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The Bioeconomy in Italy and the New National Strategy for a More Competitive and Sustainable Country

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Highlights

- Italian bioeconomy is re-connecting national economy with environment and society
- Reconciling technological advances with conservation of ecosystems.
- Benefits from largest biodiversity in Europe and high territorial specificities.
- Bioeconomy strategy aims at improving sustainability, productivity and quality of products of interconnected sectors, creating longer, locally routed value chains.
- Strategy enables coherent coordination of measures and actions at regional, national, EU and Mediterranean levels.

Abstract

Italy has the third largest bioeconomy in Europe (€330 billion annual turnover, 2 million employees), making it a core pillar of the national economy. Its sectors of excellence are food and biobased products, and it is a consistent presence in research and innovation projects funded by the EU Horizon 2020 programme (Societal Challenges 2) and the European Public Private Partnership “Biobased industry” (BBI-JU). The bioeconomy reduces dependence on fossil fuels and finite materials, loss of biodiversity and changing land use. It contributes to environmental regeneration, spurs economic growth and supports jobs in rural, coastal and abandoned industrial areas, leveraging local contexts and traditions. In 2017 the Italian government promoted the development of a national Bioeconomy Strategy (BIT), recently updated (BIT II) to interconnect more efficiently the pillars of the national bioeconomy: production of renewable biological resources, their conversion into valuable food/feed, biobased products and bio-energy, and transformation and valorization of bio-waste streams. BIT II aims to improve coordination between Ministries and Italian regions in alignment of policies, regulations, R&I funding programmes and infrastructures investment. The goal is a 15% increase in turnover and employment in the Italian bioeconomy by 2030. Based on Italy’s strategic geopolitical position in the Mediterranean basin, BIT II also includes actions to improve sustainable productivity, social cohesion and political stability through the implementation of bioeconomy strategies in this area. This paper provides an insight into these strategies and discusses the strengths and weaknesses of the sectors involved and the measures, regulatory initiatives and monitoring actions undertaken.

Abbreviations

CEN: European Committee for Standardization; GES: Good Environmental Status; KPI: key performance indicators; R&I: research and innovation.

Keywords: Bioeconomy strategy; Circular Bioeconomy; Italian Bioeconomy

Introduction

Sustainable food security, sustainable management and exploitation of agriculture, forestry, marine biological resources, and city waters and biowaste, are pivotal for Italian growth wherever the national economy, society and environment are reconnected. The Italian bioeconomy relies on the national

sectors producing and transforming biomass, namely agriculture, livestock, forestry, fisheries and aquaculture, together with the food and bio-based industries. The latter includes the wood processing, pulp paper industries, biorefineries, the modern pharmaceutical, cosmetic, chemical, textile and energy industry sectors that use biobased products, sectors that exploit municipal wastewater and biowaste, and some marine and maritime activities (**Figure 1**). As shown in Figure 1, the overall turnover of the Italian bioeconomy in 2017 was €330B, and it employed 2 million workers [1,2]. According to a recent assessment, turnover and employment in the Italian bioeconomy increased by about 1.25% per year from 2011 to 2017, and by about 2% from 2017 to 2018 [3].

The Italian bioeconomy sectors support the regeneration of rural and coastal areas as well as the restoration of industrial sites, by spurring new economic growth and boosting local job opportunities. These sectors also counteract biodiversity loss by mitigating the adverse effects of climate changes on ecosystems, protecting land against changes of use and guaranteeing the availability of water resources. In addition, the conversion of by-products and biowaste from primary production and the related transformation of biomass into valuable bio-based chemicals, materials and fuels play a pivotal role in enabling Italy to achieve its targets for resource saving and CO₂ emission reduction in the coming years. Given its proven economic, environmental and social importance in Italy, the bioeconomy sits within the strategic areas of smart specialization and innovation. In 2017 the Italian government launched a tailored national strategy (BIT) [4], which was updated in 2019 (BIT II) [5]. BIT II is part of the National Smart Specialization Strategy and will be implemented in synergy with the Italian National Strategy for Sustainable Development [6]. This approach is aligned with EU regulatory efforts focusing on energy, agriculture, forestry and marine sectors while concentrating strongly on circularity and waste management, in line with the revised European bioeconomy strategy published in 2018 [7]. Italian national legislative initiatives incorporate these guidelines and are intended to guarantee standards of sustainability in order to stimulate the marketing of bio-based products.

Objective, vision and planned activities of BIT II

The strategy for the Italian bioeconomy is to increase both turnover and jobs by 15% from 2017 to 2030 [5] and to boost the sustainable valorization and regeneration of national biodiversity (both terrestrial and marine), ecosystem services and marginal/abandoned lands or industrial sites.

This will be achieved by: a) moving from sectors to systems, by effectively interconnecting the main pillars of the Bioeconomy through leveraging of deeply rooted traditional sectors as well as local public and private stakeholders; b) creating value from local biodiversity and circularity, respecting natural harvest cycles; c) efficiently aligning regional, national and EU policies and promoting a cohesive political commitment to the implementation of the Bioeconomy; and d) promoting the bioeconomy in the Mediterranean area, to enhance local social cohesion and political stability by exploiting the PRIMA partnership [8] and the BLUEMED initiative [9], as well as the macro-regional initiatives EUSAIR [10] and WEST MED [11].

The first Italian Bioeconomy strategy (BIT) was approved in February 2017, after 2 months of public consultation. It was updated in 2019 (BIT II), following consultation within the Ministries (including those of Agriculture, Food, and Forestry Policies; of University and Research; of Economic Development; and of Environment, Land, Sea), the governments of the 21 Italian regions and autonomous provinces, and the public and private stakeholders in the national technology clusters active in the agri-food, biobased industry and blue growth domains. Collectively, these comprise the “National Bioeconomy Coordination Body” of the Italian Presidency of Council of Ministers [12]. BIT II was formally approved on May 14, 2019. The strengths, challenges, opportunities and main research and innovation priorities for each of the main pillars of the Italian Bioeconomy described in BIT II are reported in Tables 1-4.

Role, needs and opportunities of the main Italian bioeconomy sectors

The critical resources and challenges of the bioeconomy are, on the one hand, the resource efficiency and environmental sustainability of production, and on the other, the interconnection of the bioeconomy

sectors across wider, locally routed and circular value chains, capable of reconciling technological advances with conservation of ecosystems. This requires the delivery of knowledge, novel technologies and up-to-date services, which in turn relies on improved integration between scientific disciplines and cross-disciplinary education, training and technology/knowledge transfer. To be effective, socioeconomic and technological strategies must be built on these bases and support the locally routed implementation of the required interdisciplinary innovations. They must also be accompanied by initiatives to enhance public awareness and facilitate cooperation and synergy between education providers, researchers, innovators, communicators and consumer representatives, including through the facilitation of informal learning. Finally, to reverse the scattering of resources, there is an urgent need to leverage public and private stakeholders, fill the gaps in regulations and align European, national, regional research and innovation (R&I) investments and policies.

A short description of the main features, needs and opportunities of the key pillars of the Italian bioeconomy is provided below. The R&I priorities required to implement the vision and corresponding actions identified by the national strategy document are also reported.

Primary production: Agriculture, forestry and related industrial sectors

Crop and animal production in Italy contributes €33B to its gross domestic product and employs more than 900,000 workers [1,2]. The total agricultural area corresponds to 16.5M hectares, only about 80% of which is currently exploited. Rural development and diversification are undeniable priorities, especially in marginal areas, where there is a dearth of services of public interest. Nonetheless, given the variety of its land and its long, complex historical heritage, Italy has a unique richness of biodiversity and food traditions. Agriculture has a vast potential in the context of the bioeconomy, in relation to the efficient management of resources and the adoption of sustainable production models for goods and ecological and social services.

Forest covers around 11M hectares in Italy – approximately 36.5% of its total land. Given the Mediterranean location of Italy and its diverse landscape - spanning from sea to high mountains - its forests host a wide variety of plant ecosystems. It is worth noting that the sustainable management of Italian forests covered 10% of Italy's total Kyoto target for CO₂ emission reduction, and that there is a national carbon credit market for voluntary emission compensation [5]. The land surface occupied by forest has increased by 26% over the last 30 years and by 5% in the last 10 years, due to a fall in agricultural activities, especially in coastal areas and inland hills and mountains [13]. In 2017 the entire wood/furniture supply chain amounted to more than 80,000 companies employing about 400,000 people, with an annual turnover of €40B, while the cellulose industry has an annual turnover of about €22B, involving over 3,800 companies and 72,000 employees [1,2]. However, despite this remarkable industry 80% of wood is imported from other countries, especially the Balkans, which can provide raw wood materials at very low costs. The national wood processing industry is therefore highly specialized in the use of pre-treated raw material. This means that there is only modest exploitation of Italian wood production potential (about 18%), and is mainly (60%) used for energy production. In fact, solid biomass fuels are the main source of renewable energy in Italy (90% of thermal energy), in part because the bioenergy sector has developed a very dynamic value chain that includes biomass producers and traders, stove manufacturers, energy plant managers, etc. [14].

Non-wood (or wild) forest products and forest-related ecosystem services are also worthy of interest. The former include a number of products (mushrooms, truffles, herbs, cork etc.) that are often deeply rooted in traditional knowledge, local economies and forest management practices [5].

Finally, the role of wood is also gradually increasing in the national bioconstruction and bio-based chemical industry. The overall value of this industry in 2017 was about 700M, comprising 6,300 buildings: a 6% increase on 2014 [15].

Ecosystem services are increasingly recognized as an important component of forest ecosystems. However, there is still a substantial lack of integration between primary production and industrial wood

processing and valorisation pathways, with an adverse effect on both socioeconomic growth and the international competitiveness of the entire value chain. A new tailored national strategy to improve synergy within this value chain was recently launched by the Ministry of Agriculture, Food and Forestry Policies, which is also currently developing a national public-private partnership in the sector.

Food Industry

The Italian food industry generates an annual turnover of €137B and involves 400,000 jobs [1,2]. It comprises 57,000 companies, of which most are very small SMEs (over 88% of companies in the sector have fewer than 9 employees). It is one of Italy's most resilient industrial sectors, seeing growth even during the recent longstanding economic crisis. This is due above all to the worldwide success of Italian products, thanks to well-known trademarks and brands as well as the protection of high-value national products by geographical indications (822 products - Italy has more registered products than any other EU Member State). **Figure 2** lists the core Italian food products marketed internationally. The National Technology Cluster on Agri-food "CL.A.N." [16], consisting of a multi-stakeholder network of more than 120 prominent national stakeholders (companies, public and private R&I centres, universities, etc.) in the main agro-food chains, offers a noteworthy contribution to pinpointing the sector's challenges and opportunities in relation to sustainable growth.

Bio-based industry

The Italian bio-based industry has developed innovative industrial processes for manufacture of bio-based products and services from non-food and residual biomass and biowaste, in part originating from cities. It thus encompasses the national agro- and forest-based sectors and the food industry, including the processing and valorisation of its by-products and waste. It also includes the municipal wastewater and biowaste management sectors, which use innovative technologies to produce biogas, bioenergy and useful feedstocks. Finally, it includes important segments of the national pharma, cosmetic, chemical and textile industries that transform biobased ingredients, polymers, materials and biomass into high value products.

Italy is the European leader in bio-based industry. It has developed a number of innovative proprietary technologies in the chemistry and industrial biotechnology sectors [17-20], made noteworthy investments, and generated a variety of new products now marketed both nationally and internationally [5]. **Figures 3 and 4** show the distribution of biorefinery facilities and bio-based research centres, pilot and demo plants as of 2018. Bio-based plastics and rubber account for about €1.69B turnover, employing 7,000 workers [1, 2, 21, 22]. Bio-materials are also gaining attention for applications such as building envelopes, as well as in the construction sector in general. Electricity and heating from biomass and bio-energy in a broad sense (turnover more than €2B and 2,000 employees) are consolidated sectors, together with next-generation bio-fuels (€169M). Other highly specialized sectors include biopharmaceuticals (€15.022B and 36,000 employees), bio-cosmetics and bio-based chemicals (€3.112B with 7,000 employees), bio-textiles (€16.44 and 76,000 employees) and bio-based apparel (€32.804B and 200,000 employees) [1,2]; the latter two are closely linked to high-value products under the "made in Italy" brand.

The bio-based industry also valorises biological materials from vertical indoor agriculture, urban, agricultural and industrial biowaste, effluents and wastewater through the manufacture of bio-based methane, fertilizers, lubricants and essential amino acids for feed production. Italy is a leader in the high-tech environmental requalification and conversion of former industrial areas and sites into biorefineries, with over €1B of private investments. Biorefineries produce innovative or novel bio-products and bio-chemicals and include four world-beating flagship plants, the first of their kind [5]. In these plants, small, medium and large local companies and farmers work together to exploit the sustainable production and efficient use of biomass, following a cascading approach to increase the added value of

agricultural production while respecting the biodiversity of local areas. In the EU, Italy is second only to Germany in the production of biogas and bio-methane, with 1,924 installed plants [5].

The National Technology Cluster on “Green Chemistry”, SPRING [23], plays a prominent role in the promotion of the Italian bio-based sector. This national platform brings together more than 100 of the main stakeholders in the value chains, including farmers, entrepreneurs and entrepreneurial associations as well as prominent R&I centres and universities. Its private stakeholders include small, medium and large companies involved in bio-based chemicals, oleochemistry, bio-lubricants, cosmetics, wheat and corn wet-milling, bio-plastics and bio-methane production.

The Blue Bioeconomy

Italy has one of the longest coastlines in Europe, at about 8,000 km. This gives it remarkable sea-based resources, including food, microbes, energy, materials and landscapes. The blue growth sector as a whole, which also includes transportation, ship building and tourism, is estimated to have an annual turnover of is making about €45B and employs 835,000 workers [24]. About 20% of these come from fisheries and marine aquaculture and the exploitation of marine algae, microbes, enzymes, and biowaste from fishery and aquaculture product processing, as well as the biomonitoring and bioremediation of contaminated marine water/sediment systems.

Italy is the second largest fish producer in Europe, and ranks fourth for aquaculture production [25]. Nevertheless, 75% of fish consumed in Italy is imported. This is mostly owing to the eating habits of its citizens, who prefer a broader and often more “exotic” range of species and services.

About 20% of visitors to Italy are attracted by sea-based tourism, which is the second most important contributor to Italy’s international tourism economy. In addition, 64% of Italians spend their holidays in coastal locations. In relation to the blue economy, the Italian Technology Cluster on “Bluegrowth”, BIG, is a unique national organization bringing together 41 public and 41 private stakeholders with the aim of working together to improve growth, innovation and human capital in the blue (bio)economy [26].

Main challenges, opportunities and R&I needs of the Italian bioeconomy

Tables 1-4 summarize the main challenges and opportunities, not yet fully exploited, of the main sectors of the Italian bioeconomy, as well as the actions identified to address them. The text quoted in these tables originates from BIT II (2019) (5).

Measures to support the strategy’s adoption

Over the last 5 years, the Ministries of Agricultural, Food and Forestry Policies, of Education, University and Research, of Economical Development and for Environment, Land and Sea have invested about €500 million to support R&I in the domains of bioeconomy. A number of accompanying measures have been identified to create the framework conditions enabling the effective nationwide adoption of the bioeconomy and BIT II priorities, alongside initiatives to increase corporate social responsibility and social awareness on the role of the bioeconomy in a changing climate, society and ecosystem. The main measures [5] include:

1. Ensuring strong coordination between the relevant ministries and between ministries, regional authorities and public and private stakeholders, including the national bioeconomy technology clusters. This will enable the development of coherent R&I programmes, legislative frameworks and education actions by improving effectiveness and minimizing duplication and fragmentation. A permanent National Coordination Body on the Bioeconomy has been established for this purpose at the Presidency of Council of Ministers of the Italian Government. This body, which comprises representatives from all

the aforementioned stakeholders, also has a mandate to ensure the adoption of the additional measures below.

2. Ensuring demand-side innovation policy tools, such as standardization, labelling and public procurement. Life cycle thinking and an eco-design approach should be at the heart of the transition.
3. Enforcing green public procurement, promoting consumer communication and information to increase their awareness of bio-based products, highlighting their positive social and environmental impact (green jobs, social acceptance, energy efficiency, reduced greenhouse gas (GHG) emissions, benefits for the conservation of ecosystems and biodiversity), and adjusting fiscal measures and policies in order to increase private demand for bio-based products.
4. Creating a “bioeconomy marketplace” in order to match the supply and demand of biomass, technology and services (i.e. a database of the available biomass and biowaste, technological processes, research projects, etc.) to facilitate the implementation of showcase industrial symbiosis, technological innovation and best practices.
5. Supporting the growth of start-up companies through open-access infrastructures for pre-industrial scaling-up and organization of competent regional hubs for effective technology transfer.
6. Revising academic and advanced education programmes in the context of new economic and productive scenarios; creating initiatives for the education and professional training of new bioeconomy specialists through programmes for technical schools, academic courses and Executive Masters degrees in Bioeconomy, in partnership with private, industrial and agricultural stakeholders. Supporting local administrations in reinforcing their bioeconomy knowledge and skills through dedicated training courses and acquisition of expertise.
7. Supporting corporate social responsibility by proposing a methodological framework enabling companies to highlight the bio-based content and features of their bioeconomy processes and products. This can rely on life-cycle assessments, extended accounting and green reporting, the carbon balance and the environmental footprint. Promotion of voluntary labelling or other certificate schemes, to enable end users to be reached effectively and to facilitate assessment by institutional bodies.
8. Promoting the use of sustainability standards, certification schemes and labels to support the bio-based market and the creation of a ‘level playing field’ between bio-based products and conventional products;
9. Promoting consumer empowerment through relevant professional information and communication on the impact and benefits of the bioeconomy.

The regulatory framework: regulatory initiatives, standards and market pull initiatives

Regulations emanating from the EU are of key relevance for Member States, and an increasing number of national regulations derive from their direct application. However, in these cases, there is a need to ensure that the policy objectives of such regulations are consistent, timely and fully coherent, to minimize the risk of uncertainty and maximize their impact. The EU regulatory initiatives below are of relevance in this respect to steer and stimulate the full deployment of the Italian bioeconomy, as they set the overall framework within which the national regulatory initiatives are developed.

EU regulatory initiatives

- Agriculture is central to the European bioeconomy, with the greatest employment and turnover in the sector. Possible synergies with current policy tools and common agricultural policy (CAP) measures are vital to unlock the potential of the bioeconomy in rural, coastal and urban areas.
- The European Forest Strategy of 2013, updated in 2018, is the reference framework and European directive for forest actions and interventions carried out, in various capacities, by the EU and its Member States.
- The Marine Strategy Framework Directive aims to achieve the Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource upon which marine-related economic and social activities depend. In addition, it sets the explicit regulatory objective that "biodiversity is maintained by 2020" as the cornerstone for achieving GES.
- The EU's 2030 Climate and Energy Policy Framework strengthens the Paris agreement (which entered into force in November 2016) and paves the way for the EU's ongoing process of decarbonization. Building on the EU's 2020 climate and energy package, the implementation of the 2030 targets imposes changes in the existing legislation and calls for the adoption of new legal instruments, including updates to existing legislation on renewable energy and energy efficiency promotion, as well as to the EU Emissions Trading System (ETS).
- The Circular Economy Package "Closing the loop - An EU action plan for the Circular Economy", adopted in December 2015, sets ambitious targets and a timeline for reducing the pressure on natural resources and boosting the market for secondary raw materials.
- The Waste Framework Directive sets the basic concepts and definitions related to waste management, explaining when waste ceases to be waste and becomes a secondary raw material (i.e. end-of-waste criteria), and how to distinguish between waste and by-products.

National regulatory initiatives

The Environmental Annex to the 2014 Stability Law on *Measures for promoting the green economy and limiting the excessive use of natural resources* defined the important milestones for future Italian environmental strategies. Since then, many steps have been taken to reach these milestones. These include establishing the first permanent intergovernmental Natural Capital Committee (led by the Ministry of Environment, Land and Sea and comprising 10 Ministries, the National Association of Italian Municipalities, the Conference of Regions, 5 public research bodies and 9 experts) which, since 2017, has supervised the preparation of the yearly "Report on the State of Natural Capital in Italy".

The main focus is on the green economy and the circular economy, in particular through:

- (1) Green Public Procurement (GPP) setting minimum environmental criteria for new public sector purchases, including in relation to labelling and certifications;
- (2) the creation of a Natural Capital Committee to provide data on natural biomass consumption and monitor the impact of public policies on natural resources and conservation of ecosystem services;
- (3) incentives for the purchase of post-consumption materials and the management of specific waste fractions (including composting) and incentives to increase the share of collected waste;
- (4) the establishment of a payment system for ecosystem and environmental services and the production of a catalogue of environmentally-friendly and environmentally-harmful subsidies. The Italian Ministry of the Environment, Land and Sea also recently passed a regulation (End-of-Waste decree n. 62/2019) defining the criteria for the recovery and recycling of absorbent products for personal use, such as used nappies and sanitary towels. This new regulation means that the heterogeneous polyolefin-based plastics, SAPs (Super Absorbent Polymers) and cellulose deriving from the recovery of absorbent products for personal use may cease to be qualified as waste (i.e. end of waste). This will allow the development of an innovative industrial technological sector, creating new jobs and recovering as much as 900 thousand tonnes of waste every year.

The same Ministry also recently (July 2019) published the second edition of the *Catalogue of environmentally-harmful and environmentally-favourable subsidies*. These are broadly defined in accordance with the applicable legislation and include, among others: incentives, concessions, subsidized loans and exemptions. The aim of the catalogue is to support Parliament and the government

in defining environmental policies to implement EU and international recommendations. The latest edition estimates the value of favourable subsidies as €15.2 billion and of harmful subsidies as €19.3 billion. The reduction or elimination, for instance, of fossil fuel subsidies would help stimulate the uptake of a circular bioeconomy, levelling the playing field for biomass usage [27] and freeing up between €2 and 4B of resources to incentivize the development of alternative and sustainable technologies.

Standards and market pull initiatives

In the framework of the Lead Market Initiative, introduced in 2006 to boost the market uptake of bio-based products, the EC issued a number of standardization mandates to the European Committee for Standardization (CEN):

- M/429 for the elaboration of a standardization programme for bio-based products;
- M/430 on bio-polymers and bio-lubricants;
- M/491 on bio-solvents and bio-surfactants;
- M/492 for the development of horizontal standards for bio-based products.

The CEN technical committee CEN/TC411 was established in 2011, as part of mandate M/492. This technical committee focuses on horizontal aspects of the bioeconomy, providing a consistent terminology, methods for determining bio-based content in a product, application of Life Cycle Assessment (LCA) and sustainability of the biomass used, and guidance on the use of existing standards for end-of-life options. This should ultimately serve the purpose of boosting the market penetration of bio-based products. A detailed description of the key results of Mandate M/429 is provided in [28].

Although there are numerous well-developed sustainability assessment and certification schemes within the different sectors of the bioeconomy, a number of potential gaps can be identified in relation to sustainability principles, criteria and indicators [29]. The existing standards and certification schemes tend to lack focus on the assessment of end-of-life and circularity aspects, while social and economic impacts are often only superficially addressed. In any case, as demonstrated in a recent EU-funded Horizon 2020 research project (STAR-ProBio, <http://star-probio.eu>), the introduction of sustainability certification for bio-based products would lead to an increase in Italian demand for such certified products, exceeding the usual green premium associated with sustainable and green products. This, in turn, would stimulate the market uptake of bio-based products.

Implementation and monitoring of the Italian bioeconomy

The bioeconomy involves the production of a wide number of different products, commodities, intermediate goods and technologies. A great part of the future development of this evolving economy will depend on the convergence and transformation of different existing markets and industries, as well as the creation of new markets. This affects data quality and homogeneity. As bioeconomy development policies are designed and implemented through a place-based approach, the wide diversity of regional and urban sites is a critical factor. Furthermore, there are many hybrid sectors for which the official statistics do not distinguish between bio-based and non-bio-based products. For instance, biochemicals are estimated to make up a certain fraction of chemicals. Hence, the construction of monitoring tools and systems is also subject to the evolutionary process of data availability. Nevertheless, a set of key performance indicators (KPI), based on ISTAT (Italian National Institute of Statistics) and national data, for monitoring developments in the supply and demand of the Italian bioeconomy have been adopted [1,2,5]. The KPIs monitor the following dimensions: biomass availability (e.g. forestry biomass production and imports); production and employment structures (e.g. innovative start-ups and employment in bioeconomy sectors); human capacity (e.g. tertiary education, R&D employment); investments (private and public R&D expenditure); innovation (e.g. applications for intellectual property rights (patents, trademarks, designs); demographic analyses; and markets (turnover, value added, exports, imports).

Another set of indicators refers to the bioeconomy's sustainability, to monitor how proposed measures affect the environmental and social systems. Their main objectives are ensuring food security; managing natural resources sustainably; reducing dependence on non-renewable resources; coping with climate change; and enhancing economic growth. New methodological approaches (currently undergoing in-depth assessment by the EU) will also be considered in the implementation phase of the bioeconomy monitoring system, as soon as a common framework is defined [29-35].

Conclusions

The bioeconomy is a fundamental pillar of the Italian economy and an enabling element of the Italian new green deal. To further enhance the opportunities deriving from the bioeconomy throughout Italy, the government set up a national strategy for the bioeconomy (in 2017, revised in 2019) and a tailored National Coordination Group at the Presidency of the Council of Ministers, which is responsible for effective implementation of the strategy nationwide. This strategy should enable a 1.25% annual increase in turnover and employment in the Italian bioeconomy over the next years and, above all, should provide an essential contribution to steering future Italian competitiveness in this prominent sector of the European economy and Green Deal package.

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Bioeconomy in Italy in 2017

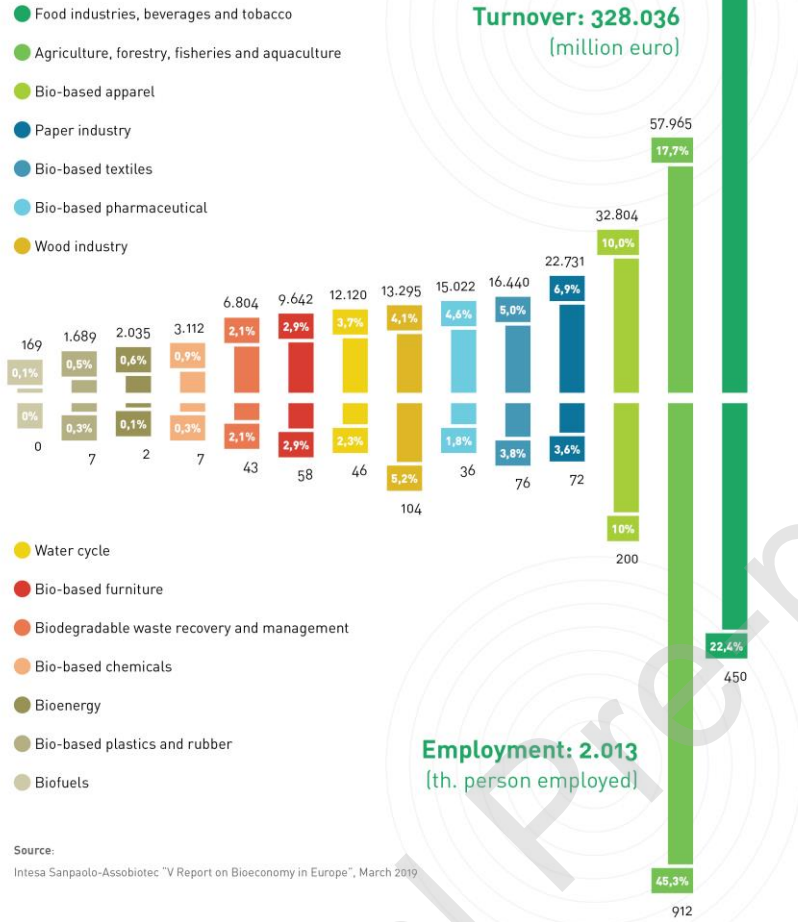


Figure 1: Turnover and employment of bioeconomy in Italy in 2017 (Eurostat data) [1,2]

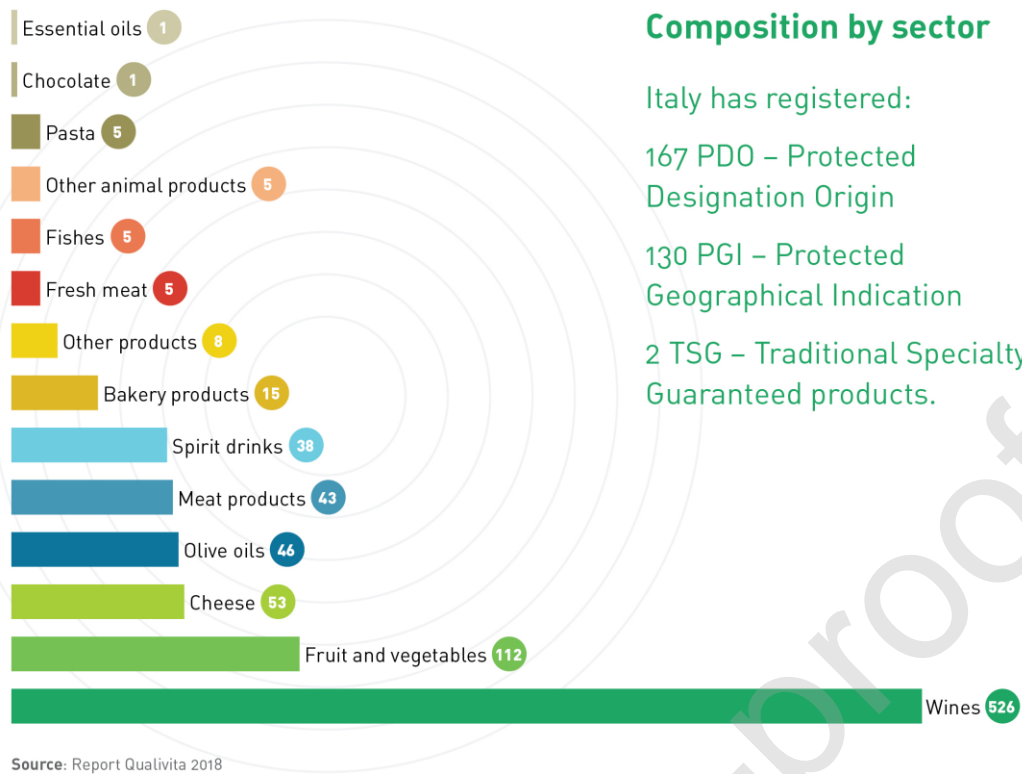


Figure 2: Core Italian quality food products of major relevance on the international markets [5]

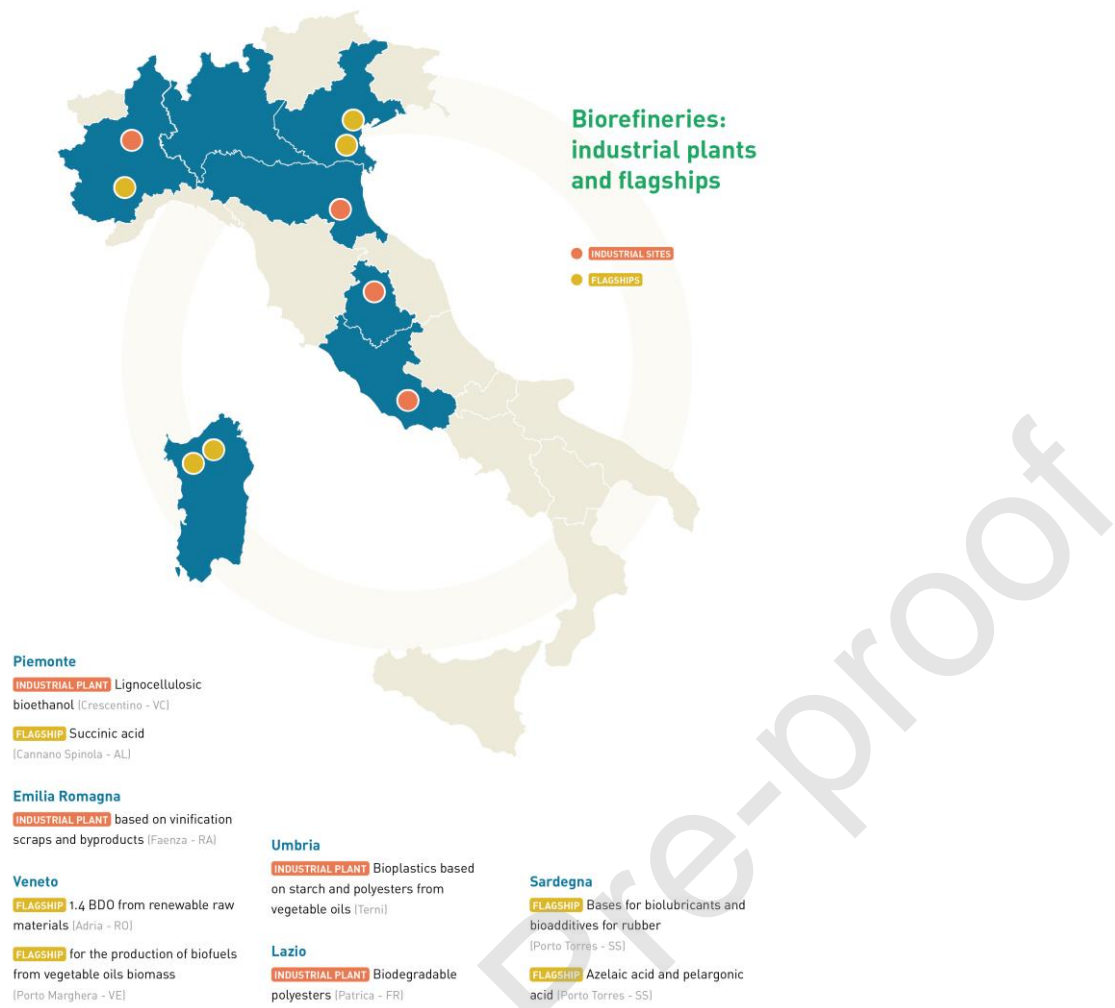


Figure 3. Main full scale biorefinery facilities available in the country [5].



Figure 4. Bio-based/biorefinery research centers, pilot and demo plants available in the country [5].

Table 1: Analysis of the main challenges and opportunities for Italian primary production and the corresponding R&I priorities and actions identified by BIT II to address them. The entire text quoted in Table 1 comes from BIT II 2019 [5], and is therefore placed in quotation marks.

Challenges	Opportunities	R&I priorities
<i>Primary production: Agriculture, forestry and related industrial sectors</i>		
<ul style="list-style-type: none"> • “Large surfaces of cultivable land no longer used (marginal/abandoned/degraded lands) due to degradation/soil organic matter depletion associated with climate change or urbanization and industrialization; • Abandoning of rural areas due to limited profitability of farms and unsatisfactory logistics services; • Weak and poorly organized local value chains; • Lack of innovation, in particular to respond to climate change, water scarcity and alien pests/plants; • Lack of effective communication, education and training of farmers about new business opportunities and innovation management; • Lack of policies to protect farmers’ income in the current value chains. “ • “Abandonment of several of the forest areas belonging to national and regional heritage with consequent biodiversity depletion also due to climate change; 	<ul style="list-style-type: none"> • “Rich local biodiversity and agricultural ecosystem services to be valorized through the empowerment of local communities; • The local crops/varieties available regionally to be adapted to climate change and low-input cultivations; • The innovative multi-purpose cropping systems able to regenerate marginal/abandoned/degraded lands, and to create value for local rural Communities; • The innovative precision-farming and breeding techniques, enabled by available digital services, allowing for input reduction, sustainable and resilient intensification of agriculture and biodiversity preservation; • The adoption of new business models for the diversification of rural incomes, adding value to local production and products/food and increasing the integration with other economic sectors such as bio-based industry; 	<p>a) To boost sustainable and resilient primary production through actions and R&I aimed at:</p> <ul style="list-style-type: none"> • “Implementing more effective models of agricultural and forestry production, such as climate smart agriculture and forestry, precision farming, ecological intensification, agroecology and regenerative agriculture to improve the productivity and resilience of animals and plants; • Using biodiversity and modern genetic programs and microbiome knowledge to improve the resilience of animals and plants to biotic and abiotic stresses; • Improving the understanding of microbiomes role as strategic biological players for the resilience but also health and productivity of plants and terrestrial and aquatic/marine animals as well as soil and water ecosystems; • Adopting multidisciplinary approaches based on the concept of Water-Energy-Food nexus to assess the global

<ul style="list-style-type: none"> • Lack of strategies for the management, genetic improvement and integrated valorization of autochthonous forestry products and ecosystem services; • Insufficient integration of the sector with the national wood processing industry, which imports medium/low quality/cost wood for producing medium low-quality wood products; • Lack of education and training of forest company managers in new business opportunities.” 	<ul style="list-style-type: none"> • The valorization of the underexploited agricultural, forestry and breeding residues and side streams with the production of food ingredients and valuable bio-based chemicals, fertilizers (eg, the recovering and recycling of phosphorus from sewage sludge, manure and food waste) and energy; • The role of agriculture in the urban and peri-urban areas (including indoor vertical agriculture) for their regeneration, for greener and healthier cities.” • “Independent Sustainable Forest Management schemes for a tailored integrated management and exploitation of forests; • Innovative techniques, based on digital services, enabling input reduction, sustainable and resilient intensification of forestry; • Nature-based and eco-designed solutions (including new sustainable organic fertilizers and bio-pesticides) enabling the preservation of biodiversity, the implementation of low-impact management protocols; • Forest certification schemes and Life Cycle Analysis practices for the sustainable exploitation of valuable national wood and deriving materials, also for the production of added value 	<p>sustainability of production processes, throughout a specific set of indicators;</p> <ul style="list-style-type: none"> • Boosting organic farming and livestock; • Exploiting the role of agriculture, including urban and peri-urban agriculture, indoor vertical agriculture, and forestry in the circular bio-based society, with a systemic view on the links between primary production, ecosystems and human health; • Implementing techniques, based on digital service and satellite monitoring, for mitigating soil erosion and preventing hydrogeological disasters.” <p>b. “To improve resource management and efficiency by:</p> <ul style="list-style-type: none"> • Developing of soil preservation and regeneration schemes, including effective risk-management strategies for the prevention of pollution deriving from the end life of materials and chemicals dispersed in the soil and water streams; • Creating locally integrated agri and forestry industrial supply chains for a better valuing of product quality and a stronger contribution to rural development.” <p>c. “To improve multiple functions and benefits of land, rural and abandoned areas by:</p>
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	<p>products and energy via tailored biorefinery schemes;</p> <ul style="list-style-type: none">• Business innovation models with local value chains deriving from forest products, like mushrooms, truffles, herbs, cork etc. as a contribution to rural development opportunities.”	<ul style="list-style-type: none">• Developing new processes for the conversion of residues and side streams of agriculture and forestry value chains into bio-products and bioenergy by following a “cascade approach”;• Developing and production of high value certified new wood products, wood-based materials, composites and bioenergy from wood obtained from the sustainable management of forests;• Promoting the creation of new integrated agricultural value chains based on best practices, on the sustainable use of biomass, and on the restoration of organic matter in soils also in marginal and abandoned lands.” <p>d. “To improve human and social capital and social innovation by:</p> <ul style="list-style-type: none">• Enhancing the skills, the human and social capital of farmers, foresters and other actors of the rural economy, also through education and digital based technologies;• Involving young land managers in the transfer and adoption of good practices, preservation and valorization of traditional knowledge and promotion of connection with the ecological and the socio-economic value of agriculture and forestry systems, thus creating possibilities for expanding farming and
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		supporting knowledge sharing, also in the less favored areas of the country.”
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Table 2: Analysis of the main challenges and opportunities for the Italian food industry and the corresponding R&I priorities and actions identified by BIT II to address them. The entire text quoted in Table 2 comes from BIT II 2019 [5] and it is therefore placed in quotation marks.

Challenges	Opportunities	R&I priorities
<i>Food Industry</i>		
<ul style="list-style-type: none"> • “High level of product counterfeiting and imitations; • Weak connection of the food industry with the primary production sectors and the small size and fragmentation of supply value chains in a landscape in which the global food demand is rapidly growing (between +50 % and +100 %, according to the latest foresight studies); • Low efficiency of food making chains with high resource consumption and excessive production of byproducts/waste (≈ 15 M T/y) which, given current national legislation, are only partially and poorly valorized and mainly landfilled; • Social reluctance to change dietary behavior; • High environmental impact associated with the large volume of packaging used and the use of “single use plastics”.” 	<ul style="list-style-type: none"> • “New “typical/quality” food products (DOP, IGP, STG, etc.) to be valorized, preserved and protected at the European and international level; • New emerging global markets seeking for safe and high-quality foods; • Alternative protein sources (insects, algae etc.) and novel food microbes utilizing pedoclimatic national areas and existing industrial infrastructures taking advantage from climate change and anticipating novel food security needs; • Food byproducts to be used for the production of food ingredients and feed, as well as of agri-food waste, to be exploited for the integrated production of bio-based chemicals, materials, energy as well as fertilizers and compost; • “New Urban Food Systems”, eg. the local food production and distribution of fresh and high nutritional value products, 	<p><i>A sustainable and competitive agri-food system for a safe and healthy diet</i></p> <p>a. “To improve healthy diets and people’s health by:</p> <ul style="list-style-type: none"> • Evaluating national consumer preferences, attitudes, needs, behaviour, improving personalized nutrition and increasing lifestyle education and communication; • Tackling obesity and other non-communicable diseases through food formulations/substitutions, changes in retail, catering practices and in consumer behavior; • Producing food with improved bioavailability of nutrients and developing smart and personalized nutrition solutions (e.g. metabotype tailored) stemming on new production/delivery technologies and

	<p>which create new business opportunities by overcoming the dichotomy between urban and peri-urban areas.”</p>	<p>ICT approaches and combining the healthy and nutritional aspects with improved taste;</p> <ul style="list-style-type: none">• Further exploiting knowledge on gut microbiome to define consumer needs for a healthy diet;• Preventing, detecting and remediating biotic and abiotic contamination of food/feed products.” <p>b. “To improve food safety, security, defense, and integrity by:</p> <ul style="list-style-type: none">• Developing rapid at-line or on-line detection tools for food and feed safety (vs pathogens, allergens, toxins, chemicals, nanomaterials, etc.) and integrating such tools in risk analysis protocols;• Establishing the vulnerability of food and feed to fraud, counterfeiting or intentional contamination or adulteration in order to develop risk prevention, protection, and mitigation strategies for food business operators;• Developing innovative packaging and smarter supply chains to support efficient delivery to consumers and prolonged shelf-life, reducing waste production;• Developing ICT tools for smart food distribution and utilization at the domestic and city level;
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		<ul style="list-style-type: none">• Exploiting microbiomes for a more sustainable food system facilitating sustainable production choices and business strategies.• Characterization of typical local food (DOP, IGP, STG, etc.) leveraging on advanced methods aiming at defending their authenticity and traceability” <p>c. “To boost sustainable, competitive, and innovative food manufacture by:</p> <ul style="list-style-type: none">• Preventing food losses and waste production, water and energy consumption and improving food preservation, distribution and logistics, by integrating Industry 4.0 tools and key enabling technologies solutions into value and supply chains;• Adopting new Urban Food Systems to overcome the dichotomy between urban and peri-urban areas, with local food production and distribution of fresh and high nutritional value products;• Promoting of networking among small agri-food enterprises for the development of novel, longer or more robust supply and value chains at regional or multi-regional level;• Developing of new models based on symbiotic society approaches in cooperation with social sciences and humanities forecasting a proactive role
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		<p>for consumers towards more sustainable food production and consumption behavior;</p> <ul style="list-style-type: none">• Developing recycling and reusing supply chains of packaging plastics, overcoming territorial resistance and developing sites capable of increasing the quantity of recycled material, the energy recovery and preventing disposal;• Developing of new technologies or innovative solutions that accompany food companies in the transition towards the circular economy model.” <p>d. “To boost food policies, supply chains, markets, and communities by:</p> <ul style="list-style-type: none">• Creating knowledge, technology and regulations for the production of food and feed ingredients from local fruit, vegetal and meat industry by- and co-products;• Promoting short local food chains for health and contrast non-market based networks of food provisioning;• Developing food products and promoting ethno food marketing, taking account of migration and changing demographics in the country;• Developing innovation support systems by integrating different production systems, sharing infrastructures and
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		logistic solutions, in order to maximize yields, efficiencies and reduce wastes.”
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Table 3: Analysis of the main challenges and opportunities for the Italian bio-based industry and the corresponding R&I priorities and actions identified by BIT II to address them. The entire text quoted in Table 3 comes from BIT II 2019 [5] and it is therefore placed in quotation marks.

Challenges	Opportunities	R&I priorities
<i>Bio-based industry</i>		
<ul style="list-style-type: none"> • “Limited and discontinuous accessibility to sustainable non-food feedstocks; • Lack of regulations and specific end-of-waste criteria regarding classification and use of industrial biowaste (this currently prevents their use as feedstocks); • Limited market for national bio-based products, also due to their higher cost with respect to “petrol-based” products; • Presence on the Italian market of products that do not comply to international standards and labeling on bio-based and biodegradable products, and insufficient clarity/transparency in the labeling; • Huge and risky investments needed for buildup of industrial flagship infrastructures in the sector and short life and slow growth of startup companies 	<ul style="list-style-type: none"> • “Agricultural, forestry and breeding residues and side streams currently underexploited; • Abandoned/marginal lands suitable for the production of autochthonous or planted industrial biomass; • Former oil refineries/industrial sites that can be partially converted into biorefineries; • New regenerative processes for cleaning polluted areas and engineering measures for the reconversion of abandoned industrial and urban sites, promoting the valorisation of brownfields rather than virgin land; • Expertise and of already assessed lab scale processes for the conversion of residues, byproducts and side streams into food/ feed ingredients, 	<p>a. “To boost production of bio-based products and bioenergy in the framework of a circular economy by:</p> <ul style="list-style-type: none"> • Fostering the demand for bio-based products from a consumers’ perspective through gathering evidence on consumers’ practices in relation to bio-based products and how these may form new market places and develop new and inclusive business solutions using bio-based services; • Mapping the biomass supply - including novel and alternative feedstocks (biowaste, CO₂, marine biological resources) building on existing knowledge, approaches and tools and developing new, innovative, energy saving logistics and preservation/stabilization strategies for different types of biomasses/biowaste;

<p>due to the lack of facilities for pre-industrial scaling-up and competent regional poles for effective technology transfer;</p> <ul style="list-style-type: none"> • Fragmentation of standards and certification schemes in the biogas and biomethane production sector.” 	<p>biochemicals, biomaterials and high-quality organic fertilizers;</p> <ul style="list-style-type: none"> • Successful case studies on bio-based products developed in Italy (i.e. compostable shopping bags/foodservice ware, biodegradable mulch film/bioherbicides/ biolubricants) and price premiums for environmentally sustainable products (Made green in Italy); • New emerging technologies for capturing and converting CO₂ into fertilizers, chemicals and polymers; • Methods for the valorization of stabilized digestates from biorefinery and bioenergy plants, to provide soils with assimilable organic carbon; • Prominent national collections of microbes (bacteria, yeasts, molds, fungi, algae, etc., also from the sea), enzymes and genetically improved microbes of industrial interest; • Large network of biomethane producing facilities (mainly fed with agri-food biowaste and municipal organic waste) and relevant potential for the valorization of wet fraction of urban waste with the production of compost to improve soil fertility in urban and rural areas; • Integration of the existing wastewater purification plants and anaerobic 	<ul style="list-style-type: none"> • Boosting the valorization of organic waste and effluent organic matter to obtain high added value bioproducts, and developing systemic approach to innovation, for the development of tailored technologies for their valorization, also with the aid of advanced digital technologies for big-data analysis, optimization and automation; • Improving flexibility in terms of feedstock and products produced by bio and chemical processing integration, and downstream processing, of the current biorefining processes and schemes, including existing biomethane producing facilities; • Creating of knowledge, technology and regulations for the production of food and feed ingredients from local fruit, vegetal and meat industry byproducts; • Updating the map of climate-change related risks and implementing mitigation strategies for urban and suburban areas, thanks to the use of Bioeconomy products coming from local chains and the exploitation of urban farming and the circularity in management of water, wastewater and organic fractions; • Developing a coherent policy framework and regulations promoting bio-based
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	<p>digestors with biorefineries schemes to combine the production of their conventional products with that of high value bio-based chemicals and compounds;</p> <ul style="list-style-type: none"> • Pioneering initiatives leveraging on Bioeconomy “every-day products” for informing, educating and engaging urban communities in urban re-generation projects (e.g. BioCities).” 	<p>products, education, training, information and communication in the bio-based sector;</p> <ul style="list-style-type: none"> • Promoting Mediterranean primary production, food and bio-based industries to enhance social cohesion and political stability, a healthier environment and new occupational opportunities in the macro-region. • Exploiting trans-national synergies and complementarities in the Mediterranean area, also via initiatives like PRIMA and BLUEMED, aiming at the long-term coordination of European and non-EU countries of the whole Basin; • Reconnecting communities and nature in urban settings through projects, research and education: building innovative linkages between humans and regenerative ecosystems to create liveable, healthier and resilient cities (BioCities). <p>“</p> <p>b. “To foster “Demonstration plants/test beds for cascading use of biomasses” by:</p> <ul style="list-style-type: none"> • Facilitating the use/conversion of former oil refineries/industrial sites but also biogas/wastewater facilities for the implementation of novel biorefineries; • Creating a network of laboratories, microbial and enzymes collections, etc. supported by new infrastructure to form
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		<p>test beds that can develop process technologies and new products in a demo-scale that underpin the development of biorefineries (industrial scale) for maximising the use of a variety of non-food biomass and biowaste;</p> <ul style="list-style-type: none">• Integrating ICT resources (e.g. mediating ICT-based interfaces) within value chains for inter-organizational governance mechanisms, aiming at satisfying the simultaneous need for control, collaboration, and adaptability.”
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Table 4: Analysis of the main challenges and opportunities for the Italian marine bioeconomy and the corresponding R&I priorities and actions identified by BIT II to address them. The entire text quoted in Table 4 comes from BIT II 2019 [5] and it is therefore placed in quotation marks.

Challenges	Opportunities	R&I priorities
<p><i>Blue Bioeconomy</i></p> <ul style="list-style-type: none"> • “The unsustainability of fishing and under-exploitation marine aquaculture; • Sea productivity adversely affected by pollution (chemical pollutants, litter etc.), invasive species and climate changes; • Increasing import of fish from areas with low environmental regulation and monitoring; • Environmental pressure on coasts stemming from tourism and recreation activities and urbanization.” 	<ul style="list-style-type: none"> • “Environmentally safe practices for marine aquaculture (multi-trophic but and also offshore) and of robust aquaculture supply chains; • New emerging business models for connecting tourism to ecosystem valorization; • Unique landscape and cultural heritage of coastal areas as resource of local communities and worth to be preserved and valorized according to sustainable and integrated schemes; • Technology for the marine bioenergy production.” 	<p>a. “To boost sustainable exploitation of marine resources by:</p> <ul style="list-style-type: none"> • Increasing the sustainability of fishery and marine aquaculture also including ethical and ecological aspects; • Promoting the production and processing of seaweed, jellyfish and phytoplankton as possible sources of human edible proteins but also of biomass for the production of bio-based chemicals, materials, energy, and methane; • Improving the resilience, ecological compatibility, robustness of the main aquatic production species via breeding programs based on genomics, microbiome management and precision phenotyping; • Improvement and integration of monitoring and control systems to prevent illegal fishery through ICT, Big Data Analytics and Industry 4.0 technologies; • Exploiting sustainably the large micro- and meso- plankton stocks for producing high value substances (e.g. pharmaceutical, cosmetic, nutraceuticals,

		<p>etc.) and bio-based products as well as enzymes for technological applications;</p> <ul style="list-style-type: none">• Exploiting marine biomass as well as byproducts and waste deriving from fishery and aquaculture value chains within an integrated biorefinery scheme (e.g. for producing pharmaceutical, cosmetic and nutraceuticals);• Exploiting the deep sea biosystems according to sustainable practices and schemes;• Implementing new business models at the land/sea interface as well as in wet lands;• Promoting the increase of the readiness level of the most promising Marine Energy technologies and their integration with other activities at sea (e.g. desalinization process, aquaculture etc.);• Fostering fisheries as a recreational activity within an ecotourism approach also by strengthening interactions with commercial fishery activity in remote coastal and rural areas.” <p>b. “To protect and valorize marine environment by:</p> <ul style="list-style-type: none">• Promoting biomonitoring and bioremediation of microplastics and xenobiotic compound contaminated sediment systems, mitigation measures for preventing new contamination due to
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		<p>plastics and other and new pollutants and development of marine degradable bio-based plastics to limit/prevent marine litter and pollution;</p> <ul style="list-style-type: none">• Analysing marine ecosystem resilience and regime shifts in relation to climate change and other natural or anthropic pressures, and develop mitigation strategies;• Promoting sustainable solutions (i.e. advanced biofuels, electric propulsion, electrification of ports) aimed at reducing maritime ports and transport pollution;• Promoting, conserving and sustainably valorizing of the marine landscapes and cultural heritage.”
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