemented and the public actively participates in the separation.

2.3. Biomass' contribution to the demographic challenge

The National Strategy for the Demographic Challenge presents environmental transition as a vehicle that offers valuable opportunities for the rural world and the so-called 'empty Spain'. These opportunities convert into specific measures in the Integrated National Plan for Energy and Climate, in the Fair Transition Strategy, and the Draft of the Climate Change and Energy Transition Law, which aim to make creating green jobs easier in the rural domain through promoting renewable energies, the bioeconomy, improved management of Red Natura 200, sustainable tourism, and forest management[13].

Throughout 2019, marches were held in different places around the country to denounce what is considered institutional and political neglect in a Spain that progresses at two speeds: urban Spain, developed and powerful, compared to rural and provincial Spain, deprived of opportunities, and therefore, limited population and resources. The logistics surrounding providing biomass facilities is one of the main assets of the biomass sector in Spain. Biomass is an intensive energy when it comes to generating and maintaining jobs[14] (including the construction, operation, and maintenance of facilities). Not just in the facility itself, but also away from it, as most of those jobs are linked to supplying biomass fuels to the facilities. This capacity for generating and maintaining jobs is invaluable in regions considered part of empty Spain, given that the investment in a biomass plant socio-economically energises the region, providing structure, and creating stable and long-term opportunities for the population. Opportunities that are also linked to energy transition and the circular bioeconomy, both strategic policies for Spain and Europe.

[12] The upgrading process manages to increase the average methane concentration of 50%-70% in biogas to over 95% methane, then being given the name, biomethane. Impurities present in the biogas (CO_2, H_2, micro-organisms, etc.) are removed at the same time, obtaining a biomethane with similar physiochemical and quality characteristics to natural gas, while being 100% renewable.
[13] General Directives of the National Strategy for the Demographic Challenge (MPTFP, 2017)
[14] Renewable Energy and Jobs – Annual Review 2019 (IRENA, 2019)

RAW MATERIALS

Biomass is defined as the biodegradable fraction of products, waste and residues from biological origin from agriculture, including vegetal and animal substances, from the forest and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin[15].

Biomass has traditionally been understood to be part of the energy domain (as bioenergy and/or biofuel). However, biomass covers a much wider spectrum, from production and mobilisation of biological resources (organic) through to their conversion, not only into energy, but into products with added value, such as food ingredients, animal foods, and biological-based products (bioproducts)[16].

Biomass raw materials can be classified by their origin[17]:

- **AGRICULTURAL biomass**

- **Dedicated crops.** Herbaceous or woody species are produced during crop growing activities on agricultural land, harvesting, and where necessary when processing collected raw materials[18]. This group also includes algae cultivation as it is produced in water.

- **Residual biomass** originating during the cultivation and initial transformation of agricultural products.

- **FOREST biomass**

- **Dedicated crops.** Biomass-derived from the main exploitation of forests through growing activities on agricultural and/or forested lands, with a subsequent harvest, and where necessary, the processing of the collected raw materials.

- **Exploitations.** Biomass originated as a product of forestry operations in forests. Non-wood forest products are also included, such as aromatic and medicinal plants, deriving from the collection in their natural habits.

- **Residual biomass** is generated during the clearance and maintenance of forests and green spaces.

- **LIVESTOCK biomass**

- **Organic wastes** generated on livestock exploitations. This is mainly a mix of livestock defecations and bedding, which is named depending on the source species: dung, liquid manure, and poultry litter.

- **INDUSTRIAL biomass**

- **By-products and wastes from industrial facilities in the agro-food sector,** such as from olive oil production, citric processing, seed oil extraction, the winemaking and alcohol industry, canning, beer making, animals, nut production, rice production, and algae processing.

- **By-products and wastes from industrial facilities in the forest sector,** such as first and second transformation forest industries (bark, sawmills, carpentry, etc.), by-products from the cellulose industry (black liquors), from recovering lignocellulose materials[19] (pallets, construction materials, used furniture, etc.).

- **DOMESTIC biomass (from urban wastes) and bio-waste**

- **The biodegradable fraction of domestic and services waste** that districts generate every day. Also sewage sludge, wastewater, and hospitality industry wastes (frying oils, etc.). As well as plant wastes from parks and gardens.

- **AQUATIC biomass (blue biomass)**

- **Renewable biological** resources from bodies of water, such as fish, algae, and other macro and micro-organisms[20].

Additionally, depending on their location, biomass raw materials can be classified into three main blocks:

- Localised biomass (accessible).
- Non-localised available biomass (inaccessible).
- Cultivated biomass[21].

Spain is a European powerhouse for all types of biomass resources. It is the third European country in terms of absolute forest biomass (only behind Sweden and Finland) and the seventh per capita[22]. Between 2004 and 2018, the forested surface area of Spain grew by 1.2%, showing constant growth (very much above the average for the EU: 0.51%). 55.2% of the total national surface area (27.9 million hectares) is vegetated, with over 66% forests[23]. Furthermore, Spain is notable for the number of biomass resources that can be used. It is the world-leading country for olive oil production (1,789,900 t during the 2018-2019 campaign)[24], with the generation of by-products like olive oil pulp of 1,200,000 to 1,450,000 t/year (2018/2019 campaign)[25], and it is one of the EU's main exporters of fruit and vegetables (13.5 million tonnes exported in 2019)[26], which creates a lot of waste. Besides, it has become number one for pork stock production in Europe, with over 28 million heads and almost 90,000 farms, generating over 50 million t/year of liquid manure. However, it sits in the sixteenth position for biomass consumption per capita[22].

The sector's priority involves enacting the use of all types of biomass to generate energy and bioproducts sustainably, fostering the potential demand for existing raw materials over the medium-term. Knowing which raw materials that industry will request and to what extent will be key in this regard, evaluating the technical, economic, and environmental viability of their mobilisation, as well as characterising them based on their use. In other words, to analyse the response that can be provided to the current demand for raw materials and also potential/future demands, both in the bioenergy and bioproduct domains.

Establishing a constant supply of biomass to the facility where it will be processed and valorised is essential. The seasonality of biomass raw materials, such as wastes from agricultural harvests, can determine supply. This means it is necessary to complement biomass with dedicated crops as a complementary raw material input to what is generated in fields, from vegetation and industries. This would help to ensure a supply to the facility, minimising the seasonality associated with certain types of biomass, as well as providing biomass of specific characteristics. These crops can be based on known species and/or varieties, preferably of lignocellulosic origin (herbaceous or woody), as well as new developments based on biotechnology that look to achieve the highly adaptable and efficient use of resources. All the same, crops for food use are to be avoided, as well as those considered invasive species and those requiring high levels of resources. When it comes to using water for irrigation, it would be good to consider using reused water for crops that tolerate it.

[15] European Directive on the promotion of the use of energy from renewable sources (EU) 2018/2001 (EC, 2018)
[16] European Bioeconomy Strategy (EC, 2018)
[17] Manual on Biorefineries in Spain (BIOPLAT and SusChem, 2017)
[18] According to the European Renewable Energies directive (EU) 2018/2001, intermediate crops, which are rapidly growing plants that can be interspersed between rows of the main crop, such as catch crops and cover crops, are considered a sustainable raw material as long as their use does not trigger demand for additional land use.
[19] Ligno-cellulose is the main component of plant cell walls and it is one of the most abundant biopolymers found in nature.
[20] The EU Blue Bioeconomy Report 2019 (EC, 2019)
[21] The Spanish group of experts working in the biomass area, represented by BIOPLAT, recommends that the dedicated crops (cultivated biomass) developed in Spain should not be food crops, or invasive species, and require limited water needs.
[22] Socio-economic balance of biomass in Spain 2017-2021 (Union for Biomass/AFI, 2018)
[23] Environmental profile of Spain 2018 (MITECO, 2018)
[24] Olive oil market newsletter – 2018/2019 campaign (AICA/MAPA, 2019)
[25] Biomass in Andalusia (AAE, 2017))
[26] Spanish exports/imports of fruits and vegetables (FEPEX, 2020)

INFOBOX 1.

The sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids, and biomass fuels in RED II

The European Commission, in Directive 2018/2001 of the European Parliament and the Council, on the promotion of the use of energy from renewable sources[16] (RED II), defines a set of sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids, and biomass fuels. Additionally, when calculating the energy share from renewable sources, it establishes that biofuels, bioliquids, and biomass fuels are not to be considered when they do not fulfil their sustainability and greenhouse gas emissions saving criteria.

Bioliquids used during transportation must comply to be counted in the general objective of 14% of renewable energy consumed by road and rail transport for 2030, and to be eligible to receive support through public funding. Some of these criteria are unchanged from the original RED, while others are new or reformulated. In particular, RED II introduces the sustainability of forest raw materials, as well as the GHG criteria for solid and gaseous biomass fuels.

The default GHG emission values and the rules for calculation are provided in Annex V (for liquid biofuels) and Annex VI (for solid and gaseous biomass for energy and heat production) for RED II. The Commission can review and update the default GHG emissions values when necessitated by technological advances. Financial operators have the option of using the predetermined GHG intensity values provided in RED II or calculating the real values for their route.

Greenhouse gas-saving thresholds in RED II

Plant operation start date	Biofuels for transport	Renewable fuels of non-biological origin for transport	Electricity, heating, and cooling
Before October 2015	50%	-	-
After October 2015	60%	-	-
Before January 2021	65%	70%	70%
Before January 2026	65%	70%	80%

RED II introduces a new approach to prevent biofuel production extending from agricultural lands to non-agricultural lands (including areas with a high-carbon stock, such as forests, wetlands, and peatland), a process known as an indirect land use change (ILUC), which can lead to the release of the CO_2 stored in trees and in the soil, running the risk of cancelling out the greenhouse gas-savings derived from increased use of biofuels. Limits are established for biofuels, bioliquids, and biomass fuels with a high ILUC risk through significant expansion into lands with a high-carbon stock. These thresholds will affect the amount of those fuels that Member States can count towards their national objectives when calculating the national overall renewable energy share and the renewable energy share in transport. Member States will still be able to use (and import) fuels covered by those thresholds, but they won't be able to include those volumes when calculating the extent to which they have fulfilled their renewable objectives. These thresholds represent a freezing of the 2019 levels for the 2021-2023 period, which will gradually decrease from the end of 2023 to zero in 2030. RED II also introduces an exemption for those thresholds for biofuels, and bioliquids, and biomass fuels certified as low ILUC risk.

Within the transport sub-objective of 14%, there is a specific objective for advanced biofuels produced from the raw materials listed in part A of Annex IX. The contribution of advanced biofuels and biogas produced from the raw materials listed in part A of Annex IX as a percentage of the final consumption of energy for the transport sector will be at least 0.2% in 2022, at least 1% in 2025, and at least 3.5% in 2030. However, Member States will be able to demand fuel suppliers supply fuel in the form of electricity or non-biological origin renewable liquid and gas transport fuels for the requisite to fulfil the minimum share of advanced biofuels and biogas produced from the materials listed in part A of Annex IX regarding those fuels. Meanwhile, the raw materials for producing biogas for transport and advanced biofuels, whose contribution to the minimum share is referred to in article 25, section 1, first and fourth paragraphs, can be considered the double of its energy content. When calculating the numerator, the proportion of biofuels and biogas produced from the raw materials listed in part B of Annex IX will be limited to 1.7% of the energy content of the transport fuels supplied for consumption or use in the market. When justified, Member States will be able to modify that limit, considering the raw material's availability.

The share of biofuels and bioliquids, as well as biomass fuels consumed in transport, when produced from food and feed crops, will not be more than one percentage point over the share of the aforementioned fuels in the final energy consumption on the road and rail transport sectors during 2020 in that Member State, with no more than 7% of the final energy consumption of the road and rail transport sectors in that Member State.

Fuels produced from raw materials with a "high risk of indirect land use change" will be limited by a more restrictive threshold on the level of consumption for 2019. The share of these produced from food and feed crops for which a significant expansion of the production area into land with high-carbon stock is observed shall not exceed the level of consumption of such fuels in that Member State in 2019, unless they are certified to be low indirect land-use change-risk biofuels, bioliquids or biomass fuels pursuant to this paragraph. From December 31st 2023 to December 31st 2030 at the latest, that limit is to gradually decrease to 0%.

Fuels used in the aviation and maritime sectors can opt to contribute to the 14% transport objective, but they are under any obligation. The share of non-food fuels supplied to those sectors shall be considered to be 1.2 times their energy content.

INFOBOX 2.

European Regulation of fertilising products: possibilities for using organic wastes/by-products

The European Council adopted a regulation in 2019 that harmonises the requisites for fertilisers produced from phosphate minerals and organic or secondary raw materials, opening up new large-scale production and commercialisation possibilities[27].

The new regulation, replacing the Regulation from 2003 regarding fertilisers, includes all types of fertilisers (mineral, organic, soil improvers, culture mediums, etc.) and is expected to enter into force in July 2022. From then, the first products with the new CE marking will become available in the market and will have to comply with certain conditions (maximum pollutant levels, defined material component categories, and labelling requisites) to enjoy freedom of movement inside the EU internal market. Manufacturers of fertilisers that don't carry the CE marking will still have the option of selling their products nationally.

As well as enabling the free movement of fertilisers throughout Europe, the new European Regulation of fertilising products will boost the circular economy and sustainable agriculture, promoting greater use of recycled materials and reduced waste and the dependence on imported nutrients. A classification based on seven new Product Functional Categories (PFC) has been established for the first time:

- **PFC 1 – Fertilisers.**
- **PFC 2 – Liming material.**
- **PFC 3 – Soil improver.**
- **PFC 4 – Growing medium.**
- **PFC 5 – Inhibitors.**
- **PFC 6 – Plant biostimulants.**
- **PFC 7 – Fertilising product blend.**

This Regulation opens the door to using ash and cinders from biomass plants when manufacturing fertilisers (improvers), as they come from easily traceable agricultural and forest biomass, as such promoting greater efficiency of resources, a reduction in growing system costs, and the circular bioeconomy.

INFOBOX 3.

Bio-wastes and by-products

The European Directive 2018/851/EC[28] regarding wastes and European Directive 2018/851, amending Directive 2008/98/EC[29] regarding wastes, establishes the following definitions:

- **By-product** – a substance or object, resulting from a production process, the primary aim of which is not the production of that item. It may be regarded as not being waste but as being a by-product only if further use of the substance or object is certain, the substance or object can be used directly without any further processing other than normal industrial practice, the substance or object is produced as an integral part of a production process; and further use is lawful (it fulfils all relevant product, environmental and health protection requirements and will not lead to overall adverse environmental or human health impacts).

- **End-of-waste status** - certain specified waste shall cease to be waste when it has undergone a recovery, including recycling, operation and complies with specific criteria when it is commonly used for specific purposes, a market or demand exists, it fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products, and as long as it will not lead to overall adverse environmental or human health impacts.

- **Bio-waste** – biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants.

By-products and end-of-waste status in Directive 2018/851/EU

In accordance with Article 6 of Directive 2018/851/EU, Member States shall take appropriate measures to ensure that waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste. The Commission shall monitor the development of national end-of-waste criteria in Member States, and assess the need to develop Union-wide criteria on this basis. The Commission uses the most stringent and environmentally protective of those criteria as a starting point.

Where criteria have not been set at European or national level, Member States may decide case by case whether certain waste has ceased to be waste or adopt suitable measures to verify that. The natural or legal person who uses, for the first time, a material that has ceased to be waste and that has not been placed on the market, or places a material on the market for the first time after it has ceased to be waste, shall ensure that the material meets relevant requirements under the applicable chemical and product related legislation.

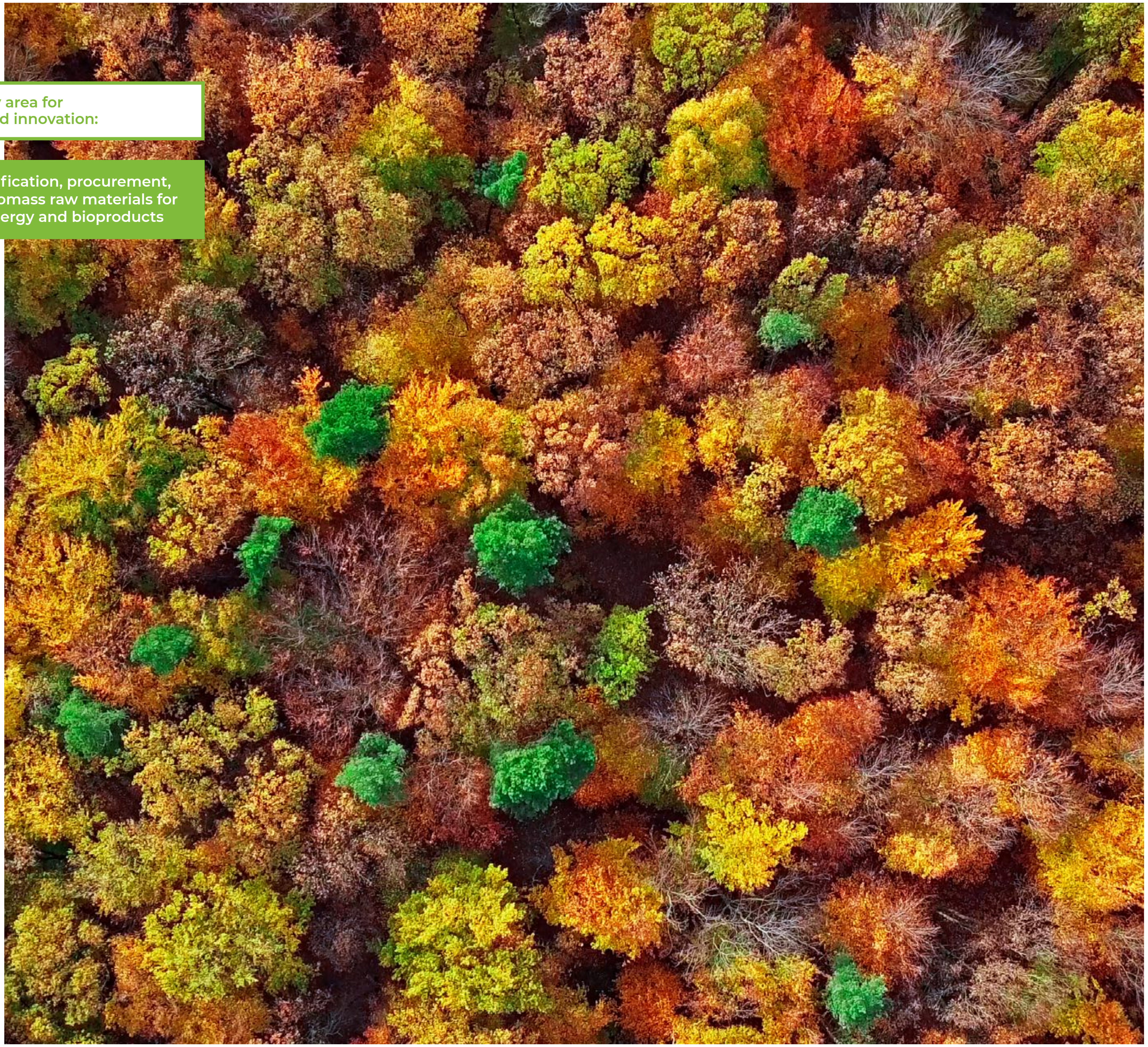
With the aim of promoting the circular bioeconomy, biomass raw materials classified as wastes should be used as much as possible. Making using these raw materials available safely and sustainably will make it possible to close productive cycles, favouring economic and environmental efficiency.

[27] European Regulation of fertilising products (EU) 2019/1009 (EC, 2019)
[28] European Directive on waste (EU) 2018/851 (EC, 2018)
[29] European Directive on waste 2008/98/EC (EC, 2008)

RESEARCH AND INNOVATION IN RAW MATERIALS

Priority area for research and innovation:

Optimising the identification, procurement, and mobilisation of biomass raw materials for different uses: bioenergy and bioproducts



Strategic considerations:

- Replacing products (materials, components), energy, and fuels for those derived from biomass would manage to replace current raw materials (non-renewable and pollutants), while keeping the same structure for consumption, market, taxes, etc. In other words, we would manage to change the source (from fossil to renewable) but we wouldn't change consumption patterns, use, taxes, and public education. The Circular Bioeconomy should serve as a lever to not only favour this transformation from fossil and imported to renewable and local but rather contribute to a different socio-economic modal to the current one, aware of the need to modify both behaviours and decision-making as productive and social models.

- There is a need to achieve sustainable mobilisation of raw materials to respond to different and specific end uses (bioenergy and/or bioproducts). The cost of biomass mobilisation needs to be admissible for each particular end-use, given that the end-use and the final market price determine the profitability of the exploitation of the different biomass. The raw material is acquired complying with certain specifications and with a set maximum price for the end-user and the business case.

- Identifying current and future market needs will be essential for the biomass offer to meet demand. Additionally, it will be essential to not only count on the existing biomass. but also biomass developed ad-hoc: dedicated crops, new biotechnological developments, and even new uses for familiar raw materials.

- Biorefineries and bioindustries should use a cascade approach when using their materials, favouring the generation of higher added value and more efficient products in terms of resources, such as biological-based products and industrial material, followed by bioenergy. An approach that will be subject to the technical-economic conditions (rather than systematically placing bioenergy at the end without carrying out a prior suitability analysis). The principle of use with a cascade is based on the single or multiple uses of a material, normally accompanied by the production of energy by burning the remaining material[30]. As such, the by-products and wastes from a production process are used in other bioproduct and/or bioenergy production processes. Biorefineries can contribute to the principles of a "zero waste society" in that way.

[30] Integrated Biorefinery (European Bioeconomy, 2018)

- For the organic fraction of household wastes and bio-wastes, it is essential to identify the purpose of a procurement adapted to each need. In other words, the challenge involves the end-use aim, not the mobilisation, the reverse approach compared to other biomass. The development of processes to extract value from the wastes will be key. Depending on the end-use, a prior separation system can be developed and implemented, considering the currently available schemes.

- Additionally, it will be very relevant to recover research into dedicated crops for bioenergy and bioproducts, both lignocellulosic (herbaceous and woody) and algae growing, as well as considering other biomass not used much up to now, such as marine biomass (fish, mollusc, or crustacean residues, as well as macro and micro-algae). This requires considering the restrictions contained in the new European Renewable Energy Directive (REDII)[16].

Research, development, and innovation challenges:

• Identification, quantification, and geolocation of biomass.

- Using airborne Lidar[31] on drones for an inventory and planning the exploitations of forest biomass, including undergrowth, in combination or -alternatively- using satellite image analysis (Sentinel[32], etc.) and traditional land inventory methods, or using new technologies (computer vision, land Lidar, etc.).

- Take an inventory of other biomass sources, from livestock defecations to wastes generated from agricultural activity and the transformation of these products by the food industry, linking the potential of available resources to their seasonality (to know whether the volume generated remains constant throughout the year or is focused on certain months).

• Biomass standardisation.

- The development of analytical methods that enable the understanding of the composition of biomass and to standardise the quality of the raw material, which form the basis for opting for pre-treatments, treatments, and indicated uses (ad hoc).

• Biomass mobilisation.

- Tests of machinery and innovative work systems for collecting forest and agricultural biomass, including crops, to develop productivity-costs models and operation manuals.

- The detection of training needs regarding administrations, companies, and workers who could be mobilisation agents, and the design of training programmes.

• Dedicated biomass crops.

- To develop genetic improvement programmes and to use biotechnological tools to obtain biomass crops adapted to regional (or location) characteristics, and which are efficient in terms of resource use.

- The optimisation of growing and scaling techniques for dedicated biomass crops (advanced growing practices, the use of technology for irrigation and water reuse, the development of machinery, etc.), preferably on marginal or surplus lands (considering their productivity and associated costs) that are within the radius of influence of the valorisation facilities, and which require few supplies (the use of technology for irrigation, water reuse, etc.).

- The detection of training needs for farmers and forest owners to increase knowledge and confidence in dedicated biomass crops.

• Biomass logistics.

- An improvement to logistics models and associated processes to optimise costs. Based on the prior study of end-user demand, the development of exploitation, storage, and transportation planning software, to fit the raw material circumstances and physical geography and climate conditions of the different biogeographical regions of Spain (Atlantic, Mediterranean, continental, mountains, and Macaronesian).

- The development of new biomass logistics operators based on the distribution of biomass in the regions to ensure the availability of the resource throughout the year. Agro-food cooperatives can play a very important role as biomass logistics centres.

- The study and implementation of sustainable and suitable logistics channels to replace fossil-derived raw materials with biomass with the subsequent development of biomass transformation hubs at strategic points in the country so that the exploitation can work as a cascade and be economically viable, but also from a sustainability and environment point of view.

• Biomass storage.

- The optimisation of biomass storage systems in valorisation facilities to prevent their degradation, as well as to ensure that they don't become the focus of other problems (like the spreading of insects, etc.).

• The relationship between using forest biomass and fire prevention.

- A study using tools to simulate the effects of the exploitation within the parameters of the fire risk simulation models and the development of prescriptions for the treatments. An evaluation of the reduction in costs of those tasks and/or the self-financing terms. A possible test of machinery and innovative work systems.

• Biomass value chain traceability.

- The application of remote measurement technologies (stereometry, Lidar, computer vision, ultrasounds) when measuring the quality and humidity of the biomass. The application of Blockchain technology to value chain traceability.

• Activation of raw materials and bio-based monomers.

- The development of new. more selective catalysts, which can increase the reactivity of raw materials and bio-based monomers. Their reactivity is currently more limited than their equivalents derived from oil (bisphenol A, diisocyanates, etc.). Finding new catalysts that activate bio-based monomers would be a very relevant milestone for the development of the new biorefinery, as it would mean the new processes can compete with traditional processes.

- The use of oils (and waste derivatives) not only as a potential raw material for biofuels for aviation but also to obtain new bioproducts that are alternatives to the oil-derived commercial options. The structural versatility of oils leaves a lot of room for obtaining both *commodities* and high-value products (for sectors like cosmetics) that can compete with current options in the market and provide higher profit margins.

[31] A Lidar *(Light Detection and Ranging o Laser Imaging Detection and Ranging)* is a device that enables the measurement of the distance from an emitting laser to an object or surface using a pulsed laser beam.
[32] Sentinel Online (ESA, 2020)

BIOENERGY

The energy union and the fight against climate change are strategic priorities for the European Commission. The European Strategic Energy Technology Plan (SET-Plan) and its Declaration of Intentions (SET-Plan DOI)[33] aim to transform the production and use of energy in Europe to become world leaders, as well as reducing costs in energy production through technological solutions to achieve the set energy objectives over the medium and long-term. The SET-Plan defines the European research and development programme in energy through 10 research and development priorities and objectives that cover the entire European energy system. These objectives aim to accelerate the decarbonisation of the energy system and the transport sector, making technologies more profitable and with better yields.

Action 8 of the SET-Plan "Renewable fuels and bioenergy for sustainable transport" has three common objectives for the bioenergy domain: to improve yield and the efficiency of the production, to reduce GHG emissions throughout the value chain and to reduce the costs of the process. Specific approaches are described for use with renewable fuels for sustainable transport (automotive and aviation fuels, as well as hydrogen produced from renewable sources), bioenergy (biosolids, bioliquids, and biogases) and the intermediate bioenergy carriers[34].

December 2018 saw the entry into force of the reviewed Renewable Energy Directive 2018/2001/EU (REDII)[16], as part of the Clean Energy Package for all Europeans, which aims to keep the EU as world leaders in renewable energies, and in more general terms, promote that the EU fulfils its commitments to reduce emissions in light of the Paris Agreement. EU countries were urged to develop integrated national energy and climate plans (abbreviated to NECPs) for the 10 year period from 2021-2030, which outlines how they will fulfil the new 2030 objectives regarding renewable energy and energy efficiency.

The new Directive establishes a new binding objective for renewable energy for the EU for 2030 of at least 32%[16], with a clause for a possible review upwards for 2023. The Directive includes updated sustainability criteria for the biofuels used in transport, gas biofuels, and for the solid biomass used for heating and electricity.

INFOBOX 4.

The biofuels used to fulfil the objectives set out in the European Renewable Energy Directive[16] must fulfil sustainability criteria

Energy deriving from biofuels, bioliquids, and biomass fuels will be considered for the following purposes, only if the sustainability criteria and the greenhouse gas emission reduction criteria established in the Directive are fulfilled:

- Contribute to the established objective that the Member States shall collectively ensure that the share of energy from renewable sources in the Union's gross final consumption of energy in 2030 is at least 32%.
- Fulfil the obligations regarding renewable energies, particularly the obligation to integrate renewable energies into the transport sector.
- Opt for financial support on consuming biofuels, bioliquids, and biomass fuels.

Sustainability requisites. Article 29 of the Directive sets out the sustainability and greenhouse gas emissions saving criteria for biofuels, bioliquids and biomass fuels.

Greenhouse gas emissions saving. The greenhouse gas emissions saving derived from using biofuels, bioliquids and biomass fuels will be:

a. at least 50% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations in operation on or before 5 October 2015;

b. at least 60% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 6 October 2015 until 31 December 2020;

c. at least 65% for biofuels, biogas consumed in the transport sector, and bioliquids produced in installations starting operation from 1 January 2021;

d. at least 70% for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021 until 31 December 2025, and 80% for installations starting operation from 1 January 2026.

Raw material providence. It is appropriate, in general, to limit food and feed crops-based biofuels, bioliquids and biomass fuels promoted under this Directive and, besides, to require Member States to set a specific and gradually decreasing limit for biofuels, bioliquids and biomass fuels produced from food and feed crops for which a significant expansion of the production area into land with high-carbon stock is observed. Low indirect land-use change-risk biofuels, bioliquids and biomass fuels should be exempt from the specific and gradually decreasing limit.

Obligation compliance. The verification of the established requisites could be undertaken using a national system that each Member State must develop or rather by using a voluntary scheme recognised by European Commission.

[33] Strategic Energy Technology Plan (SET-Plan) (EC, 2020)
[34] Strategic Energy Technology Plan Action 8 - Implementation Plan (ETIP-Bioenergy, 2019)

In Spain, the Strategic Framework for Energy and Climate[35] presented in 2019 set the route to follow to fulfil the energy and climate targets. It is comprised of legislative proposals that include the Draft of the Climate Change Law and Energy Transition, the Integrated National Energy and Climate Plan 2021-2030 (NECP)[36] , the Fair Transition Strategy, and the National Energy Transition Strategy.

The definitive NECP document sent to Brussels (official draft) establishes some significantly more ambitious energy objectives than those established by the European Union, on setting 42% of renewable energies from the country's final energy use in 2030 (above the 32% established for the EU as a whole); which would imply that the renewable percentage in 2030 accounts for 74% of the electricity sector. And it estimates that the external energy dependence reduces by 15 percentage points, from 74% at present to 59% in 2030. When it comes to energy efficiency, it is estimated to improve by 39.6%.

In the socio-economic domain, the estimated impact on GDP in 2030 is 1.8% (0.18% a year) and an impact of 253,000 to 348,000 net jobs a year (direct and indirect) throughout the decade, in the renewable and energy efficiency sectors. Additionally, the investment up to 2030 is expected to be 241,000 million euros, 80% of which will be private investment and 20% public, shared across central, regional, and local governments, plus European funds.

The main objective of the NECP is to reduce greenhouse gas emissions by 23% from 1990 levels. At the end of 2017, Spain was 18 percentage points above that reference. However, this objective is below 40% demanded by the Paris Agreement and the European Union.

The NECP considers biomass and looks for technological solutions that enable the optimisation of the value chain, from obtaining the resource to its valorisation, looking to reduce costs and improve efficiency in the facilities and processes. Biomass is indicated as a technology that contributes to the adaptability and optimisation of the entire electricity system and among the dedicated measures for decarbonisation, energy safety and efficiency, or the reduction of GHG emissions, there are specific programmes for exploiting biomass, energy efficiency measures in agricultural exploitations, communities of irrigators and agricultural machinery, and measures to reduce GHG emissions in the agricultural and livestock sectors, in waste management, in construction, and industry.

INFOBOX 5.

Biomass has outstanding capacities for contributing to the challenges of empty Spain

The biomass sector characteristics (the need for a constant supply of raw materials, a marked industrial character) make it an option of interest for the rural Spanish domain. Biomass facilities can form part of other industrial facilities present in the region, or they could be unique facilities for distributed energy generation with strong links to primary and secondary sectors, whose existence would imply the creation and consolidation of markets (or interconnected networks of micro-markets) capable of ensuring the supply of the biomass resource that the industry requires from the local biomass resources themselves.

The establishment of this industrial sector would lead to the creation of new jobs located in the areas where these resources are generated and where the facilities are located, which would be mainly rural. Biomass is a renewable energy that has outstanding capacities for contributing to the challenges of empty Spain. This technology offers a wide range of professional opportunities, particularly in rural areas at risk of depopulation that often coincide with the regions with a large potential of biomass resources. This sector would both contribute to creating jobs, making it viable through the development of the biomass sector by undertaking rural development policy objectives, enabling injection of wealth and creating stable and quality jobs.

[35] Strategic Framework for Energy and Climate (MITECO, 2019)
[36] Integrated National Energy and Climate Plan 2021-2030 (MITECO, 2020)

INFOBOX 6.

Hydrogen production from biofuels

Hydrogen as an energy vector with significant potential for decarbonisation mainly in industry and transport should count on renewable sources as energy resources from the outset to ensure that it is “green” hydrogen. Along with wind and solar, biomass can play a significant role, as hydrogen can be obtained directly from lignocellulosic biomass using heat and chemical processes (gasification and pyrolysis), as well as indirectly by reforming the compounds resulting from biological processes (biomethane from anaerobic digestion and bioethanol from alcohol fermentation).

Liquid biofuels, like bioethanol, have the advantage of their capacity for storage and ease of transportation to generate hydrogen in an adapted manner and close to demand, without the difficulties associated with storing produced hydrogen, avoiding infrastructure problems, safety issues, and the space it requires.

A way of promoting the use of biomass in Spain would include biomass and its fuels derived from hydrogen production. In Spain, there are companies with proprietary technology in the reforming processes required to convert liquid biofuels, such as bioethanol, into renewable hydrogen. The scaling of these processes (already existing on a small scale) shows outstanding potential for reducing the cost of hydrogen production because it is from chemical industries, as well as a significant opportunity for diversification for the biofuel plants, aligning them with biorefineries.

RESEARCH AND INNOVATION IN BIOENERGY

Priority area for research and innovation:

Extending and optimising the technical-economic and environmental response of the processes involved with bioenergy generation

Research, development and innovation challenges:

- **To analyse the real possibilities of adapting old coal-fired power stations to biomass (even if the power output/capacity is lower).**

  - To identify which coal-fired power stations are scheduled to close, their location, and the available biomass resources in those geographical areas. If viable, to make use of the existing infrastructures resulting from the process to dismantle coal-fired power stations to create biomass power stations within them (or co-combustion in which the fossil fuel plays a support role to the use of biomass). Fully replacing the capacity of the coal-fired power station with biomass wouldn’t be needed, rather than projects would be developed based on the available resource, making the most of the existing infrastructures. Additionally, the locations of industries close to the new biomass power station need to be identified to promote cogeneration (making use of the heat, achieving more efficient processes) or rather making use of its by-products (ash, CO_2) promoting circularity. It will have to adapt to the Fair Transition Strategy from the Ministry for Environmental Transition and the Demographic Challenge to occur.

- **Hybridisations between biomass facilities and other renewable technologies.**

  - To increase the technical-economic and environmental efficiency of the hybrid solutions, both for electricity biomass with other renewable sources (with focused solar, biogas, etc.) and thermal biomass facilities with other thermal renewables (geothermal, thermal solar, etc.) for buildings and industries, in unique facilities and heating grids. Along with researching tri-generation solutions (hot and cold water, steam, and electricity), particularly for integration into the industrial sector.

- **Optimising savings during the complete biomass cycle, particularly during the supply phase.**

  - To increment the yield of every process involved in the bioenergy value chains (electricity, heat, biofuels), maximising their suitability to the specific conditions of Spain (native biomass and existing agro-industrial by-products, climatology, water shortages, etc.).

- **Advanced pretreatments.**

  - A key aspect, particularly for lignocellulosic biomass, involves pre-treatment to separate different fractions (mainly lignin, hemicellulose, and cellulose). The economic viability of this phase is essential and it is worth optimising traditional treatments like autohydrolysis, acid or alkaline hydrolysis, as well as continuing to investigate more innovative treatments such as the organosolv process, biological pretreatments or using enzyme catalysts, ionic liquids, torrefaction, pyrolysis, hydrothermal liquefaction (HTL), hydrothermal carbonisation (HTC), or the use of Deep Eutectic Solvents (DES). Industries that implement these pretreatments will be of particular interest, such as the paper and cellulose industry.

- **Innovation in combustion processes to increase energy efficiency and control emissions.**

  - To optimise processes, implementing, even improving where possible, the ecodesign requisites of Regulation EU2015/1189[12] applicable to solid fuel boilers with a rated heat output ≤ 500 kW, and those regarding the inclusion to the Spanish legislative order (Royal Decree 1042/2017) of EU Directive 2015/2193, regarding the limitation of emissions to the air from certain polluting agents from medium fuel installations, with a rated heat output ≤ 50 MW.

- **To foster lines of research that enable the integration of biomass as a fuel for industrial processes** to replace the imported fossil fuels used widely in all types of industries in Spain.
  - To increase the knowledge of the industry regarding the prior preparation of biofuels (standardisation and homogenisation will play a key role) and advanced pretreatment technologies.
  - To innovate in the continuous and in situ characterisation of the feed biomass using artificial intelligence technologies, to facilitate the adaptation of the transformation process to the characteristics of the feed biomass.
  - To promote widespread circularity in the Spanish industrial sector, implementing processes that use biological base by-products and residual flows that come from recycling previous products as a raw material.
  - To integrate industrial process lines into industries (such as the petrochemical industry), fed by biomass in which fossil carbon (from oil derivatives) can be replaced by renewable carbon (from biomass).
- **To make use of the biodegradable fraction of municipal waste, sewage sludge or liquid manure to produce biogas or biomethane.**
  - To explore innovative fraction technologies for this type of bio-waste, to optimise the process involved with anaerobic biodigestion and biomethane purification technologies for its direct use in internal combustion engines. To ensure the valorisation of the digestate resulting from biodigestion.
- **Research into streamlining the costs of upgrading[13] biogas to obtain biomethane compatible with injection into the gas grid or for vehicle use.** Scaling significantly conditions the profitability of upgrading costs.
  - The development of P2G stations (*Power-to-Gas*).
  - The development of more efficient absorbents, (based on ionic liquids, etc.).
  - The application of process intensifying technologies (modified membranes, micro-reactors, membrane reactors) to improve yields and reduce the production of by-products.
  - The direct conversion of biogas into synthetic natural gas (without separating CO_2), in hydrogen, or methanol.
- **An analysis of the biomass energy capacities in the electricity mix** as a back-up to non-manageable renewables (wind and photovoltaic), a system regulator and stabiliser for the electricity grid, providing manageability, and a base green load. Integration into smart grids.
- **Research and innovation into thermochemical, chemical, and biologic technologies for producing advanced biofuels and bioliquids (thermal and electricity use),** individually, or combined (CHP) or with other renewable fuels (like renewable hydrogen).
  - The extraction of biomethane from the methanation reaction between CO_2 from biotechnological processes and H_2 from renewable processes.
  - The development of more efficient and/or sulphur resistant catalysts, (using ionic liquids or graphene, etc.).
  - The development of highly selective enzymes.
  - The application of process intensifying technologies to increase the process yield (micro-reactors, membrane reactors, bioreactors).
  - New carbon materials from biomass to accumulate energy.
  - The development of processes for obtaining energy products that minimise the carbon footprint of the fuels produced.
  - Research into the integration of hydrogen production in biofuel production plants.
- **The development of technologies to produce sustainable biofuels for aviation that represent an advance on the hydrogenation of vegetable oils,** which are advanced technologies and recognised by the International Civil Aviation Organisation (ICAO) using alternative raw materials (lignocellulose biomass, FORM, etc.).
- **To investigate the transformation of current bioindustries (forestry/paper mills, textiles, agro-industrial, chemical, mineral oil refineries, etc.) into biorefineries** to facilitate the integration of biofuel production and the final conversion of intermediate bioproducts in existing industries. To identify the raw materials that could be used and to develop integrated valorisation processes.
  - The use of CO_2 in the synthesis of biofuels or chemical products.
  - The replacement of CO with CO_2 in chemical synthesis.
  - The valorisation of waste biomass from agriculture or forests for producing new carbon materials.
  - The valorisation of lignin waste from the paper industry and cellulose in (bioproducts) and energy.
  - The valorisation of hemicellulose waste from the paper industry and cellulose in (bioproducts) and bioethanol or other biofuels.

RECOMMENDED REFERENCE DOCUMENT

The Manual on Biorefineries in Spain, published by BIOPLAT and SusChem-Spain in 2017, defines the transformation or valorisation processes that can be undertaken in biorefineries, and they presented the types of biorefineries that could be developed in Spain.

- **The development of intermediate bioenergy vectors:** research into optimising densifying processes, pyrolysis, torrefaction, hydrothermal carbonisation and the associated by-products (granulometric reduction, drying, etc.) to optimise costs and improve efficiencies of the overall cycle, as well as the integration of biomass into industrial processes.
- **The introduction of processes for integrating residual biomass flows (pyrolysis processes, hydrothermal liquefaction (HTL),** biomass gasification), with or without prior treatment, in industrial processes already implemented in industrial complexes for fossil hydrocarbon flows (oil refineries), to produce advanced biofuels.
- **Research and innovation into hydrogen production technologies from biomass.**

BIOPRODUCTS

According to the European Commission, **bio-based products** are wholly or partly derived from materials of biological origin, excluding materials embedded in geological formations and/or fossilised. In industrial processes, enzymes are used in the production of chemical building blocks, detergents, pulp and paper, textiles, etc. By using fermentation and bio-catalysis instead of traditional chemical synthesis, higher process efficiency can be obtained, resulting in lower energy and water consumption, and a reduction in toxic waste[37].

A three-dimensional approach is required to obtain effective development and the progressive implantation of the use of bioproducts in the framework of the circular bioeconomy[38]:

- **Raw materials:** to ensure a sustainable supply of biomass, to increase productivity, and to promote the creation of new supply chains.
- **Biorefineries:** to firmly invest in Research and Development and Innovation to achieve efficient processes and to show their efficiency and economic viability in biorefineries on a large scale.
- **Markets, products, and policies:** to develop markets for biological products and to create conditions for the domain that make it possible to develop bioproducts, adapting legal frameworks and speeding up standardisation processes.

This decade from 2020-2030 will be essential when it comes to progressing towards the bioeconomy, preparing society for a post-oil era in which oil-derived products (oil derivatives) are replaced with bio-based products. Although biomass was traditionally associated with precursors for biofuel and bioenergy production, biomass can also be used as a precursor for biomaterials, biocarriers and in a wider context, bioproducts.

As long as the investment goes into Research and Development and Innovation in biorefineries, it will be feasible to drive this transition from an industrial model based on oil to a multidisciplinary model in which renewable resources can come from very different sources, as all biomass can be used to produce bioproducts. In fact, for example, any raw material rich in fermentable sugars could generate bioproducts. From municipal solid wastes (after previously collecting separated organic material, preventing dumping), wastes or by-products from the food industry (largely underused), as well as dedicated biomass crops and agricultural and forest wastes, which could burn out of control with the significant associated environmental damage.

On the other hand, biorefineries could be both new facilities (unique or individual biorefineries), as well as those integrated into existing industries (sugar mills, biofuels, paper mills, oil producers, alcohol producers), which use biomass as raw material and a range of different technologies to produce energy and/or biofuels alongside chemical products, materials, foods, and fodder[18].

BIO-BASED INDUSTRIES VALUE CHAIN

Figure 6: The biotechnological sector value chain (Source: BBI JU modified by BIOPLAT)[39].

[37] Bio-based products (EC, 2017)
[38] About BBI JU –The catalyst for sustainable bio-based industries in Europe (BBI JU, 2020)

Bioproducts are intrinsically linked to the biomass raw materials from which they are generated. Factors such as availability and price of the original raw materials are decisive when it comes to estimating the cost of a bioproduct, which also defines the success of its market penetration. It is important to have a 'driver bioproduct' as a base for the biorefinery. It would be the precursor on which the process would be structured and the base for justifying the mobilisation/logistics of biomass and investment. Ensuring a constant supply of raw materials turns out to be essential for establishing stable prices for bioproducts and subsequently to ensure their presence and competitiveness in the market. The business model must guarantee that the bioproducts are produced sustainably, both environmentally (ensuring their origin, life cycle, etc.) and economically (enabling every agent on the value chain to make a profit).

Bioproducts must be competitively priced to ensure they are accepted into the market. However, most bioproducts are more expensive than their equivalents, the oil derivatives that they compete against. One of the reasons why bioproducts are currently less competitively priced is because the environmental cost (depletion of raw materials, emissions) is not included in the price of the products. This is a major disadvantage, given that it hasn't generated the need to acquire them among consumers and they don't identify sufficient benefits to assume the additional cost associated with their consumption. In order to maximise the cost of raw materials as much as possible, it is essential to use waste biomass or by-products from industrial processes, creating a convergence of the **biorefinery and circular economy** concepts.

Bioproducts will play an increasingly important role in the transition from a linear to a circular economy. **Biorefineries** themselves are at the heart of the **circular economy**, playing a vital role in the development and adding value to the principles of a 'zero waste' society. The biorefinery concept is analogous to that of the petrochemical refinery processes, except that biorefineries use renewable raw materials rather than fossilised carbon[39]. The exploitation of biomass covers a large range of raw materials, processes, and end products, from the production and mobilisation of biological resources (organic) to their conversion into added-value products (Figure 7).

[39] Commission Expert Group on Bio-based Products – Final Report (EC, 2017)

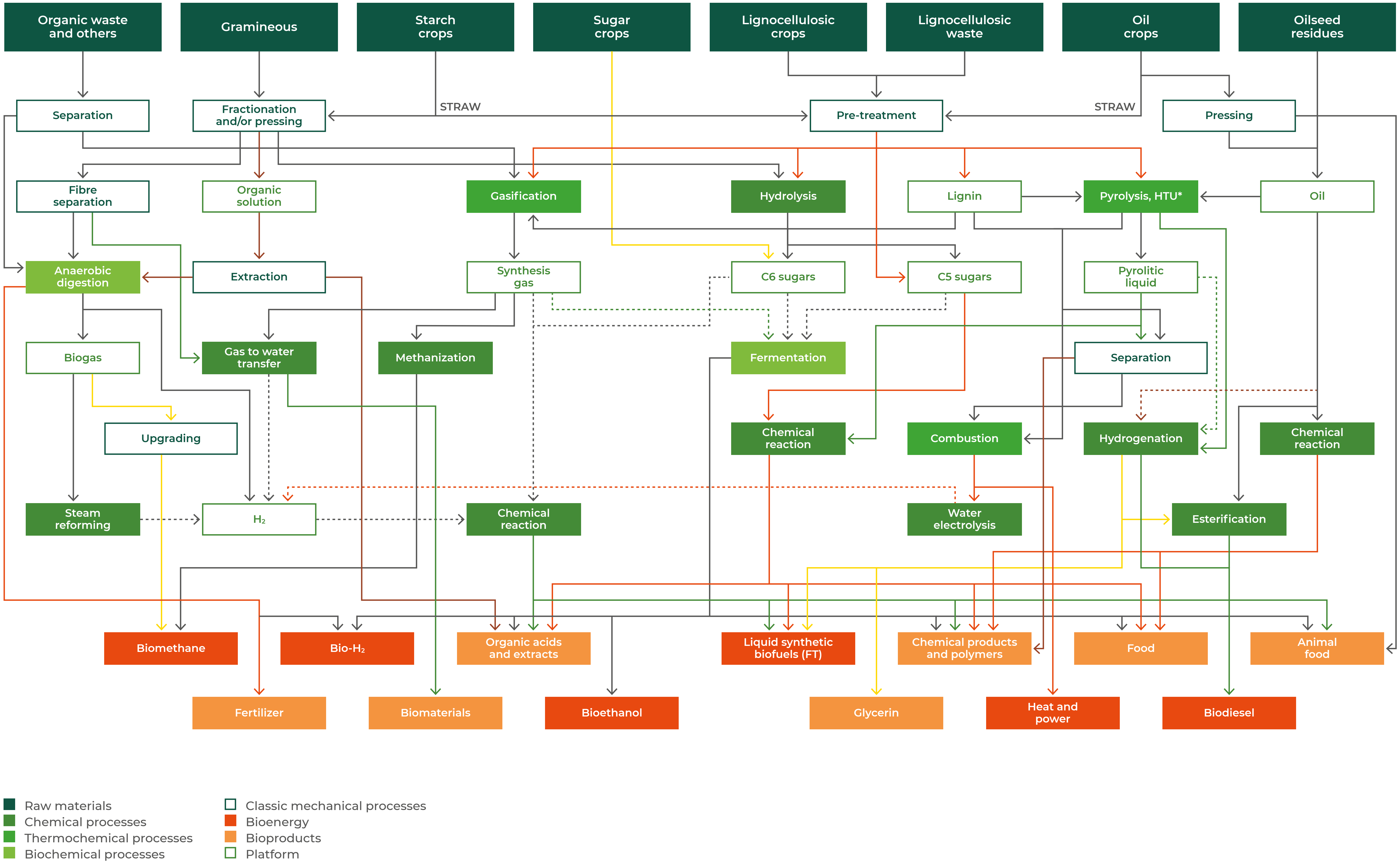


Figure 7: Biorefinery classification system scheme[18].

Chemical bioproducts can generally be classified into two groups[40]:

- **Drop-in bioproducts**

Bioproducts that can replace existing conventional products, like oil derivatives, on being chemically identical to existing chemical products derived from fossils. Subsequently, a market already exists when the bioproduct is generated, along with some established logistics networks, so it can be produced at a larger scale (being able to replace existing products considered *commodities*). However, should the price be higher than existing products, it will find penetrating the market difficult.

- **Smart drop-in bioproducts:** These are a special subgroup of drop-in bioproducts. They are also chemically identical to the existing chemical products based on fossil hydrocarbons; however, their biological pathways offer benefits compared to conventional pathways. We consider that they are 'smart incorporations' if at least two of the following criteria are fulfilled:

- The efficiency of using the biomass present in the raw material is significantly greater than with other drop-in bioproducts.
- Their production requires significantly less energy compared to other production alternatives.
- The production time is shorter because of the shorter and less complex production routes compared to their counterpart based on fossils or other alternatives.
- The by-products generated during the production process are less toxic or aggressive compared to their counterparts of fossil origin or other drop-in bioproducts.

Dedicated bio-based chemicals

These are bioproducts that don't replace any existing products, rather than they are produced using a specific pathway and represent a new use. They can be used to produce products that cannot be obtained using traditional chemical reactions and products that can offer unique and better properties that cannot be achieved with fossil-based alternatives. Therefore, a prior market doesn't exist and they need to be standardised and certified (procedures end up being complex and discourage innovation among companies), and they also need regulation on occasion. They are normally produced on a smaller scale (speciality chemicals).

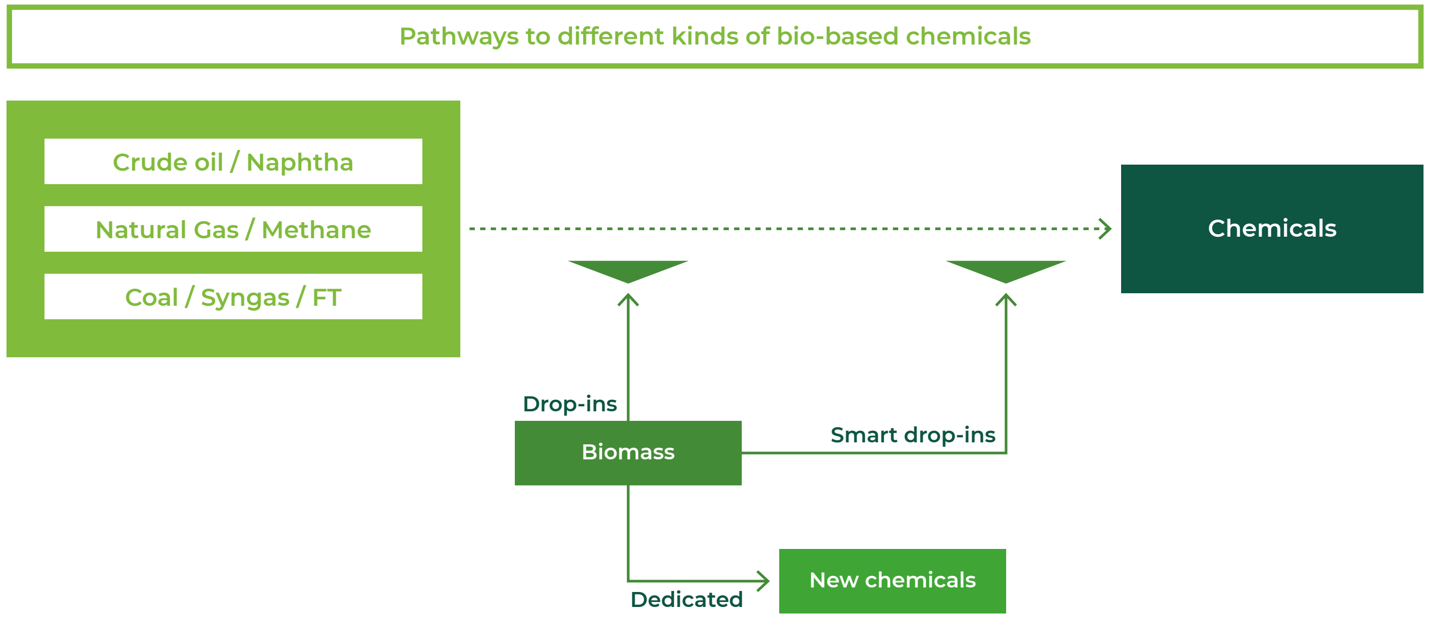


Figure 8: Schematic differentiation of the pathways of drop-in, smart drop-in, and specific innovative bioproducts (Source: RoadToBio)[41].

In both cases, there will be the need to arouse a need among consumers to acquire bioproducts, highlighting their environmental benefits, health benefits, because they generate fewer emissions during their production cycle, because of the improved capacity for recycling, or other strategic factors that make the bioproducts more appealing and favourable for society as a whole compared to traditional oil-derived products. Public administrations have tools to promote the consumption of new bioproducts (through innovative public spending, tax measures, among others) or penalise those from deriving from oil.

The group of experts that work on bioproducts, represented by BIOPLAT, considers that the final objective should always involve developing truly sustainable products, which produce tangible environmental improvements and which are economically viable.

The developed bioproducts will need to establish a comparison between the life cycle analysis (LCA) and the analysis of the life cycle costs compared to those of its counterpart (fossil-derived) to show that they represent an alternative with a higher level of sustainability and economic profitability. This translates into more pressure to achieve excellence than the fossil alternatives on having to ensure environmental and economic efficiency throughout the value chain, from raw material to market[41].

Additionally, there are other obstacles for the roll-out of new products (or new applications for products), such as those deriving from the legal requisites and regulations, a lack of awareness and acceptance among customers, limited public (industrial) demand and private demand (in terms of purchase and use), the resistance of established industrial sectors, or the public's unfavourable perception towards bio-based products and applications. When it comes to legislation and regulations, these include directives, safety aspects, labelling, and certification. On tackling these requisites, the value chain agents and those responsible for formulating the policies and regulations should interact closely to understand and harmonise both the options and needs in play. This coordination will be essential, as bioproducts that fulfil every legislation and regulatory requirement will be appealing products for markets[41].

[40] Bio-based drop-in, smart drop-in and dedicated chemicals (RoadToBio, 2017)
[41] Strategic Research and Innovation Agenda (BIC, 2017)

INFOBOX 7.

Integrated production of bioproducts in the olive oil industry

The olive oil industry in Spain generates mainly two by-products: olive leaf and olive pulp. Olive leaf is generated during the olive collection process and due to pruning the trees. Olive pulp, on the other hand, generates during the extra virgin olive oil production process and is mainly comprised of water, stone residue, and pulp from the fruit.

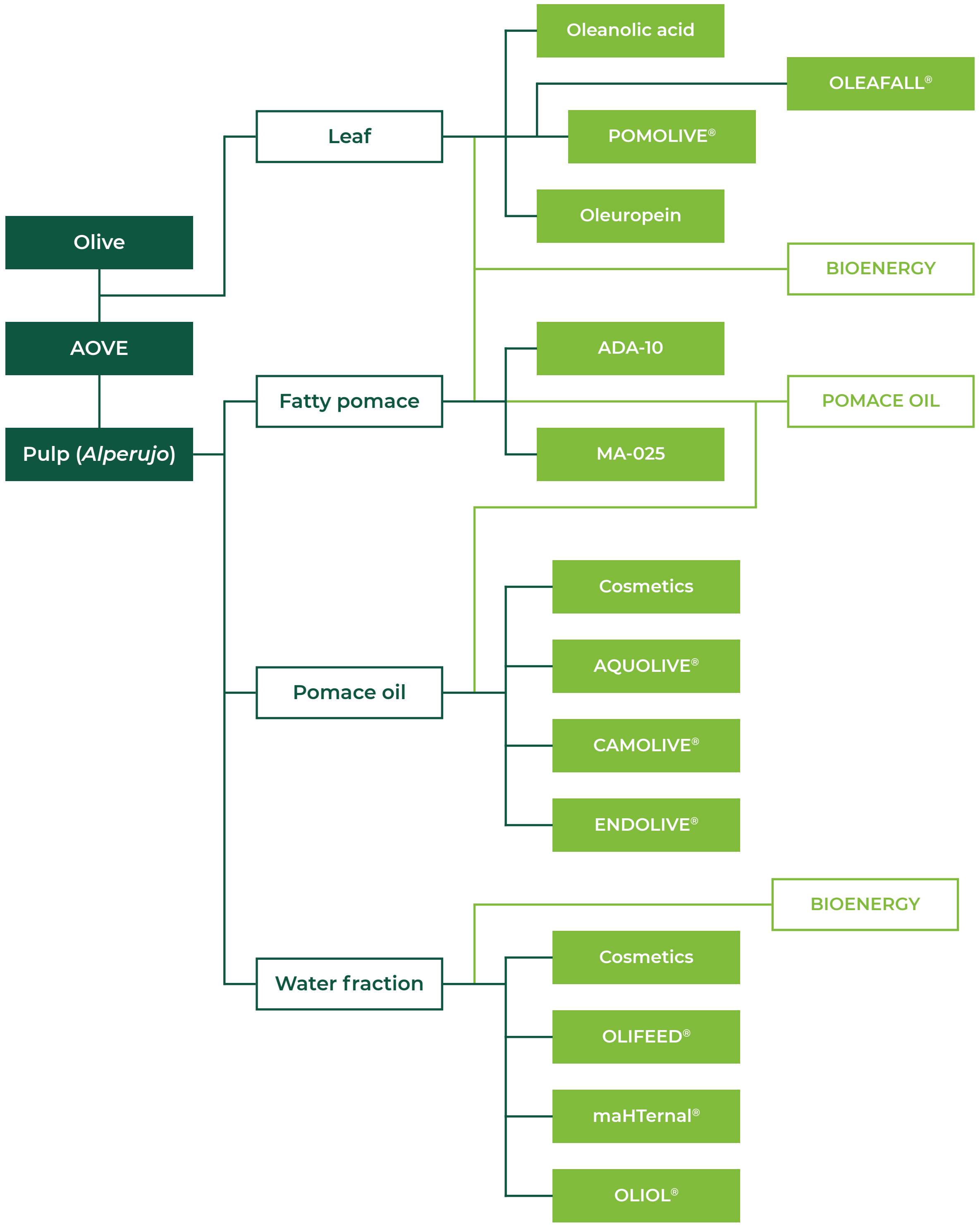
This pulp is sent to major processors for treatment and valorisation, which mainly consists of producing olive pulp oil and electricity and thermal bioenergy through cogeneration. During the processing, the olive pulp is subjected to another centrifugation process, this time in three phases, to recover the small fraction of oil still present (olive pulp oil), and to separate the aqueous phase (murga) from the solid phase (oily pomace), which produces a second type of pomace oil through extraction with hexane. Lastly, all the generated biomass is subjected to combustion in biomass boilers to produce bioenergy.

In this context, the Spanish company, Natac, has developed a series of technological processes to extract, concentrate, and isolate different bioactive compounds that are in olive tree by-products, with great potential for developing ingredients with high added value. The developed processes are integrated into the current olive biomass management process, as such contributing to reducing the environmental impact of its processing, and to re-valorising the sector.

A range of innovative products has been developed for different markets with high added value, mainly for the nutraceutical, pharmaceutical, food, animal nutrition, and cosmetic sectors.

Some of these developed products are:

- ENDOLIVE and POMOLIVE. Clinically tested nutraceutical products for improving cardiovascular health and controlling metabolic syndrome.
- AQUOLIVE. A natural additive for use in salmon aquaculture that will help to raise their resistance and fish quality profitably.
- ADA-10. An additive for animal nutrition for land species.
- NT97. A high value product aimed at the pharmaceutical industry.



RESEARCH AND INNOVATION IN BIOPRODUCTS

Priority area for research and innovation:

Sustainable and competitive production of bioproducts on a commercial scale

Table 1 below lists the bioproducts that should be investigated and innovated in Spain to achieve production to a sufficient scale to enable their commercialisation. These bioproducts will be generated from certain biomass transformation processes that can be divided into four major groups[18]:

- **Physical processes.** Basic operations that change the material's properties, applying mechanical energy, cleaning and separation processes, densifying processes, milling processes, and extraction processes (including the direct extraction of macro molecules for biotechnology use).
- **Thermochemical processes.** Transformation operations using temperature changes that sometimes involve chemical transformations in the raw material.
- **Chemical processes.** Basic operations for transforming the material using chemical reactions and chemically catalysed conversions.
- **Biotechnological processes.** Enzymatically catalysed conversions, fermentation and decomposition processes by micro-organisms, entomological processes (insects).

These processes, and their combinations, give rise to a range of bioproducts that can be classified by their main current use (Table 1). However, each bioproduct listed in the table can potentially be used for other uses. The options for use will expand as more is learned about them until they become established as sustainable and competitive alternatives to oil-derived products.

Scaling influences the ability of new bioproducts or innovative products to enter the market. In some cases, despite the technology readiness level (TRL[42]) of the bioproduct development being over 9, and being theoretically ready to enter the market, industrial production of certain bioproducts is not always viable given that there can be a loss in quality on scaling up the production process. This derives from the importance of promoting Demo, Flagship, First of its kind, etc. facilities, using funding structures that enable the amortisation of the business risk (national or European funding tools for Research and Development and Innovation, EIB programmes, seed capital, etc.). There are currently bioproduct manufacturing technologies with high TRLs in Spain.

BIOPRODUCTS	MARKET	Examples
Food additives (antioxidants, preservatives, etc.)	Human food, animal nutrition, cosmetics	Rosemary extract, grape seed extract, olive extract
Zootechnic additives	Animal nutrition	Plant extracts, essential oils, prebiotics
Food ingredients with healthy properties	Human food and the nutritional supplement sector	Standardised plant extracts, prebiotics
Pharmaceutical active ingredients	The pharmaceutical industry	Plant extracts and purified compounds, with European Pharmacopoeia quality
Cosmetic active ingredients	The cosmetics industry	Purified extracts and compounds
Biofertilisers, biostimulators	Agrochemical	
Natural bioproducts	Paper	Cellulose, hemicellulose, starch, sugars, chitin, plant fats and oils, lignin, natural rubber, terpenes
Biochar and activated carbon	Catalysis, absorption (chemical industry) Environment	Depolluting Catalysts
Biotechnology sourced bioplastics	Food	PHAs
Monomers	The chemical industry, paints,	Mono ethylene glycol, lactic acid, succinic acid, 1,4BDO (1,4 butanediol), 2,3BDO (2,3 butanediol), 1,3Propanediol, IBMC (isosorbide bis-methyl carbonate)), levulinic acid, 1,3 propanediol, xylitol
Polymers	The chemical industry, paints, adhesives, coverings,	Polyesters, polyolefins, polyurethanes, polyamides, epoxides
Solvents	The chemical industry	Ethanol, MEK (methyl ethyl ketone, lactate esters)

Table 1: Reference bioproducts for research and innovation in Spain.

[42] Technology Readiness Levels (TRL) – Annex G H2020 Work Programme 2016-2017 (EC, 2017)

ADDED VALUE

Biomass has been used to produce energy in the form of heat since prehistoric times. It is still widely used at present, not only in developing countries where it accounts for 10% of the world's primary energy supply but also in the OECD countries, where it represents 6% of the primary energy supply. In Europe, biomass energy consumption has historically been a lot higher than the consumption of other renewable energy sources. Up to the 2000s, the consumption of renewable energy was dominated by the consumption of hydraulic and biomass sourced electricity, but renewable sources have diversified notably since. Furthermore, energy generation from biomass throughout the world is mainly in the form of thermal energy, essentially heat, ahead of electricity generation[43].

Spain is a European powerhouse for all types of biomass resources. However, it is at the bottom of the European ranking for the exploitation of forest and agro-livestock resources for generating electricity, thermal energy, biogas/biomethane, and the valorisation of the organic fraction of municipal wastes. Significantly less biomass is consumed in Spain compared to the average for Europe. According to EurObserv'ER (2018), Spain is ranked 22 from the EU-28 for the consumption of energy from solid biomass per capita (0.117 toe/inhab)[44], with the leading countries ranked as Finland, Sweden, Latvia, Estonia, Denmark, Austria, and Lithuania.

Despite this evident underuse of biomass resources, the biomass sector in Spain is generating significant economic, social, and environmental value in the regions. Biomass energy valorisation is a source of economic activity with a significant industrial component and a notable capacity for job creation, particularly in rural areas, where most of the biomass resources from forests, fields, livestock farms and industries are found. This capacity for creating jobs represents a vector for a population settling in the region, enabling it to maintain its socio-economic activation and structure, while actively boosting the bioeconomy.

There is a range of economic activities linked to biomass plants. They run from the extraction and mobilisation of biomass resources, pretreatment, transportation and storage, through to actual energy valorisation in electricity or thermal energy generation stations. The AFI report (2018)[22] values the economic contribution of the biomass sector linked to current facilities at 2,732 million euros of Gross Added Value, 32,945 direct, indirect, and induced jobs, and 1,101 million euros for public funds (in terms of VAT, company tax, energy production tax, personal tax, and social security payments).

Added value is created along the value chain from mobilising raw materials (agricultural, livestock, etc., biotechnology for improving plants, dedicated biomass crops) through processes to generate bioenergy and bioproducts. In other words, as well as the value provided through generating the end product itself (bioenergy/bioproducts), the entire production process up to obtaining the end product provides value for other connected sectors, such as the agricultural sector (farmers can extract additional value from the remains of their harvests), the industrial sector (additional value on reusing by-products that they didn't use before), etc.

Additionally, the added value of using biomass as a raw material is increasing, as its use - traditionally for energy - is being expanded for use as a raw material for manufacturing bioproducts. Within the framework of the transition to a circular bioeconomy and considering the consumption model currently in place in society, there is a need to diversify, open up the range of resources, and reuse/recycle. In this context, there is the need to improve inefficient applications, reduce the resources dedicated to each use, and minimise wastes. To sum up, the aim is to maximise efficiency to increase the range of outputs that can become products (bioproducts, bioenergy, biofuels), making the most of this form of using biomass.

ECONOMIC VALUE

Exploiting biomass (agricultural, forest, livestock, industrial, or municipal) requires constantly moving human resources, on having to ensure a continuous supply of biomass at the facilities where they are valorised (to be transformed into bioproducts and/or bioenergy). The economic value of these productive processes - strictly the generation of incomes and direct and indirect jobs - can be estimated from their contribution to GAV* and the creation (and maintenance) of jobs in the Spanish economy. This is known as 'the economic value' of biomass, which has a positive impact on the primary sector (agricultural, forest, and livestock) and on the secondary sector (agro-food, forest, chemical, materials industries, etc.).

* Gross Added Value.

SOCIAL VALUE

Biomass makes a social policy contribution, in aspects such as collectives (mainly with links to rural centres) with limited opportunities to find and maintain a job in their regions being put to work, slowing down rural depopulation, providing structure for the region, or the economic saving generated from treating waste (potentially relevant for local councils). It represents an opportunity to create jobs associated with innovative production models. This is why exploiting biomass may be an effective tool to help to keep people in rural areas and activate the economy in the regions, promoting rural development and re-industrialisation.

ENVIRONMENTAL VALUE

Biomass helps to reduce CO_2 emissions on replacing the use of fossil-derived fuels and materials and because of the valorisation of certain biomass wastes generating diffuse emissions, such as livestock defecations (a significant point source of methane), as such making use of native biomass and helping to convert potentially problematic wastes (that can ignite, leach, etc.) into resources. Furthermore, it represents a positive impact on ecosystem management, with fewer forest fires occurring, deriving in the sustainable management of forests. Biomass promotes a socio-economic model based on sustainable development and actively contributes to mitigating climate change, within the framework of the bioeconomy.

Figura 9: Positive externalities generated by the exploitation of biomass (Source: prepared by the authors).

Currently, society is requesting changes to production models and forms of consumption, influencing how companies behave and how they advertise it. This trend presents the idea of new opportunities for the biomass sector. These include the elimination of single-use plastics[45], the need for industries to replace conventional materials with recycled or biologically sourced, biodegradable materials, among others. Allied with the gradual increase in the price of CO_2, it opens up a window of opportunity for the biomass sector.

As part of the transition towards the bioeconomy, a positive perception from consumers about the benefits of bioenergy and bioproducts will be essential for achieving progressive and successful implementation in Spain. In addition to policies to promote the bioeconomy by public administrations, information and awareness actions will be required for society as a whole to understand the need to use bioproducts and bioenergy, as well as to appreciate the added value induced in both productive cycles, a value that transfers directly to the regions, generating highly valuable environmental and socio-economic benefits.

[43] Biomass in Spain. Generation of added value and prospective analysis (FEDEA/BIOPLAT, 2019)
[44] Solid Biomass barometer 2019 (EurObserv'ER, 2019)
[45] European Directive on Plastics (EU) 2019/904 (EC, 2019)

INFOBOX 8.

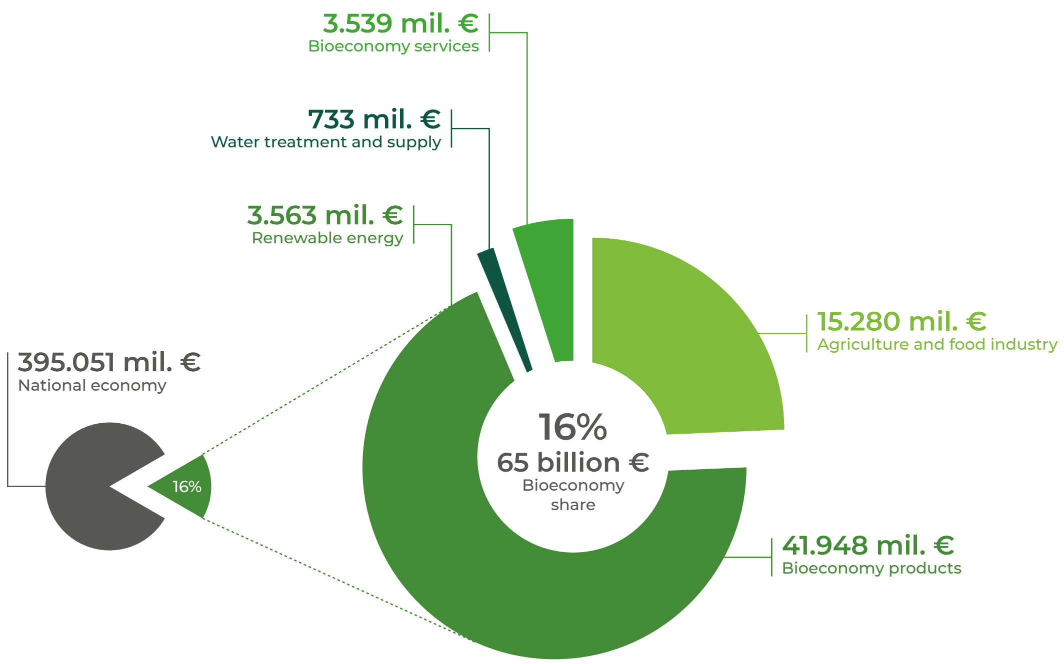
The bioeconomy in Finland[46]

Finland has taken the decisive step to invest in the bioeconomy as a country, as an integrated system that includes industrial processes, work, and well-being, which goes further than environmental sustainability. It represents integral economic sustainability, as an alternative to being oil-dependent.

Experts concur that this is a new trend in the global economy and that achieving success will require a large number of new technologies and innovations. Finland is positioned very well at present, not only in terms of research but also in the practical implementation of the bioeconomy.

In Finland, the entire society is involved in developing the bioeconomy with the aim that one day, everything that they eat, buy, or use will be made from biomass.

Finland's Bioeconomy Strategy for 2025 aims to increase current investment in bioeconomic production from the current 60,000 million euros to 100,000 million euros and during the process, create numerous new jobs and help drive the national economy.



Bioeconomy share of Finnish national output[47]

INFOBOX 9.

Bioeléctrica de Garray, the driving force of the circular bioeconomy

The Garray biomass plant (Bioeléctrica de Garray, 17 MW) is located in the province of Soria, which has a population density of under 10 inhab/km^2 (the threshold of a population desert), so it is considered a priority area within the scope of the REINDUS plans and its designation as an EU disadvantaged region is being processed.

As well as providing an additional 30 direct jobs, this plant has acted as a node to attract other industries, leading to the location of a large greenhouse in the adjoining plot, which creates over 300 direct jobs and will make use of the heat supply from the biomass power station.

Additionally, a CO_2 capture, cleaning, and use station are projected to be installed, which will involve new investment and direct and indirect jobs. As well as being exported to the grid, the bioenergy generated in the biomass plant will be able to meet energy needs, whether for electricity or heat from the CO_2, capture and compression plant, as such contributing to reducing CO_2 emissions in energy-intensive industrial sectors[48].

Additionally, there are plans to promote a fertiliser production plant that will use ash from the biomass power station in the manufacturing process. This all means that the biomass plant can be stated to be acting as a driving force for bioeconomy in an area needing a huge industrial investment.

The bioenergy is generated through biomass combustion, and as well as being exported to the grid, it will satisfy the energy needs, both electricity and heat, for the CO_2 plant. Part of the combustion gases coming from the boiler will pass through a filter and will then be directed to the capture, cleaning, and compression plant. The CO_2 will be distributed to customers from there, reducing transport needs and increasing the sustainability of industrial processes used due to its renewable source.

In addition to the creation of direct jobs (in the construction and O&M[49] of the industries) and indirect jobs (biomass logistics, local supplies and workshops, etc.) associated with these investments, which has a positive impact on the region's socio-economic activation, the settling of population, and the region's structure; the environmental benefits and circularity it induces are equally significant:

- Gross annual production of renewable electricity ≈ 120,000 MWh.
- Annual production of renewable CO_2 ≈ 50,000 t for industrial and food uses.
- The reduction of emissions due to biomass decomposition (plant pruning residue and wastes).
- The reduction of CO_2 from transportation (on bringing renewable CO_2 production closer to regional customers).
- An increase in biomass combustion of over 15,000 t/year, contributing to the sustainable maintenance of forests (only using forest and agricultural waste) and the strengthening of the forest-rural industrial fabric.
- The reduction in cost of agricultural production methods when the fertilisers are marketed, as well as closing the productive cycle on using the ashes from generating bioenergy as a raw material for fertiliser production.

[46] The Finnish bioeconomy: An incredible future (This is Finland, 2014)
[47] Bioeconomy share of Finnish national output - John Kettle, International seminar "Bioeconomy and development: opportunities through cooperation between Nordic countries and the Southern Cone" (CIECTI, 2018)
[48] Project Life CO_2 Int Bio (2019)
[49] O&M: Operation and Maintenance.

RESEARCH AND INNOVATION IN ADDED VALUE

The added value generated by biomass valorisation within the framework of the circular economy is cross-sectional concerning the raw materials and bioenergy, biofuel, and bioproduct generation. This is why the focus isn't only placed on one main research and innovation area, rather than a series of domains are prioritised, which require action through auxiliary studies and sustainability, technical-economic, regulatory, and market penetration analyses, research and demonstration projects, educational and communication strategies, among others. These will contribute to increasing knowledge about sustainability and excellence during bioenergy and bioproduct production.

Research, development and innovation challenges:

- **A demonstration of the benefits and good practices of the biomass sector, to show them and raise awareness about the contribution of bioeconomy to the objectives of other strategic policies for Spain and its regions.**
  - The quantification of the socio-economic and environmental impacts of the complete value chain on the sector as a whole, its sub-sectors, and even production units.
  - The implementation of demonstration projects and the implementation of actions targeting the valorisation of potentially problematic biomass resources (they can leach, emit GHG, burn uncontrollably, etc.).
  - To analyse the potential added value that dedicated biomass crops can induce, quantifying their ecosystem services and the benefits derived from ensuring supply to the biomass facilities (on being used alongside current biomass flows).
  - In the incorporation of new bioproduct developments into the market, analysing the key performance indicators (KPIs) and how the sectors relate with each other.
  - The introduction of sustainability criteria or indicators into good practices.
- **The identification of the barriers to the development of the bioeconomy and its sub-sectors (bioenergy, biofuels, bioproducts).**
  - To examine the barriers from any area (technological, regulatory, economic, market, social, etc.) that prevent the sector from evolving and subsequently limiting the creation of added value; to have the capacity to articulate potential solutions and alternatives based on analysing and understanding the barriers to development.

- **A life cycle analysis (LCA) of the bioeconomy value chains.**
  - An analysis of the complete production cycles (from the source of the raw material to the possible wastes/emissions derived from generation) to ensure the environmental benefits (and energy where applicable) from bioproducts, bioenergy, and biofuels, compared to energy alternatives and oil-derived products, which they are to set to replace in the market (carrying out LCA before introducing new bioproducts to the market is strongly recommended).
- **An analysis of the social impact of the bioeconomy.**
  - An analysis of the effects induced by investing in biomass valorisation facilities to generate bioproducts and bioenergy/biofuels, both in aspects relating to creating and maintaining jobs (quantifying the number, unemployment benefit payments avoided, the GAV/GDP generated, taxes collected), and aspects relating to settling population in regions.
- **A study of the role of biomass in the energy mix as a necessary technology to achieve the 2 °C (or 1.5 °C) scenario.**
  - The modelling of energy scenarios considering existing biomass, from the traditional to the most innovative (Power-to-Gas, biohydrogen, etc.).
  - An analysis of the electricity generation domain regarding the capacities of biomass (solids, biogas, renewable wastes) as 100% manageable renewable technologies, capable of providing a green baseload and stabilising the electricity grid.
  - An analysis of the heat generation domain regarding the capacities of biomass (solids, biogas, renewable wastes) as highly efficient and competitive renewable technologies when generating heat for buildings and industries.
  - An analysis of the domain of fuels regarding the characteristics of biofuels (liquids, biomethane, bio-jet fuel) as sustainable alternatives to conventional fuels for transport.
  - For both cases, establishing cost analyses compared to the fossil alternatives would be of particular interest.
- **The cascading use of biomass.**
  - To complete a conceptual development that comprises the analysis of the opportunities and benefits.
  - To ensure that the order of the selected processes in each cascade business model is ideal based on the technological-economic criteria (not systematically placing bioenergy at the end of the cascade without having undertaken this analysis).
  - To integrate the use of sub-products and wastes from biomass processes into the production cycle. To study the benefits of agriculture and forestry adapted to the application of biofertilisers/biostimulators that come from biomass components (crop residues, pruning, and forest waste, along with ashes from the combustion of woody biomass, from sewage sludge, etc.). Evaluating sustainability is key.
- **To advance the fight against forest fires.**
  - To economically quantify the potential added value from avoiding forest fires through the valorisation of the biomass obtained from the sustainable management of forests (emission savings, the economic estimation of lost lives, biodiversity and properties).
  - To study the characteristics of extracting biomass to be more effective at preventing fires. To analyse the cost of implementing these measures, what would be saved, to obtain an economic balance on which to base decision-making.
- **To analyse potentially establishing forests on agricultural lands.**
  - To determine the added value that this practice induces in terms of the carbon input into the soil, the contribution to biodiversity (birds and other animals), the reuse of water for crops, and soil retention against erosion.
- **The development of ecosystem services relating to forest biomass.**
  - These services are very diverse. They can be linked to keeping a forest at a low level, using forest crops, etc. They favour the presence of insectivores, improve the quality of surface water on preventing erosion/scrubbing, contribute to regenerating the habitat of numerous species, and improve the environmental connectivity for species that travel longer distances (like the wolf, deer).
- **To analyse the competition for land use.**
  - To determine the effects induced for using land for energy generation facilities corresponding to other renewable technologies compared to the use for biomass (both facilities and dedicated crops).
- **To promote formal education on the circular bioeconomy during primary and secondary education, as well as in universities and vocational training centres.**
  - To expand knowledge during early education stages using the introduction of content related to the circular bioeconomy, biomass, bioproducts, bioenergy, and biofuels in primary and secondary education programs.
  - To incorporate educational subjects regarding the circular bioeconomy, biomass, bioproducts, bioenergy, and biofuels in university degrees and masters relating to the sector.
  - To advance the professional qualifications required before level II and III vocational training to train and certify (through professional permits) professional profiles with links to the circular bioeconomy.
- **To design communication strategies targeting society as a whole.**
  - To extend knowledge and social awareness of the circular bioeconomy (biomass, bioproducts, bioenergy, and biofuels), to help the change in how energy and products are consumed, providing consumers with the necessary information for decision-making when to comes to more sustainable consumption of biomass-based options.
  - To show public administrations (national, autonomous region, and local) the socio-economic and environmental benefits induced with the circular bioeconomy in the regions, as well as the potential contribution of the bioeconomy to the administrations' other strategic policy objectives.
  - To produce communication documents that establish comparisons based on technical, economic, viability analyses, etc. regarding the myths (about biomass practices and technologies) compared to the actual situation. Each myth could derive from research and a specific deliverable.

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FIGURES

INFOBOXES

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