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Table of Abbreviations

Abbreviation	Description
AD	Anaerobic Digestion
AVO	(CZ) Association of Research Organisations
BBTs	Bio-Based Technologies
BGK	(PL) Polish Development Bank
BIG	(IE) Bioeconomy Implementation Group
BIT	(IT) National Bioeconomy Strategy
CAEM	(EL) Centre of Agricultural Entrepreneurship of Messinia
CAP	Common Agricultural Policy
CAP SP	(PL) National Strategic Plan of the Common Agricultural Policy
CDTI	(SP) Centre for Industrial Technological Development
CeRSAA	(IT) Centre for Agricultural Experimentation and Assistance
CERTH	(EL) Centre for Research and Technology – Hellas
CHP	Combined Heat Power
CNR	(IT) National Research Council
CO2	Carbon dioxide
CREA	(IT) Council for Agricultural Research and Economics
CSCM	Complete Supply Chain Management
CSIC	(SP) Spanish National Research Council
CSO	Central Statistics Office
CTA	(SP) Andalusian Technological Corporation
CTIA	Czech Trade Inspection Authority
CZ	Czechia

Abbreviation	Description
D	Deliverables
DAFM	Department of Agriculture, Food, and the Marine
EAFRD	European Agricultural Fund for Rural Development
EAGF	European Agricultural Guarantee Fund
EBS	(IT) Solid Biomass Energy Association
EC	European Commission
ECBF	European Circular Bioeconomy Fund
EFSI	European Fund for Strategic Investment
EI	Enterprise Ireland
EIB	European Investment Bank
EIC	European Innovation Council
EIP-AGRI	European Innovation Partnership for Agricultural productivity and Sustainability
ELSAT	(EL) Hellenic Statistical Authority
EMFF	European Maritime and Fisheries Fund
EPA	Environmental Protection Agency
ES	Spain
ETBE	Ethyl tert-butyl ether
ETS	Emissions Trading Scheme
EU	European Union
EU CAP	European Commission Common Agricultural Policy
FAN	Forestry and Agricultural Network
FAO	Food and Agriculture Organization of the United Nations
FDI	The food, drink and tobacco industry sectors

Abbreviation	Description
GDP	Gross domestic product
GHG	Green House Gases
GJ	Gigajoule
GNI	Gross National Income
GR	Greece
GSRT	(EL) General Secretariat for Research and Technology
GVA	Gross Value Added
HVO	Hydrogenated Vegetable Oil
IBEC	(IE) Irish Business and Employers Confederation
iBO	(EL) Institute for Bio-Economy and Agri-Technology
IE	Ireland
IFAPA	(SP)Andalusian Research and Training Agricultural, Fisheries, Food and Organic Production
IMBB	(EL) Institute of Molecular Biology and Biotechnology
INE	(SP) National Statistical Institute
INFC	Italian national forest inventory
IRCrES	(IT) Sustainable Economic Growth Research Institute
IRNAS	(SP) Natural Resources and Agrobiology of Seville
IRWiR PAN	(PL) Institute of Rural and Agricultural Development of the Polish Academy of Sciences in Warsaw
ISIF	(IE) Irish Strategic Investment Fund
IT	Information technology
IT	Italy
IWMU	Integrated Waste Management Units
JA	(SP) Andalusian Regional Government - Junta de Andalucía

Abbreviation	Description
KIS	(PL) Polish National Smart Specialisation Strategy
KOWR	(PL) National Support Centre for Agriculture
LEOs	(IE) Local Enterprise Offices
LULUCF	Land Use, Land Use Change and Forestry
MACC	(EL) Mediterranean Agri-Food Competence Centre
MASAF	(IT) Ministry of Agriculture, Food Sovereignty and Forests
MIUR	(IT) Ministry of University and Research
MS	Member States
K	Thousands
NACV	(CZ) National Agency for Agricultural Research
NCBiR	(PL) National Centre for Research and Development
NECP	(IT) National Plan for Energy and Climate
NGEU	Next Generation EU Programme
NRRP	(IT) National Recovery and Resilience Plan
NTMA	(IE) National Treasury Management Agency
NUT	Nomenclature of territorial units for statistics
OFMSW	Organic Fraction of Municipal Solid Waste
OG	Operational Group
PAN	(PL) Institute of Agriculture and Food Biotechnology of the Polish Academy of Sciences
PDO	Protected Designation of Origin
PFR	(PL) Polish Development Fund
PGI	Protected Geographical Indication
PL	Poland

Abbreviation	Description
POME	Palm Oil Mill Effluent
PRN+	(PL) Polish Rural Network +
PRTR	(SP) National Recovery, Transformation and Resilience Plan
R&D	Research and Development
R&I	Research and Innovation
RDF CM	(EL) Regional Development Fund of Central Macedonia
RDP	Rural Development Programme
RES	Renewable Energy Sources
RIS3	National Research and Innovation Strategy for Smart Specialization
RRF	Recovery and Resilience Facility
S3	(IT) Regional Smart Specialisation Strategy
S4Andalucia	(SP) Smart Specialisation Strategy for the Sustainability of Andalusia
SBCI	(IE) Strategic Banking Corporation of Ireland
SEAI	(IE) Sustainable Energy Authority of Ireland
SEP	State Environmental Policy
SFI	(IE) Science Foundation Ireland
SIOSE	(SP) Information System of Land Occupation of Spain in Andalusia
SLS	Sanitary Landfill Sites
SMEs	Small and Medium Enterprises
SWOT	Strengths, Weaknesses, Opportunities, and Threats analysis
TMU	Transitional Management Units
TRL	Technology readiness level
TUC	(EL) Technical University of Crete

Abbreviation	Description
UAA	Utilised agricultural area
URE	(PL) Polish Energy Regulatory Agency
VA	Value Added
VC	Venture Capital
VUPT	Fodder Research Institute in Troubsko
WDC	(IE) Western Development Commission
WMU	Waste Management Units
WP	Work Package
WTS	Waste Transfer Stations

Table of Units

Abbreviation	Description
€	Euro
B€	Billion euros
GJ	Gigajoule
GWh	Gigawatt hours
ha	Hectares
hab.	Habitants
J	Joule
k€	Thousand euro
kg	Kilograms
kJ	Kilojoule
kJ/kg	Kilojoule per-kilo

Abbreviation	Description
km	Kilometres
km2	Square kilometres
kt	Kilo tonnes
ktoe	Thousand tonnes of oil equivalent
kWh	Kilowatt hours
m	Metres
m.a.s.l.	Metres above sea level
M€	Million euro
m2	Square metres
m3	Cubic metres
Mha	Million hectares
MJ	Megajoule
mm	Millimetres
Mt	Million tonnes
MWe	Megawatt electric
MWh	Megawatt hours
PJ	Petajoule
t	Tonnes
tCO2e	Tonne of carbon-dioxide equivalents
TWh	Terawatts hour

Executive Summary

This document provides an overview on regional dynamics in terms of OGs activity, maturity of BBTs and potential in each of the six representative regions in BBioNets project. The report offers a characterization of each region going through geographical, economical, agricultural and forestry and bioeconomy regulations aspects considered as levers and barriers for the use of Biobased Technologies (BBTs) in the different regions. Economic indicators were extracted from the Rural Observatory database from European Union so that they are comparable. Then it focuses on the current state of biomass valorisation, considering the main aspects such as biomass availability, managements, bio-products, R&D systems and support and financing policies. In addition to this, an analysis of the Operational Groups (OGs) funded in each region was mainly conducted using information provided by EIP CAP Network Project Database and complemented with other local databases such as national visors of OGs and regional calls resolutions. This overview allows to understand the context, level, and trends of the work conducted by OGs in the region/country.

The key result of this study is a classification of each region/country in green, yellow, or red light according to its capability of implementing BBTs. A “green light” means that the country has the economic resources and financial support to implement BBTs, and in addition, its action plans include valorisation as an action that helps to mitigate carbon emissions; a “yellow light” means that the country has only one of the above aspects; and a “red light” means that it has none of the above aspects. This analysis was conducted according to the characteristics of the region such as the economic situation or available resources, the economic support environment, and the availability of biomass, in order to get a picture of the current situation in each of the regions. South Moravian in Czech Republic is reported as red light; Poland and Greece (Crete and Peloponnese) as yellow light, while Ireland, Italy (Piemonte, Valle d’Aosta & Liguria), Spain (Andalusia) and Greece (Central Macedonia) are green light.

1 Introduction

This document gathers the reports on high-level study in terms of OGs activity, maturity of BBTs and potential in each of the regional dynamics conducted by BBioNets partners in each region/country. This deliverable is a result of the T2.3 from the work package 2. CTA formulated the guidelines and provided it to partners for them to conduct a literature review at their national/regional level accordingly.

This document has three main objectives. Firstly, to introduce and characterize the region/country providing an in-depth understanding of regional dynamics, maturity and potential. This includes a brief geographical, economic and bioeconomic description of the region, as well as the characterization of the agricultural and forestry sectors. In the second place, to provide an accurate picture of the biomass valorisation in the region. Finally, to present an overall analysis and description of current practices regarding OG-identified and locally implemented BBTs to understand the context, level, and trends in the region/country. A detailed analysis of the technological aspects of BBTs has also been undertaken. Based on the literature review and the analysis of the context that facilitate the uptake of BBTs, the region/country is classified in green, yellow, or red light according to its capability to implement them in the primary sector.

This deliverable provides a comprehensive description of the current state of OG-identified and locally applied BBTs to be used as a benchmark for future assessment when presenting suitable alternatives and their cost-effectiveness to primary producers together with T2.1 and T2.2 results.

1.1 EU bioeconomy framework

1.1.1 EU bioeconomy strategy

The European Bioeconomy Strategy emerged in 2012 recognising that bioeconomy, currently worthing 2.3 trillion in turnover and accounting for 8.2% of the EU's workforce, plays a key role in addressing EU challenges. It was identified five objectives to which the strategy was to contribute: (i) ensuring food security, (ii) managing natural resources sustainability, (iii) reducing dependence on no-renewable resources, (iv) mitigating and adapting to climate change, and (v) creating and maintaining EU competitiveness.

In a recent report by the European Commission, titled "Bioeconomy Strategy Development in EU Regions", the development of bioeconomy strategies at the regional level within the EU-27 was analysed. The Figure 1. EU regions with bioeconomy strategy.Figure 1 presents the importance and the status of the bioeconomy strategies in the different regions.

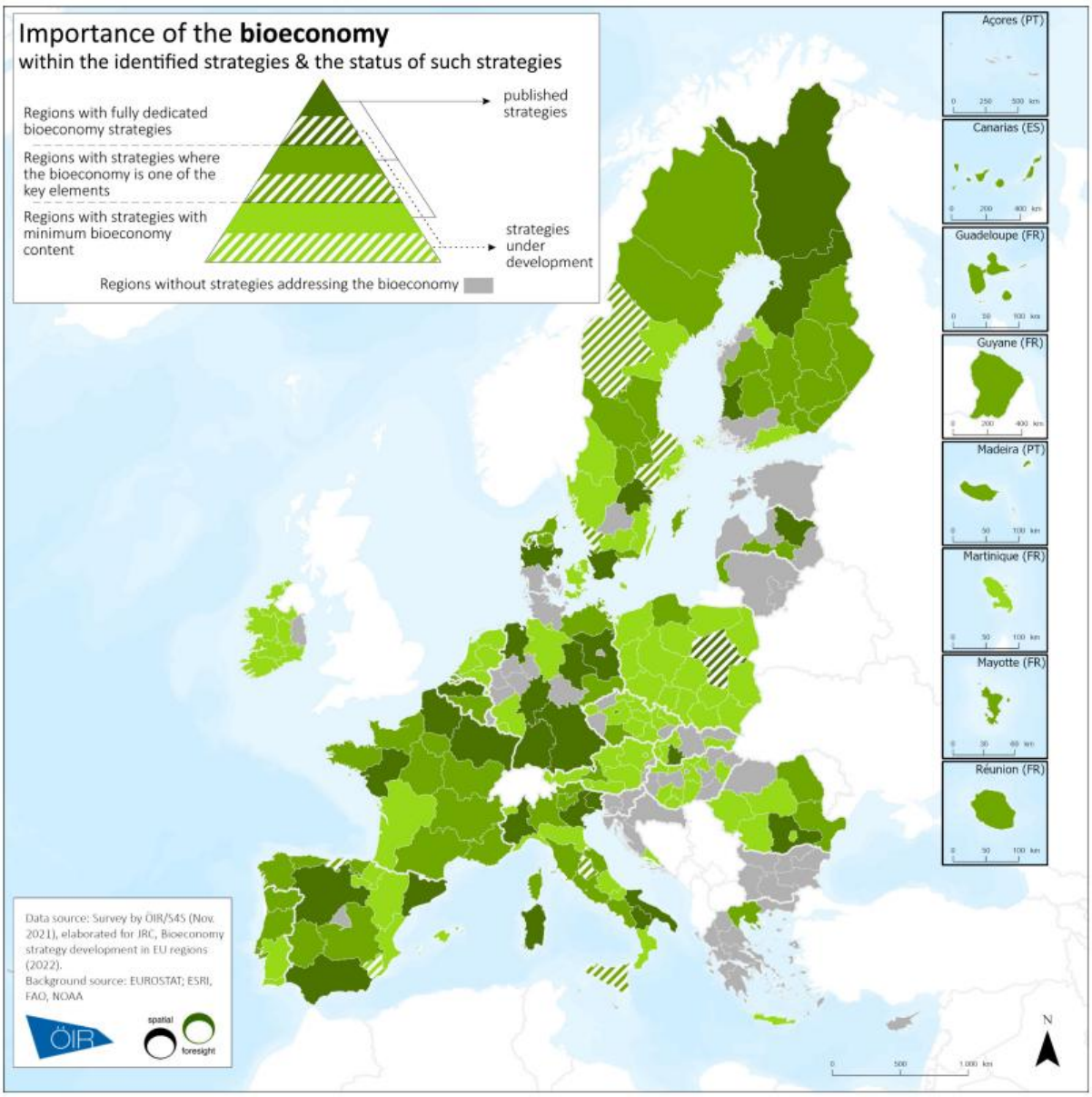

Figure 1. EU regions with bioeconomy strategy.

In particular, the Strategy succeeded in mobilising Research and Innovation funding in bioeconomy by a) doubling the EU Research and Innovation funding dedicated to the bioeconomy under Horizon 2020, b) increasing support to private investment and public/private partnerships through the launch of the BBI JU, and c) encouraging Research and Innovation investments in the Member States.

1.1.2 EU funding programmes

At European level, there are a number of programs providing technical assistance and funding facilities for projects and innovative ideas in bioeconomy and agri-food sector, like the Marie Skłodowska-Curie actions, Eurodesk, European Cooperation in Science and Technology (COST). Other European Initiatives and Financial Instruments, potentially supporting bioeconomy are listed below:

- **European Investments Bank loans** – Loans for projects in agriculture, forest based, blue economy, waste management. Loans guaranteed by European Fund for Strategic Investments for high-risk investment in production and processing of food, biobased materials, and bio energy.
- **European Circular Bioeconomy Fund (ECBF)** - Investment in late-stage bioeconomy starts-ups.
- **LIFE –** Programme for the Environment and Climate Action.
- **InnovFin** – Loans and guarantees to innovative businesses for research and innovation activities.
- **Innovation Fund** – Funding supporting the deployment of biobased solutions in carbon intensive sectors.
- The **European Agricultural Fund for Rural Development (EAFRD)** focuses on new value chains based on the smart and integral use of agro-waste and specialized crops for industrial uses to be grown on marginal lands, creating the necessary interface for agro-energy and bio-based industries. They provide financial support for sustainable agricultural practices, the development of bio-based industries, and the valorisation of agricultural and forestry residues.
- **European Agricultural Guarantee Fund (EAGF) -** helps the EU's farmers to provide a secure supply of safe, healthy, and affordable food. EU countries can also use the EAGF to fund specific schemes to help small and medium sized farms, farmers who operate in areas of natural constraint, and sectors undergoing difficulties. The EAGF also funds measures to support and stabilise agricultural markets. These measures operate as part of the Common Market Organisation.
- **European Maritime and Fisheries Fund (EMFF)** - helps fishers to adopt sustainable fishing practices and coastal communities to diversify their economies, improving quality of life along European coasts.
- **EIT - European Institute of Innovation and technology.**
- **SMP – EUROCLUSTERS: Single Market Programme – Joint Cluster Initiatives**
- **PRIMA Programme**
- **COSME Programme**
- **Interreg Programmes**

- Horizon Europe, specifically Cluster 6.

2 Czech-Republic - Southern Moravia and Highlands

2.1 General description of the region

2.1.1 Geographic description of the region

The Czech Republic is a landlocked country situated in the western part of Eastern Europe. The Czech Republic is the 21st largest country in Europe, with a total area of 78,864 square kilometres. It is low-lying, with an average elevation of 433 metres above sea level. The highest mountain peak is Sněžka, which reaches 1,602 metres. The country has no access to the open sea and is bordered directly by four neighbouring countries: Austria, Germany, Poland, and Slovakia.

Vysočina Region - Czech Highlands

The Vysočina Region, often referred to as the Czech Highlands, is located in the central part of the Czech Republic, spanning the historical lands of Bohemia and Moravia. This region is notable for its picturesque rolling hills, extensive forests, and numerous artificial lakes and ponds. Covering an area of approximately 6,800 square kilometres, Czech Highlands has a population of around 517,960 people, 4.75% of the country's total population.

The Region is distinguished by its rugged topography, elevated altitude, and sparse population density. The region is characterised by a moderately cool climate, with relatively high precipitation and moderate temperatures [13]. This climatic condition is conducive to agricultural activities, particularly the cultivation of crops such as cereals, potatoes, and fodder plants. However, the region's cool and moist climate can occasionally impede the maturation of crops and the commencement of the harvest period, potentially resulting in delays. In terms of livestock, the climate is conducive to dairy farming and cattle breeding, due to the presence of extensive pasturelands and the suitability of conditions for the growth of fodder crops. The forestry sector in Vysočina benefits from these conditions, with a significant portion of the region covered by forests, predominantly spruce and pine. These climatic conditions facilitate robust forest growth, yet they also present challenges, such as an increased susceptibility to pests and diseases during wetter periods [6].

South Moravia

South Moravia, located in the southeastern part of the Czech Republic, is renowned for its fertile landscapes and extensive vineyards Covering about 7,188 square kilometres, it is one of the most important agricultural regions in the country, particularly known for wine production. The South Moravia Region has a population of 1,226,749 people, 11.25% of the country's population, with the capital city being Brno, the second-largest city in the Czech Republic with 10,900,55 people [6].

In comparison to other regions of the Czech Republic, South Moravia is characterised by a warmer and drier climate, which has resulted in the region becoming one of the most agriculturally productive areas in the country. The region's climate is conducive to viticulture, with extensive vineyards producing high-quality wines. Furthermore, crops such as cereals, sunflowers, and vegetables flourish in this climate. The warmer temperatures and longer growing seasons have a beneficial effect on crop yields and quality. The region is also conducive to livestock farming, with cattle and pig farming being particularly well-suited to the environment, which offers an abundance of feed crops. In forestry, the drier climate limits tree growth rates compared to more humid regions, but the region still maintains a substantial forested area with species such as oak and beech. However, climate change poses a risk

of increased droughts, which can stress both agricultural and forestry activities, necessitating the adoption of climate-smart practices to sustain productivity.

The climatic conditions have a marked impact on the agricultural, livestock and forestry sectors in both Czech Highlands and South Moravia. This emphasises the necessity for tailored practices to optimise productivity and sustainability in each region [2].

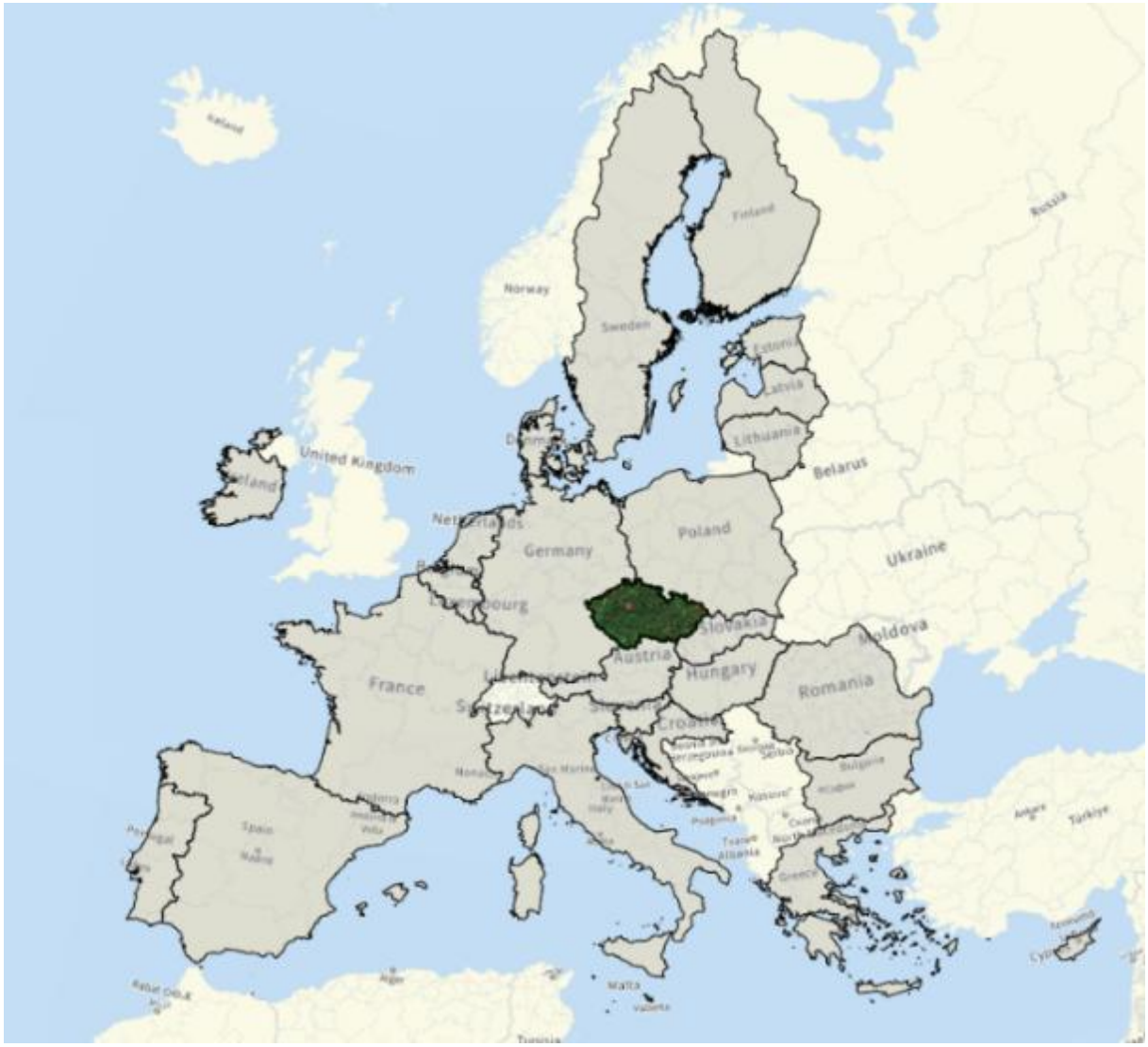

Figure 2: Location of Czech Republic in Europe (Source: Rural Observatory) [9].

2.1.2 Agriculture and forestry sectors in the region

Agricultural sector

In the Czech Republic in 2023, the total area of agricultural land under cultivation was 3,534,000 hectares. Of this, 71% was arable land, 27% was permanent grassland, and the remaining 2% was distributed among hop fields, vineyards, and orchards. The cereal harvest was 3% lower than the previous year, which had been above average. Conversely, the rape crop yielded more oilseeds (+9%). In comparison to the previous year, the production of legumes, root crops and fodder crops was found

to be lower, with decreases of 10%, 7% and 6%, respectively. Conversely, the yield of vegetables and hops exhibited positive growth, with increases of 15% and 57%, respectively. However, the harvest of fruit and vines experienced a notable decline, with reductions of 23% and 16% respectively [6].

The aggregate production of the items listed in the Figure 3 in the Czech Republic in 2023 was 28,040 tonnes. The aforementioned production figures relate to the following crops: cereals per grain, wheat, barley, legumes and protein crops for grain, potatoes, sugar beet, rape, and corn on the cob. The total production in the Highlands region is 2,834 tonnes, representing 10.1% of the total production. In the region of South Moravia, the total production is 3,255 tonnes, which represents 11.6% of the total production [6].

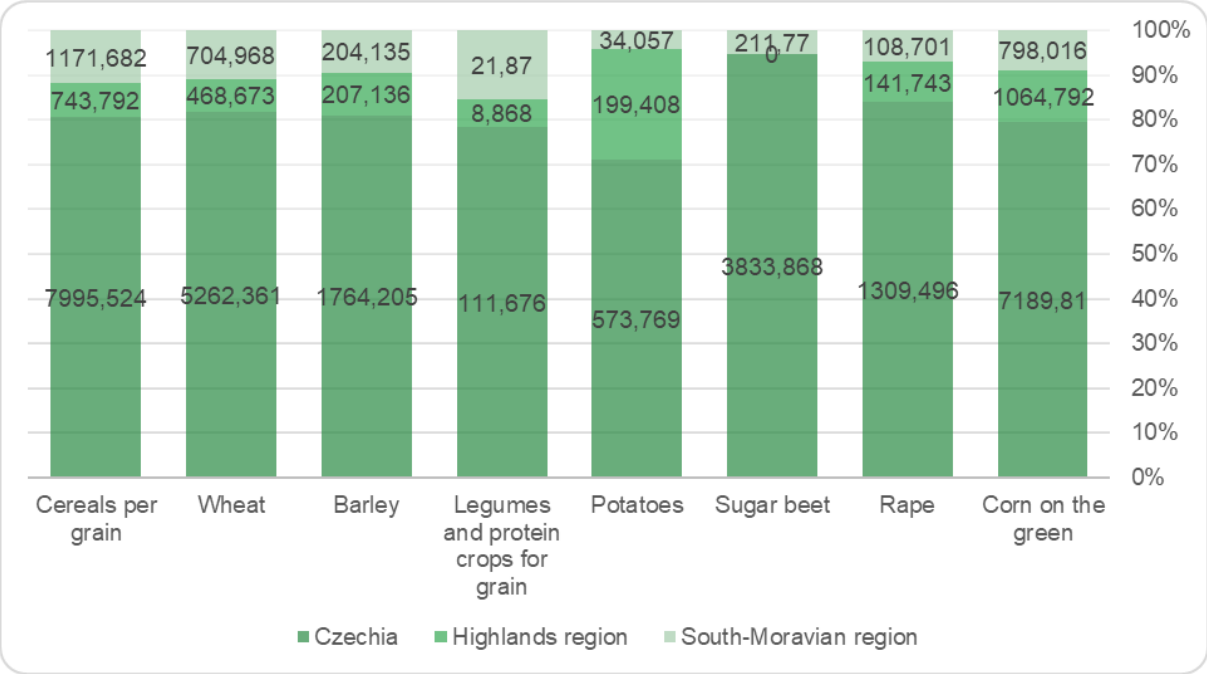

Figure 3: Main crops according to production quantities (t) (Czech Statistical office) [6]

Livestock sector

The agricultural industry represents one of the most significant sectors of the Czech economy, with farms accounting for 44% of the country's total land area. The country's agricultural production is characterised by a high degree of diversification. The principal export products are milk, livestock, grains, sugar, and malt. Approximately 13.7% of the Czech Republic's agricultural land is dedicated to organic farming practices.

Excluding poultry, the Czech Republic's most prevalent livestock species in 2023 were cattle (38.6%) and pigs (38.4%), with the generated livestock units exceeding those of cows, sheep, and goats combined. Conversely, in the Highlands region, the largest census was that of pigs (47.6%), followed by cattle (35.3%). In the South Moravia region, cattle constituted 29.9% of the livestock, with a significantly larger proportion of pigs (52.5%). The Figure 4 presents a graphical representation of the highest percentage of livestock in the Czech Republic and the Czech Highlands and South Moravia regions. The Table 1 provides a comprehensive overview of the livestock in the Czech Republic, organised by species and in numerical terms.

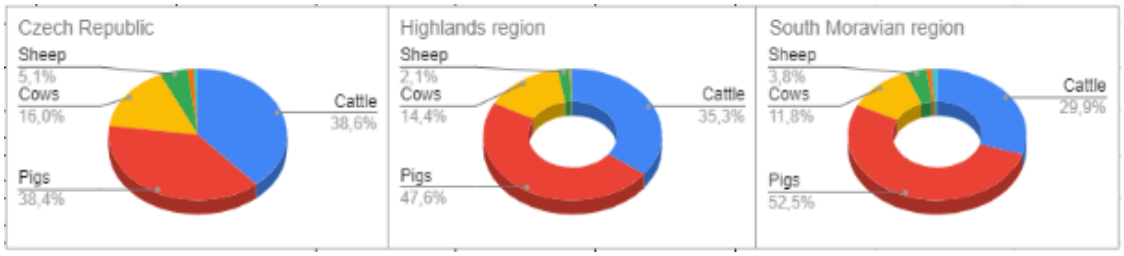

Figure 4: Chechia, Highlands and South Moravia region % of livestock production, 1st Q 2024 [6].

Table 1. Chechia, Highlands and South Moravia region of livestock production in pieces, 1st Q 2024 [6].

Livestock	Czech Republic	Highland region	South Moravian region
Cattle	1,369,593	218,932	65,687
Pigs	1,362,275	295,214	115,408
Cows	568,472	89,365	26,016
Sheep	179,158	12,803	8,452
Horses	37,087	1,812	1,977
Goats	28,757	2,311	2,422
Poultry	23,026,197	462,346	3,603,768

In the Czech Republic, the total quantity of meat produced in slaughterhouses during the initial three-month period of 2024 was 109,381 tonnes, representing an 0.8% increase in comparison to the same period in the previous year. This figure includes a 0.1% decrease in beef production, a 2.1% increase in pork production, and a 0.5% reduction in poultry production. The direct purchase of milk from producers demonstrated a 3.2% increase in comparison to the previous year. The total volume reached 338,391.9 litres, with 63,787.4 litres in the Czech Highlands region and 20,913.7 litres in the South Moravia region. [6]

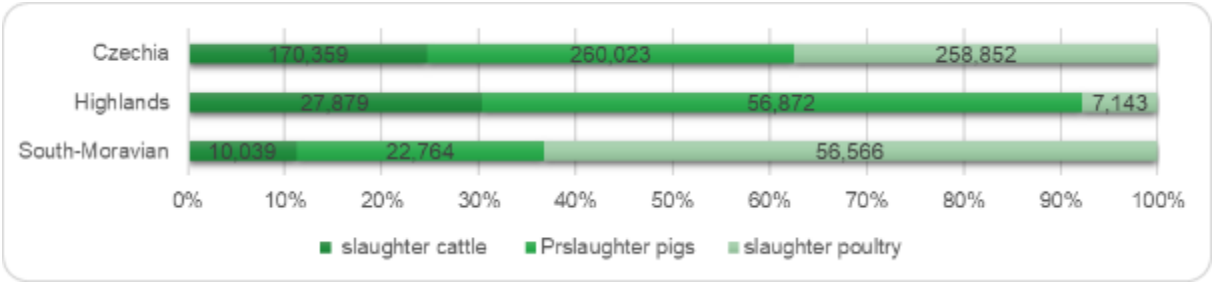

Figure 5: Chechia, Highlands and South Moravia region livestock production in t live weight, 1st Q 2024 [6]

Forestry sector

By the end of 2023, in the Czech Republic, forest land had been designated to an area of 2,681,764 hectares, with state forests accounting for 54% of this total.

The volume of wood harvested for processing in 2023 was 18.5 Mm³ of bark-free wood, representing 59.7% of the total volume harvested. Of this, 11.0 Mm³ was processed as part of random logging.

As in previous years, the majority of trees harvested were coniferous (89.8%), with deciduous trees accounting for 1.9 Mm³. Overall, spruce was the most prevalent species (74.4%), followed by pine (11.0%), beech (4.1%), and larch (3.3%).

Furthermore, the afforested area exhibited a decline in 2023, with a reduction of 4,747 hectares compared to the previous year, resulting in a total of 35,222 hectares. The majority of the forested area consisted of coniferous trees (52.7%). The most frequently used species in afforestation were spruce (31.8%), followed by beech (18.1%), oak (15.6%) and pine (8.1%).

The greatest extent of reforestation was observed in the Highlands Region, encompassing 8,044 hectares, which constituted 22.8% of the total afforestation in the Czech Republic.

The area of natural forest regeneration in the Czech Republic experienced a slight decline of 522 hectares, reaching a total of 9,566 hectares, representing a 5.2% reduction. Conifers were the most prevalent, comprising 55% of the total, while spruce (42.4%) was the most frequently utilised wood species. The most extensive natural forest regeneration also occurred in the Highlands Region (1,627 ha, representing 17% of the total natural forest regeneration in the Czech Republic) [6].

The South Moravian region encompassed 201.9 thousand hectares of forest land at the conclusion of 2023, representing 7.5% of the national total. In the preceding year, 1,364.4 thousand tonnes of wood were harvested from South Moravian forests. Of this quantity, 1,015.5 thousand m³ consisted of random mining, and thus excluded the wood without bark.

In the year 2023, the quantity of coniferous wood harvested was 1,024.6 thousand cubic metres. In terms of the composition of the harvested coniferous timber, spruce accounts for 52.8% and pine for 11.7%.

The extraction of deciduous trees in the South Moravian region exhibited a slight decline compared to the preceding period, reaching a volume of 339.8 thousand m³ of wood. This volume represents the largest output among the regions. The South Moravian Region is the primary producer of oak wood in the Czech Republic, with a yield of 116,000 m³ in the previous year.

In 2023, the volume of wood processed through random logging in the South Moravian Region was 1,015.5 thousand m³.

In the South Moravian Region, 446.1 thousand cubic metres of wood were processed due to insect pests in 2023, representing a 45.5% decrease compared to the previous year. As a consequence of natural disasters, the volume of wood obtained was 213.1 thousand m³, representing a year-on-year decrease of almost two fifths.

In 2023, a total of 4,464 hectares of land were afforested in the South Moravian Region. During the planting process, deciduous trees were selected as the preferred species, comprising 56.6% of the forested area. Additionally, 1,939 hectares of coniferous trees were planted in the South Moravian

Region [6]. The Figure 6 below shows the relationship between hectares of forest covered and timber harvest in the regions studied.

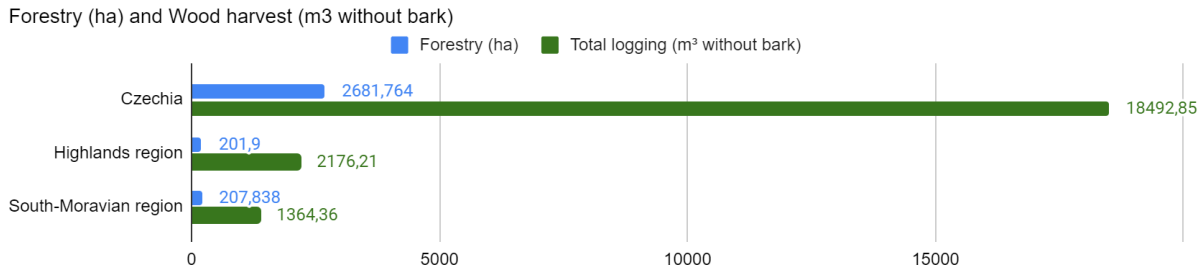

Figure 6: Forest Area in ha and Wood harvest in m³ without bark (Czech Statistical office) [6].

Table 2: Detailed information in Czech Republic

Location	Forestry area
Czech Republic	2,681,764 hectares
South Moravian region	Forestry area: 201.9 hectares
Species	Spruce, pine, beech, larch.

Agroindustry

According to data provided by the Czech Statistical Office, the agricultural sector in the Czech Republic comprised 22,839 registered enterprises in 2017. These enterprises are classified into three principal categories: large, medium, and small. The largest category, comprising 1,671 enterprises, accounted for 7.0% of the total, while the medium-sized category, which included 7,262 enterprises, represented 31.9%. The smallest category, which consisted of 13,806 enterprises, constituted 60.0% of the total. The data indicate that in the Highlands region, large enterprises constituted 9% of the total. In the context of the entire Czech Republic, the South Moravian Region is home to the largest number of small-sized agricultural enterprises, with 2,263 such enterprises managing 16% of all small farms in the country. The structure of land holdings of agricultural holdings operating in the decisive types of production and expressed in economic size classes confirms that traditional agricultural holdings of a universal multi-sectoral structure belonging to a mixed crop and livestock production group remain the dominant forms of production focus, characterised by a high concentration of land holdings. The second most significant category of enterprise is that of field production, which accounts for over 50% of the largest size group. The third most important type of production orientation in terms of land tenure is livestock farming of fodder [12].

According to the latest integrated survey of the Czech Statistical Office from 2020, the most recent reports indicate that, the least numerous groups in the Czech Republic are large agricultural enterprises, which make up 7% of all, almost 29,000 agricultural entities. However, these enterprises manage 63% of the total area of agricultural land and participate in livestock breeding from 77 % [17].

2.1.3 Economic Indicators

Southern Moravia positions itself as a significant economy in the Czech Republic with a gross domestic product (GDP) of over 33.6B€ (11% of the Czech Republic total). The GDP per capita is 27.73B€ [6]. Regarding its productive structure, in terms of gross value added (GVA), in 2023, the agriculture, forestry and fishing sector accounted for 794,100€ which represents 13.5% of the total. Accordingly, in the Highlands (with a population of only 518k) the 2022 GDP of the region is equal to 9.8B€, 3% of the Czech total, while the GDP per capita is at 19B€. In the same year, the GVA in the agriculture, forestry and fishing sector accounted for 8.7B€ [3].

South Moravia has an employment rate of 51.2%, below the Czech Republic total (81.7%). Agricultural activity is the main source of employment for 1.5% of the region's population [6]. In the Highlands, the employment rate is at 57.7%, and 6.9% of the total employment is in the agricultural sector [3].

The employment generated by the bioeconomy amounts to roughly 383,900 people (2021), of which 35.8% is attributed to agriculture, and 5.7% to the forestry sector. In agriculture and forestry, the number of people employed by these bioeconomy sectors has decreased by 1.9% and 0.7% respectively in the last five years. The agricultural GVA accounts for 31.5% of the total bioeconomy GVA at 3.67B€ (in 2021) and presented an increase of 22.6% in the span of 5 years (2017-2021). In terms of sectoral turnover, the sector contributes 9.97B€, 23.5% of the total bioeconomy turnover (2021) with an increase of 26.4% in 5 years. In the forestry sector, the GVA accounts for 6% of the total bioeconomy sector at 705.7M€ (2021), with a decrease of 27.4% between the years 2017 and 2021. Despite that, the forestry turnover in these 5 years has increased by 22.7% with 2.43B€, 5.7% of the total bioeconomy turnover in 2021 [8].

Table 3. Economic indicators by region/country [3].

Region/Country	Population (M hab)	GDP (kM€)	GDP per capita (k€)	GVA (kM€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
South Moravian, Czech Republic (2023)	1.22	33.6	27.73	0.794	51.2	1.5
Vysočina Region/ Highlands, Czech Republic (2022)	518K	9.833	19.306	8.678	57.7	6.9
Czech Republic (2023)	10.83	305.97	28.39	5.88	81.7	2.9

2.1.4 Bioeconomy regulatory framework

The Czech Republic has yet to establish a dedicated regulatory framework for the bioeconomy and bio-based economies. Currently, any relevant regulations are implemented in accordance with the EC

directives, and they are aligned with the existing legislation issued by the Ministry of Agriculture, the Ministry of Trade and Industry, and the CTIA (Czech Trade Inspection Authority) [3], [15].

The State Environmental Policy of the Czech Republic (SEP) outlines a strategy for the effective implementation of environmental protection measures in the Czech Republic up to 2020. The primary objective is to guarantee a healthy and favourable environment for Czech citizens, to make a substantial contribution to the efficient utilisation of all resources and to minimise the detrimental effects of human activities on the environment, including transboundary impacts. This will facilitate an improvement in the quality of life in Europe and worldwide. The SEP is focused on the areas of the conservation and sustainable utilisation of natural resources, climate protection and improvements to air quality, the protection and preservation of nature and landscapes, and the creation of a safe environment [3],[4].

In formulating the State Environmental Policy of the Czech Republic, the following fundamental principles have been considered: firstly, environmental policy integration ensures that environmental considerations are incorporated into all sectors of policymaking for cohesive and sustainable development. The prevention principle emphasises the implementation of initiative-taking measures with the objective of averting environmental damage before it occurs. In contrast, the precautionary principle suggests the adoption of precautionary actions in situations of scientific uncertainty, with the aim of preventing potential harm. The "polluter pays" principle stipulates that those who generate pollution are responsible for bearing the costs associated with its management, thereby ensuring the prevention of potential damage. The principle of cost-effectiveness is concerned with achieving environmental objectives in a manner that is both efficient and economical, with the objective of ensuring the optimal allocation of resources. An increase in public awareness leads to a greater demand for more robust environmental protection and sustainable practices. Ultimately, the principle of international responsibility emphasises the necessity for collaborative and concerted action among nations to address global environmental challenges [3],[4].

2.2 State of the art of biomass valorisation

2.2.1 Biomass resource availability

Agricultural biomass

The agricultural sector is traditionally noteworthy in the Czech Republic. The most important crops in the country are cereals, green harvested crops (maize and other forage crops), sugar and starchy crops and oil crops, e.g. rape, while permanent crops cover a relatively small percentage of the cropping area. Cereal grains are the main exported biomass of the country, whereas fruits and vegetables are the main imported commodities. Tertiary residues mainly in the form of food waste and human waste are also relevant with an annual production of around 0.8 Mtonnes of food waste and 0.219 Mtonnes of human waste (mainly in the form of sludge).

A significant percentage of the produced biomass is directed towards the livestock sector, either as feed or as animal bedding, which is estimated based on the number of recorded livestock and/or the stabling practices. The main source of feed are grains, the consumption of which is based on the animal food production and feed conversion ratios.

Currently, less than 1 Mtonnes of agricultural biomass is used in combustion or biofuel production. The biofuel production consumes around 650 Ktonnes of biomass, mainly rapeseed and sugar beets.

The overall technical use of straw is estimated at a maximum of 200 ktonnes. There are two major incineration plants of straw in the Czech Republic, one in Kutná Hora consuming around 70 ktonnes of straw annually and one in Jindřichův Hradec with similar supply. Annually, small straw pellet mills are estimated to consume around 20 ktonnes of biomass, and an estimation of maximum 10 ktonnes of straw is annually valorised for insulation or the production of construction materials [13].

Livestock biomass

The yearly production of cattle in the Czech Republic is relatively steady. However, there is a relative decline of pork meat production in the span of the last decade, from roughly 234 tonnes in 2013 to 198 tonnes in 2023. In contrast, the poultry production is more unsteady, with an increase from 2013 until 2022 with 261 tonnes, when the 2023 production was only 168 tonnes.

In the years between 2005 and 2013 the consumption of livestock manure was declining. However, in the last few years, the utilisation of livestock by-products has been widespread in farming practices. In 2023 the Czech Republic consumed a little over 2 tonnes per ha of utilised agricultural area of organic fertilisers (and only 109 kg of mineral fertilisers), continuing a steady yearly increase compared to 2018 where 1.6 tonnes per ha was consumed [6].

Agro-industrial biomass

The basic resources of the food-processing industry are domestic agricultural products, forest, and water management products, and imported raw materials. Organic crop materials are less than 1% of commercial market products, with a lack of harvesting and processing equipment being a deterrent of investing in this market. The bulk of the agro-industry is concentrated in the fertile lowland areas of the Czech Republic, including South Moravia where most vineyards are found. The food production industry mainly consists of foodstuff or beverage production, with the second having a prominent place in the country's tradition [13].

Table 4. Key pillars of processing industries [13].

Foodstuff Production	Production of Beverages
Processing meat and meat products	Beer making
Processing fruit and vegetables	Wine making
Dairy products	Liquor making
Production of flour and starch products	Production of mineral water and soft beverages

Forestry biomass

In the Czech Republic, forestry is a deeply anchored tradition, with a total forest area of 2.7M ha in 2023, of which 66% responds to coniferous and 29% of non- coniferous tree species [16], making forestry an important landscape and ecosystem element. However, in recent years the sector has been facing challenges brought by the effects of climate change and an unbalanced forestry cover formation, due to a bark beetle infestation.

In forestry, biomass is predominantly available in the form of stemwood, primary, and secondary residues. However, in terms of bioenergy and bio-material potential, stemwood's conversion to energy is not particularly efficient and therefore not the preferable use.

Timber forests in the Czech Republic account for 26Mha of forest land. Timber forests in the Czech Republic account for 2.6M ha of forest land. However, the Czech Republic has a lower relative timber consumption, due to insufficient timber-processing capacities and low customer demand, resulting in a prevalence of export of raw wood.

The secondary by-products of forestry biomass mainly refer to wood processing industrial residues such as sawdust, bark and black liquor. Their availability and exploitation depend completely on the development of timber and paper industries, while pellet production is largely contained within the sawmill industry [13].

2.2.2 Management and logistics of biomass resources

The difficulties in the logistics of biomass valorisation and its line of production are greatly described by the forestry industry due to the inherent difficulties caused by the rigidity and mass of the products. As in most cases, the transport of the biomass is one of the biggest undertakings, with the load on the local and municipal roads being one of the leading factors of damage and after increase of danger on commonly used roads. After transport, long-term storage of biomass requires vast spaces and is usually preceded by the need to dry or change the product. Apart from spatial challenges, there is a great gap between the available on- site technologies and workforce and the actual needs of the industry, which will make the biomass production process easier, safer, and more profitable.

In forestry, forest maintenance and all forest care up to timber logging fall under the Ministry of Agriculture. Related activities from transport to later processing of biomass fall under the administration of the Ministry of Industry and Trade, while administration of employment and relations between employees and employers are under the responsibility of the Ministry of Labour and Social Affairs. Following the same example, many biomasses related industries fall under the authority of different ministries, regional authorities, or private organisations, since their exploits are bordering with many different jurisdictions. Clear borders of responsibilities and a cohesive approach in management and expectations are key for the survival, advancement, promotion, and evolution of biomass valorisation in the Czech Republic [13].

2.2.3 Bio-products target market

Conversion of biomass into secondary products which are in demand by either business or customers, are a key step in the value chain of the bioeconomy. The Czech Republic has a long history of success during the age of industrial manufacturing, which acts as an advantage in both the existing but also for the potential target markets.

Table 5 below shows some chosen examples of the above-mentioned target industries. For the full list of the relevant Bioeconomy Stakeholders in the Czech Republic, refer to the National Bioeconomy Dossier CZ, CELEBio [5].

Table 5. Examples of Key Actors of Biomass Target Markets [5].

Actor	Market
HEMPOINT	Agriculture - Hemp specialisation
Research Institute for Fodder Crops, Ltd. Troubsko	Agriculture research
The Czech Hemp Cluster	Agriculture - Hemp specialisation
AGRI ČR+	Agriculture - food information
EKOVERMES	Agriculture - organic fertiliser
VUC Services spol. s r.o.	Agriculture - ground covering
UHUL (ÚSTAV PRO HOSPODÁŘSKOU ÚPRAVU LESŮ BRANDÝS NAD LABEM)	Forest Management Institute
The Forest of the Czech Republic	Forest Management
PEFC	Forestry Certification
The Institute of Circular Economy	Environment - circular economy
EKO-PLASTY.CZ	Waste reuse
EKOKOM	Waste reuse
LIKO-S	Housing construction
NAFIGATE Corporation, a. s	Bio-based industry
Syncare Plus	Producer of bio-end products
Snový svět	Textiles

Textiles

The textile industry has been prominent in the Czech Republic since the 20th Century. The focus is now on technical textiles, which are used in the automobile industry, agriculture, healthcare and aviation, which could present an opportunity for bio-based textiles. Some companies are using biological textile waste as a source for material to be re-used in construction or insulation. Included in the value chain is sourcing, waste process, and finishing the materials sourced from wool, hemp or flax fibre, cellulose, and used rugs or other textiles.

Biotechnology

The biotechnology sector has seen many achievements regarding nanotechnology, pure biotechnology, and human healthcare. Nanotechnology is a promising Czech inventory sector, with the bright examples of expanding from the traditional chemical structures to biological materials, producing a range of organic and inorganic nanofibers, the conversion of waste frying oils into bacterial bioplastics called polyhydroxyalkanoates (PHA), immune cell therapies for treatment of cancers, veterinary products, and molecular biology reagent manufacturing.

Bioplastics

Bioplastics manufacturing is a popular demand worldwide and there are a number of plastics producers in the Czech Republic. With society growing more environmentally conscious, and the regional and national authorities being all the more interested in environmental protection, new entrants to this market will see an increase in output and eventual competition for this sector.

Furniture

With the significant importance of forestry in the Czech Republic, the majority of the wood biomass is primarily used in the furniture making industry or as lumber for construction, with a small amount used to produce heating pellets. Using wood for heating should be moderated, as the air quality levels due to this practice in the Czech Republic is below the acceptable limits. There is the possibility of creative uses for wood in many areas, like novel packaging of consumer goods.

Apart from the existing biomass valorisation options, there are opportunities to investigate and optimise existing or new ways to advance the industry, including solid biomass combustion with wood waste, pyrolysis to convert biomass into syngas and biochar, or hydrolysis to sugars. Many of these processes would need investment into infrastructure and recruitment of experts. The sugar industry used to be prominent in the Czech Republic, however nowadays sugar hydrolysis is taking place primarily abroad. The bark beetle infestation gives the opportunity to repurpose the biomass into the production of biochar, which can also be used locally to help in water retention and increase nutrient content in agricultural fields. The use of manure as a fertilising agent is even more popular but is managed in-farm. The introduction of anaerobic “closed loop” digesters would allow for a utilisation of manure as an added source of biogas [5].

2.2.4 R&D system associated with biomass valorisation.

The Czech Republic has an active participation of Research Institutes and SMEs specialising in agriculture research under the scope of bioeconomy. There are a number of Associations of like-ventured SMEs and organisations, creating a valuable network of collaboration between specialists.

The Fodder Research Institute in Troubsko (VUPT) is counting 30 years specialising in research in the fields of agriculture, food industry, and biotechnology. They lead a number of international projects of applied research and innovation transfer in the field of bioeconomy with the support of their subsidiaries, Agricultural Research (ZVT) and Agrolab (AGL). Apart from the international projects, VUPT is also active in national bioeconomy related projects, many of which are focusing on biomass valorisation or biofuel production. The currently running projects can be found in Table 6 [VUPT].

Table 6. National bioeconomy projects ongoing.

Project Name	Description
Research and development of biofuels from agricultural residues (1/2024-12/2025)	Development of fuel from agricultural waste from the processing and preparation of selected seeds and food products
Utilisation of silage made from "beet cuttings and grain straw" in a critical shortage of corn silage. (7/2024-6/2028)	Verifying the possibility of using silage made from "beet cuttings and grain straw" for the needs of keeping biogas production or the operation of biogas stations (BPS) in case of a shortage of key corn biomass affected by extreme weather.
The importance of the lignocellulosic complex from intercrop biomass for improving the soil environment (1/2021-12/2025)	Assessing the quality of plant biomass entering the soil when using the intercropping system as a source of organic matter to support soil processes reflected in soil fertility.
Analysis and adjustments of compost application schemes aimed at strengthening the soil protection system within the framework of stabilising production capacity. (1/2022-12/2024)	Supporting the effect and quality of stable organic matter in the form of compost, to find the key parameters and behaviour of compost when it is applied to the soil surface without incorporation in terms of emissions, safety, and health risk with the aim of reducing the costs of compost application.

VUPT is also a member of the Association of Research Organisations (AVO), the only organisation representing the R&D sector in private companies (that include private research organisations and also business units). There are several industry sectors represented in AVO, like Agriculture, Engineering, IT, Chemistry, and Medicine. AVO is the Czech research capacities, currently involving roughly 75 institutions and 7800 experts involved in R&D. They take part in projects focused on the financial support and commercialisation of research, as well as the development results [1].

2.2.5 Support and financing policies.

In the Czech Republic, projects and initiatives related to bioeconomy can receive National or European funding. At this time, the Ministry of Agriculture supports R&D projects under the COUNTRY Program: Ministry of Agriculture Applied Research Program 2017-2025 (Resolution of the Government of the Czech Republic No. 313 of April 11, 2016). The COUNTRY II: Program to support applied research of the Ministry of Agriculture for the period 2024–2032, was approved by Resolution No. 83 of the Government of the Czech Republic dated February 1, 2023.

The national subsidies for research and development projects financed from special-purpose funds of the Ministry of Agriculture have been provided by the National Agency for Agricultural Research (NAZV) since 1994. The Agency ensures the complete preparation and announcement of departmental

research programs of the Ministry, the announcement and course of public tenders and the later administration of funded projects in the field of agricultural, food, forestry, and water management research. NAZV employees continuously conduct on-site inspections of recipients of targeted R&D support following Act No. 320/2001 Coll., on financial control in public administration and the amendment of certain laws. NAZV also organises information seminars for applicants in public tenders, for evaluators of project proposals and information seminars, and project managers [National Agency for Agricultural Research (NAZV)][14].

Apart from the National Agency for Agricultural Research, there is a number of other funding sources in the Czech Republic for research- related activities, such as:

- The Technology Agency of the Czech Republic (TA ČR)
- The Czech Science Foundation (GA ČR)
- Agency for the Czech Republic health research (AZV ČR)
- J. W. Fulbright Commission
- The National Agency for European Educational Programmes (NAEP)
- The Centre for International Cooperation in Education (DZS)

Also important to note is The International Visegrad Fund, a donor organisation established in 2000 by the governments of the Visegrad Group countries– Czechia, Hungary, Poland and Slovakia, that supports regional co-operations through Grants, Scholarships and Artists Residencies. The aim is to help the region progress in seven principal areas of Culture, Education, Innovation, Democratic Values, Public Policy, Environment and Tourism, and Social Development. [Euraxess]

2.3 Analysis of Operational Groups

2.3.1 Operational groups characterization

A review of the EIP-AGRI project database from the EU CAP network in Europe reveals that only one operational group was funded between 2015 and 2023 in the Czech Republic, specifically in the South Moravia region. The total budget for this project was 192,007€ [18]. For the purposes of this analysis, 10 projects have been selected for investigation, spanning the period from 2017 to 2023. The projects have been classified according to their operational periods, which range from 24 to 60 months. The total budget for all of the projects, inclusive of the cost of coordination, amounts to 5,434,190€ [16].

The Figure 7 below illustrates the BBT operational expenditure for each project during its respective operational period. The mean cost per project is 550,000€, with the maximum and smallest funded amounts being 1,178,606€ and 234,775€, respectively.

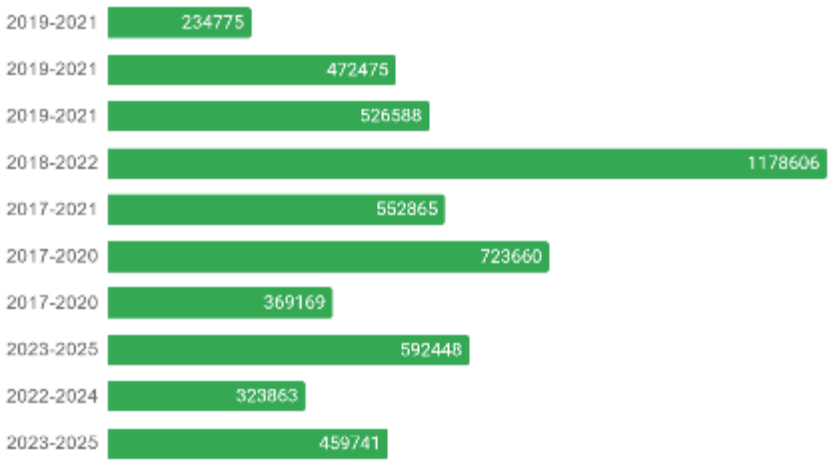

Figure 7: Funds granted to each project (€) (Source: Starfos) [16].

2.3.2 Bio-based Technologies (BBT) developed by OGs

This section provides a more detailed examination of the technological aspects associated with the projects found in the aforementioned area that have been developed under the BBT framework, as previously discussed.

The first step is to analyse the type of biomass that is being used. In order to conduct this analysis, ten regional projects that have developed BBTs were considered. The data shows that nine of the projects (90%) utilised crop residues and perennial plants. The second most prevalent approach was the use of designer crops for optimised biomass content, with seven projects employing this strategy. Thirdly, five projects employed biorefineries. In conclusion, the fourth and final category, which was represented by three projects and one project respectively, involved the utilisation of waste or recycled materials in conjunction with microbial-assisted processing.

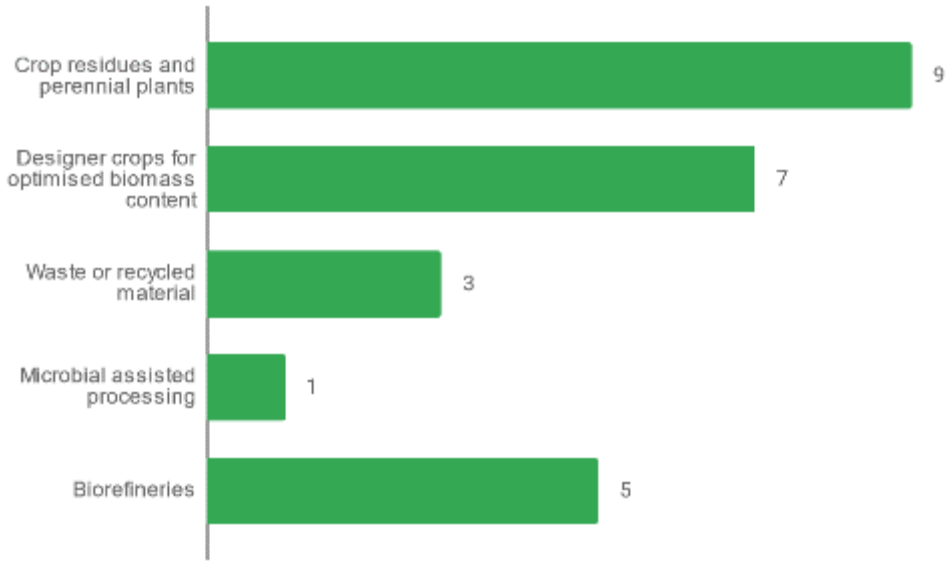

Figure 8: Biomass used developed BBTs (Source: Starfos) [16].

In addition, the BBTs developed by the projects were examined to determine their anticipated outcomes in relation to the ultimate user. It was determined that 80% of the projects were used by farmers, while 50% were employed by either foresters, processors, or retailers. The consumers, as the final users, accounted for a further three projects. The remaining two categories, including two and one projects, respectively, were advisors and other final users [16].

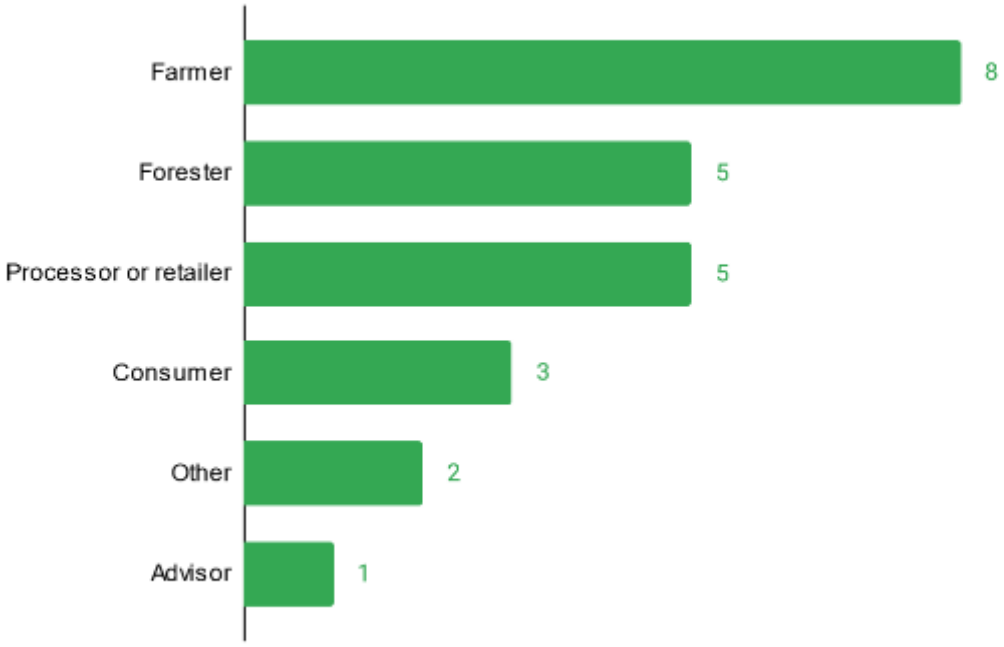

Figure 9: Expected results for the category of final users (Source: Starfos) [16].

In terms of technological maturity, information is available for all 10 projects. Moreover, nearly half of the technologies developed have reached the Technology Readiness Level (TRL) 6, which signifies a

technology that has been demonstrated in a relevant environment. In the case of key enabling technologies, this refers to an industrial-relevant environment.

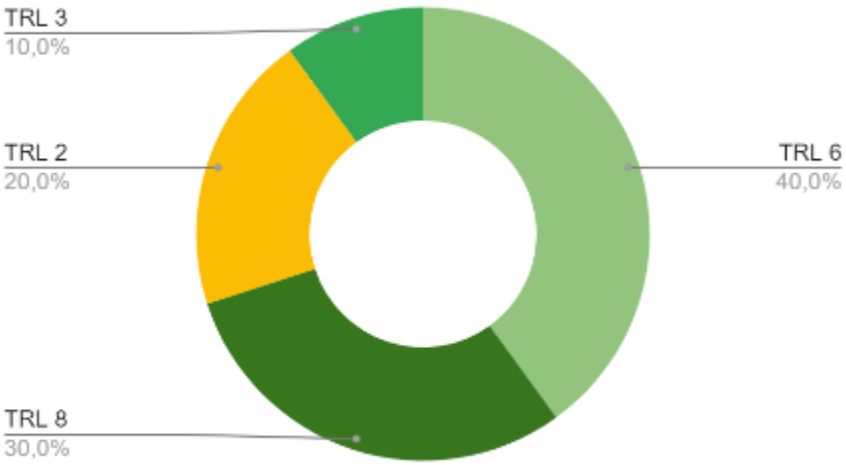

Figure 10: TRLs for each project developed BBTs (Source: Starfos) [16].

2.4 Discussion of previous sections

As expressed in the present report, the Czech Republic is the smallest country in the European Union in terms of the number of OGs.

In terms of available funding and R&D system associated with biomass valorisation, we have highlighted the different programmes available at various levels (European, national, and regional), both public and private.

Therefore, considering the geographical, regulatory and technical point of view, and looking at the amount of biomass availability as well as knowledge available in the region, we can conclude that the Czech Republic has a **yellow light** in terms of BBTs implementation.

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3 Greece – Central Macedonia, Crete & Peloponnese

3.1 General description of the region

3.1.1 Geographic description of the region

Central Macedonia

Central Macedonia is one of the thirteen administrative regions of Greece, consisting of the central part of the geographical and historical region of Macedonia. With a population of almost 1.8 million, it is the second most populous region in Greece after Attica.

Figure 11: Central Macedonia Region.

The region of Central Macedonia is situated in Northern Greece, bordering the regions of Western Macedonia (west), Thessaly (south), Eastern Macedonia and Thrace (east), and bounded to the north at the international borders of Greece by the Republic of North Macedonia and Bulgaria. The southern part is coastal and is bathed by the Thermaic, Toroneos, Singitic and Strymonic gulfs. The largest city and capital of the region is Thessaloniki. Serres is the second most populous city, followed by Katerini, Veria and Giannitsa. Central Macedonia is basically lowland and, with many rivers, is highly developed, both in the primary and the secondary sectors. The largest plain in Greece is situated in Central Macedonia. Thessaloniki, the metropolis of Macedonia, is the second largest Greek city.

The highest mountains of the region of Central Macedonia are Mount Olympus (2,918m), Voras Mountains (2,524m), Pierian Mountains (2,193m), Vermio Mountains (2,065m) and Mount Athos (2,033m). The largest rivers are the Haliacmon, the Axios, the Loudias and the Gallikos (Echedoros), which all flow into the Thermaic Gulf. Koroneia, Volvi, Doiran and Kerkini lakes are situated in Central Macedonia.

Crete

Figure 12: Crete region.

Crete is an island in the eastern Mediterranean Sea that is one of 13 administrative regions of Greece. Crete is the fifth largest island in the Mediterranean and the largest of the islands forming part of modern Greece. It is relatively long and narrow, stretching for 260km on its east-west axis and varying in width from 12 to 60km. The administrative centre is Irákleio (Heraklion; historically, Candia), on the north coast. Crete is dominated by harsh mountains rising out of the sea. The island's east-west mountainous range consists of four main groups that rise to the island's highest point, Ídi mountain, 2,456m in elevation. To the west the Lefká ("White") Mountains reach 2,452m, and to the east the Díkti Mountains extend to 2,148m in elevation. Those mountains rise above the high upland plains of Nída, Omalós, and Lasíthi and are marked by several gorges, the best known of which is the Samariá Gorge. The gradually sloping northern coast provides several natural harbours and coastal plains, where such major towns as Chaniá (Khaniá; historically Canea), Réthymno (Réthimnon; historically Rhithymna), and Irákleio are found. The Mesara (Messára) Plain extends along the south-central part of the island for about 29km and is Crete's major expanse of flatlands. Crete has six small rivers as well as springs, seasonal watercourses and ponds, one natural freshwater lake (Lake Kournás), and several artificial lakes.

Peloponnese

The Region of Peloponnese is located in the Southern part of mainland Greece and consists of the Regional Units of Argolis, Arcadia, Corinthia, Laconia, and Messenia. Its capital is Tripoli in Arcadia.

Figure 13: Peloponnese region.

The Regional Unit of Argolis has its capital in Nafplio and covers an area of 2,154 km². It borders the Regional Units of Corinthia and Arcadia and is washed by the Argolic and Saronic Gulfs. Points of particular interest include Mycenae and Epidaurus. The Regional Unit of Arcadia is the centre of the Peloponnese and borders all the counties that belong to the Peloponnese. A notable feature of Arcadia is its rivers and lakes, specifically the Alfeios and Ladon, which irrigate the land, the Erymanthos, used for water supply, and the Lousios, whose natural beauty is ideal for water sports. Additionally, there is Lake Taka, the artificial Lake Ladon, which aids in irrigation, and Lake Moustos, a haven for wild birds. The Regional Unit of Corinthia covers an area of 2,289 km², is washed by the Corinthian and Saronic Gulfs, and borders the Regional Units of Argolis, Arcadia, Achaia, and Attica. It has small water streams, but it is home to Lake Stymphalia, known from the labours of the mythical hero Hercules. The Regional Unit of Laconia covers an area of 3,636 km² and is located in the southernmost part of mainland Greece. It borders the Regional Units of Arcadia and Messenia and is washed by the Myrtoan Sea, the Messenian Gulf, and the Laconian Gulf. Its most touristy spots are Mystras and Elafonisos, the only island of Laconia. The Regional Unit of Messenia covers an area of 2,991 km² and borders the Regional Units of Elis, Arcadia, and Laconia. Natural borders are formed between Messenia and the Regional Unit of Elis by the Neda River. The Mani Peninsula is shared between Messenia and Laconia and features coves known for their natural beauty.

The Peloponnese is a large peninsula in southern Greece, notable for its diverse and dramatic geography. The region is almost an island, connected to mainland Greece by the narrow Isthmus of Corinth, which is cut by the Corinth Canal. Peloponnese is mountainous, with several significant mountain ranges, including the Taygetus, Parnon, and Aroania (or Chelmos) mountains. It is also characterized by a highly indented coastline with many gulfs and inlets, including the Gulf of Corinth, Gulf of Patras, Argolic Gulf, and the Messinian Gulf. The climate varies from Mediterranean along the coast, characterized by hot, dry summers and mild, wet winters, to more continental conditions in the interior, with colder winters. The region is rich in natural resources, with fertile plains, especially in Messinia and Laconia. Major agricultural products include olives and olive oil, citrus fruits, grapes and wine, and various vegetables. Livestock farming is also significant, with sheep and goat herding being prevalent.

3.1.2 Agriculture and forestry sectors in the region

Central Macedonia

In the Figure 14, the cultivated area, and the production of different crops during the period 2010-2018 in the region of Central Macedonia are reported. In the region of Central Macedonia during 2018 a decrease of 32.3% of the harvested area cultivated with cereals was observed, resulting in a decrease in 36.7% of production. During 2018, the area cultivated with all the other crops increased compared to the reference year 2010.

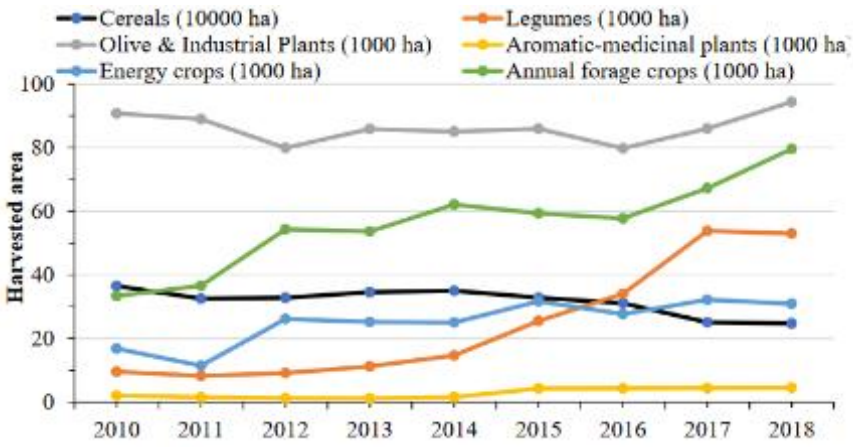

Figure 14: Agricultural production in Central Macedonia.

Based on the cultivated areas, in the region of Central Macedonia the main crops are cereals, olive and industrial plants, annual forage crops and legumes. Giving a closer look to the percentage distribution of the crops during the year 2018 it was observed that cereals represent the main crop produced in the region covering 48.5% of the area harvested but only of 38.2% of the production. Olive and industrial plants and forage crops, on the other hand, cover 18.5% and 15.6% of the area with a production of 12.8% and 41.6%, respectively.

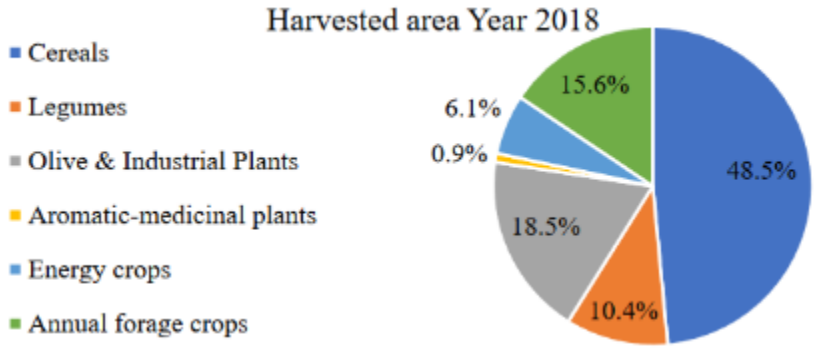

Figure 15: Harvested area in 2018.

The percentage of the area harvested as well as the production of crops in the region of Central Macedonia in relation to Greece as a whole is presented in the Figure 16. It is clear that up to 2012, more than 50% of the area harvested with Energy crops in Greece was in Central Macedonia covering more than 81.8% and 62.0% of the total production of Greece. Aromatic-medicinal plants are another

product that Central Macedonia produces in considerable amounts. The area harvested in Central Macedonia with aromatic plants stands for 39% of the total area cultivated in Greece with such plants while the production represents 59.9% of the total aromatic plants produced in Greece. Legumes are another important crop, with production in Central Macedonia region representing 42% of the production of legumes in Greece during year 2018.

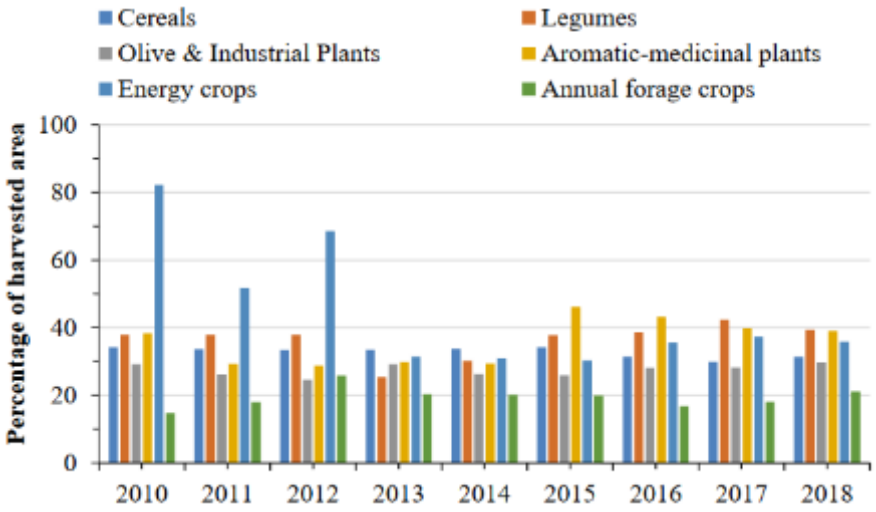

Figure 16: Types of different plant production 2010-2018.

During 2018, in the region of Central Macedonia, the main harvested area with fruits is made of stone fruit trees and olive trees covering 46.6% and 31.3% of the total area of the region cultivated with fruit trees. The respective production percentage is 70.8% and 1.1% of the total production of fruits in the area. During the period 2010 to 2018, a slight variation is observed in the area cultivated with fruit trees and their respective production. A decrease in the area harvested compared to the year 2010 was observed only for pomerium trees, grapes for raisins and olive trees.

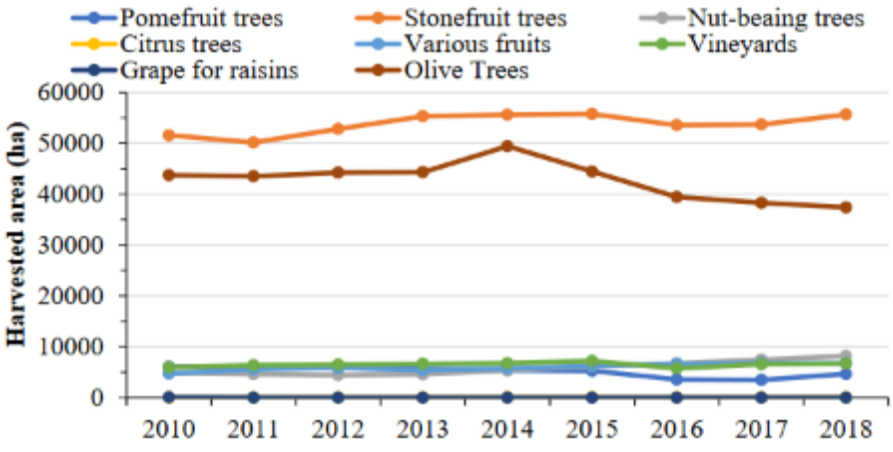

Figure 17: production of fruits & vegetables in the period 2010-2018.

For the category of animal production (animals and animal products) data were obtained from Agricultural Financial Accounts of Central Macedonia, Eastern Macedonia and Thrace and Greece and are shown in Figure 18. According to ELSTAT (Hellenic Statistical Authority) during 2017 the animal

production in the region of Central Macedonia represented 20.8% of the animal production of Greece. This value is a high level of production at country level and is similar to the respective value for the plant production (20.1%). Animal production stands for 41.6% whereas animal products represent the remaining 58.4% of the total animal production of Central Macedonia. At country level, these values are 53.4% and 46.6% for the animals and animal products, respectively.

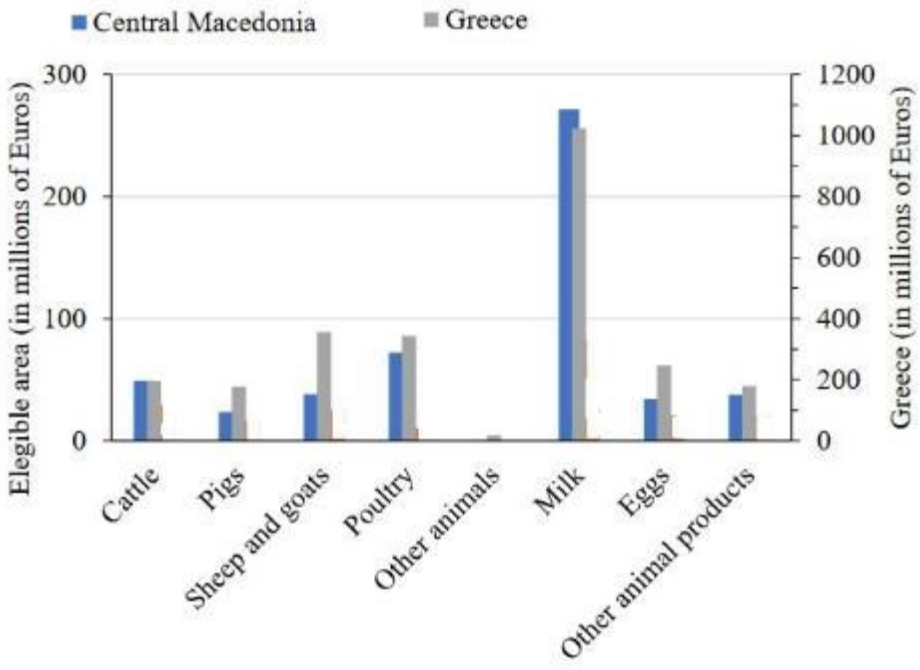

Figure 18: Animal production in Central Macedonia.

Crete

The primary sector holds a dominant position both in terms of product and employment, but it is characterized by small and scattered landholdings, dependency on traditional models and crops, and structural deficiencies with incomplete infrastructure. Production systems are largely outdated and offer low post-production added value. Additionally, the percentage of irrigated land in Crete is much lower than the national average of Greece, while the structure of crops emphasizes traditional cultivation. Livestock farming is also scattered, with very few organized livestock units, although there are significant conditions for the development of dairy products.

The Prefecture of Heraklion has the greatest area of cropland. The most extensive cropland in Heraklion is found in the Messara valley. Olive and vine plantations are the main trees, covering a large part of the lowlands and hilly areas, but also parts of the uplands. The most significant expansion of olive groves occurred during the last forty years after maquis and shrub vegetation were eliminated. Vine plantations declined significantly due to destruction by phylloxera. New plantations, with increased resistance to phylloxera, have appeared in the area in the last decade. Cereals drastically declined in Crete after 1950 and were replaced mainly by olive trees or vines.

Olive groves are found across Crete. The island of Crete, and especially the Messara valley, faces significant problems of water resource over-exploitation due to the expansion of irrigated cropland, such as olive groves. Although the Valley receives on average about 600mm of rainfall per year it is estimated that about 65% is lost to evapotranspiration, 10% as runoff to sea and only 25% goes to

recharging the groundwater. An extensive network of pumping stations has been installed since 1984 in which rain-fed olive groves have been converted to irrigated olives. The consequences are an increase in crop production accompanied by a dramatic drop of up to 20m in the groundwater level in some places, and intrusion of brackish water in the aquifers.

According to the 2021 Annual Agricultural Statistical Bulletins of ELSTAT for Crete, the total agricultural land amounts to 1,354,369.94 ha. The largest percentage of agricultural land (40.3% or 545,392 ha) pertains to tree crops, mainly olive groves. The arable land, with 55,720.92 ha, accounts for 4.1% of the agricultural land. The largest areas of cultivation are tomatoes and cucumbers, which are mainly grown in greenhouses, the area of which is 0.5% of the cultivated area with 6,276.27 ha while significant areas are also occupied by barley, oats, potatoes, vetch, alfalfa, etc. In some places, significant areas are also occupied by clover, peppers, watermelons, spinach, green beans, fresh broad beans, etc. In addition to the large-scale crops and greenhouses, arable land also includes fallow land and areas kept in good agricultural and environmental condition. Vineyards and raisin-producing vineyards account for 2.7% of the agricultural land in the region.

Table 7: Crete cropland areas.

Geographic region in Crete	Cropland area (ha)					
	Total (including fallow land)	Arable land	Vines and grape vines	Greenhouses	Crop trees	Other crops
Crete	1,354,369.94	55,720.92	37,209.75	6,276.27	545,392	710,008.13

Cultivated land covers 42% of the island, while dry land is used mainly as pasture as the next most important land use covering 39.3% of the island. Climatic and soil characteristics accompanied by EU policies on subsidising crops in the last two decades, have greatly favoured the extensive expansion of olive and vine plantations in the area which provides farmers with higher incomes. Olive groves in Crete occupy an area of about 193,813 ha covering almost 23.3% of the island. The olive oil production in Crete is up to 150,000 tonnes per year. Orange plantations and vegetables grown in greenhouses have been mainly expanded in the lowland areas of the island. Considerable amounts of fertilizers have been applied up until the last decade. However, farmers have realized the negative impacts on the environment and the increasing cost of crop production and thus the amount of applied fertilizers have steadily decreased. Drip irrigation has been expanded in the cropland areas to ensure increasing crop production. However, the over-exploitation of the aquifers has resulted in deterioration of water quality (high soluble salt content), thereby affecting soil salinization. The lack of good quality water has stimulated the construction of small reservoirs for increasing water availability for irrigation. The intensification of agriculture resulted in accelerated rates of soil erosion in the hilly areas of the island. Furthermore, water pollution of the aquifers has become a critical issue due to over-fertilization of the land and overuse of plant protection chemical products. Land desertification due to salinization in the lowlands and due to soil erosion in the sloping areas has become a critical issue. Organic farming and integrated land management practices have been set up in some areas for the protection of soil quality and ecosystem functions.

Crete has less forest wealth compared to other regions of the country and an incredibly low percentage of forest cover. Nevertheless, its forest wealth is significant and rare, with important and notable

forests such as the Samaria National Park in the Chania region, the Rouvas Forest in the Heraklion region, and the Palm Forest in the Lasithi region, among others.

The forest ecosystems on the island of Crete have been degraded in terms of both area and quality. The main causes are grazing, tourism, and extensive monocultures. Where forests exist, oak species (Quercus spp.) and conifers (Cupressus sempervirens in the west and Pinus brutia in the east) are predominant.

Table 8: Detailed information in Crete

Location	Forestry area
Greece	3,901,800 hectares
Crete	Low
Species	Quercus, Cupressus sempervirens and Pinus brutia.

According to ELSTAT, in 2021, the number of purely livestock farms in the Region of Crete was 898, down from 1,056 in 2009. These are categorized into 80 farms with cattle, 10,348 with sheep, 7,394 with goats, 700 with pigs, and 10,711 with poultry. The respective reductions since 2009 are 61.7% for cattle, 21.6% for sheep, 39.8% for goats, 60.7% for pigs, and 52.9% for poultry.

Peloponnese

The agricultural sector is generally characterised by fragmentation of agricultural land into plots smaller than the national average, a high coefficient of spatial dispersion, and a high average age of those employed in agriculture. Additionally, the production model of mountainous agriculture includes livestock farming, forestry, and to a lesser extent, some tree crops. The primary sector is of major importance to the Peloponnese Region, which has unique characteristics and positively contributes to shaping its economy. According to data available from regional services, the Peloponnese produces:

- 40-45% of the national olive oil production, with 120,000 tonnes produced and 7 PDO products (1 in Messinia, 3 in Argolida, and 3 in Laconia) and 1 PGI product (Laconia).
- Over 20% of the national production of Kalamata table olives, with 1 PDO product (Kalamata).
- 70% of the national citrus production, with over 550,000 tonnes produced (Argolida, Laconia, and Corinthia).
- Pome fruits with a production of 6,000 tonnes and 1 PDO product (Arcadia).
- Wines with over 70,000 tonnes produced, featuring 3 PDO products and 9 PGI products, and two "national ambassador" varieties: Agiorgitiko from Nemea and Moschofilero from Mantineia, out of the 4 national varieties.
- 35% of the national production of Corinthian raisins, with a production of 10,000 tonnes.

Table 9: Number of agricultural holdings and used agricultural area.

Number of holdings	**68,576**
Holdings with used agricultural area	68,357
Utilized agricultural area (hectares)	2,558,637
Holdings with irrigated areas	38,975
Irrigated areas (hectares)	798,288

Table 10: Purely agricultural, purely livestock, and mixed holdings.

Purely agricultural	**61,875**
Purely livestock	488
Mixed	6,213

Table 11: Distribution of holdings by main categories of use.

Arable crops	**6,855**
Vineyards and raisin vineyards	10,556
Tree crops	65,705
Greenhouses	644
Other areas	20,601

Table 12: Distribution of used agricultural area of holdings by main categories of use (hectares).

Arable crops	**244,299**
Vineyards and raisin vineyards	150,533
Tree crops	1,818,893
Greenhouses	3,400
Other areas	341,510

Table 13: Holdings with animals by type of animal.

Cattle	514
Sheep	4,001
Goats	3,563
Pigs	334
Poultry	6,856

Table 14: Number of animals by type.

Cattle	16,403
Sheep	354,190
Goats	365,201
Pigs	67,043
Poultry	1,390,470

3.1.3 Economic indicators

Central Macedonia

According to the Regional Accounts published by ELSTAT with data for 2020, Central Macedonia, the most populous region in the country after Attica with 1.7 million inhabitants, does not even rank in the top five among all territories, with a per capita GDP of only 12,043€ and a decrease of 9.7% from 2019. At the same time, with 19.7B€ of gross value added in 2020, it represents only 13.6% of the total territory, with Attica amassing a staggering 47.8%.

The financial situation of residents in Thessaloniki and neighbouring cities in Central Macedonia is not any better. According to data from the Bank of Greece, the average deposits in the region's bank accounts amount to approximately 4,500€, while in Attica they exceed 7,200€. Furthermore, Central Macedonia has a distressing rate of population at risk of poverty and social exclusion, reaching 23.8%. This is clearly explained by the high unemployment levels in the region, which exceed 15%, compared to around 8% in the capital.

In terms of business outward orientation, according to a study by the Association of Exporters for 2021, Central Macedonia experienced a 17.7% increase in export value to 6.2B€, representing 15.6% of Greece's total exports, or 19% excluding petroleum products. The largest and most populous region of Attica understandably leads the ranking with over 20 billion euros in exports, recording a much larger increase of 23.4% within the year, accounting for 52.7% of the total.

Crete

The evolution of the GDP of the Region of Crete presents a similar picture to that recorded for the

country as a whole, albeit with more pronounced characteristics. Specifically, during the period from 2013 to 2018, the Region of Crete experienced an increase in its GDP by 6%, rising from 8,596 M€ in 2013 to 9,071 M€ in 2018.

This growth in Crete's GDP reflects a broader trend seen across the nation, although the region's growth rate is notably more robust. The increase in GDP is indicative of the region's economic resilience and its ability to recover and grow despite the economic challenges faced during that period. The sectors contributing to this growth likely include tourism, agriculture, and other key industries that have historically been strong in Crete.

In parallel, the evolution of the per capita GDP in the Region of Crete also mirrors the national trend, with even more pronounced characteristics. From 2013 to 2018, the per capita GDP in Crete increased by 5%, rising from 13,634 € in 2013 to 14,302 € in 2018.

This increase in per capita GDP suggests not only an overall economic improvement but also an enhancement in the average economic well-being of the residents of Crete. The growth in per capita GDP indicates that the economic benefits of the region's growth are being distributed among its population, leading to improved living standards. The sustained economic development during these years can be attributed to various factors, including effective regional policies, investments in infrastructure, and the thriving tourism industry, which is a significant contributor to the island's economy.

The Region of Crete's economic performance between 2013 and 2018 demonstrates a robust growth trajectory that exceeds the national average, both in terms of overall GDP and per capita GDP. This performance highlights Crete's strategic importance within the Greek economy and underscores the region's potential for continued economic prosperity.

Peloponnese

The relative position of the primary sector in the Region of Peloponnese, compared to the sector's size in the country, is particularly significant. In 2016, the Region of Peloponnese contributed 9.06% to the Gross Value Added of the primary sector in the country. The secondary sector holds particular importance in the economy of the Region of Peloponnese, contributing 22.21% to the total Gross Value Added of the Region, compared to 14.53% contribution of the secondary sector at the national level.

The gross domestic product of the Peloponnese was 8.2 B€ in 2018, representing 4.5% of the Greek economy. The per capita GDP adjusted for purchasing power was 17,400 €, which was 57% of the average of the European Union of 27 member states that year. The GDP per worker was 68% of the EU average.

The Peloponnese follows the majority of the Greek Regions, dominating the rural character of the area. Primary sector accounts for 7.1% of the GVA of the region with the vast majority of businesses (90.2%) in plant and animal production, hunting and related activities. Although the turnover of enterprises engaged in plant and livestock production is below the turnover of fisheries and aquaculture enterprises, it is over 20.2% above the national average.

Table 15. Economic indicators.

Country - Region	Population (M hab)	GDP (k M€)	GDP per capita (€)	GVA (k M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Greece – Central Macedonia	1.78	30.3	16,990	1.69	65.6	12
Greece – Crete	0.62	11.01	14,302	0.75	69.4	14
Greece - Peloponnese	0.53	10.37	17,400	0.84	70.5	27

3.1.4 Bioeconomy regulatory framework

Central Macedonia

In a recent comprehensive report by the European Commission, which aimed to map and analyse the development of bioeconomy strategies at the regional level within the EU-27 (titled "Bioeconomy Strategy Development in EU Regions"), the Region of Central Macedonia has distinguished itself by ranking first among the 13 Greek regions in terms of the number of Action Plans focusing on the promotion of bioeconomy. The report highlights that, although bioeconomy is embedded as a priority in several strategic documents -such as the Long-Term Strategy 2050, the National Strategy for the Circular Economy, the New Action Plan on Circular Economy, and the National Waste Management Plan 2020-2030- Greece still lacks a dedicated bioeconomy strategy at national level.

At regional level, many regions, including Attica, Epirus, and Thessaly, acknowledge the importance of circular economy and bioeconomy within their strategic frameworks. However, they currently do not have specific plans or strategies in place. Out of the 13 Greek regions, only 2 have published actionable plans dedicated to the promotion of circular economy and bioeconomy: the Region of Central Macedonia, with two Action Plans, and the Region of Crete, with one Action Plan. The Region of Central Macedonia has successfully developed and published two Action Plans for promoting circular economy and bioeconomy.

Crete

Crete has started to link bio-economy development with their Research and Innovation Strategies for Smart Specialization (RIS3). The Region of Crete, for the planning of entrepreneurship actions in the field of circular economy within the framework of the Programming Period 2021-2027, conducted a mapping of the existing circular economy actions in the Region, with the creation of a calendar for the agri-food sector. Based on the mapping data of existing circularity actions and relying on the responses

of the participants, it is found that from the studied sample (34 participants), 2 out of 3 businesses (23 out of 34 participants) either implement or participate in symbiotic circular economy actions (regardless of whether they are aware of it or whether these actions are capitalized on). Due to the very small sample size, it is extremely risky to generalize this -at least impressive- performance to the entire food and beverage processing industry in Crete. It is also extremely risky because the experience with the profile of participants in similar surveys through questionnaires, especially for businesses, has shown that the participants are particularly sensitized in the relevant field and that is precisely why they participate in the research. Even so, this performance is a strong indication that circular actions exist in Crete, even if they do not fully constitute a business model, highlighting at the same time the enormous potential of the agri-food sector in this direction.

Regarding the "closing the loop", that is, the products or raw materials produced from the identified circular actions, four (4) levels of added value emerge based on the value of corresponding competitive products in the conventional market. Specifically, depending on the output product - raw material, these levels include the following emerging value chains:

- Soil improver - compost and hydro-fertilization means as competitive products against corresponding products containing chemical instead of biological additives.
- Solid biofuel (dry biomass and/or olive pomace) as a competitive product against conventional fossil fuels (oil and natural gas).
- Organic substances with high nutrient content (e.g., waste fractions from brewing and winemaking, biomass fractions from fruit processing, certain special categories of plant residues, etc.) For the production of animal feed as a competitive raw material against animal feed with chemical additives.
- Raw materials of biological origin (e.g., olive kernel for the production of olive pomace oil and soaps, grape marc for the production of high-distilled alcoholic beverages, etc.) For the production of high-added value products, potentially innovative ones such as snail shells as a raw material for the production of exfoliating cosmetics.

Further investigation is needed into the capitalisation potential of each stage of the value chains, considering factors beyond business operations. A significant issue is the lack of a framework for waste declassification and quality criteria for produced products, affecting the competitiveness of circular value chain products. Additionally, there is a transition gap in the commercial availability of agri-food products to consumers. Circular actions by businesses do not outwardly target consumers to add value to the sector's products, meaning the environmental benefits are not communicated to consumers through information about environmental performance.

Peloponnese

The bioeconomy regulatory framework in Peloponnese does not differ from the corresponding broader national framework. Although Greece has not yet established a dedicated national strategy for the Bioeconomy, there are several government initiatives that prioritize resource efficiency, energy-efficient practices, and low-carbon investments. Currently, these governmental efforts are somewhat sporadic and dispersed. The Ministry of Environment and Energy in Greece leads bio-economy policies through key strategies such as the National Strategy for the Circular Economy (2018), which focuses on waste management and supporting green businesses. Supporting documents like the Green Growth Strategic Action Programme (2010-2015) promote green procurement and facilitate

easier access to capital for biotechnology centres. The National Renewable Energy Action Plan (2010) aligns with EU targets, and Law 4414/2016 introduces a support scheme for renewable energy and climate change mitigation. Collectively, these policies highlight Greece's commitment to sustainability, circular economy principles, and the adoption of renewable energy.

3.2 State of the art of biomass valorisation

3.2.1 Biomass resource availability

Central Macedonia

In the Region of Central Macedonia, the main biomass producers are plant and forest residues (firewood, twigs, straw, sawdust, olive kernels, seeds), animal waste (manure, waste), plants grown on energy plantations for energy use, as well as municipal waste residues of the food industry, agricultural industry, and the biodegradable fraction of municipal waste. More specifically, the crops that can produce biomass from their residues are mainly cereals and energy crops because they have plenty of straws and stalks which can produce high levels of biomass. From the crop plans it is observed that the main cultivations of Central Macedonia are cereals (hard and soft wheat), cotton and maize and in some regional units such as Pella and Imathia the main cultivations are fruit trees.

Table 16: Biomass types in Central Macedonia.

Crops	Residues type	Output of residues (tonnes/ha)	Humidity %	Biomass (tonnes/ha)
Alfalfa	Straw	0.76	0.15	0.66
Apples	Pruning	0.61	0.4	0.35
Apricots	Pruning	0.40	0.4	0.25
Barley	Straw	0.68	0.15	0.58
Cherries	Pruning	0.63	0.4	0.38
Cotton	Straw and shell (overground)	1.06	0.4	0.63
Cotton	Straw and shell (root)	0.33	0.56	0.15
Hard Wheat	Straw	0.40	0.15	0.35
Kiwi	Pruning	0.40	0.35	0.25
Maize	Stalks and cobs	2.65	0.55	1.18
Nectarines	Pruning	0.73	0.4	0.43
Olive Trees	Pruning	0.43	0.5	0.23
Peaches	Pruning	0.73	0.4	0.43
Rapeseed	Straw	1.01	0.53	0.48
Rice	Straw	0.96	0.25	0.73
Set Aside	Not applied	0.00	0	0.00

Olive trees has the highest percent of the cultivated area of the regional unit of Chalkidiki 41.50%, since Chalkidiki is well known in Greece for the olives and the virgin olive oil. The crops that follows are hard wheat with 21.82% and set aside areas with 16.04%. The cultivations with lower percent than

10% are barley with 5.74%, soft wheat with 4.92%, oats with 4.32%, vetch with 3.43% and sunflower with 2.23%. The total selected cultivated area of Chalkidiki regional unit is 300,799.6 ha. The regional unit of Imathia has 263,048.5 ha total selected cultivated area. The main crops of the regional units are fruit trees and arable crops. Analytically, the peaches hold 28.05% of the existent cultivated area followed by cotton with 25.16%. Under of the 10% of the cultivated area hold maize with 9.23%, alfalfa with 8.54%, hard wheat with 7.45%, nectarines with 6.02%, apples with 4.02%, rice 2.50%, soft wheat 2.30% and barley 2.30%. The existent crop plan of the regional unit of Imathia had set aside area 4.27% e 42.16% of the cultivated area of the existent crop plan of the regional unit of Kilkis is covered by hard wheat. The soft wheat holds the 24.52% and 10.92% is set aside area. All the other crops which fill the existent crop plan of the regional unit of Kilkis presented percentage under 10%. Specifically, 7.51% is cotton, 4.86% is alfalfa, 3.91% is barley, 3.74% is maize and 2.38% sunflower.

As regards the regional unit of Pella, the highest percentage holds the peaches with 21.88%, followed by cotton (15.42%), maize (11.70%) and cherries (10.77%). Lower percentages had the hard wheat (8.17%), the alfalfa (7.60%), the set aside area (6.88%), the soft wheat (5.69%), the barley (5.59%), the nectarines (4.06%) and the apricots (2.24%)

Pieria is well known for the cultivation of kiwis and tobacco, but the main cultivations are the cereals. The highest percentage in Pieria regional unit holds the hard wheat with 20.53%, followed by soft wheat (15.70%) and tobacco (10.20%).

Cotton with 9.30%, set aside with 8.70%, alfalfa with 7.00%, olive trees with 6.70%, kiwi with 6.50%, barley with 5.30%, maize with 3.70% and rice with 2.10% are the other main cultivations of Pieria. More analytically, it is observed that the regional unit of Serres has mainly arable crops and cereals. The cultivated area of hard wheat participates in the existent crop plan with 25.11%, the cultivated area of maize with 18.08% and the cultivated area of cotton with 11.10%. Soft wheat, sunflower and alfalfa participate with 8.93%, 8.05% and 7.62% respectively. The 6.18% of the cultivated area is set aside and barley holds the 5.86%. The cultivated area of olive trees, rice, tobacco, and rapeseeds are followed with percentages lower than 5%.

Crete

The levels of lignocellulosic biomass in Greece are estimated to be 2,132,286 tonnes annually, values that are very close to the cases of other Mediterranean countries like Italy and Portugal. In respect to the total agricultural residues, Crete produces 1,959,124 tonnes/year. The most significant streams in Crete are identified to be olive pits and olive pruning.

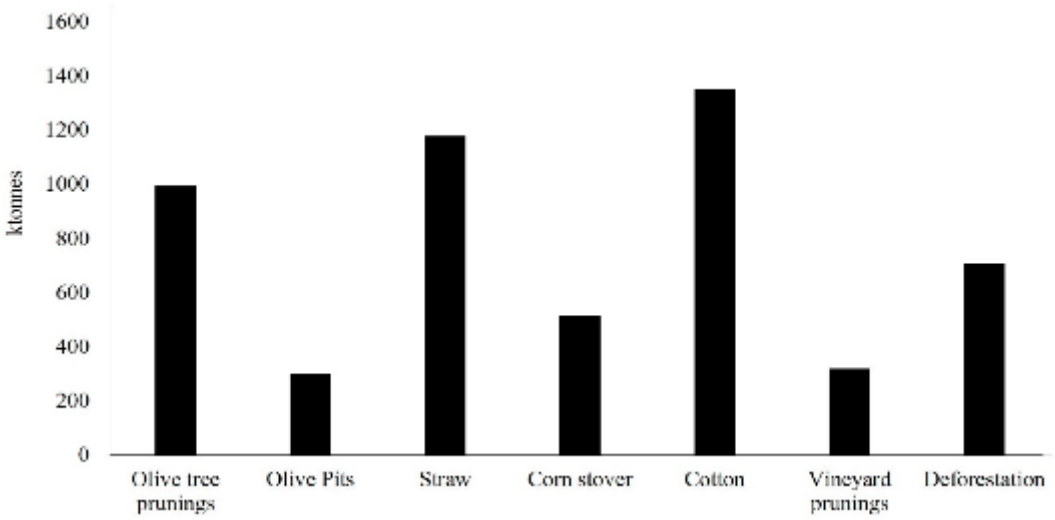

Figure 19: Annual biomass production, in ktonnes, by agricultural waste category in Greece.

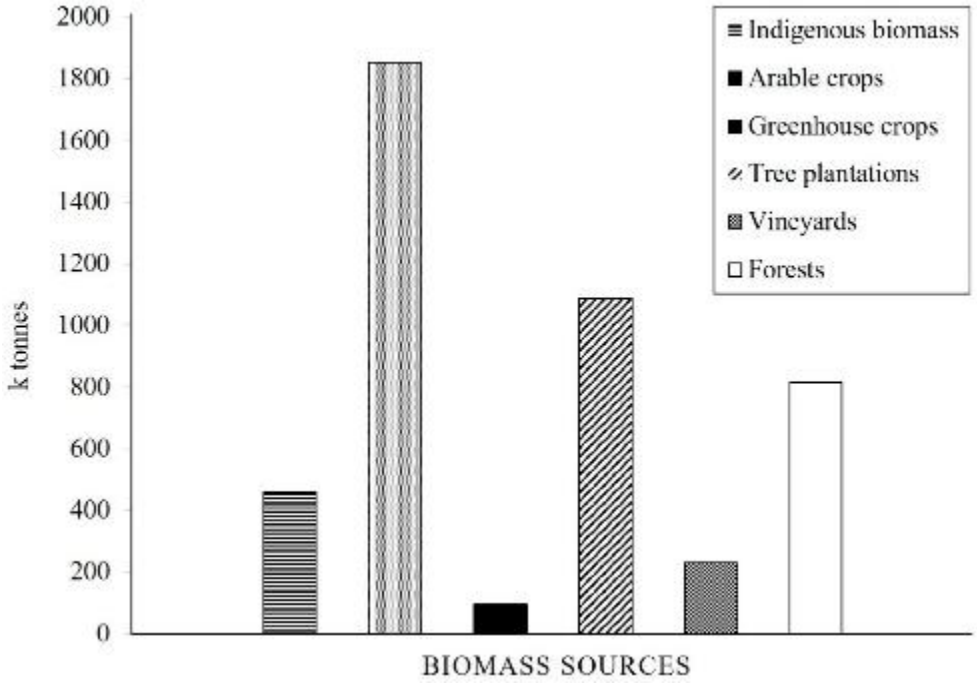

Figure 20: Biomass per source in Greece.

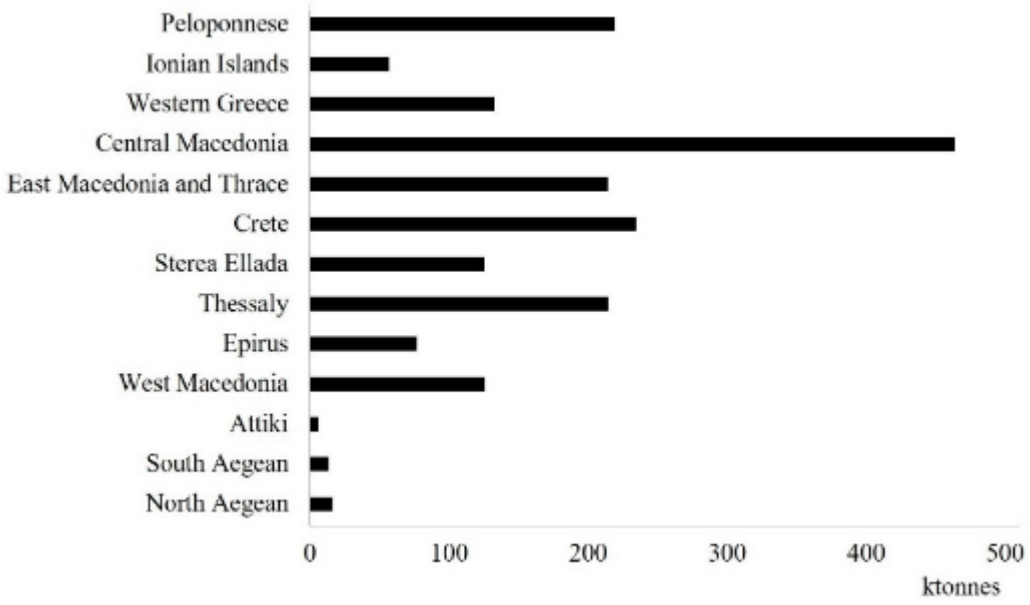

Figure 21: Potential of woody biomass (tree plantations and forests) in Greece by region (ktonnes).

For the quantities of biomass from tree crops and forests, Central Macedonia is again the first, producing 463,849 tonnes, followed by Crete with 234,741, and Peloponnese with 219,595 annual tonnes. Crete, due to its geomorphology and insularity, a single biomass collection system can be designed more easily, with cooperation of locals and farmers and then to be exploited in a gasification unit. Electrical and thermal energy could be used for the needs of the island of Crete.

Table 17: Annual quantities of pruning product in Crete.

Types of Biomass	tonnes/year
Tree crops	14,647
Vineyards	44,800
Agricultural crops	59,447
Total	118,894

Of particular interest is olive mill waste, due to the large quantity of olive oil production on the island. The main part of the biomass is a byproduct of the primary processing of olives. The estimation of the residual biomass of the mills is based on the view that the two-stage mills, in the near future, will eliminate those with three phases. The main type of waste is olive oil, containing the olive-pomace and the rest of the plant walnuts. Three-phase oil mills can be completely absent of liquid waste but are characterized by a high moisture content (62-65%). The Table 18 shows the estimated quantities of solid waste from the two-phase oil mills per peripheral unit of Crete.

Table 18: Agricultural holdings in the Region of Crete (land in K hectares).

Area	Total Trees		Olive Trees		Trees Except Olive Trees	
Sub Regions	Tree Crops	Areas	Trees Crops	Areas	Tree Crops	Areas
Iraklion	41,409	279.6	41,236	275.2	3777	4.5
Lasithi	12,344	78.9	12,341	77.7	1987	1.2
Rethymo	12,520	102.4	12,489	97.5	2449	4.8
Chania	20,165	135.2	19,622	122.2	5266	12.9
Total	86,439	596.1	85,688	572.6	13,479	23.4

Table 19: Quantities of bi-phase oil mills.

Regional Unit	tonnes/year
Iraklion	261,234
Lasithi	78,200
Rethymno	25,880
Chania	130,262
Total	495,576

The Figure 22 illustrates the biomass potential by source and regional unit in Crete. Iraklion has substantial biomass from tree plantations and greenhouses, while Lasithi follows with significant, though slightly lesser, biomass potential. The energy available from tree plantations can reach 1,950,124GJ per year, highlighting a significant renewable energy potential. Regional variations are crucial for developing targeted biomass use strategies. In Iraklion, efforts could focus on perfecting tree plantations and greenhouses, while in Lasithi, enhancing existing biomass sources could significantly impact Crete's energy landscape.

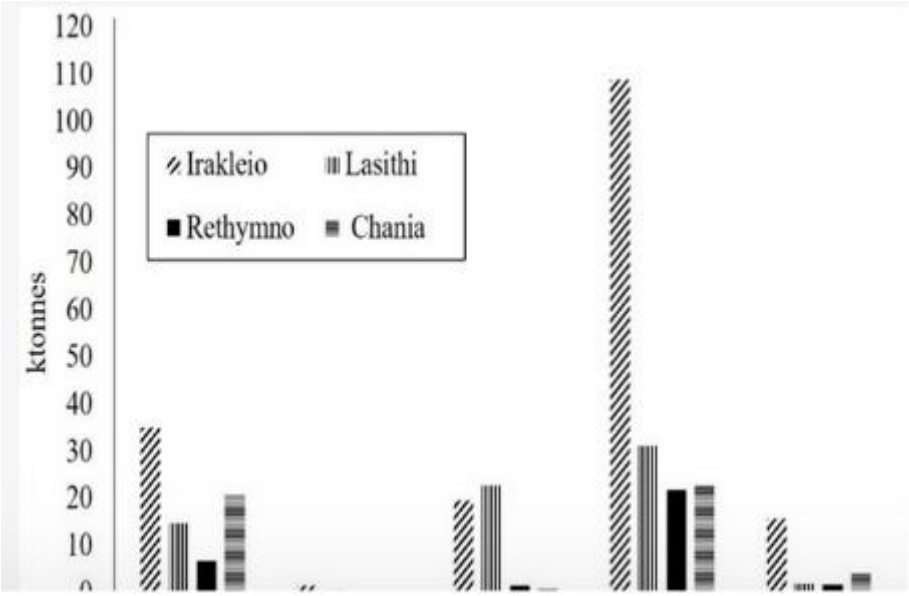

Figure 22: Biomass potential by source and Regional Unit of Crete (in ktonnes).

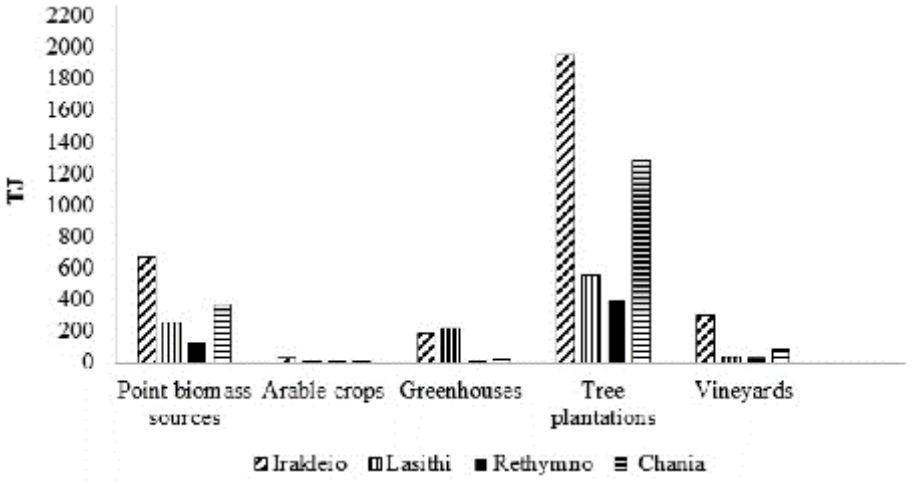

Figure 23: Biomass potential.

In the Figure 24, there is a calculation of the annual tonnes of biomass potential from all biomass sources, with tree plantations in first place with 234,741, followed by point biomass sources, with 77,607 annual tonnes of productivity.

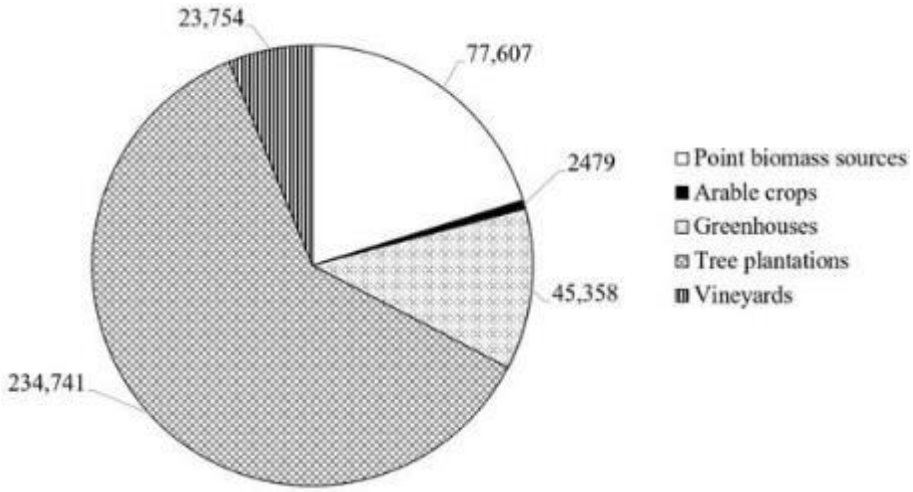

Figure 24: Total Biomass potential in the Region of Crete (in tonnes) by biomass source, 2010

Regarding the renewable energy installations in the Heraklion Regional Unit that have production licenses, there is only one biomass installation with a capacity of 1.5MW, which is located in the Heraklion Industrial Area by the company "Yfantis Alexandros & SIA EE". The rest of the renewable energy production comes from wind farms.

Peloponnese

The biomass potential in the area is notably high, largely stemming from agricultural land primarily dedicated to tree crops, comprising 62.6% of the region's agricultural landscape. Other land types contribute 18.9%, while annual crops occupy 12.5% of the area. Olive cultivation dominates in the Peloponnese, particularly in Messenia, where approximately 16 million olive trees exist. Annual olive oil production exceeds 50,000 tonnes, driving economic growth in the region. Tree plantations alone contribute around 3,800,000 GJ of biomass energy potential, predominantly from olive trees.

The inevitable byproduct of olive cultivation is its waste, particularly significant in our research domain: biomass, specifically olive pomace. A substantial part of this waste remains unutilized daily, contributing significantly to local environmental pollution due to the absence of restrictions or legal mandates for its processing.

Table 20: Quantities of agricultural waste (in tonnes/year, 2007).

Regional Unit of Messenia – Cutting Quantities (tonnes/year)					Pomace (tonnes/year)
Olives	Vineyards	Orange	Mandarins	Lemons	Waste of Two-Phase Oil Mills
382,589	14,324	3335	781	101	194,072

In managing waste, including agricultural waste such as pruning residues, the aim for the Peloponnesian region is sustainable practices (reuse, recycling, energy recovery, and safe disposal), with significant participation from the private sector in commercially practical areas. Furthermore, efforts prioritize the adoption of best available techniques, considering both technological feasibility

and economic viability.

3.2.2 Management and logistics of biomass resources

Central Macedonia

In the Region of Central Macedonia, the priority sectors for the bioeconomy include Agriculture, Livestock, Agroindustry, Chemical Industry, and Energy. The region has a high territorial sensitivity, and a sustainable bioeconomy addresses global challenges like climate change and ecosystem degradation while meeting the growing demand for food, feed, and energy. This dual approach helps to modernise industries and to protect the environment.

The bioeconomy in Central Macedonia is still in its initial stages but significantly impacts the region. Environmentally, it reduces CO_2 emissions, water consumption, and enhances soil fertility. Socially, it boosts employment in agriculture, waste management, and energy sectors. Economically, it fosters the growth of startups and other enterprises, promoting modernisation.

A SWOT analysis of Central Macedonia's bioeconomy revealed the following:

Strengths

- Government and public sector services enhance knowledge about the bioeconomy.
- Management systems support recycling and implementation.
- Presence of consulting engineering companies.
- Development of waste-to-energy plants, like biogas facilities.
- High production capacity of biomass from agriculture, livestock, agri-food, forestry, and fishing.

Weaknesses

- Lack of regional bioeconomy governance models.
- Absence of mandatory systems for monitoring and improving small enterprises' productivity.
- Farmers focus more on compensations than on enhancing agricultural management skills.
- Overuse of certain plants, excluding others.
- Limited knowledge of diverse biomass resources for innovative bioproducts.

Opportunities

- Availability of European and governmental funding for new systems, techniques, and processes.
- Potential for new intra-European trade and business opportunities.
- Growing interest in sustainable investment.

Threats

- Possible negative impacts of increased biomass use on society.
- Reduction of biomass resources due to climate change.
- Entrepreneurs prioritise livelihood issues over modern technologies and bioeconomy

approaches.

- Bureaucratic and administrative obstacles hinder entrepreneurship.

Crete

On May 26, 2017, the first biomass power plant was inaugurated in Heraklion, Crete. This "green" investment, amounting to 6 M€, was constructed by a private investor (Sychem group of companies) and financed under the European program Jessica–Crete Operational Program. In addition to environmental protection, this station contributes to the local community by creating new jobs (starting from the construction phase) and by supporting farmers and livestock breeders who can dispose of their waste.

The station incorporates particularly advanced technologies at critical points in the production process, such as in the reception and management of organic waste, the deodorization process, and the system for using the heat produced by the station. Additionally, it has an advanced system for the biological treatment of liquid residues, which is particularly important for the Heraklion region and Crete, where tourism flourishes and waste disposal into the environment is not an option.

This station produces biogas and electricity. The main sources of raw materials are agricultural (farming and livestock waste), which, as analysed above, are abundant on the island, as well as expired food from food service establishments, hotels, and supermarkets.

Peloponnese

The proposed technology for gasification is the Pyrox TYPE P850 CHP gasifier, a small-scale cogeneration unit that begins with wood chips. These wood chips undergo a thermo-chemical process to convert them into a combustible gas, which is then cleaned, cooled, and fed into an internal combustion engine. This system will use 7,956 tonnes of biomass annually, producing 6,630 MWh of electricity and 8,580 MWh of thermal energy, with a total cost of 4.3 M€.

The raw material must meet specific standards (dry matter ≥ 60%, maximum moisture content 40%, and particle size 20-100 mm for at least 90% of the material). The plant's annual heat consumption is 4,773.6 MWh for processing 7,956 tonnes of raw material, as the drying system requires a 10% reduction in moisture, using 0.6 kWh/kg (2.16 MJ/kg). The excess thermal energy generated will be repurposed for other uses, such as greenhouse crop heating, to minimize environmental discharge. Combustion residual ash will be collected from the bottom of the bed, transported by a screw conveyor, and stored. This ash will have 10–20% unburnt coal in addition to inorganic components.

The raw material will consist of deciduous olive residue from nearby areas. Trucks will consistently deliver the biomass as it is produced, and it will be stored appropriately before being chopped and dried according to the plant's requirements. Ensuring the raw material's quality and size is crucial, as is verifying its origins and sorting out any unsuitable pieces before they enter the shredder.

Also, the Municipality of Kalamata has created "green spots" where pruning and gardening waste can be deposited. The purpose is the composting of wooden chips for use in the parks and the flower beds of the Municipality of Kalamata

3.2.3 Bio-Products target market

Central Macedonia

At this stage of market development in the Central Macedonia Region, there does not appear to be

any specific market targeting documented.

Crete

At this stage of market development in the region of Crete, there does not appear to be any specific market targeting documented.

Peloponnese

Once lagging in waste management, the Peloponnese Region has now (2023) appeared as a national leader, boasting the three most advanced Waste Management Units (WMUs) in Greece and among the most modern in Europe. Through a 167 M€ investment (70 M€ funded by the National Strategic Reference Framework - NSRF), the region is embracing the circular economy by recovering and using over 80% of biodegradable materials, recycling high-quality recyclables, diverting at least 50,000 tonnes of liquid waste from landfills, and generating green energy sufficient for 6,000 households, all while preventing 24,000 tonnes of CO_2 emissions.

The largest of these units, the Arkadia Waste Processing Unit, currently manages more than 50% of the urban solid waste produced in the Peloponnese. The remaining waste is processed at Transitional Units in Messinia and Laconia, which are expected to be fully operational by 2024.

In just a few months of operation, the Arkadia unit has surpassed conventional waste handling abilities thanks to modern technology, demonstrating the urgent need for effective waste management in the region. Furthermore, since its implementation, the Peloponnese has been freed from European fines for past illegal practices and has achieved the lowest operational cost among similar facilities in Greece. This cost will decrease further with the introduction of the Green Fund and the completion of the Waste Transfer Stations (WTS) network by Regional Association of Solid Waste Management Bodies, resulting in significant savings for residents.

The project encompasses three main Subsections - Management Units within the Peloponnese Region, including:

- Three Integrated Waste Management Units (IWMUs), specifically:
    - Three Waste Processing Units (WPUs).
    - Three Sanitary Landfill Sites (SLSs).
    - Two Waste Transfer Stations (WTSs).
- Three Transitional Management Units (TMUs), which will function until the IWMUs are fully completed.
- Improvements to access roads to WPUs and WTSs.

The TMUs/WMUs-SLSs are situated in Arkadia, Messinia, and Laconia, while the WTSs are in Corinth and Argolis. This strategic placement ensures that waste collection occurs within a 50 km radius from the regional capitals, reducing transportation needs from municipalities.

Using innovative technology, the project keeps a minimal environmental and energy footprint, aligns with the Peloponnese Regional Waste Management Plan, complements local municipal recycling programs, and adheres to the best practices of the circular economy.

The project has created 800 jobs during the construction phase and will provide 200 permanent jobs over the next 27 years of operation. Additionally, it will generate indirect employment and benefits in

related sectors such as transport, recyclable trading, and personnel accommodation.

3.2.4 R&D system associated with biomass valorisation.

Central Macedonia

The Institute for Bio-Economy and Agri-Technology (iBO) is one of the five institutes within the Centre for Research and Technology – Hellas (CERTH), which runs as a private non-profit entity under the oversight of the General Secretariat for Research and Technology (GSRT) within Greece's Ministry of Development and Investments.

iBO specialises in agro-technology and biosystems engineering, integrating various interdisciplinary research fields. Its research focuses on effective environmental management, sustainability assessment of bio-production processes, and enhancing human interactions in these activities, all aimed at promoting circular economy principles.

Crete

The Technical University of Crete (TUC) is a leading institution in biomass valorisation through its School of Environmental Engineering. The school focuses on converting organic waste into valuable products such as biofuels and biochemicals, emphasizing sustainable waste treatment and resource recovery processes. In renewable energy, TUC improves the efficiency and sustainability of biomass-based systems while integrating biomass valorisation with circular economy principles.

TUC takes part in numerous EU-funded projects, collaborating with international academic, research, and industry partners to advance biomass technologies. Their research includes developing technologies for converting agricultural residues and other biomass sources into high-value products, using both thermochemical processes like pyrolysis and biochemical processes like anaerobic digestion. The university partners with local and international companies to pilot and scale biomass technologies, aiming to bridge the gap between research and commercial application. TUC's ultramodern laboratories and interdisciplinary approach enhance research quality and innovation. Through its robust research infrastructure, interdisciplinary approach, and strong industry collaborations, TUC is at the forefront of developing sustainable biomass use solutions, contributing significantly to sustainable development and renewable energy advancements in Crete and beyond.

Peloponnese

The University of Crete, a leading academic institution in Greece, plays a significant role in advancing the bioeconomy through its research and educational programs. Located on the island of Crete, the university uses the region's rich agricultural and natural resources to drive innovation in sustainable practices and renewable energy. Its Department of Biology, Chemistry, and the Institute of Molecular Biology and Biotechnology (IMBB) are at the forefront of research on biomass use, bioprocessing, and environmental sustainability. The university's researchers are engaged in various projects that explore the conversion of agricultural residues, such as olive mill waste and grape pomace, into biofuels, bioplastics, and other high value bioproducts. Through collaborations with local industries, government agencies, and international bodies, the University of Crete eases the development and implementation of cutting-edge technologies that support the circular bioeconomy. Additionally, the institution offers specialized courses and training programs that equip students and professionals with the skills needed to contribute to the bioeconomy sector. The university also participates in numerous

EU-funded projects aimed at promoting sustainable agricultural practices and renewable energy solutions. By integrating research, education, and community engagement, the University of Crete significantly contributes to regional and national efforts to transition towards a more sustainable and circular economy. This integration helps create a knowledge-based economy that not only addresses environmental challenges but also promotes economic growth and social well-being in Crete and beyond.

3.2.5 Support and financing policies.

Central Macedonia

The Regional Development Fund of Central Macedonia (RDF CM) was set up in 1997 under the legislation of L. 2218/94, amended by art. 12 par. 10 of L. 2307/95 and art. 4 par. 3 of L. 2503/97, and is overseen by the Ministry of Interior (Home office). It runs as a Private Law Legal Entity and is managed by a nine-member board including representatives from various productive bodies, chambers, officials, economic and executive committee members, and the major opposition. The Governor of Central Macedonia serves as the President of the Management Board.

The RDF CM has a dual function: it acts as an accountant project manager for the Public Investment Programme and supports the region's development process by using its expertise in implementing European Programmes, Initiatives, and various studies, research, and services. Its goal is to promote dissemination, entrepreneurship, innovation, and innovative technologies in the region's priority areas.

The RDF CM's responsibilities include:

- Managing credits from the Public Investment Programme, funding for public sector bodies and other legal entities, and funds from European Union Programmes and other international organizations related to regional (ROP CM) and sectoral (OP FM, RDP, FEAD, etc.) Development programmes.
- Submitting proposals and implementing European Programmes and Initiatives (such as INTERREG and HORIZON) and supporting the region's participation in international networks and collaborations.
- Providing technical support to the region through studies, research, and services assigned by the region, aimed at more efficient resource use. This support also includes dissemination actions targeting the region's priority areas, such as agri-food, tourism, and health.

Crete

Support and financing policies in Crete do not differ from the corresponding broader national framework.

Peloponnese

Support and financing policies in Peloponnese do not differ from the corresponding broader national framework.

3.3 Analysis of Operational Groups

3.3.1 Operational groups characterization

Central Macedonia

Within the region of Central Macedonia, there are four (4) OGs with active participation in the bio-mass industry.

(1) Aeforika Kipeftika is an OG that aims to incorporate non-commercial oregano into (greenhouse/outdoor) vegetable crops for the protection against soil fungi. Specifically, they aim to control downy mildew, caused by soil fungi, with negative effects on production in the context of circular economy and the adoption of good agricultural practices. They investigate optimum doses of oregano that must be incorporated into the rhizosphere in order to obtain best results and assess disease and productivity and quality indicators.

(2) BioAnimalChar is an OG for the exploitation of agricultural biomass for the production of animal food supplements. They aim to use agricultural biomass by-products to create a new, low-cost, biochar-based feed supplement, which will significantly improve the quality of pig feed.

(3) SoilCircle is an OG that aims to implement all the procedures for the certification of compost of agri-food origin in order to create an environmentally friendly business model for the conversion of agri-food waste into a value-added product (organic production). However, it is not clear if and how they take part in the utilization or production of BBTs.

(4) Innovative Rice Residue Management Practices return rice production residues to the soil for improved soil health and fertilization.

Two more examples of OGs that run within the wider region of Macedonia are also included, given that some of them have dynamic potential in the field of biomass valorisation.

(1) Proud Farm, in Kozani (Western. Macedonia) is an OG that envisions a sustainable future for Greek sheep and goat farming. Services provided to new and existing sheep and goat farmers include incubator support for young farmers, education, production of educational audiovisual material, management support services, and many others. They have already produced a market ready product, using residue sheep wool pellets for supporting soil health, fertilization needs and soil water retention.

(2) HEGIARTOS in Eastern Macedonia is an OG aims for the development of a yogurt dessert from goat's milk enriched with antioxidants from espresso coffee residue extract.

Crete

There is no documented OGs for the region of Crete at the moment, despite the region's impressive potential for bio-mass production and use. However, here we will report on a dynamic organisation that coordinates a number of unofficial OGs and other producer organisations and they plan to make their operations official in the next call for financing OG formations. The Mediterranean Agri-Food Competence Centre (MACC) is dedicated to advancing the bioeconomy within the Mediterranean region's agri-food sector. Its mission centres on fostering innovation, sustainability, and competitiveness through research, development, and technology transfer. MACC focuses on the adoption of advanced technologies and innovative practices in agri-food production and processing, driving efforts to create a more sustainable agricultural landscape.

Key activities include collaborative projects with academic institutions, research organizations, and industry stakeholders to develop modern technologies and sustainable practices. MACC also provides training programs to enhance the skills and knowledge of farmers and food producers, ensuring they are equipped to adopt sustainable bioeconomic practices. Networking and partnerships are crucial, as MACC builds collaborations within the Mediterranean agri-food ecosystem to share knowledge and resources effectively. Policy advocacy is another essential aspect, with MACC engaging policymakers to support bioeconomic innovation and sustainability.

The centre's efforts are particularly focused on sustainable agriculture, promoting practices that improve soil health, water efficiency, and biodiversity. Food safety and quality are also prioritized, ensuring products meet ambitious standards through better practices and technologies. Climate change adaptation is a significant area of focus, with MACC developing strategies to help the sector respond to environmental challenges. Additionally, perfecting the agri-food value chain from production to consumption is key to their strategy.

Peloponnese

The region of Peloponnese, hosts 2 official OGs, described below:

(1) HIPO-ENERGY focuses on the utilisation of the leaves of the Hippophage plant, which is characterized as a super-food, for the production of high nutrition additives for soft drinks. They extract the bioactive elements from the leaves for the production of added value nutritional products.

(2) OLIHERB, aims for the exploitation of olive leaves (rich in polyphenols and other bioactive ingredients) to produce herbal infusions and natural food additives. They use the significant quantities of olive leaves produced as by-products during cultivation (pruning), harvesting of olives and olive oil production (milling stage) for developing innovative products with special chemical and nutritional properties.

As with the region of Crete, here, we also describe the operations of an organisation that supports and helps many different unofficial OGs and other producer formations. The Centre of Agricultural Entrepreneurship of Messinia (CAEM) is an essential initiative in the Peloponnese, focusing on promoting the bioeconomy through innovation, sustainability, and entrepreneurship in agriculture. This centre enhances the productivity and competitiveness of the region's agricultural sector, particularly known for high-quality olives and olive oil. CAEM supports local farmers and entrepreneurs by offering speciallysed training programs and workshops on bioeconomic practices, sustainable farming, and value-added agricultural products. These programs aim to educate participants on modern farming techniques, business management, and market opportunities, ensuring they are well-equipped to thrive in a bioeconomy-focused environment. The centre collaborates with universities and research institutions to promote research in agricultural science, focusing on crop improvement, pest management, and sustainable practices. By encouraging the adoption of innovative technologies such as precision farming, smart irrigation systems, and renewable energy sources, the centre helps enhance productivity and sustainability. Sustainable practices are a key focus, with CAEM promoting environmental stewardship and organic farming methods. The centre supports sustainable farming practices that protect the environment, conserve natural resources, and ensure long-term agricultural productivity.

3.3.2 Bio-based technologies (BBT) developed by OGs

Central Macedonia

Fertiwool is an organic fertiliser produced from 100% Greek sheep wool. It is a unique product suitable for all types of crops. Rich in nutrients, it has the ability to keep water and expand, reducing irrigation needs by up to 30% and improving soil structure. It requires only one application every six months due to its slow-release nutrient properties. Additionally, it is 100% biodegradable. This sheep wool-based organic fertilizer is a product of 100% circular economy.

Crete

MACC, in collaboration with Mills of Crete, ABEA and Quality Plus, developed calcium soap from olive oil fatty acids for use in animal feed. This product enhances the reproductive performance of ruminants and contributes to higher milk yield, improved fertility and better animal health. This project promotes the economic value of olive oil by-products, reducing their environmental footprint and enhancing sustainability through the circular economy.

Peloponnese

As part of CAEM's activities, no bio-based technology has been developed yet.

3.4 Discussion of previous sections

In Greece, the regions of Crete, Central Macedonia, and Peloponnese are beginning to embrace the concepts of circular economy and bioeconomy, reflecting a growing recognition of their potential to foster sustainable development and economic resilience. Although these initiatives are still in their initial stages, there is an optimistic outlook for their future.

The circular economy in these regions aims to minimize waste and make the most of resources. Crete, known for its rich agricultural heritage, is exploring ways to reduce waste in the food production sector. By reusing agricultural by-products and improving recycling practices, the region hopes to create a closed-loop system that enhances resource efficiency. Similarly, this approach not only reduces environmental impact but also stimulates innovation and economic growth.

In Peloponnesus, efforts are being made to integrate circular economy principles into everyday life, a key economic driver. By promoting sustainable everyday practices, the region aims to preserve its natural beauty while attracting environmentally conscious agri-food consumers.

The bioeconomy, which involves the use of renewable biological resources to produce food, materials, and energy, is also gaining traction. In Crete, there is significant potential for developing bio-based industries due to its abundant agricultural resources. Central Macedonia is leveraging its strong agricultural and food processing sectors to explore bio-based products, such as bioplastics and biofuels. The Peloponnese is similarly looking to harness its agricultural by-products for bioenergy production, contributing to energy sustainability.

It could be argued that Crete and Peloponnese are "yellow" for implementing bio-based technologies and Central Macedonia could be considered as a "green" region.

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4 Italy - Piemonte, Valle d'Aosta & Liguria

4.1 General description of the region

4.1.1 Geographic description of the region

The area that encompasses Piemonte, Valle d'Aosta (VDA), and Liguria regions (Italian FAN reference territory) is in north-west of Italy, and it is bordered by France to the west, Switzerland to the north and facing the Ligurian Sea to the south. The three regions cover an area of 34,064 km², accounting for 11% of the Italian territory (ISTAT, s.d.),with 5.9 million inhabitants, which represent 10% of the Italian population and 1.3% of the EU27 (EUROSTAT, s.d.);and an average population density of 162 hab/km^2, with a minimum of 38 hab/km^2 in Valle d'Aosta and 279 hab/km^2 in Liguria.

This regions under study includes 13 provinces (NUTS 3), that is, Aosta, Torino, Cuneo, Novara, Vercelli, Biella, Verbania Cusio Ossola, Asti, Alessandria, Genova, Savona, Imperia and La Spezia.

There are 1,512 municipalities and, according to the Italian typological classification of rural areas, 12 municipalities are classified as areas "A-Urban poles"; 273 as areas "B-Rural areas with intensive and specialized agriculture"; 702 as areas "C. Intermediate rural areas" and; "525 as areas "D. Rural areas with comprehensive development problems" (RRN, 2020).

The climate of the Italian FAN reference area varies significantly due to diverse geographical features of the territory, which includes mountains, coastal areas, and valleys. In the mountainous areas, such as the regions near the Alps, the climate is alpine with cold winters, heavy snowfall, and cool summers; the temperatures can drop significantly in winter. The lower areas, including the plains around the Po River, experience a more continental climate, with humid summers and cold, foggy winters and precipitation is evenly distributed throughout the year, with a slight increase in the spring and autumn. The coastal areas have mild, wet winters and hot, dry summers; the sea has a moderating effect on temperatures, preventing extreme highs and lows.

Figure 25: Location of Italian FAN (Piemonte, Liguria, Valle d'Aosta) in Europe (Source: ISTAT)

4.1.2 Agriculture and forestry sectors in the region

Agricultural sector

In the area that encompasses Piemonte, Valle d'Aosta, and Liguria Regions, according to the last Agricultural Census (2020), there are 65,523 agricultural exploitations which carry out their activity in

the 1,026,141.97 hectares of useful agricultural area (UAA), representing the 6% of Italian farms and 8% of Italian UAA (ISTAT, s.d.). Within the Italian FAN reference territory farms represent just under 1% of European agricultural enterprises.

The standard total production average by exploitation in the Italian FAN reference area is 174,120.03 € (Valle D'Aosta 63,293.67; Piemonte 244,818.9, Liguria 73,863.29) (RICA, s.d.).

Regarding the businesses in the agricultural sector, is mainly made up of small and medium small companies (nearly 60%): Small (4,000-25,000 €) 16,444; Medium Small (25,000-50,000 €) 8,550; Medium (50,000-100,000 €) 7,209; Medium Large (100,000-500,000 €) 8,657; Large (>500,000 €) 1,047. A positive fact concerns the presence of owners under 40 years of age, which has been growing also thanks to the RDP policies since 2016 and which in 2022 reached 14% of the total (Piemonte, s.d.).

This accounts for an average establishment size of 15.66 ha, which is above the national average agricultural establishment size that is 11 ha (ISTAT, s.d.). The evolution over the years of useful agricultural area is shown in the Figure 26, where some critical points and a general downward trend can be observed.

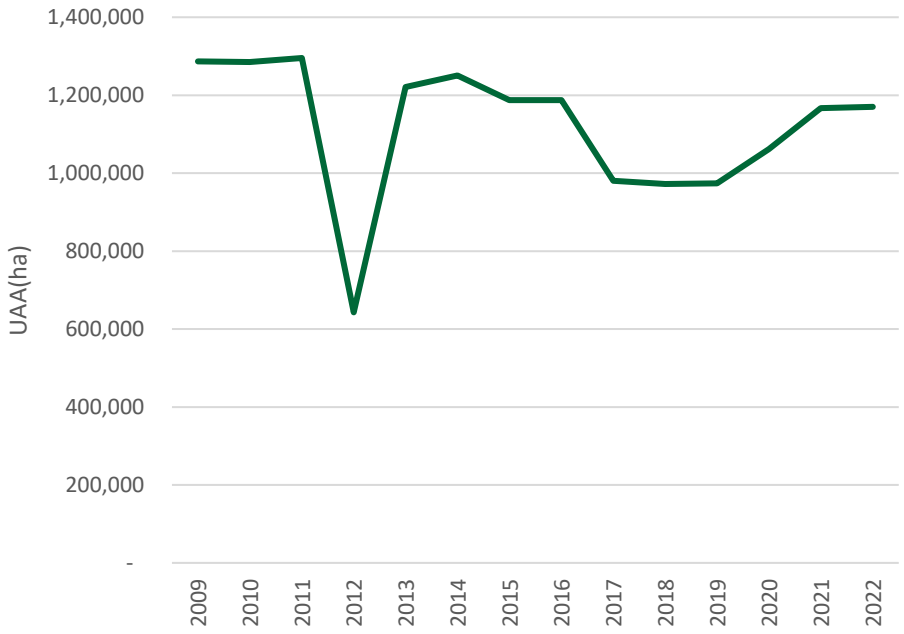

Figure 26: Useful agricultural area (ha) in Italian FAN over the years (ISTAT, s.d.)

Land use in the Italian FAN reference area is characterised by an important presence of arable land (43%), followed by permanent meadows and pastures (25%) and woodlands, permanent crops (woody) (8%). It is important to highlight that the FAN area is largely localised in the mountains. (ISTAT, 2023).

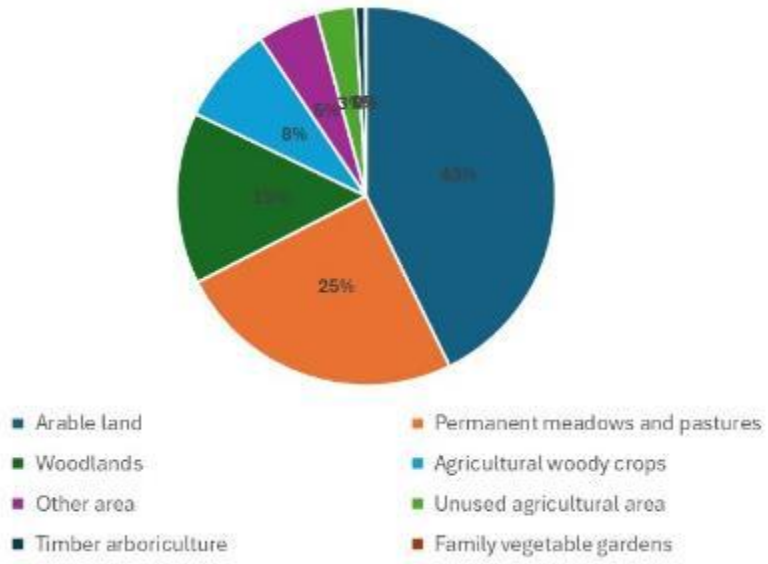

Figure 27: Land use in the Italian FAN area 2020 (Census) (ISTAT, 2023).

Table 21 reports detailed indications about agricultural production in the Italian FAN reference area, both in terms of UAA and quantitative production. It is worth highlighting, among other information, the importance of cereals, especially corn; wine grapes (90% of production is under quality certification); hazelnut groves, which is growing as markedly and interesting crop; and olives, especially in the Ligurian region where olive oil production is particularly important.

Table 21: Area and agricultural production in the Italian FAN reference area 2022 (Annuario) (CREA, 2023)

	Total Italian FAN reference area		*Piemonte*		*Valle d'Aosta*		*Liguria*	
	UAA (ha)	Harvest (t)	UAA (ha)	Harvest (t)	UAA (ha)	Harvest (t)	UAA (ha)	Harvest (t)
CEREALS								
Durum wheat	2,146	6,652	2,146	6,652				
Common wheat	76,028	351,494	75,885	351,112	8	30	135	353
Corn	130,751	1,253,517	130,645	1,253,042	6	45	100	430
INDUSTRIALS								
Rapeseed	1,278	2,544	1,278	2,544				
Sunflower	7,017	14,493	7,017	14,493				
Soybeans	18,151	48,069	18,151	48,069				
OLIVES								
Total olives	17,199	27,977	158	113	1	4	17,040	27,860
GRAPES								
Table grapes	219	1,807	217	1,792			2	15
Wine grapes	45,887	329,593	43,536	316,097	450	2,599	1,901	10,897
FRUIT								
Kiwi	3,356	56,044	3,332	55,938	1	20	23	86
Apricot	650	8,212	593	7,545	3	20	54	647
Cherry	328	2,665	318	2,610			10	55
Apple	7,264	132,007	7,025	126,210	210	5,500	29	296
Nectarine (nectarine peach)	1,924	29,728	1,919	29,713			5	15

	Total Italian FAN reference area		*Piemonte*		*Valle d'Aosta*		*Liguria*	
Hazelnut	27,542	30,199	27,516	30,180	1	1	25	18
Pear	1,562	18,101	1,540	17,871	5	85	17	145
Peach	1,477	20,606	1,371	19,818			106	788
VEGETABLES (in the open air)								
Artichoke	93	972					93	972
Cauliflower and broccoli	50	1,074	40	774			10	300
Endive (curly and escarole)	42	721	21	418			21	303
Radicchio or chicory	48	882	48	882				
Common potato	1,707	31,956	888	24,446	80	1,750	739	5,760
Pepper	125	2,350	119	2,254			6	96
Tomato	323	7,188	194	5,780			129	1,408
Industrial tomato	2,728	135,903	2,728	135,903				
VEGETABLES AND FRUIT (in greenhouses)								
Strawberry	258	45			18	7	240	38
Lettuce	1,004	322			4	2	1,000	320
Eggplant	330	82			30	27	300	55
Pepper	323	104			23	19	300	85
Tomato	865	881			65	146	800	735
Melon	1	1			1	1		
Zucchini	820	242			20	20	800	222
AGRUMES								
Orange	14	117					14	117
Clementine	-	-						
Lemon	24	262					24	262
Tangerine	8	44					8	44

Livestock sector

According to the 2020 Agricultural Census (ISTAT, 2023), the FAN area has 24,089 livestock farms (36% from the total agricultural exploitations) and represent the 10% of the livestock Italian establishments (ISTAT, 2023): the Balassa index value estimated for the Italian FAN reference area is over 1,65, which indicates a relevant specialisation, particularly in the Piemonte region. Most of these livestock farms produce beef and dairy cattle; however, differences are seen in the three regions of the FAN. - In Val d'Aosta, the focus is on extensive dairy cattle breeding in the mountains to produce high-quality local cheese. Breeding in Piemonte is mainly based on meat production, with a local breed of particular value, the *Piemontese*; milk production is also important, both on the plains and in the mountains, as well as the pig industry and a niche production of autochthonous sheep with threefold aptitude (the *Sambucana* sheep). In the Liguria region, on the other hand, breeding is not particularly developed.

Table 22: Farms with animals on 1 December 2020 (census).

	Total FAN area	Piemonte	Valle d'Aosta	Liguria
Total Farms	22,092	17,378	1,425	3.289
Cattle	11,720	9,917	993	810
of which dairy cows	*3,446*	*2,348*	*833*	*265*

	Total FAN area	Piemonte	Valle d'Aosta	Liguria
Buffaloes	19	17	0	2
Goats	4,345	3,162	273	910
Sheep	3,168	2,119	177	872
Pigs	1,742	1,484	27	231
Poultry	3,793	2,802	95	896
Beehives	3,892	2,878	231	783
Others	4,744	3,478	147	1.119

Figure 28: Piemontese cattle & Sambucana sheep.

Forestry sector

According to the third Italian national forest inventory INFC2015 (Carabinieri & CREA, 2021) the wooded territory of the Italian FAN reference area exceeds 1.5Mha (43%). The wooded area is composed by forests that include the so-called “Tall trees forest” and “Temporarily unstocked areas”, “Plantations for timber and wood production” and “Other wooded land” (short trees forests, sparse forests, scrubland and shrubs). 39.1% of the wooded area is covered with forests of different categories.

Table 23: Extension of forest, other wooded land and total wooded area (ha) (Source: Inventario Nazionale delle Foreste e dei serbatoi di Carbonio 2015 – INFC 2015) (Carabinieri & CREA, 2021).

	Forest (ha)	Other wooded land (ha)	Total wooded area (ha)	Total area (ha)
Piemonte	890,433	84,991	975,424	2,539,983
Valle d’Aosta	99,243	8,733	107,976	326,322
Liguria	343,160	44,084	387,244	542,024
Total FAN area	1,332,836	137,808	1,470,644	3,408,329

Forest areas in Italy often recall mountain and hilly landscapes; nevertheless, forests are distributed over a wide range of altitude classes. As for the FAN territory, the 0-500 m.a.s.l class hosts 34% of the total wooded area, followed by the 500-1000 m.a.s.l. class, with 33%. The other three classes (1000-1500, above 1500 m.a.s.l.) include 21% and 12% of total wooded area, respectively. The forest area at the highest altitudes (>2000 m.a.s.l.) is almost totally found in the Alpine regions and in particular in Valle d'Aosta (62%) above 1500 m.a.s.l. prevails (Carabinieri & CREA, 2021).

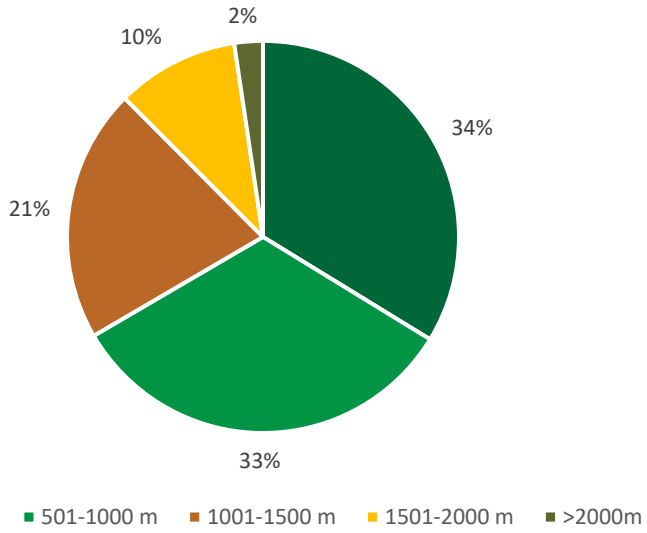

Figure 29: Distribution of forest at different altitudes. (Source: Inventario Nazionale delle Foreste e dei serbatoi di Carbonio 2015 – INFC 2015) (Carabinieri & CREA, 2021).

Accessibility to and availability of wood supply are important for the economic value of forests and allow their use for other purposes. However, the presence of wooded areas not accessible or not available for wood supply is normal given the geographical features of Italy. INFC2015 has estimated that approximately 1.4 million hectares of the total wooded area of the FAN are accessible, accounting for 91% of its total. The percentage is higher in Forest (94%) and remarkably lower (66%) in Other wooded land. The main reasons of the unavailability concern economic limitations (wood production is not cost-effective), followed by legal restrictions due to land or resources protection.

In the Italian FAN regions, the forest area consists mainly of pure broadleaved forests, except for Valle d'Aosta where pure coniferous forests are predominant. Tree species richness is a key element of forest biodiversity, from the ecosystem level to the regional and national one. It is a prerequisite for having forests in different environmental conditions, diversified for ecology and more suitable for the provision of ecosystem services, relevant for the human well-being.

Figure 30: Pure and mixed forests of conifers and broadleaves.

Table 24: Detailed information in Italy

Location	Forestry area
Piemonte region	890,433 hectares
Valle d´Aosta region	99,243 hectares
Liguria region	343,160 hectares
Species	Pure broadleaved and coniferous forests

Agroindustry

The food, drink and tobacco industry (FDI) play a key role within the national manufacturing sector. The number of FDI employees in 2022 reaches around 48,000 workers, while sold production value is estimated to be of 3,880M € (CREA, 2023). The FDI includes around 6,000 active businesses, with an average size of 8.3 employees per business, below the national average for the manufacturing industry (10.2 employees/business). The most important industries in the Italian FAN regions are: i) wine processing that counts on a huge number of quality schemes well known at the national level, such as Barolo and Barbaresco; ii) olive oil (in Liguria we can find Taggiasca oil); iii) milk and milk products sector (Fontina and Gorgonzola cheese); iv) cattle beef as well as “Piemontese” breed; v) colonial products processing (coffee and chocolate); vi) and a very spread network of local production as pesto in Liguria.

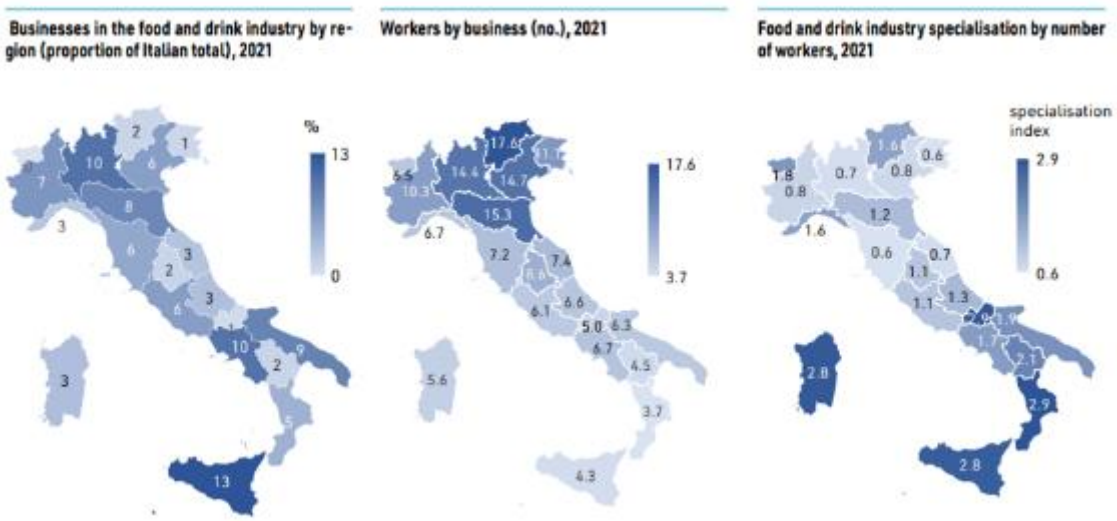

Figure 31: Distribution of business in the food and drink industry, workers by business and food and drink industry specialised by number of workers (Source: CREA (CREA, 2023)).

4.1.3 Economic Indicators

As already described, the Italian FAN reference area is composed of three regions (NUTS 3), which have different socio-economic, morphological, and structural characteristics. For this chapter, it is considered proper to propose a separate view of the three regions.

Piemonte

Piemonte, found in the northwest of Italy, is one of the most industrially developed and economically significant regions of the country. Known for its rich cultural heritage and robust economic landscape, Piemonte contributes significantly to Italy's overall economic performance.

In recent years, Piemonte has shown resilient economic performance despite facing various economic challenges. Piemonte's GDP was approximately 156B€ in 2023. This positions Piemonte as one of the top regions in Italy in terms of economic output, contributing about 8% to the national GDP. Piemonte's GDP per capita stands at around 36,780 €, higher than the national average of Italy. This shows a relatively high standard of living and economic productivity compared to other Italian regions. Agriculture plays a vital role in Piemonte's economy, although its contribution to the overall GDP has diminished over the years due to industrial growth. In 2023, the agricultural sector contributed approximately 1.6% to the region's GDP. Piemonte is renowned for its diverse and high-quality agricultural products, including wines (such as Barolo and Barbaresco), rice, truffles, and several types of fruit and vegetables. Despite the small contribution to GDP, agriculture is still a crucial source of employment in Piemonte, employing about 2.4% of the region's workforce. This reflects the region's commitment to keep its agricultural heritage and supporting rural communities.

The bioeconomy is gaining traction in Piemonte. The sector employs approximately 140,000 people, which accounts for about 6.5% of the region's total employment. This includes jobs in agriculture, forestry, fisheries, food production, and bio-based industries. The GVA generated by the bioeconomy in Piemonte is significant. In 2021, it contributed roughly 7B€ to the region's GVA, highlighting the sector's role in Piemonte's economic framework.

Liguria

Liguria is also located in the northwest of Italy and is renowned for its stunning coastal landscapes, historical significance, and substantial economic contributions to Italy. With a strong maritime and port tradition, Liguria plays a crucial role in the country's trade and logistics sectors.

Liguria's GDP was approximately 57B€ in 2023. This places the region among the significant contributors to the Italian economy, accounting for about 3% of the national GDP. Liguria's GDP per capita stands at around 38,280 €, which is slightly above the national average.

Agriculture, while not the dominant sector in Liguria, stays important, particularly for certain high-value products like olive oil and wine. In 2023, the agricultural sector contributed approximately 1.3% to the region's GDP. Liguria is known for its unique agricultural products, including its famed *Pesto* sauce made from basil, olive oil, and pine nuts. Agriculture provides employment for about 1.4% of the region's workforce. Although this percentage is relatively low, it underscores the significance of agriculture in supporting rural economies and preserving the cultural heritage of the region.

The bioeconomy sector in Liguria employs approximately 45,000 people, which accounts for about 4% of the regional total employment. The GVA generated by the bioeconomy in Liguria is notable. In 2021,

the bioeconomy contributed roughly 2.5B€ into the region's GVA, indicating its growing importance in the economic structure.

Valle d'Aosta

Valle d'Aosta is a unique and significant region known for its stunning alpine landscapes and rich cultural heritage. As the smallest and least populous region in Italy, it has a distinctive economic profile characterized by a mix of traditional industries and emerging sectors.

Valle d'Aosta's economic performance is relatively modest but stable. The region's GDP was approximately 5.79 B€ in 2023. Valle d'Aosta boasts a high GDP per capita, around 47.040 €, which is significantly above the national average. This shows a high standard of living and economic productivity, making it one of the wealthiest regions in Italy on a per capita basis. Agriculture in Valle d'Aosta plays an essential role in the region's economy and cultural identity. In 2021, the agricultural sector contributed approximately 2.3% to the region's GDP. The region is known for its dairy products, such as Fontina cheese, as well as its vineyards producing renowned wines. Agriculture stays a crucial source of employment in Valle d'Aosta, engaging about 3.5% of the region's workforce. This higher percentage compared to other Italian regions highlights the importance of agriculture in sustaining rural communities and keeping the region's traditional ways of life.

The bioeconomy sector in Valle d'Aosta employs approximately 7,000 people and the GVA it generates contributed around 500M€ to the region's GVA, underscoring its importance in the regional economic framework.

Table 25: Economic indicators by region/country (European Union, s.f.).

Region/Country	Population (M hab)	GDP (kM€)	GDP per capita (€)	GVA (M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Italian FAN area	6	220	37,37	3		2,2%
Piemonte	4,25	156,33	36,78	2,24	72,2	2,4%
Valle d'Aosta	0,123	5,79	47,07	0,063	77,3	3,5%
Liguria	1,51	57,7	38,3	0,54	72,2	1,4%

4.1.4 Bioeconomy regulatory framework

Italy has developed a comprehensive regulatory framework to support the bioeconomy and the valorisation of biomass at both the national and regional levels. This framework includes a range of policies, strategies, plans, and laws aimed at promoting sustainable economic growth through the efficient use of biological resources.

To further exploit the whole Bioeconomy potential, the Italian Government promoted, at national level, the setup of a **National Bioeconomy Strategy in 2017 (BIT**) (Government, 2017) and, more

recently, its update as **"A new Bioeconomy strategy for a sustainable Italy", BIT II, 2019** (Government, 2019). The BIT II aims to interconnect more efficiently the main economic sectors composing the Italian bioeconomy, namely the production of renewable biological resources and their conversion into valuable food, feed, bio-based products, wooden products, and bioenergy, along with the transformation and valorisation of bio-waste streams. Moreover, BIT II aims to a better governance model through increased coordination of Ministries, Regions and autonomous Provinces and the alignment of policies, regulations, R&I funding programs and investments in infrastructures. The overall goal is a 15% increase of the current turnover and jobs of the Italian Bioeconomy by 2030 by implementing priority actions and an R&I agenda, which are accompanied by measures creating and guaranteeing the framework conditions.

Due to the strategic geo-political role of Italy in the Mediterranean basin, BIT II also includes actions to improve sustainable productivity, social cohesion, and greater political stability through the implementation of Bioeconomy in the Mediterranean area, in line with the PRIMA partnership, and the BLUEMED and WESTMED initiatives.

Furthermore, the Bioeconomy Strategy aligns closely with various national and EU strategic plans, regulations, and funding measures, enhancing the implementation of specific bioeconomy initiatives.

The **National Energy Strategy** (Ministero dello Sviluppo Economico, s.d.)**,** published in 2017 includes significant provisions for the development of bioenergy. It encourages the use of biomass for energy production, which is seen as a crucial part of Italy's transition to a more sustainable energy system. This strategy aligns with EU directives on renewable energy and sustainability. The NECP or **National Plan for Energy and Climate** (MISE, s.d.) for the period 2021-2030 deals with the target that Italy aims to reach in terms of renewable energy, emissions and energy efficiency. The updates of the "National Energy Strategy" and the "National Plan for Climate and Energy" provide the framework within which the diverse sources of energy will develop in order to achieve the targets on GHG emission reduction and renewable energy share. In addition, Italy has adopted a "**National Adaptation Strategy**" (Ministero dell'ambiente e della sicurezza energetica, s.d.) and is putting into place the "National Adaptation Plan". The Bioeconomy can play a significant role in both senses, in terms of providing clean energy sources and ensuring a long-term conservation of natural resources and ecological systems, also through nature-based solutions.

The **European Agricultural Fund for Rural Development (EAFRD)** focuses on new value chains based on the smart and integral use of agro-waste and specialized crops for industrial uses to be grown on marginal lands, creating the necessary interface for agro-energy and bio-based industries. They provide financial support for sustainable agricultural practices, the development of bio-based industries, and the valorisation of agricultural and forestry residues.

Italian Circular Bioeconomy Cluster (Cluster SPRING (Anon., s.d.)) is a national cluster that brings together stakeholders from industry, academia, and government to promote the development of the bioeconomy in Italy. It eases collaboration on research projects, technological development, and the commercialization of bio-based products.

It is necessary to emphasize how the Italian Bioeconomy Strategy is part of the implementation process of the National Smart Specialization Strategy 2021-2027 (S3) (territoriale, s.d.). The Smart Specialisation Strategy aims to name priorities for investment in research, development and innovation that complement the resources and productive capacity of territories to build comparative advantage and sustainable growth path in the medium and long term. The S3 is implemented a

regional level and aims to boost innovation and competitiveness in the regions by using their strengths in agriculture, food processing, and green chemistry. The strategy supports collaborative projects between universities, research centres, and industries to drive advancements in the bioeconomy sector.

Indeed, at regional level different projects are implemented to take advantage of the specific characteristics of territories. For example, **The Piemonte Bioeconomy Technology Platform** (Dupont-Inglis, et al., 2021) is a good practice of a regional policy model designed to support bio-based value chains. The platform aims to stimulate circular production ecosystems on a regional scale by leveraging supply chains. In this way, it helps sustainable growth with low environmental impact and lays the foundation for the long-term development of the bioeconomy in the region. Another exemplary initiative at regional level is the BIOFAT project in Liguria (sostenibile, s.d.). This project focuses on cultivating microalgae for producing bio-chemical products. The significance of this project lies in its cultivation of a diverse range of species, which offer significantly higher productivity per hectare compared to traditional green plants. Furthermore, it underscores the potential of bio-based technologies in various industrial sectors, including cosmetics and pharmaceuticals. In addition, agro-energy projects involving the use of agricultural residues as a renewable energy source have been implemented in many regions. Agri-energy is a growing bioeconomy sector on national soil because of its potential in generating income for farmers as well as promoting sustainable practice.

Lastly, in recent year, the **National Strategy for the Circular Economy** (Italiano, s.d.) and the **National Waste Management Programme** (Ecologica, s.d.), two reforms envisaged by the NRRP (National Recovery and Resilience Plan) (MEF, s.d.) and approved in June 2022, outline the programmatic framework for Italy's ecological transition, identifying the actions, objectives and measures to be pursued. Within the National Strategy, considerable space is also given to more efficient use of natural resources, with specific objectives for water (e.g. to encourage the reuse of treated wastewater and possibly widen the application of reclaimed water to industrial or urban use) and soil (e.g. to promote the rehabilitation of contaminated sites, industrial conversion of reclaimed land and initiatives to reduce soil sealing). The strategy will specifically measure and track the progress of the transition to the circular economy through circularity indicators.

4.2 State of the art of biomass valorisation

4.2.1 Biomass resource availability

In 2019, the added value of the Bioeconomy was approximately 103B€, 6.4% of the national added value (Intesa San Paolo, Giugno 2022). The agri-food chain represents the most significant activity in all geographical areas, with percentages ranging from 46% in the Central regions to 78% in the Southern regions. In the North-West, where the Italian FAN is located, the agri-food chain accounts for 56%, while in the North-East the percentage is 62%. At the regional level there are notable differences in absolute terms for added value generated: Lombardia, Veneto, Emilia-Romagna and Toscana together represent more than 50% of the overall added value; Piemonte contributes with 7.8%, while Liguria only with 1.9% and Valle d'Aosta with 0.1%. In relative terms (weight of the Bioeconomy on the productive fabric of each territory), however, Umbria is in first place, with an incidence of VA of 9% and with a greater relevance of agriculture and the bio-based fashion system, followed by Trentino-Alto Adige (8.9%), where the weight of the agri-food and wood supply chains emerges. Piemonte, Liguria and Valle d'Aosta show values below the national average.

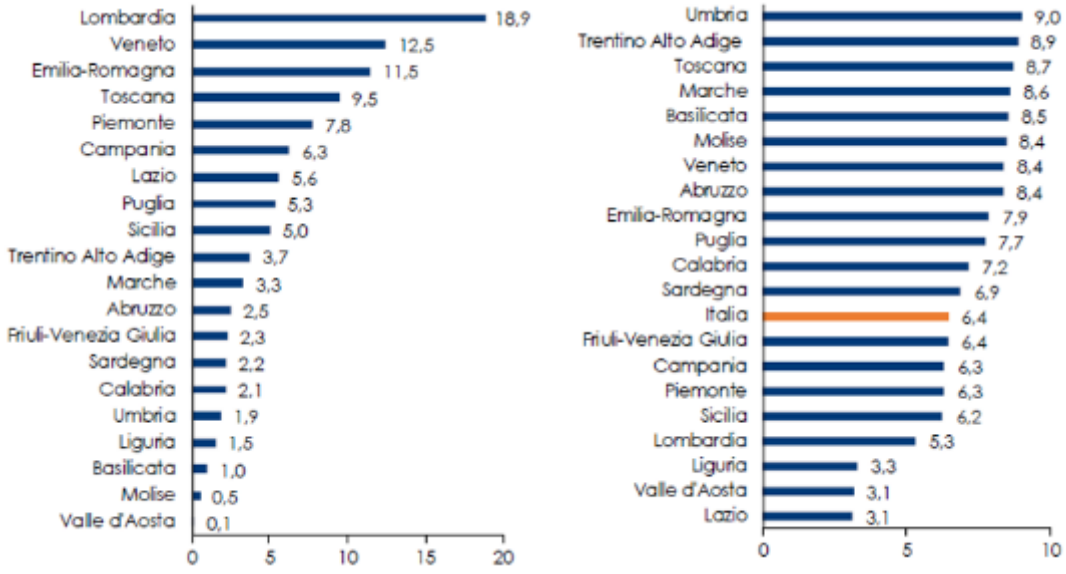

Figure 32: Bioeconomy value added by region (billion euros, 2019) Weight of Bioeconomy value added to total regional VA (%, 2019) (Intesa San Paolo, Giugno 2022).

Given the lack of data, several studies produced estimates on the availability of biomass in Italy. For example, the EU H2020 ENABLING project shows a potential availability of approximately 25 Mtonnes/year of agricultural and agro-industrial residues at national level.

Table 26: Economic indicators by region/country (ITABIA, 2020)

	Agricultural (tonnes/year)	Agroindustry (tonnes/year)	Total (tonnes/year)	% Total
North	13,132,966	1,228,249	14,361,215	57.5%
Center	3,316,313	317,929	3,634,242	14.6%
South and Island	5,445,309	15,311,198	6,976,507	27.9%
Total	**21,894,588**	**3,077,376**	**24,971,964**	**100%**

According the 10th Report on "*La bioeconomia in Europa*", in 2023, the activities connected to the bioeconomy in Italy generated an estimated output of 437.5B€, employing approximately two million people, and accounting for 10% of the total output, 7.6%, considering employment of the total Italian economy, up from the previous three-year period (Intesa San Paolo, 2023).

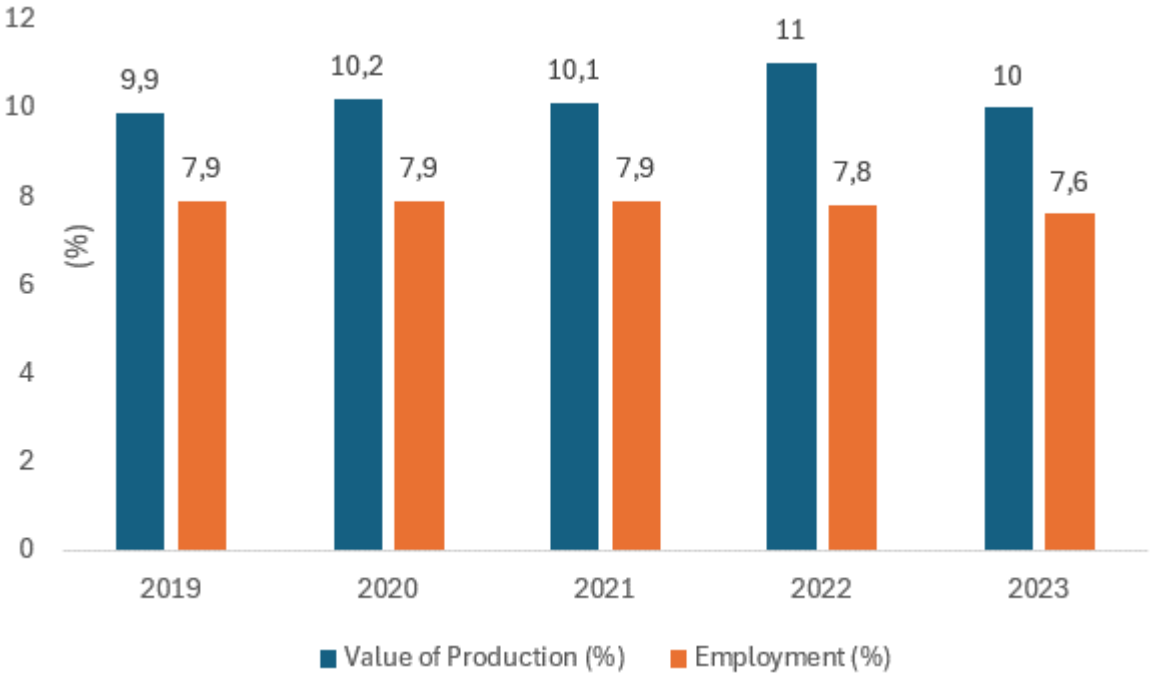

Figure 33: The evolution of the weight of the Bioeconomy in Italy in terms of value of production (% of total economy) and in terms of employment (% of total economy) (Intesa San Paolo, 2023).

After the significant acceleration in 2022, with the bioeconomy production value reaching 428.3B€ — an 18% increase from 2021 (+65.5B€), partly due to a substantial rise in production prices—growth in 2023 continued but at a slower pace of 2.2%. This outcome reflects the varied performance across different bioeconomy sectors. Employment remained stable, with around 2 million people employed throughout the 2021-2023 period.

Table 27: Italian overview of bioeconomy.

	Value of production (M€)				Weight (%)	Occupation 2022	
	2019	2020	2021	2022		thousands	%
Total Bioeconomy	338,356	319,604	358,245	415,308	100	1.996	100
Agriculture, Forestry and Fisheries	61,202	60,519	64,671	69,940	17.4	895	44.8
Food, beverage and tobacco	141,904	139,814	150,615	176,900	42.1	485	24.3
Bio-based textiles	9,598	7,695	9,292	10,998	2.7	51	2.5
Bio-based clothing	15,290	12,246	14,625	17,962	4.1	95	4.8
Bio-based tanning and leather goods	16,663	12,513	15,276	18,898	4.8	76	3.8
Wood and wood products	13,348	11,667	15,873	19,104	4.6	91	4.5
Paper and paper products	24,226	22,689	26,006	33,569	7.6	86	4.3
Bio-based chemicals	4,911	3,612	4,547	5,540	1.7	9	0.4
Bio-based pharmaceuticals	14,296	14,034	14,288	16,407	4.1	37	1.9
Bio-based rubber and plastics	1,360	1,163	1,417	1,630	0.4	5	0.3
Bio-based furniture	10,780	9,995	12,489	14,011	3.4	63	3.1
Bioenergy	3,525	2,209	2,818	4,150	0.9	2	0.1
Biofuels	340	292	1,843	ND	ND	ND	0
water cycle	12,499	12,417	14,369	15,375	3.7	50	2.5
biofuels management	8,445	8,471	10,116	10,824	2.5	52	2.6

The most significant contribution to the growth of the bioeconomy in 2023 is that of the agri-food supply chain, which represents approximately 60% of the total value, with an output of approximately 276B€ (of which 195 billion generated by the food, beverage and tobacco industry), closed with an increase in production value of 6.8%, strongly influenced by inflationary dynamics, although less intensely than observed in 2022.

The production value of the agri-food supply chain grew by 18.6%, contributing over 7% to the overall growth of the bioeconomy. Also, in terms of employment, the agrifood is the most relevant sector in the bioeconomy: in 2023, there were 872,000 people employed in the agricultural sector and 492,000 in the food, beverage and tobacco industry, amounted to 44% and 24.9% of the total national, respectively. The development in 2023 confirmed the trend already seen in 2022, reporting a decline in employment in the agriculture, but an increase in the downstream processing sector.

Some estimates show that in Italy the main use of biomass of agricultural and agro-industrial origin (about 78%) occurs in the zootechnical sector as food and/or litter and only a minimal part is applied for bioenergy and/or biomaterial purposes (Gurria, et al., 2020). In particular, for straw the percentage

that can be sustainably collected for purposes other than current use is approximately 40% of the total, while for pruning this percentage varies between 45-50%, for grape marc it is approximately 33% of the total product and for citrus pulp it is only 10-15% of the total (ENAMA, 2021).

The *Atlante Biomasse* (ENEA, s.d.) provides data on the main biomass products at provincial level, with reference to different years for the different types of products.

Totally, the agricultural waste contributes with 2,853,631 tonnes of dry matter in 2022 in the Italian FAN reference area (Liguria, Piemonte and Valle d'Aosta), mainly from Piemonte (Table 28). Among agricultural waste 2,454,853 tonnes of dry matter consist of straw. Regarding wood from forest (2005), with a total of over 319,500 tonnes, there is a more balanced distribution in the three regions considered in absolute terms, even if the contribute of Liguria and Valle d'Aosta is important considering the available surface area. The energy crops have a residual impact on the total, with only 795 tonnes, of which 581 are produced in Piemonte.

Table 28: Agricultural waste (tonnes of dry matter per year; 2002) Wood Forests (t/year;2005) and Energy crops (t/hectare; 2005) per Fan area and NUTS 3.

Biomass	FAN	*Imperia*	*Savona*	*Genova*	*La Spezia*	*Cuneo*	*Asti*	*Alessandria*	*Torino*	*Vercelli*	*Novara*	*Biella*	*Verbano Cusio Ossola*	*Aosta*
Agricultural waste	**2,853,631**	***41,751***	***6,966***	***12,357***	***5,679***	***613,221***	***174,208***	***479,764***	***678,436***	***507,954***	***291,159***	***38,351***	***1,059***	***2,726***
Straw	2,454,853	-	*976*	*15*	*280*	*531,121*	*129,107*	*431,421*	*668,476*	*414,642*	*245,008*	*32,702*	*916*	*189*
Pruning	161,349	*34,282*	*4,529*	*9,349*	*3,952*	*55,408*	*26,571*	*18,476*	*3,934*	*584*	*1,117*	*806*	*104*	*2,237*
Lawn husks	149,812	-	-	-	-	*239*	-	*10,758*	*233*	*91,058*	*43,477*	*4,047*	-	-
Shells	11,900	*3*	*5*	*38*	-	*6,951*	*3,044*	*1,476*	*363*	*7*	-	*12*	*1*	-
Grape marc	39,086	*250*	*165*	*38*	*602*	*13,393*	*14,003*	*8,582*	*906*	*106*	*368*	*342*	*31*	*300*
Pomace	12,133	*7,200*	*1,164*	*2,895*	*840*	*7*	*7*	-	*11*	-	*7*	*1*	*1*	-
Oil	18,065	-	-	-	-	*1,955*	*1,300*	*7,552*	*4,263*	*1,384*	*1,171*	*436*	*4*	-
Seeds	5,835	*6*	*114*	*22*	*4*	*4,073*	*176*	*1,006*	*244*	*172*	*11*	*5*	*2*	-
Pastazzo	24	*10*	*13*	-	*1*	-	-	-	-	-	-	-	-	-
Tomato Peel	574	-	-	-	-	*74*	-	*493*	*6*	*1*	-	-	-	-
Wood Forests	**319,568**	***26,109***	***32,885***	***11,473***	***17,901***	***12,520***	***10,547***	***54,964***	***13,801***	***29,205***	***5,266***	***29,918***	***66,587***	***8,391***
Hardwoods	290,610	*25,747*	*32,005*	*10,902*	*16,953*	*12,275*	*9,340*	*54,478*	*13,427*	*27,880*	*4,916*	*24,542*	*52,341*	*5,804*
Conifers	27,234	*362*	*804*	*448*	*820*	*97*	*1,096*	*369*	*190*	*1,035*	*177*	*5,230*	*14,120*	*2,486*
Arboriculture	134	-	-	-	-	-	-	-	-	*134*	-		-	-
Energy crops	**795**	**-**	***37.8***	***61.4***	***64.2***	***74.2***	***55.4***	***58.6***	***92.0***	***78.0***	***86.6***	***73.1***	***63.2***	***50.7***
Arundo	225		*10.7*	*17.4*	*18.2*	*21.0*	*15.7*	*16.6*	*26.1*	*22.2*	*24.5*	*20.7*	*17.9*	*14.4*
Miscanthus	180		*8.5*	*13.9*	*14.5*	*16.8*	*12.5*	*13.2*	*20.8*	*17.6*	*19.6*	*16.5*	*14.3*	*11.5*
Panicum	135		*6.4*	*10.4*	*10.9*	*12.6*	*9.4*	*9.9*	*15.6*	*13.2*	*14.7*	*12.4*	*10.7*	*8.6*
Thistle	73		*3.5*	*5.6*	*5.9*	*6.8*	*5.1*	*5.4*	*8.4*	*7.1*	*7.9*	*6.7*	*5.8*	*4.6*
Sorghum	183		*8.7*	*14.1*	*14.7*	*17.0*	*12.7*	*13.5*	*21.1*	*17.9*	*19.9*	*16.8*	*14.5*	*11.6*

Funded by the European Union

4.2.2 Management and logistics of biomass resources

As regards biogas and biomethane plants, in Italy more than 2,000 biogas plants are operating in Italy (of which 1,700 in the agricultural sector), 80% of which are fuelled by agricultural biomass (livestock effluents, agricultural waste, agro-industrial by-products, energy crops) (Anon., 2021). To produce biomethane, the most used technology is the upgrading of biogas to biomethane (separation of methane from carbon dioxide). Potentially, Italy could produce up to 8.5 billion m^3 of biomethane by 2030, equal to approximately 12-13% of the current annual need for natural gas.

83.4% of the total national production of electricity from biogas is provided by the regions of Northern Italy; 34.6% of the total is concentrated in Lombardy, followed by Veneto (15.3%), Emilia-Romagna (14.6%) and Piedmont (12.6%) (Agrillo, et al., 2022).

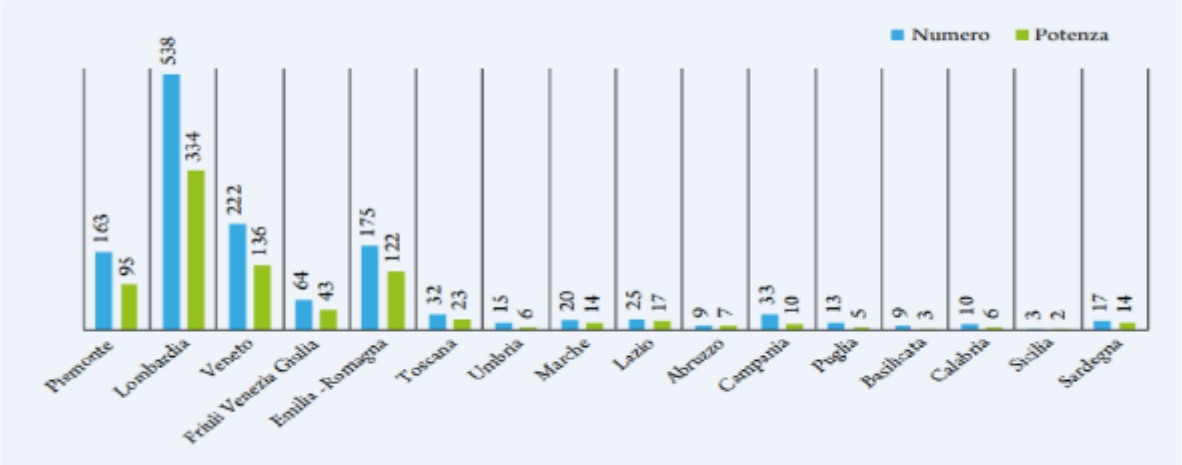

Figure 34: Number and Power of Biogas Plants Nationwide (No., MW)

At the end of 2020, there were 19 active plants to produce biomethane from the agricultural supply chain. In addition to these, there are the biomethane plants from OFMSW active in Italy (27), for a total of 49 connected plants (Agrillo, et al., 2022).

Moreover, the introduction of sustainability certification for bio-based products could lead to an increase in Italian demand for such certified products, stimulating, in turn, the market uptake of bio-based products, as showed by the STAR-ProBio project (Anon., s.d.).

4.2.3 Bio-products target market

Italy boasts the third-largest bioeconomy in Europe, with an annual turnover of 330 B€ and a workforce of 2 million, making it a vital part of the nation's economy. The Italian bioeconomy is based on the sectors producing and processing biomass, which is agriculture, livestock, forestry, fisheries and aquaculture, and food and bio-based industries. The latter includes the wood processing, pulp paper industries, biorefineries, but also the pharmaceutical, cosmetic, chemical, textile and energy industry sectors that use biobased products, and other sectors that exploit municipal wastewater and biowaste, as well as some marine and maritime activities.

The country excels in sectors such as food and biobased products and is actively involved in EU-funded research and innovation projects, particularly within the Horizon 2020 programme (Societal Challenges 2) and the European Public Private Partnership “Biobased industry” (BBI-JU).The Italian Bioeconomy strategy (BIT) (Government, 2017) was approved in 2017, after 2 months of public consultation, and

updated in 2019 (BIT II) (Government, 2019), following consultation within different Ministries, 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. The strategy for the Italian bioeconomy is aimed at increasing both turnover and jobs by 15 % from 2017 to 2030 (R. Piamonte, s.d). in addition, it aims to boost the sustainable valorisation and regeneration of terrestrial and marine biodiversity, ecosystem services and marginal/abandoned lands. Italian national legislative initiatives are intended to guarantee standards of sustainability in order to stimulate the marketing of bio-based products.

Indeed, Italy is a European leader in bio-based industry and has developed a number of innovative proprietary technologies in the chemistry and industrial biotechnology sectors. In addition, a variety of new products was generated now marketed both nationally and internationally (Fava, et al., 2021). The bio-products target market in Italy encompasses a diverse range of sectors, reflecting the country's strong bioeconomy. Key target markets and their relative turnover are reported in the Figure 35.

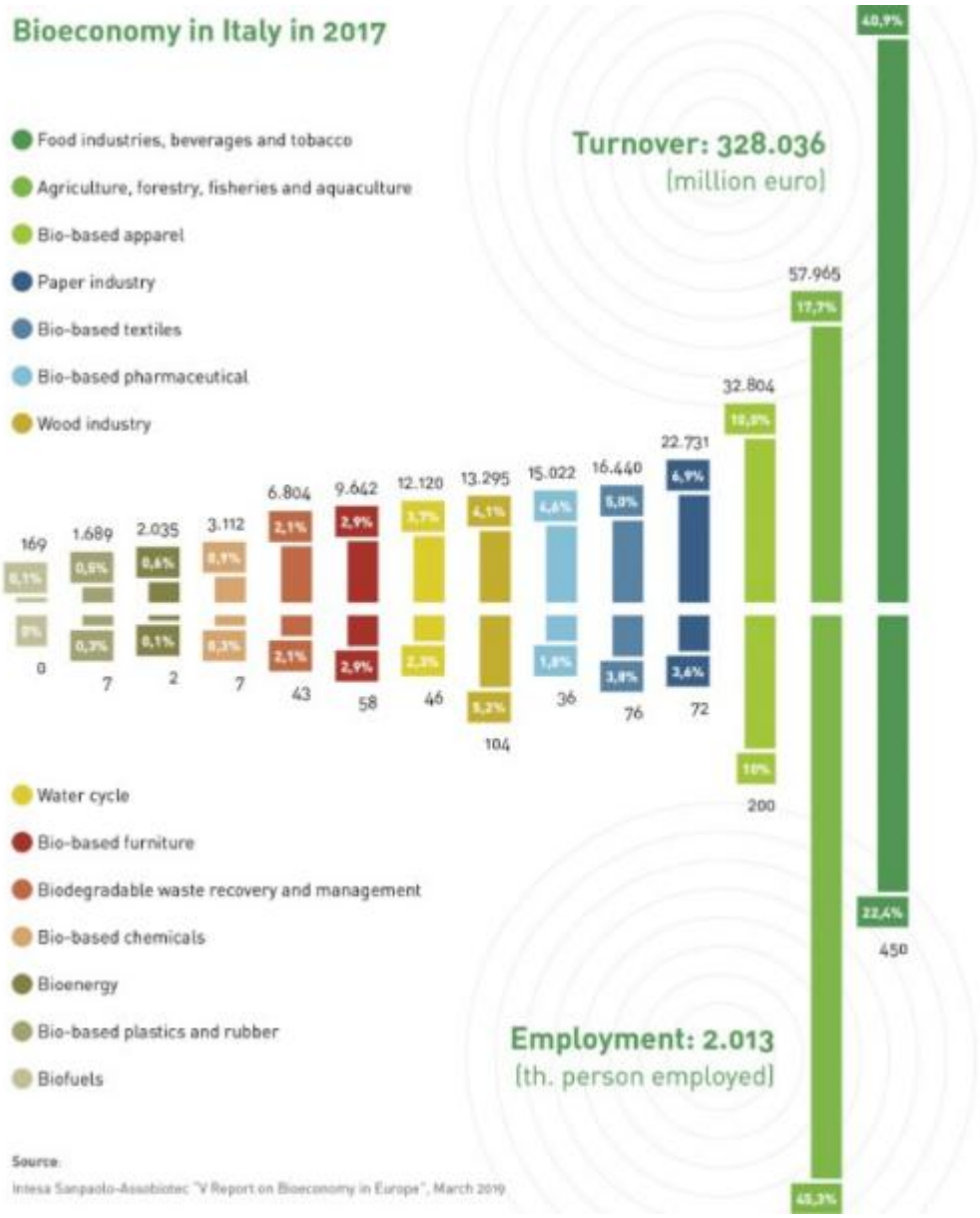

Figure 35: Turnover and employment of bioeconomy in Italy in 2017 (Eurostat data).

In 2019, the European Commission conducted a survey on 15 success stories across Europe, including Italy, focusing on specific products aimed at addressing potential investor concerns in the growing bio-based sector. The report highlights that although the target markets for bio-products are highly diversified, the market itself and the pricing set for these types of products pose a risk factor for companies.

The higher price of bio-based products compared to fossil-based alternatives often presents a significant challenge for market success. Various mitigation strategies have been observed, including efforts to reduce production costs through improvements in technologies, processes, and feedstocks, as well as scaling up production.

In terms of market penetration, bio-based products often face a conservative, skeptical, and well-established market. Successful cases highlight the advantage of having owners or management with prior experience in the sector. This includes partnerships with established players in their go-to-market strategies and focusing on co-developing showcase applications with potential customers.

Demonstrating the superior performance of bio-based products compared to fossil-based ones can help offset the price difference.
Another mitigation approach involves finding and targeting market segments less sensitive to price, such as specific applications, customer segments, or product types. To achieve positive market reception, the performance-to-price ratio of the product must be well regarded. Success stories illustrate strategies such as raising general awareness, collaborating with influencers (e.g., bloggers), and investing in certifications documenting the product's sustainability and its feedstock. Additionally, obtaining documentation and approvals to prove performance aspects plays a crucial role in market acceptance (European Commission, 2019).

The gathered experiences confirm that the bio-based industry market is still in the development phase, presenting limitations and areas for improvement. However, it appears to have the potential for these success stories to spread and become fully integrated into current market economies.

Bio-based industry

The bio-based industry (Government, 2019) is the segment of the bioeconomy that uses renewable biological resources in innovative industrial processes for manufacturing biomass-derived goods/products and services. Hence it concerns industrial sectors, which traditionally use biological resources as their main feedstock or catalysts (forest-base sector, biofuels/bioenergy, biotechnology), and others for which biomass is part of the raw material portfolio (e.g. Chemicals, Plastics, Consumer goods). Thanks to the levels of innovation already achieved through a number of proprietary technologies developed in the chemistry and industrial biotechnology sectors, the investments made, the range of products such as green catalysts and microbes, and the value chains available, Italy is playing a leading role in the bio-based industry. Bio-based plastics and rubber account for about 1.7B€ of turnover and involve 7,000 employees. Biomaterials are gaining attention also for applications as building envelopes and in the construction sector in general. Electricity and heating from biomass and bioenergy in a broad sense (2 B€ of turnover corresponding to 0,6% of the bioeconomy and 2,000 employees, namely 0,1%) are consolidated sectors, together with next-generation biofuels (169 M€). Also, biopharmaceutics (turnover: 15B€, corresponding to 4,6% of bioeconomy and 36,000 employees), biocosmetics and bio-based chemicals (turnover 3 B€ with 7,000 employees) are highly specialized sectors taking part in the bioeconomy. Bio-textiles (turnover of 16,4 B€ accounting for 5% of bioeconomy and 76,000 employees) and bio-based apparel (32,8B€ corresponding to 10% of the bioeconomy and employing 200,000 workers) are crucial segments of the bioeconomy, strongly connected to high value manufacturing productions of the made in Italy. The bio-based industry also embraces production activities aimed at the effective valorisation of biological materials for residential buildings (e.g. vertical indoor agriculture, etc.), bio-waste, urban, agricultural and industrial effluents/wastewater, agriculture and livestock residues, the production of bio-methane, bio-fertilizers, bio-lubricants, and essential amino acids for feed production. Bio-based chemistry is one of the few sectors where Italy is a leading player in a high-tech environment, with large private investments, and important projects underway for the reconversion of industrial sites affected by the crisis into bio-refineries for the production of bio-products and bio-chemicals from renewable sources. Over a billion euro has already been invested in the re-industrialisation of decommissioned or no longer competitive sites of national importance and for the construction and launch of four flagship plants – the first of their kind in the World. Notably, the Italian bio-based industrial sector is characterized by a network of large, medium and small size companies which work together,

leveraging on the sustainable production and efficient use of biomass, following a cascading approach to increase the added value of agricultural production with complete respect for the biodiversity of local areas, in collaboration with the agricultural world and creating partnerships with local actors.

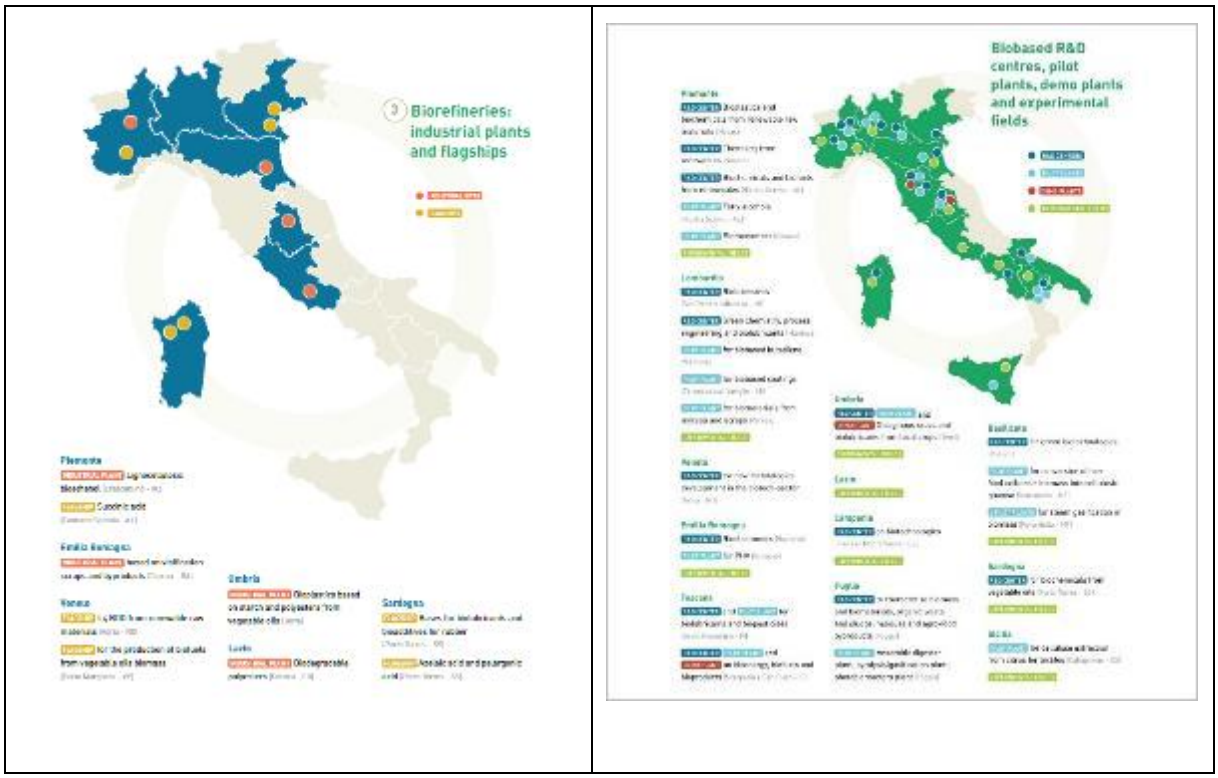

Figure 36: Bio-based biorefinery plants, research centres, pilot and demo plants available in the country (Government, 2019)

Among the 13 Italian producers of electricity from solid biomass that have grouped together in the Solid Biomass Energy Association (EBS) two operators are located in the Italian FAN reference area. There are 15 Italian plants producing 250 Mt/year of virgin solid biomass and an allied industry of more than 5,000 direct and indirect employees (Anon., s.d.).

Table 29: Italian producers of electricity from solid biomass (Anon., s.d.).

Region	Society	Plants	MWe	Website
Calabria	Ecosesto S.p.A.	1	15	-
	Biomasse Crotone S.p.A.	1	31	-
Emilia Romagna	Sorgenia Bioenergie	1	27	www.sorgenia.it/biomasse
	Tampieri Energie SRL	2	35.5	www.tampieri.com/
Lazio	Bonollo Energia	1	26.6	www.bonolloenergia.it/
Lombardia	Biomasse Olevano SRL	1	21	www.olevanolomellina.it/
Molise	C&T S.p.A.	1	13.5	www.cetspa.it
Piemonte	C&T S.p.A.	1	13.5	www.cetspa.it
	Idroblins SRL	1	7	www.idroblins.it/
Sardegna	Sardinia Bioenergy SRL	1	13.5	www.sardiniabioenergy.it/
Sicilia	SPER S.p.A.	1	18.7	-
Veneto	CEB SRL	1	6	-
	Zignago Power SRL	2	21	www.zignagopower.com

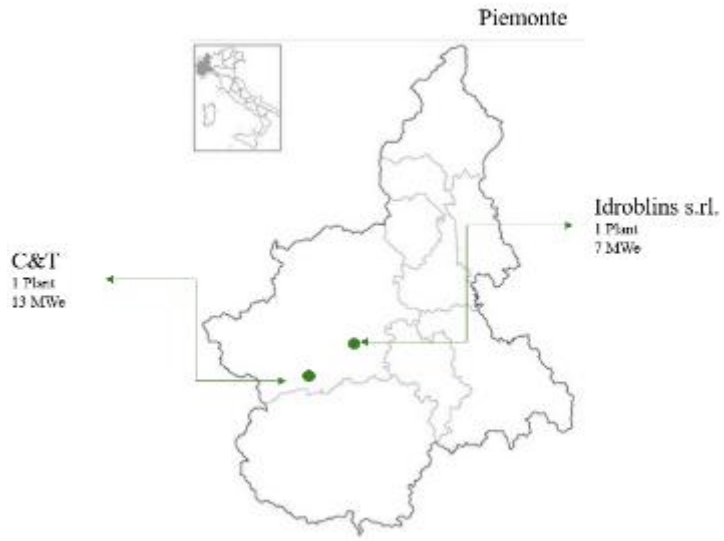

Figure 37: Solid biomass power plants in Piedmont (Anon., s.d.).

4.2.4 R&D system associated with biomass valorisation

The Italian R&D system has a national institutional structure. The responsibilities and decision-making roles are assigned to the Ministry of University and Research flanked by other ministries which handle research in specific sectors, such as Ministry of Agriculture, Food Sovereignty and Forests, Ministry of Health, Ministry of Environment and Energy Security, etc.

The main public research institutions are:

- the universities (67 structures) that deal with higher education and research and are rather uniformly distributed in the regional territories.
- the public research bodies (22 institutions) that deal with research and, often, support public institutions like ministries and regions, to implement policies and take technical decisions/choices.

The most known public research institute is the National Research Council (CNR), which counts on several departments and laboratories, found across the country and covering all scientific specializations.

The Council for agricultural research and economics (CREA) is dedicated to agricultural topics, including the implementation of agricultural policies; it is organized in 12 Research Centres and its structures are distributed across the country.

There are also many private research structures, some of which recognised by the Ministry of research and others are part of enterprises.

Regions do not have an autonomous competence on research, but they run under national rules. However, some regions have regional research centres, which are usually specialised on topics of local relevance, including those related to agriculture and forestry.

Two Italian research programs promote the bioeconomy and the valorisation of biomass: the National Research Program 2021 -2027, managed by the Ministry of University and Research (MIUR, s.d.) and

the Strategic Plan for Innovation and Research in agriculture, forestry and food 2024-2027 (under revision), managed by the Ministry of Agriculture, Food Sovereignty and Forests (MASAF, s.d.).

The National Research Program includes a specific section for bioeconomy “Bioindustry for bioeconomy” under the thematic area “Food Products, bioeconomy, natural resources, agriculture, environment”. This section is articulated in other subsection: Multifunctional valorisation of forest production, Circular bioindustry, Recovery and valorisation of waste and end-of-life organic products for soil regeneration and environmental protection, Innovative business models for the modern bioeconomy. The Strategic Plan for Innovation and Research in agriculture, forestry and food includes a thematic area dedicated to bioeconomy, namely, “Sustainable utilization of biological resources and utilization of residues/waste and/or by-products for agricultural, craft, energy and industrial purposes” articulated in three subareas: development and rationalization of biomass and biofuel supply chains with adequate environmental and economic sustainability requirements; development of biorefineries for the production of industrial materials and technical means from agricultural residues and wastes and/or by-products with a view to the adequate remuneration of the agricultural sector; valorisation of residues and wastes and/or by-products for agricultural and artisanal purposes. These programs are the framework for all the initiatives (European, national and regional) of research promotion and funding.

The organization described above implies the possibility for the Italian research institutions to work in all national territory and on all topics; this is the most common behaviour. Certainly, on topics like agriculture, closely connected with pedoclimatic context, the universities and other research bodies tend to specialize on regional or local issues.

Valle D’Aosta, Piemonte and Liguria can count on the following research institutions:

- University of Torino,
- University of Eastern Piedmont,
- University of Gastronomic Sciences,
- Polytechnic of Torino,
- University of Genova,
- Council for agricultural research and economics (CREA) with local structures of its research Centres,
- National Research Centre (CNR) with his local institute and department of research,
- Experimental Zoo prophylactic Institute.

The University of Torino is organized in Departments focused on different topics; the Department of Agricultural, Forestry and Food Sciences has a research line named Engineering, ICT and bioenergy with two working groups on biomass valorisation: Green chemistry and valorisation of biomass, wastes and residues and Agri livestock biomass management.

The University of Eastern Piedmont "Amedeo Avogadro" (Italian: Università degli Studi del Piemonte Orientale "Amedeo Avogadro"; shortened to UNIPMN or UPO) has its structures in Alessandria, Novara and Vercelli, and it is articulated in seven departments: Economics, Law, Letters and Philosophy, Mathematics, Physics and Natural Sciences, Medicine and Surgery, Pharmacy and Political Sciences.

The University of Gastronomic Sciences, founded in 2004 by the international non-profit association Slow Food in cooperation with the regions of Piemonte and Emilia-Romagna, is a government-recognized, private non-profit institution. It has more than 150 partner institutions and companies,

and it offers training, research and consulting services for its network to find the best circular economy and sustainable solutions.

The Polytechnic University of Turin has been the first Italian Engineering School founded in the wave of the technical and scientific innovation. Recently, it has set up a partnership with the Re-Cord Consortium - research centre specialized in bioeconomy and renewable energy - with the aim to share the best knowledge and expertise in the field of bioeconomy and circular economy. In particular, the collaboration focuses on research, testing and development of thermochemical, chemical, biochemical and biological processes to convert biomass and waste into high-value sustainable products, in line with the goals of the Green Deal and the new Next Generation EU plan. Innovative processes are to be developed and demonstration plants built to multiply the opportunities for large-scale transfer of knowledge and innovations acquired to the industrial world.

The University of Genova, in Liguria, is organized in several departments one of which, the Department of Earth, Environmental and Life Sciences, has a working group on fisheries and aquaculture, with a view to the circular economy.

CREA, being specialised in agricultural topics, has at least four research groups working on biomass valorisation, namely, CREA Cereal and industrial crops, CREA Vegetable and Ornamental Crops, CREA Forestry and wood and CREA Engineering and Agro-Food Processing.

The National Centre of Research (CNR) is composed of several departments and institutes working in different scientific areas of research. Among these, those working on biomass are “Institute of Bioeconomy (Department of Bio Agri-Food Sciences)” and the “Sustainable Economic Growth Research Institute (IRCrES)”.

The Zoo prophylactic Institute is a part a network of similar institutes spread across the national territory. They are coordinated by the Ministry of Health, and they provide epidemiological surveillance, experimental research, staff training, laboratory support and diagnostics in the context of official food control. In recent years, they conducted research on animal-related circular economy issues.

The three regions of the FAN also have some regional research centres:

- Institute Agricole Regional,
- Foundation for research, innovation and technological development of Piemonte agriculture - AGRION.
- Centre for Agricultural Experimentation and Assistance (CeRSAA).
- Regional institute for floriculture.
- IRES Piemonte.

The Institute Agricole Regional is in Aosta. It is a foundation for education, research and experimentation, but it is committed to study especially local agricultural products. AGRION was set up in 2014 by the Piemonte region and Unioncamere Piemonte. It has four experimental structures in the province of Cuneo and Alessandria and deals with fruit, horticulture, viticulture and coryliculture. With reference to the issue of sustainable production, AGRION has been working on the valorisation of crop residues.

The Centre for Agricultural Experimentation and Assistance (CeRSAA), founded in 1961, is a Special Agency of the Chamber of Commerce, Industry, Crafts and Agriculture of Liguria; its headquarters are in Albenga. of its main mission is to experiment innovative technologies, techniques and products to

meet the challenges posed by a constantly evolving and updating agriculture. CeRSAA participates, as a partner or lead partner, in project activities financed at European, national and regional level, some of which deal with the utilisation and treatment of agricultural waste and renewable energy in agriculture.

The Regional institute for floriculture, located in Sanremo, is an instrumental body of the Liguria region whose aim is to favour the economic development and competitiveness of the Ligurian floricultural enterprise system. it does not have specific research and experimentation activities on biomass valorisation.

In Piemonte socio-economic research in support of local government planning took off by initiative of the Provincia di Torino by Ires Piemonte.

4.2.5 Support and financing policies

In terms of bioeconomy-related initiatives and projects, it is worth highlighting the innovation projects supported under the National Recovery and Resilience Plan (NRP) (MEF, s.d.) that is part of the Next Generation EU (NGEU) programme, namely the 750B€ package – of which about half is in the form of grants – that the European Union negotiated in response to the pandemic crisis. Mission 2 'Green Revolution and Ecological Transition' allocates a total of 68.6B€ (59.3B€ from the RRF Facility and 9.3B€ from the Fund) with the main goals of improving the sustainability and resilience of the economic system and ensuring a fair and inclusive environmental transition.

Figure 38: Mission 2 of the National Recovery and Resilience Plan.

Table 30 shows European R&I projects coordinated by Italy, funded by H2020 (Societal Challenges 2, 3, 5), important for the Bioeconomy:

Table 30: Major European R&I projects coordinated by Italy, funded by H2020 (Societal Challenges 2. 3, 5), important for the Bioeconomy (RIAV, s.d.).

PROJECT TITLE	PROJECT ACRONYM	PROJECT SIGNATURE DATE	PARTICIPANT LEGAL NAME	PROJECT INSTRUMENT/ FUNDING SCHEME/TOPIC
Effective Management of Pests and Harmful Alien Species - Integrated Solutions	EMPHASIS	19/02/2015	UNIVERSITÀ DEGLI STUDI DI TORINO	RIA SFS-03a-2014
Jellyfish Barge - A floating greenhouse	JFB	20/05/2015	PNAT SRL	SME-1
Novel Ozone and Thermal Shock Conservation Process for Vegetables	SCHOCKO3	25/05/2015	FIORDELISI SRL	SME-1
PROVIding smart DElivery of public goods by EU agriculture and forestry	PROVIDE	27/05/2015	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	RIA ISIB-01-2014
Flagship demonstration of an integrated biorefinery for dry crops sustainable exploitation towards biobased materials production	FIRST2RUN	10/06/2015	NOVAMONT SPA	BBI-IA-FLAG
Design of an agricultural greenhouse for intensive growing of microalgae in fresh / sea water with a syngas production plant and organic farming of chickens and pigs outdoors	ECO-LOGIC GREEN FARM	22/07/2015	SOCIETÀ AGRICOLA SERENISSIMA S.S.	SME-2
Food treatment process based on high voltage nanopulsed electric discharges in liquid phase	EMILK	20/08/2015	LASERLAM SRL	SME-1
Drone-based integrated monitoring system for early detection of crop pathology and pest control in high tech greenhouse agriculture	GIDROM	26/08/2015	ABO DATA SRL	SME-1
RLTProFood - Remote Lighting Technology for processing and production of food	RLTProFood	02/09/2015	IODA SRL	SME-1
Vegetable ozone therapy for the defence of greenhouse crops	O3MET	15/09/2015	MET s.r.l.	SME-1
COMPostable cap-SULE for instant coffee delivery based on an innovative chemical functionalization of biobased plastics	COMPSULE	28/10/2015	POINT PLASTIC SRL	SME-1
Pest Organisms Threatening Europe	POnTE	29/10/2015	CONSIGLIO NAZIONALE DELLE RICERCHE	RIA SFS-03a-2014
Mobile wireless Device microcantilever- based biosensor to identify and measure the aflatoxin B1 in animal food and M1 in the milk-chain	MEDIuM	19/11/2015	INFORMATICA SYSTEM S.R.L.	SME-1
Optimum, sustainable solution for seed drying and conservation	DryCoolerSeeds	25/11/2015	MARCOLD GROUP	SME-1
From plants for plants: enhancing crop potential and resilience through reliable new generation biostimulants	Plants for Plants	04/12/2015	LANDLAB SRL	SME-1
A resource-efficient granulation process for advanced formulation of any compound in food and pharma production	AGS	17/12/2015	POLIBIOTECH SRL	SME-1
Submersible Tension Leg Fish Cage for Mariculture in Unsheltered and Offshore Areas	SubCage	17/12/2015	REFA MED SRL	SME-1
Cost-effective CO2 conversion into chemicals via combination of Capture, Electrochemical and BI-ochemical CONversion technologies	CELBICON	04/02/2016	POLITECNICO DI TORINO	RIA ISIB-06-2015
Linking genetic resources, genomes and phenotypes of Solanaceous crops	G2P-SOL	05/02/2016	ENEA	RIA SFS-07b-2015
Integrated and innovative key actions for mycotoxin management in the food and feed chain	MycoKey	09/02/2016	CONSIGLIO NAZIONALE DELLE RICERCHE	RIA SFS-13-2015
A compact, unmanned, renewables- powered and self-sufficient vessel able to pick up marine litter and to treat it on board for volume reduction and energy recovery	Sea Litter Critters	12/02/2016	IRIS SRL	SME-1
Agricolus Decision Support System	Agricolus DSS	15/02/2016	TEAMDEV SRL	SME-1
A sustainable organic solution to the decline of bees	MICRO4BEE	22/02/2016	MICRO4YOU SRL	SME-1
Valorisation of corn processing byproducts into plastic bio-composites	CORNposite	27/02/2016	CORN VALLEY SRL	SME-1

PROJECT TITLE	PROJECT ACRONYM	PROJECT SIGNATURE DATE	PARTICIPANT LEGAL NAME	PROJECT INSTRUMENT/ FUNDING SCHEME/TOPIC
A feasibility study to investigate and verify the commercial and industrial viability of a wastewater processing solution to generate bioplastics from agri-food and municipal wastewater sources	EggPlant	29/02/2016	EGGPLANT SOCIETA A RESPONSABILITA LIMITATA	SME-1
DevelopMent AnD application of integrated technological and management solutions FOR wasteWATER treatment and efficient reuse in agriculture tailored to the needs of Mediterranean African Countries	MADFORWATER	22/04/2016	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	RIA SC5 WATER-5c-2015
de-Fluoridation technologies for imprOving quality of WatEr and agRo-animal products along the East African Rift Valley in the context of aDaptation to climate change	FLOWERED	02/05/2016	UNIVERSITÀ DEGLI STUDI DI CAGLIARI	RIA SC5 WATER-5c-2015
Urban metabolism accounts for building Waste management Innovative Networks and Strategies	URBAN_WINS	03/05/2016	COMUNE DI CREMONA	RIA SC5 WASTE-6b-2015
Unique radar-drone used for subsurface water detection for precision agricultural irrigation	AGRI-DONE	16/05/2016	ADANT SRL	SME-1
First industrial use of bio and ecocompatible geopolymers produced from metakaolin to manufacture tanks for wine, beer, vinegar and olive oil production and storage via 3D printing technology	GeoFood	21/05/2016	CIBAS DI POLI FABIO & C SAS	SME-1
Partnership for Research and Innovation in the Mediterranean Area	4PRIMA	31/05/2016	MINISTERO DELL'ISTRUZIONE, DELL'UNIVERSITÀ E DELLA RICERCA	CSA SC5-12-2016
Scale-up of low-carbon footprint material recovery techniques in existing wastewater treatment plants	SMART-PLANT	01/06/2016	UNIVERSITÀ POLITECNICA DELLE MARCHE	IA WATER 1b-2015
Marine Ecosystem Restoration in Changing European Seas	MERCES	01/06/2016	SZN	RIA SC5-07-2015
Advanced solutions for ensuring the overall authenticity and quality of olive oil	OLEUM	08/07/2016	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	RIA SFS-14a-2014
Short supply chain Knowledge and Innovation Network	SKIN	23/09/2016	UNIVERSITÀ DEGLI STUDI DI FOGGIA	CSA RUR - 10-2016
BLUEMED	BLUEMED	27/09/2016	CONSIGLIO NAZIONALE DELLE RICERCHE	CSA BG-13-2016
Xylella fastidiosa Active Containment Through a multidisciplinary- Oriented Research Strategy	XF-ACTORS	11/10/2016	CONSIGLIO NAZIONALE DELLE RICERCHE	RIA SFS-09-2016
A Revolutionary, Safe and Cost-effective Industrial Process for Gluten Detoxification in Cereals	New Gluten World	16/10/2016	NEW GLUTEN WORLD S.R.L.	SME-2
Application of high power ultrasounds (HPUs) to improve the sustainability in meat TENderize and BRINe processes	TENBRIN	14/11/2016	RI-LAVO SRL	SME-1
A Novel Double Wheel Rake Machine to provide high quality fodder and high operational speed	RA-RAKE	19/11/2016	REPOSSI MACCHINE AGRICOLE SRL	SME-1
Innovative tag system providing affordable time-temperature quality control of individual temperature sensitive products	T-TAG	28/11/2016	SCRIBA NANOTECNOLOGIE SRL	SME-1
RESources from URban BIo waSte	RES URBIS	01/01/2017	UNIVERSITÀ "LA SAPIENZA" DI ROMA	RIA CIRC 05-2016
Antibiotic resistance- free meat and dairy products	ARMeD_free	22/01/2017	SACCO SRL	SME-1
On-field innovative system to detect very low concentrations of aflatoxins in milk	SAFEMILK	31/01/2017	IDP SRL	SME-1
BIOPEN	BIOPEN	27/04/2017	CIAOTECH Srl	JTI-BBI-CSA BBI-2016-S03
Sustainability Transition Assessment and Research of Bio-based Products	STAR-ProBio	28/04/2017	UNIVERSITÀ DEGLI STUDI DI ROMA UNITELMA SAPIENZA	RIA BB-01-2016
A novel and integrated approach to increase multiple and combined stress tolerance in plants using tomato as a model	TomRes	28/04/2017	UNIVERSITÀ DEGLI STUDI DI TORINO	RIA SFS-01-2016
Insect-borne prokaryote-associated diseases in tropical and subtropical perennial crops	TROPICSAFE	28/04/2017	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	RIA SFS-11-2016

PROJECT TITLE	PROJECT ACRONYM	PROJECT SIGNATURE DATE	PARTICIPANT LEGAL NAME	PROJECT INSTRUMENT/ FUNDING SCHEME/TOPIC
Detergent free steam cleaning system for modular conveyor belts in the food industry	Steammatic	30/04/2017	REA STEAM CLEANING SRL	SME-1
Automated system for packaging fresh meat with reduced waste/giveaway, processing time, human involvement and contamination	AUTOMEATIC	01/05/2017	GRASSELLI SPA	SME-1
Establishing a Multi- purpose Biorefinery for the Recycling of the organic content of AHP waste in a Circular Economy Domain	EMBRACED	03/05/2017	Fater S.p.A.	JTI-BBI-IA-DEMO
New bio-based food packaging materials with enhanced barrier properties - BioBarrier	BioBarr	05/05/2017	TECNOALIMENTI S.C.P.A.	JTI-BBI-RIA BBI-2016-R05
Microbial Uptakes for Sustainable management of major bananA pests and diseases	MUSA	10/05/2017	CONSIGLIO NAZIONALE DELLE RICERCHE	RIA
Brazil-EU Cooperation for Development of Advanced Lignocellulosic Biofuels	BECOOL	01/06/2017	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	RIA SC3 LCE-22-2016
A Novel Double Wheel Rake Machine to provide high quality fodder and high operational speed	RA-RAKE	28/06/2017	REPOSSI MACCHINE AGRICOLE SRL	SME-2
Solaris energy tobacco for the creation of a European sustainable biojet fuel value chain	SOLARIS	09/08/2017	IDROEDIL SRL	SME-2
Mobilization of a plurality of voices and mutual learning to accelerate the Bio-based sector	BIOVoices	04/10/2017	AGENZIA PER LA PROMOZIONE DELLA RICERCA EUROPEA	CSA BB-05-2017
Enhance New Approaches in BioBased Local Innovation Networks for Growth	ENABLING	05/10/2017	FEDERUNACOMA SRL UNIPERSONALE	CSA RUR-10-2016-2017
Turning climate-related information into added value for traditional MEDiterranean Grape, Olive and Durum wheat food systems	MED-GOLD	30/10/2017	AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE	RIA SC5-01-2016-2017
Engineered microbial factories for CO2 exploitation in an integrated waste treatment platform	ENGICOIN	01/01/2018	IIT FONDAZIONE ISTITUTO ITALIANO DI technological	RIA NMBP BIOTEC-05-2017
Nite Carbon Nanoclusters, a natural antioxidant for the food industry made from agricultural waste	NCN	05/02/2018	HYDRA SRL	SME-1
Innovative Method for Affordable Generation IN ocean Energy	IMAGINE	01/03/2018	UMBRAGROUP SPA	RIA SC3 LCE-07-2016-2017
Innovative biomaterials production from wine industry waste	VegeaTextile	03/04/2018	VEGEA SRL	SME-2
Development of Integrated Web-Based Land Decision Support System Aiming Towards the Implementation of Policies for Agriculture and Environment	LANDSUPPORT	13/04/2018	UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II	RIA RUR-03-2017
Separation, fractionation and isolation of biologically active natural ubstances from corn oil and other side streams	EXCornsEED	26/04/2018	UNIVERSITÀ DEGLI STUDI DI ROMA LA SAPIENZA	JTI-BBI-RIA BBI.2017.R4
Breeding for Resilient, Efficient and Sustainable Organic Vegetable production	BRESOV	27/04/2018	UNIVERSITÀ DEGLI STUDI DI CATANIA	RIA SFS-07-2016-2017
Green Aquaculture Intensification in Europe	GAIN	27/04/2018	UNIVERSITÀ CA' FOSCARI VENEZIA	RIA SFS-32-2017
Virome ngs analysis of pests and pathogens for plant protection	VIROPLANT	27/04/2018	CONSIGLIO NAZIONALE DELLE RICERCHE	RIA SFS-17-2017
Advanced sustainable BIOfuels for Aviation	BIO4A	01/05/2018	CONSORZIO PER LA RICERCA E LA DIMOSTRAZIONE SULLE ENERGIE RINNOVABILI	IA SC3 LCE-20-2016-2017
Development and demonstration of an automated, modular and environmentally friendly multi-functional platform for open sea farm installations of the Blue Growth Industry	The Blue Growth Farm	03/05/2018	RINA CONSULTING SPA	IA BG-04-2017
Novel Products for Construction and Automotive Industries Based on Bio Materials and Natural Fibres	ReInvent	04/05/2018	CENTRO RICERCHE FIAT SCPA	JTI-BBI-IA-DEMO BBI.2017.D5
Project Ô: demonstration of planning and technology tools for a circular, integrated and symbiotic use of water	PROJECT O	08/05/2018	IRIS SRL	IA SC5 - CIRC-02-2016-2017

PROJECT TITLE	PROJECT ACRONYM	PROJECT SIGNATURE DATE	PARTICIPANT LEGAL NAME	PROJECT INSTRUMENT/ FUNDING SCHEME/TOPIC
Stacking of ecosystem services: mechanisms and interactions for optimal crop protection, pollination enhancement, and productivity	EcoStack	24/07/2018	UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II	RIA SFS-28-2017
Controlling mIcRobiomes CircuLations for bEtter food Systems	CIRCLES	05/10/2018	ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA	IA LCSFS-03-2018
SaFe and sustaInable soluTions FOR the integRatEd USE of non-conventional water resources in the Mediterranean agricultural sector	FIT4REUSE	2019	Alma Mater Studiorum - University of Bologna (UNIBO)	RIA A PRIMA Project
A novel integrated and sustainable approach to monitor and control Bluetongue in the Mediterranean region	Blue-Med	2019	Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise (IZSAM)	RIA A PRIMA Project
FRUIT CROPS ADAPTATION TO CLIMATE CHANGE IN THE MEDITERRANEAN BASIN	FREECLIMB	2019	Università degli Studi di Milano - La Statale (UMIL)	RIA A PRIMA Project
Utilization of local genetic diversity to understand and exploit barley adaptation to harsh environments and for pre-breeding	GENDIBAR	2019	Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria - Centro di Genomica e Bioinformatica (CREAGB	RIA A PRIMA Project
IMProving RESilience to Abiotic stresses in durum wheat: enhancing knowledge by genetic, physiological and "omics" approaches and increasing Mediterranean germplasm biodiversity by crop wild relatives-based introgressiomics	IMPRESA	2019	Dipartimento di Scienze Agrarie e Forestali - Università degli Studi della Tuscia (DAFNE)	RIA A PRIMA Project
Developing new strategies to protect strawberry crop in Mediterranean countries	ed-Berry	2019	Alma Mater Studiorum University of Bologna (UNIBO)	RIA A PRIMA Project
Towards a sustainable water use in Mediterranean ricebased agro-ecosystems	MEDWATERICE	2019	Università degli Studi di Milano (UMIL)	RIA A PRIMA Project
Self-sufficient Integrated Multi-Trophic AquaPonic systems for improving food production sustainability and brackish water use and recycling	SIMTAP	2019	University of Pisa (UNIPI)	RIA A PRIMA Project
Strategies for increasing the WATer use efficiency of semi-arid Mediterranean watersheds and agrosilvopastoral systems under climate Change	SWATCH	2019	Dipartimento di Ingegneria civile, ambientale ed architettura, Università di Cagliari (UNICA)	RIA A PRIMA Project
ADAPTING MEDITERRANEAN VEGETABLE CROPS TO CLIMATE CHANGE-INDUCED MULTIPLE STRESS	EG-ADAPT	2019	Università degli Studi di Torino (UNITO)	RIA A PRIMA Project
Valorisation of thistle- curdled CHEESEs in MEDiterranean marginal areas	VEGGIE-MEDCHEESES	2019	Università Politecnica Delle Marche (UNIVPM)	RIA A PRIMA Project
Increasing grain quality through advanced oxidation treatment during storage	QUALIGRAIN	01/10/2014 (CLOSED)	LA SANFERMESE SpA	SME-1
FREE and open source software tools for WATer resource management	FREEWAT	02/12/2014 (Closed)	SCUOLA SUPERIORE DI STUDI UNIVERSITARI E DI PERFEZIONAMENTO S ANNA	CSA WATER-4a-2014
Automatic Hydraulic Jack with improved capacity, safety and efficiency for agricultural implements	Novel Jack	09/11/2017 (CLOSED)	SIMOL SPA	SME-1
BIOmethane as SUstainable and Renewable Fuel	BIOSURF	1/1/2015 (closed)	ISTITUTO DI STUDI PER L'INTEGRAZIONE DEI SISTEMI (I.S.I.S) - SOCIETÀ COOPERATIVA	CSA SC3 LCE-14-2014
Increasing Social Awarness and Acceptance of biogas and biomethane	ISAAC	1/1/2016 (closed)	AZZERO CO2 SRL	CSA SC3 LCE-14-2014
Building Research environments fostering Innovation, Decision making, Governance and Education to support Blue growth	BlueBRIDGE	1/9/2015 (closed)	CNR	RIA Infrastructure di ricerca
Modelling and Imaging Development for precision Agriculture	MIDA	12/05/2017 (CLOSED)	METACORTEX Srl	SME-1
Professional support to the uptake of bioeconomy RD results towards market, further research and policy for a more competitive European bioeconomy	ProBIO	16/02/2015 (CLOSED)	AZIENDA SPECIALE INNOVHUB - STAZIONI SPERIMENTALI PER L'INDUSTRIA	CSA ISIB-08b-2014
Innovative oxygen- free wine bottling process	RiCaMo	22/06/2016 (CLOSED)	ENTER S.R.L.	SME-2

PROJECT TITLE	PROJECT ACRONYM	PROJECT SIGNATURE DATE	PARTICIPANT LEGAL NAME	PROJECT INSTRUMENT/ FUNDING SCHEME/TOPIC
Smart cuvette and portable Time-Resolved FRET for fast analysis of milk	I-Cuvette	25/11/2017 (CLOSED)	ISS BIOSENSE SRL	SME-1
Managing crOp water Saving with Enterprise Services	MOSES	26/05/2015 (closed)	ESRI ITALIA SPA	IA SC5 WATER-1a-2014
Fermentation processes for functional foods from RAPeseed, Sunflower and Other EU matrices Devoted to Young animals. Zero-miles model boosting safety and competitiveness of livestock sector	RAPSODY	27/01/2015 (CLOSED)	METHODO CHEMICALS SRL	SME-1
3Bee Hive-Tech	3Bee Hive-Tech	31/01/2018 (CLOSED)	3BEE SRL	SME-1

Regarding the national level, the Italian CAP Strategic Plan aims to turn into value the opportunities that can arise from the ecological and digital transition, enhancing the bioeconomy, circular economy, cascading use of wood products, food waste reduction, and agroecology, including by promoting the digitization of production processes. Specific goals also include initiatives to increase and diversify employment opportunities with a view to sustainability (e.g., sustainable tourism, bioeconomy, green jobs, social agriculture). These initiatives should strengthen agricultural and forestry multifunctionality, enhance rural landscapes of historical interest, and foster the creation of new business and employment opportunities, with specific reference to young people and women.

Moreover, the National Research Plan 2021-2027, plays a key role in the bioeconomy at the national level. In fact, it includes, among the 6 “Major Areas of Research and Innovation,” a specific area related to “Food products, bioeconomy, natural resources, agriculture, environment”.

Finally, in the Regional Smart Specialisation Strategy (territoriale, s.d.) (hereinafter S3), that aimed at identifying R&D&I investment priorities that complement the resources and production capacity of a territory to build comparative advantages and sustainable growth paths in the medium and long term, the following development trajectories are present with reference to:

- SR_04 Regional Smart Specialisation Strategies – Green Chemistry S 04_PIEMONTE_01 Biorefineries and non-food biomass conversion plants for the production of chemical products, biofuels, bioplastics.
- SR_04 Regional Smart Specialisation Strategies - Green Chemistry S 04_VALLEDAOSTA_01 Bio-processes for biomass pre-treatment and for energy production (biofuel production).
- SR_06 Regional Smart Specialisation Strategies - Energy (and environment) S 06_VALLEDAOSTA_01 Applications and systems for distributed generation, cogeneration/trigeneration of energy, especially in the field of biomass and mini- and micro-hydro for the sustainable management of natural resources.
- SR_09 Regional Smart Specialisation Strategies - Health S 09_PIEMONTE_08 Pharmaceutical biotechnology.
- SR_09 Regional Smart Specialisation Strategies - Health S 09_PIEMONTE_09 Bioinformatics and ICT for health research
- SR_09 Regional Smart Specialisation Strategies - Health S 09_PIEMONTE_12 Bioengineering and surgical robotics.

- SR_09 Regional Smart Specialisation Strategies - Health S 09_PIEMONTE_13 Advanced biomedical solutions.
- SR_11 Regional Smart Specialisation Strategies - Technologies for Living Environments S 11_VALLEDAOSTA_02 Green building, bio-climatic architecture and new materials.

4.3 Analysis of Operational Groups

4.3.1 Operational groups characterization

The EU EIP-AGRI project database, published on the website of the EU CAP Network, includes information about 2,892 projects of Operational Groups (OG) funded across Europe by the 2014-2022 Rural Development Programmes (RDP). Data from the CAP National Strategic Plans approved in 2022 shows that over 6,000 OGs should be funded during the current programming period, evidence of the interest that the implementation of these projects raised in the MS.

The analysis of the OGs for Italy is based on data published in the national database for OGs, available in the innovation portal of the Italian rural network (RRN, s.d.), which includes information of all OGs funded during the past programming period (with the exception of the Latium and Molise regions). As to the OGs to be supported in the current programme period, to the 30/06/2024 only the autonomous province of Bolzano has approved one project, while the selection process is ongoing in Emilia-Romagna and Veneto. Data about the new projects will be included, upon communication from regional authorities, in the database available in the innovation portal.

According to the OGs database of Innovarurale, 784 OGs have been funded and implemented during the 2014-2022 programming period (almost 200 more of those initially envisaged), accounting for 258.6 M€. 473 of these projects are closed, while the others will conclude their activities in 2025 at the latest. The OGs are located throughout the national territory (Figure 39)Figure 39, except Valle d'Aosta, which did not implement the OGs measure in the past programming period; this decision is confirmed for the current period. The two regions in red, that is, Latium and Molise, have not communicated the final data in relation to projects approved.

National OGs were not planned in the past programming period, and this decision has been confirmed in the present one. Financial support to OGs was only granted at regional/provincial level, based on the Rural Development Programmes approved in the 19 regions and 2 autonomous provinces. This justifies the differences in terms of number of projects implemented, financial resources distributed to the OG measure and to single projects, as well as the establishment of specific objectives to be achieved or industries to be targeted by OGs. Choices at regional/provincial level also influence implementing procedures, including the composition of partnership (Giarè & Vagnozzi, 2022). Furthermore, Liguria and Piemonte published a call dedicated to the forestry sector.

The proposed innovations regard different issues and sectors (Figure 40). Over 21% of the innovations implemented involve multiple sectors, followed by projects concerning animal husbandry, viticulture, fruit and horticulture.

Figure 39: Number of 2014-2022 OGs project per region/autonomous province (RRN, s.d.)

Table 31: Budget of 2014-2022 OGs per region/province and average budget per project (RRN, s.d.)

Region/Province	Budget (€)	Average budget per project
Abruzzo	1,811,702	129,407
Basilicata	2,800,000	254,545
Calabria	1,935,285	96,764
Campania	22,278,201	297,043
Emilia-Romagna	48,733,412	208,262
Friuli V. G.	2,265,943	283,243
Lazio	3,400,000	n.a.
Liguria	1,951,116	92,913
Lombardia	19,350,944	450,022
Marche	16,312,516	281,250
Molise	50,000	n.a.
P.A. Bolzano	1,997,116	332,853
P.A. Trento	4,639,252	331,375
Piemonte	14,007,566	451,857
Puglia	22,608,595	471,012
Sardegna	8,944,076	447,204
Sicilia	29,898,408	490,138
Toscana	15,756,869	303,017
Umbria	9,546,622	561,566
Veneto	23,763,598	424,350
Total	**252,051,221**	

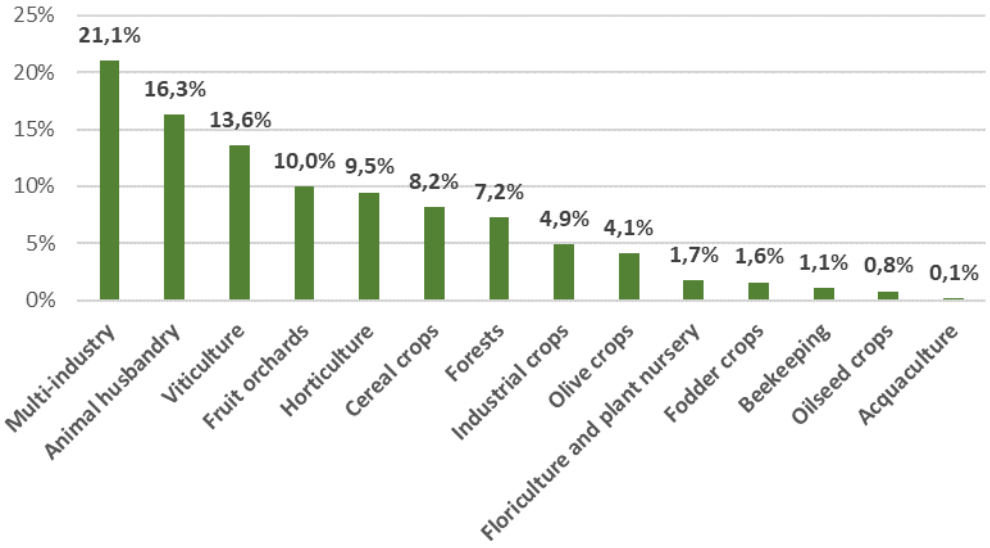

Figure 40: Percentage of OGs per sector (RRN, s.d.)

As already mentioned above, Valle d'Aosta did not include OGs in its RDP, while Liguria and Piemonte supported, respectively, 21 and 31 OGs. Of these, five OGs projects focus their work on BBTs, two of them are in Piemonte and three in Liguria. These small numbers in these two regions follow the trend identified at national level, where 16 projects working on the development of BBTs have been identified.

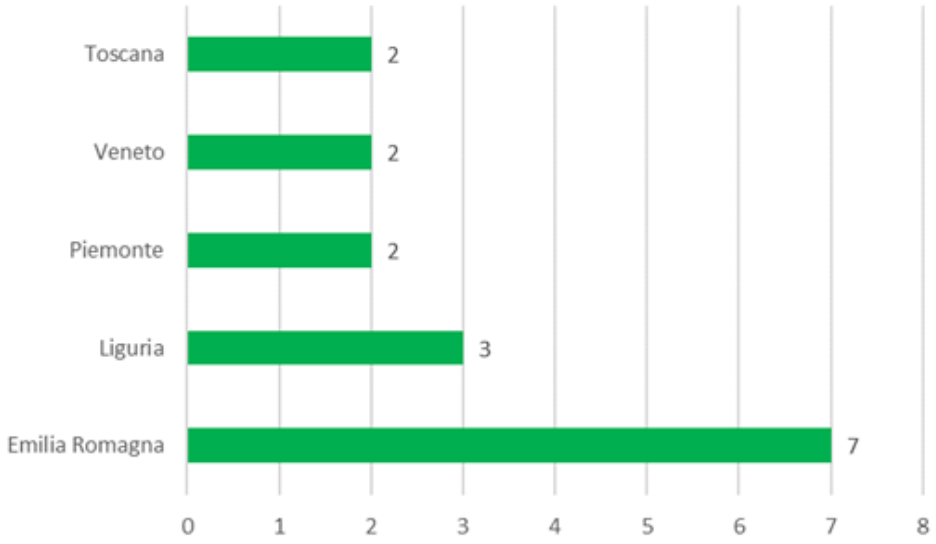

Figure 41: Number of 2014-2022 OGs working on BBTs per region/autonomous province (RRN, s.d.)

The analysis of the projects identified, both at national and Italian FAN reference territory level, does not highlight peculiarities of the BBTs-related projects in terms of budget and partnership composition. In Piemonte a substantial difference is identified in the budget of projects selected under the forestry-dedicated calls. The budget of these projects (290,000€) is significantly below the average calculated considering all OGs funded in the region. The same difference has not been found in Liguria, where the budget of forestry projects does not differ from all other OGs.

Analysing materials and document produced by the OGs, it is possible to identify different actors, approaches and strategies to face farming problems using BBT technologies. The work of the project "Powerfood", funded by the Piemonte RDP, is strongly linked to the renewable energy sector; its scope is to enhance the use of thermal energy from biogas to improve the integrated production of feed and food proteins. Specifically, the objective is to validate protein biomass production technologies (such as algae and insects) by utilizing thermal energy, carbon dioxide (CO_2), and digestate produced by existing anaerobic digestion plants through the establishment of pilot plants in the farms of the region. The project, coordinated by the Monviso Agroenergia Consortium, involves two academic institutions (University of Milan – Department of Agricultural and Environmental Sciences – Production, Territory, Agroenergy; University of Turin – Department of Agricultural, Forest, and Food Sciences) and three farms (Azienda Agricola La Gaia s.s.; Azienda Carrera; Società Agricola Maracuja). Powerfood represents a lever to promote circularity in the agricultural sector and enhance the competitiveness of the livestock industry. By removing the barrier of the unsustainable impact of production activities on the territory, this approach paves the way for new investments in the livestock sector. This would facilitate the production of high-quality, sustainable "made in Italy" food and cater to expanding markets.

4.3.2 Bio-based Technologies (BBT) developed by OGs

This section presents in more detail some technological aspects regarding the BBTs developed by OGs in Piemonte and Liguria. All projects considered are concluded.

The biomass used by the identified projects come from the forestry sector (2), the flower production and plant nursery (2) and the breeding sector (1). Biomass residues are used to increase energy efficiency and valorise both farms directly involved in the project and other farms located in the area. One project aims to use biomass residues (bark and ashes) to produce fertilisers with low environmental impact.

In terms of technological maturity, two projects developed technologies corresponding to TRL 9, with an actual system proven in operational environment; one project technology corresponds to TRL7 and the other two to TRL3.

4.4 Discussion of previous sections

The Italian FAN reference area (Piemonte, Valle d'Aosta, and Liguria Regions) has a particularly interesting context for the development of the bioeconomy: the agribusiness system is complemented by a particularly rich industrial, research and innovation system.

The Italian Bioeconomy Strategy offers a shared vision of the environmental, economic, social and international cooperation opportunities and challenges related to the development of an Italian Bioeconomy rooted in the territory.

In terms of available funding and R&D system associated with biomass valorisation, we have highlighted the different programmes available at different levels (European, national, and regional), both public and private.

Regarding the availability of information, there is an easily and completed accessible database on the OGs in the region, despite the fact that information from OG's that deal with biobased technologies are limited.

Therefore, considering the geographical, regulatory and technical point of view, and looking at the amount of biomass as well as knowledge available in the region, we can conclude that Italian FAN area that encompasses Piemonte, Liguria and Valle d'Aosta have a **green light** in terms of BBTs implementation.

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5 Ireland

5.1 General description of the region

5.1.1 Geographic description of the region

The Republic of Ireland, located in the North Atlantic Ocean, is a country in Western Europe that occupies most of the island of Ireland. It borders Northern Ireland, part of the United Kingdom. The country covers an area of approximately 70,273 km². Ireland has a population of around 5.4 million people standing for approximately 1% of the European Union's total population (EU27). The country is divided into 26 counties, and a significant proportion of the population, about 37%, resides in rural areas which emphasizes the importance of agriculture and rural development in the country's socio-economic landscape (*Population and migration estimates*, 2023).

The capital city, Dublin, is the largest city, and other major cities include Cork, Limerick, Galway, and Waterford. Ireland's landscape is characterised by rolling plains, rugged cliffs, and numerous lakes and rivers, contributing to its rich agricultural heritage and significant potential for agricultural and forestry biomass and residues.

Figure 42: Location of Ireland in Europe (adapted from: European Union).

5.1.2 Agriculture and forestry sectors in the region

Agricultural sector

In Ireland, the agricultural sector is a vital component of the economy, with numerous farms and agricultural holdings spread across the country. According to the latest data, there are approximately 139,000 agricultural exploitations (135,000 farms, 2,000 fishing vessels and aquaculture, and 2,000 food production and beverage enterprises) operating over an area of 4.5 million hectares of agricultural land. Of this total, 82.1% of the agricultural area is utilised for grassland. Conversely, the Irish forest area reached a coverage of 11.6% of the total land area amounting to a total 808,848 hectares (Coford, 2022; CSO, 2020; Department of Agriculture, 2024).

The average farm size in Ireland in 2022 was at 45 hectares with dairy farms being larger averaging 65 hectares and cattle rearing farms smaller at 33 hectares (*Teagasc National Farm Survey 2022: Final*

Results. Agricultural Economics and Farm Surveys, 2023). The distribution of farm sizes varies across the country and based on the farm type, with larger farms typically found in the south and midlands and smaller holdings more common in the west and north regions. The main agricultural activities in Ireland include dairy farming, livestock production, and the cultivation of crops such as barley, wheat, and potatoes. The Figure 44 below shows the evolution of Utilised Agricultural Area (UAA) over the years, and despite slight fluctuations the UAA overall has been around 4.5 million hectares since 2000.

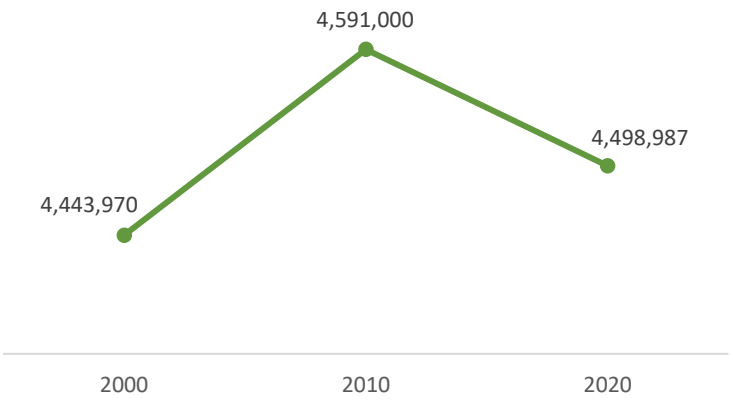

Figure 44: Utilized Agricultural Area (ha) in Ireland over the years (Agricultural Census 2000: Main Results, 2001; Farm Structure Survey 2010, 2010; Census of Agriculture 2020 detailed results: Organics, 2020)

The correlation between farm size and output in Ireland is evident, with smaller farms typically generating lower outputs and larger farms producing higher outputs. Specifically, 81% of farms with a Standard Output of less than 8,000€ were either less than 10 hectares or between 10-20 hectares. In contrast, farms with a Standard Output between8,000 € and 50,000€ were predominantly between 10 and 50 hectares. Moreover, over 60% of farms with a Standard Output greater than 50,000€ were either 50-100 hectares or over 100 hectares, indicating a strong positive correlation between larger farm sizes and higher agricultural output (*Census of Agriculture 2020 - Detailed Results: Standard Output*, 2021).

Over 50% of farms in the South-East region had a standard output of over 25,000€ in 2020. Kilkenny (34,525€) had the largest followed by Wexford (31,876€), Waterford (31,001€), Tipperary (26,701€) and Carlow (26,268€), while most of Northern and Western NUTS2 region counties had median standard outputs of less than 11,000€ in 2020 (*Census of Agriculture 2020 - Detailed Results: Standard Output*, 2021). Regarding the demographic composition of the farms, 33% of farm holders were aged 65 or older, while 7% of holders were aged under 35, and 13.4% of farm holders were female (*Press Statement Census of Agriculture 2020*, 2021).

The three main cereals (wheat, oats and barley) were produced at 2,013,000 tonnes in 2020, and the production of potatoes was at 300,000 tonnes in 2020 (*Area, Yield and Production of Crops 2020*, 2021). The Figure 45 below shows the crop production by type of crop from 2010 to 2020 in Ireland.

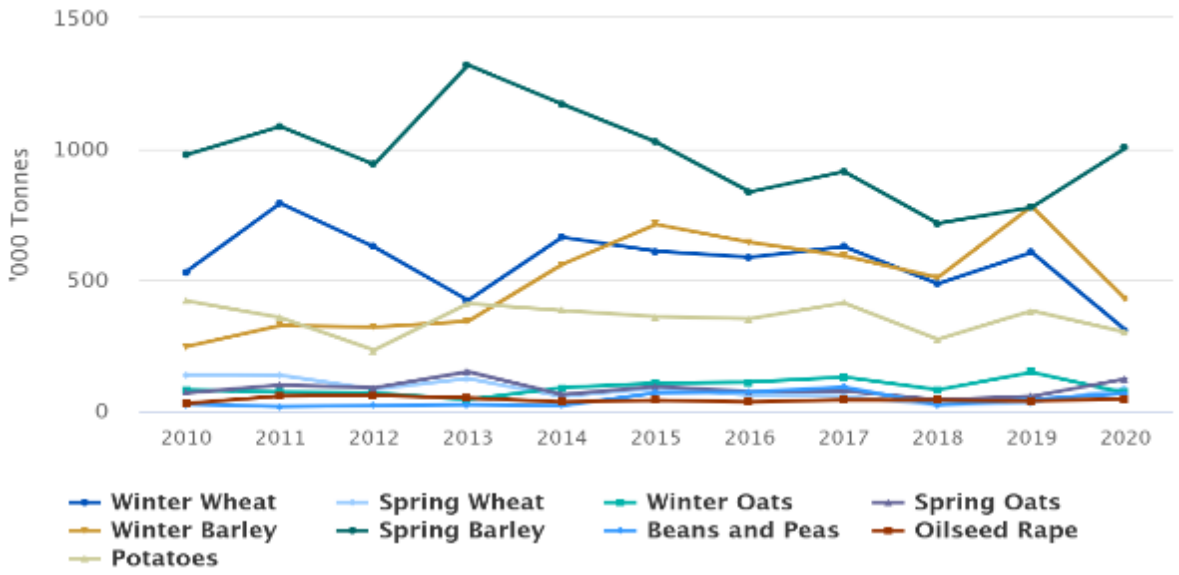

Figure 45: Main crops production 2010-2020 (Area, Yield and Production of Crops 2020, 2021)

The Figure 46 illustrates the distribution of different types of farms in Ireland, highlighting that the majority of farms (54.9%) are engaged in Specialist Beef Production, while crop farms include almost 12% of total farms.

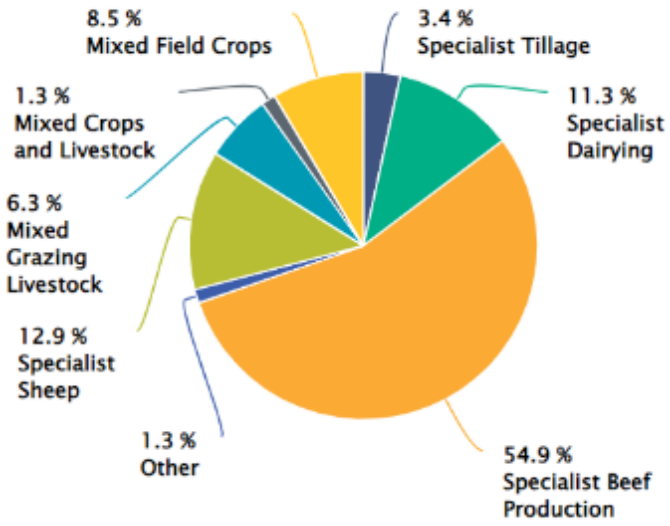

Figure 46: Farms by type, 2020 (Census of Agriculture 2020 - Preliminary results, 2021)

It should also be noted that grasslands and croplands comprised over 67% of Ireland's terrestrial and transitional ecosystems in 2018, and grasslands supplied a total of 21.7 million tonnes of crops including grazed biomass in 2022 (Central Statistics Office, 2024b). The Figure 47 below depicts land

utilization in Ireland from 1991 to 2020 and as it can be seen grassland has constantly had the major proportion in comparison to grazing, cereals and cropland.

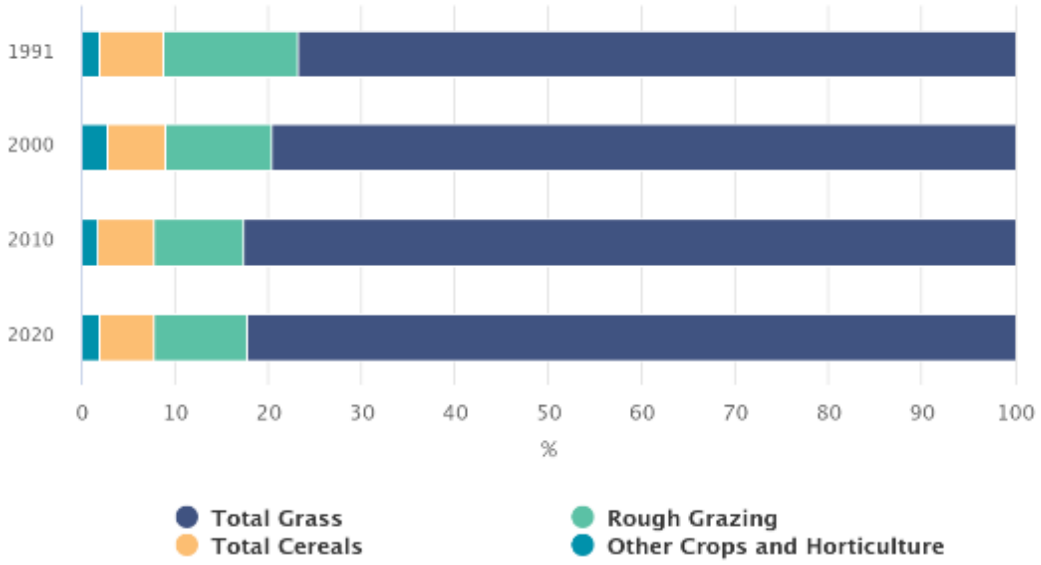

Figure 47: Land use 1991-2020 (Census of Agriculture 2020 - Preliminary Results: Land Utilisation, 2020).

Livestock sector

As mentioned above, over half (74,159) of farms' main activity in Ireland is specialist beef production, followed by specialist sheep farms (17,435) and specialist dairying farms (15,319). The total number of sheep in Ireland in 2023 was 5,674,400, the total number of cattle was 7,341,500 and the total number of pigs was 1,661,300. The total area under crops and pasture was 3,368,500 ha with mid-west region having the highest area (602,600 ha) followed by south-west region with 564,700 ha (Central Statistics Office, 2024a). According to Teagasc, cattle rearing farms' average income was 8,324 €, cattle other farms were at 18,554€, sheep farms were at 16,324€ in 2022 (*Teagasc National Farm Survey 2022: Final Results. Agricultural Economics and Farm Surveys*, 2023).

The figure below illustrates the distribution of the total cattle and sheep across different regions in Ireland in 2023. The Mid-West and South-West regions have the highest number of cattle while West region, followed by Border region, have the highest sheep populations.

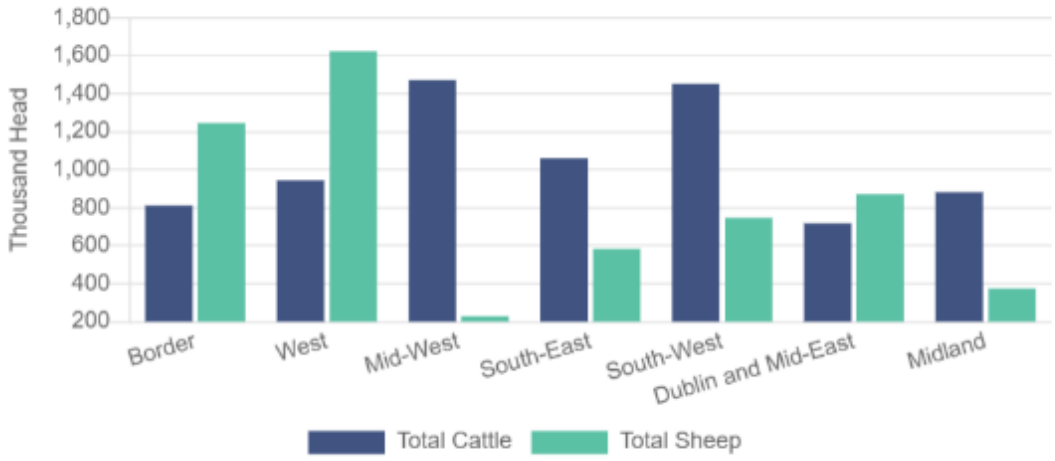

Figure 48: Total cattle and sheep in each region in 2023 (Central Statistics Office, 2024a)

Recent data show that county Cork contains the greatest number of cattle and dairy cows (Central Statistics Office, 2024a). The national farm survey of 2022 also show that average dairy farm income was at 148,598€ which is indicative of the fact that dairy farms are particularly prominent as the most profitable agricultural activity in Ireland with 59% of the total farm income (*Teagasc National Farm Survey 2022: Final Results. Agricultural Economics and Farm Surveys*, 2023). The domestic milk intake was 947 million litres in April 2024 with butter production at 29,300 tonnes and skimmed milk powder production at 14,500 tonnes (Central Statistics Office, 2024a). Total Meat supply was at 1.48 M tonnes with 1.19 M tonnes of total slaughtering of which beef and veal accounted for 621,000 tonnes, pig meat 333,000 tonnes, poultry meat 171,000 tonnes and sheep meat 68,000 tonnes in 2022. Also, poultry meat is the only meat that Ireland is not self-sufficient in (Central Statistics Office, 2024c).

Forestry sector

Forests in Ireland cover 808,848 ha or 11.6% of the total land area, and 70% of the forest trees are less than 30 years old. The forest estate in Ireland consists of 69.4% conifers (mainly Sitka spruce, Norway spruce, and Scots pine) and 30.6% broadleaves (including oak, beech, and ash). On the other hand, the extent of hedgerows and non-forest wooded land is estimated at 375,301 ha, with hedgerows forming a large part of the agricultural landscape that play a key role in providing shelter for animals and a habitat for biodiversity (*Forest Statistics - Ireland 2023*, 2023). Of the total forest area, 397,364 ha or 49.1% are publicly owned, primarily by Coillte, while the rest are privately owned. Leitrim is the county with the highest percentage of forest cover at 20.1%, followed by Wicklow at 18.5%, and Clare at 18%. The counties with the lowest forest cover are Louth (2.9%), Monaghan (4.6%), and Meath (5.9%) (Ireland's Forests - Statistics 2023, 2023).

Ireland's forestry sector produces a variety of outputs that significantly contribute to the national economy. The primary output is timber, with softwood timber being the predominant product due to the extensive planting of coniferous species. Softwood timber is widely used in construction, paper production, and various industrial applications. Hardwood timber, derived from broadleaf species, is less common but valued for high-quality furniture, flooring, and specialty products. In 2022, the total roundwood harvest (excluding firewood) was 4.14M m^3, with the majority coming from private sector forests, highlighting the increasing role of private forestry in timber production. Additionally, the forestry sector generates pulpwood, which is essential for paper and paper products, and biomass,

which supports renewable energy production and contributes to Ireland's sustainable energy goals (*Forest Statistics - Ireland 2023*, 2023). The Figure below shows the range of products from roundwood removals with the majority being large sawlog, followed by pulpwood and small sawlog.

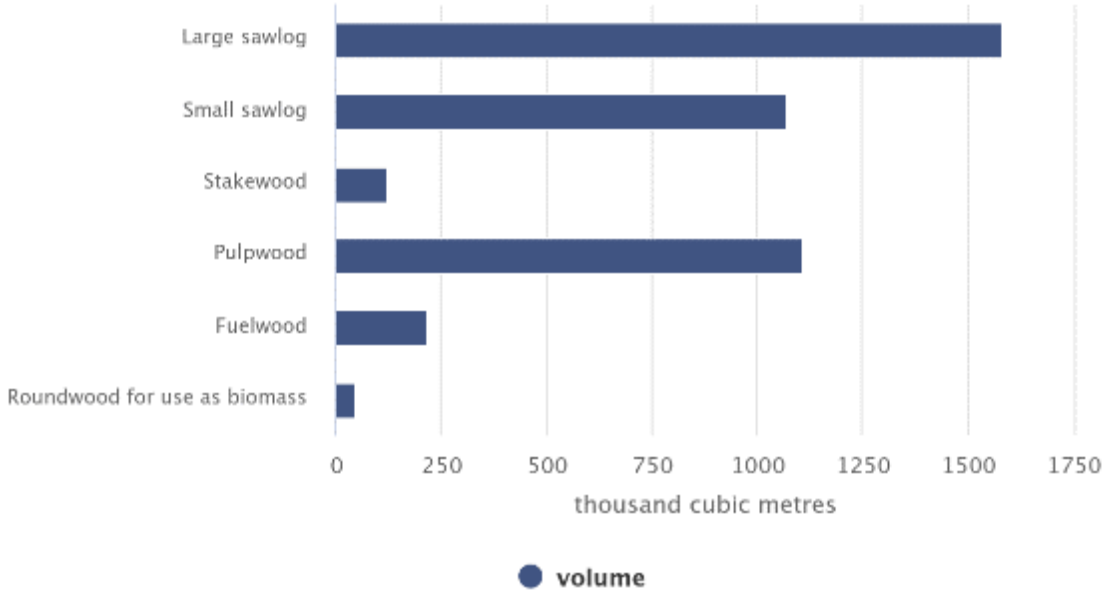

Figure 49: Roundwood removals by product in 2022 (Forest and Wood Removals 2022, 2023).

Non-timber forest products also play a significant role, with the production of Christmas trees primarily for the domestic market. The sector also contributes to forest recreation and eco-tourism, enhancing its economic value. The most recent figures estimated 29.1 million visits to Irish forests per annum, and values forest recreation at 179 M€ per annum. Furthermore, Ireland's forestry sector (logging and manufacture of wood products) supports around 9,400 jobs directly and indirectly, demonstrating its importance for rural employment. Collectively, these outputs make the forestry sector a vital component of Ireland's economy, generating substantial revenue and contributing significantly to exports. The forestry sector is also a significant contributor to carbon sequestration, playing a crucial role in Ireland's climate action efforts by absorbing atmospheric carbon dioxide. In 2021, Ireland's forests removed 1.8 $MtCO_2$ (*Forest Statistics - Ireland 2023*, 2023).

Table 32: Detailed information in Ireland

Location	Forestry area
Ireland	808,848 hectares
Species	Sitka spruce, Norway spruce, scots pine, oak, beech, ash.

Agroindustry

Ireland's agri-food sector is the oldest and largest native exporting industry which spans the entire country and exports to more than 180 nations globally. Ireland's agri-food exports were a record 19

B€ in 2022 with the dairy exports being the 8th largest exporter in the world. In 2022, it employed 164,900 individuals, accounting for 6.5% of the national workforce, across 135,000 farms, 2,000 fishing vessels and aquaculture sites, and approximately 2,000 food production and drink enterprises. The sector manages 4.5 million hectares of agricultural land and over 800,000 hectares of forestry, contributing to 9% of Ireland's annual exports (*Annual Review and Outlook for Agriculture, Food and the Marine 2023*, 2023).

The most prominent agroindustry in Ireland includes the dairy industry, which is the largest in terms of production value and export, renowned for its high-quality milk and dairy products. The beef industry is the second most important, known for its significant turnover and extensive exports. Additionally, Ireland has exported more than €1 billion in each of beef, butter, cheese and whiskey in 2022 (*Annual Review and Outlook for Agriculture, Food and the Marine 2023*, 2023).

5.1.3 Economic Indicators

Ireland ranks as one of the top economies in Europe with a gross domestic product (GDP) of 504.6M€, contributing significantly to the EU total, and the GDP per capita at 94,320€ in 2023 (European Commission, 2024b). Meanwhile, the Irish GDP registered an annual growth of 9.4% in 2022, which was notably the highest in the EU27, and the gross national income (GNI) was 363.6 B€ and the GNI per capita was 52,688 € (*Measuring Ireland's Progress 2022: Economy*, 2023). In Ireland, agriculture and food production play a crucial role in the economy and society, particularly for rural and coastal communities. In terms of its productive structure, the agri-food sector, measured by gross value added (GVA), accounted for 3.8% of the total GVA in 2022 with the share of primary agriculture at 1.5%, reflecting its role in the economy (*Annual Review and Outlook for Agriculture, Food and the Marine 2023*, 2023). Further details on economic indicators are available in next table.

The bioeconomy includes industries involved in the conservation, utilization, processing, distribution, or consumption of biological resources from terrestrial and aquatic environments. It is linked with sectors like agriculture, horticulture, forestry, food processing, and organic waste management, as well as terrestrial and marine ecosystems, though for the purpose of this analysis only the three primary production sectors of agriculture, forestry and aquaculture have been taken into account. In Ireland, the bioeconomy's value added reached 4 B€ across agriculture, forestry and aquaculture, with a total turnover of 10.9 B€ in 2021. The three sectors are important employers nationally and particularly in rural and coastal areas within the bioeconomy that employed 107,230 people in the same year (Lasarte-López, 2023).

Table 33: Economic indicators by region/country (European Commission, 2024b).

Region/Country	Population (M hab)	GDP (k M€)	GDP per capita (€)	GVA (M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Ireland	5.27	504.62	94,320	4,430	79.1	4

5.1.4 Bioeconomy regulatory framework

Ireland has developed several policies, strategies, plans, and laws at both national and regional levels to support the bioeconomy and biomass valorisation. Project Ireland 2040 is the Irish government's development plan which highlights the potential of the circular bioeconomy in promoting more efficient use of renewable resources, while supporting economic development and employment in rural Ireland. As part of Project 2040, the National Policy Statement on the Bioeconomy published in 2018 and sets out a vision, common principles, strategic objectives, and an implementation framework to develop the bioeconomy across relevant sectors. According to the National Policy Statement, the key actions required to expand the bioeconomy include: 1) promoting greater coherence between the many sectors of the bioeconomy, 2) strengthening the development of promising bio-based products and growing the relevant markets for them, and 3) accessing funding available at EU level as well as leveraging private investment. Established following the National Policy Statement, Bioeconomy Implementation Group (BIG), with representatives from 11 Irish government departments and 8 state agencies, oversees the development of the bioeconomy, ensuring strategic development and investment in innovation and infrastructure (*Bioeconomy policy*, 2023; *Ministers McConalogue and Ryan publish first National Bioeconomy Action Plan*, 2023).

Further strategies and plans such as the Food Vision 2030, Climate Action Plan 2021, Our Rural Future 2021-2025, and Impact 2030 incorporate bioeconomy goals to achieve broader environmental and economic objectives. Also, the National Bioeconomy Action Plan 2023-2025 outlines 33 actions across seven pillars, focusing on governance, research, innovation, agriculture, food, forestry, marine, and the circular economy. It aims to embed sustainable scientific practices and biobased innovation in various sectors, supporting farmers, foresters, and agri-food companies. This action plan considers the EU council's conclusions on bioeconomy as well as FAO's initiatives to promote a sustainable and circular bioeconomy. It also brings about an important perspective that Ireland and Northern Ireland, sharing similar climate and sustainability challenges, with the same agriculture, land use and marine activities possess significant potential synergies for collaboration (*Bioeconomy Action Plan 2023-2025*, 2023; *Bioeconomy policy*, 2023).

Moreover, the 2023 Bioeconomy Demonstration Initiative which is part of the EU Just Transition Fund for Ireland focuses on piloting and demonstrating bioeconomy projects within the Midlands region, which includes counties such as Laois, Longford, Offaly, Westmeath, Roscommon, and parts of Galway, Kildare, and Tipperary. The initiative aims to foster collaboration among local stakeholders, including SMEs, research organizations, and community groups, to transition bioeconomy innovations from research to practical applications (*2023 Bioeconomy Demonstration Initiative – EU Just Transition Fund*, 2023). Likewise, the Circular Bioeconomy Cluster Southwest launched by Munster Technological University promotes the development and support of bioeconomy projects in the South-West region of Ireland. It focuses on fostering innovation and collaboration among local enterprises and research institutions to enhance the regional bioeconomy (University College Dublin, 2024). It is worth mentioning that the annual event Bioeconomy Ireland Week which involves multiple regional partners highlights regional bioeconomy activities and projects across Ireland and aims to raise awareness and showcase local bioeconomy initiatives, fostering regional development and collaboration (Jesko Zimmermann, 2023).

5.2 State of the art of biomass valorisation

5.2.1 Biomass resource availability

Agricultural biomass

According to statistics of 2022, Ireland's agricultural biomass mainly consists of cereals, straw, fodder crops, grass and other crop residues amounting to a total of 35.9 million tonnes (*Material Flow Accounts 2022: Key findings*, 2023). The Figure 50 below shows the main sources of biomass and their quantity in Ireland, and it can be seen that the major sources of biomass are grass at 18.4 million tonnes representing over 50% of the total biomass in agriculture and fodder crops at 12.1 million tonnes followed by cereals and straw.

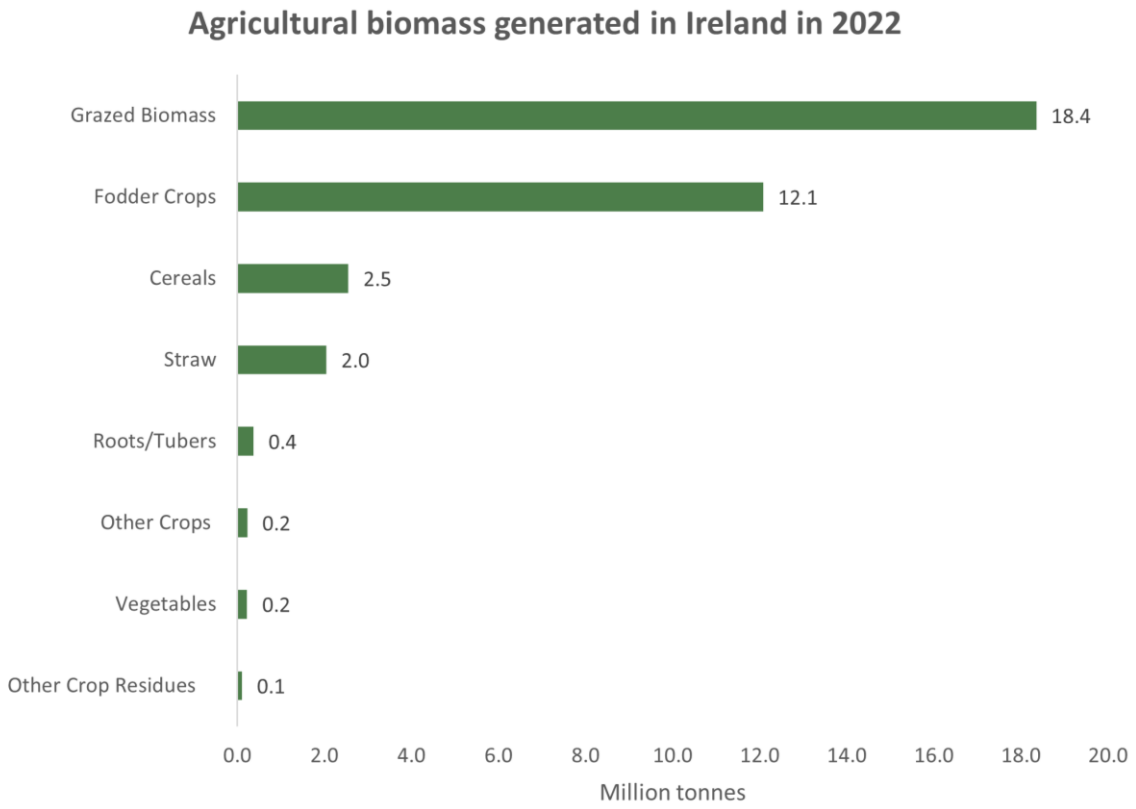

Figure 50: Biomass resources generated in 2022 in Ireland (Material Flow Accounts 2022: Key findings, 2023)

The residual biomass may be put to further economic use such as for bedding material in livestock husbandry, as animal feed, for energy production, and as industrial raw material, though as suggested by the Department of Agriculture, Food and the Marine (DAFM), has a good potential to be used for renewable energy production and therefore the agricultural feedstocks can be destined for the anaerobic digestion (AD) sector (*Annual Review and Outlook for Agriculture, Food and the Marine 2023*, 2023). AD is a process that converts organic material into biogas and digestate through microbial activity in the absence of oxygen (Teagasc, 2017). The resulting biogas can be used to generate electricity, heating and or fuel for transport and the digestate can be used as fertilizer and soil conditioner.

Livestock biomass

Given the number of livestock in Ireland and especially the bovine a high quantity of animal by-products can be expected of which manure is at over 84 million tonnes annually (Köninger, 2021), and as indicated by the environment protection agency of Ireland 90% of national ammonia emissions come from livestock manure. Based on the statistics of animal slaughters mentioned in previous sections and the carcass weight at approximately 55% of live weight for beef (Teagasc, 2022b), 76% for pig (*Teagasc pig herd performance*, 2017), 72% for chicken (Fernandes, 2013) and 50% for sheep (*What is the ideal weight for a market lamb?*, 2014), it can be estimated that about 508,000 tonnes of bovine meat residues, 68,000 tonnes of sheep meat residues, 105,000 tonnes of pig meat residues and 66,000 tonnes of poultry meat residues totalling to about 747,000 tonnes of animal meat residues were produced in 2022 in Ireland.

Manure, liquid or solid, is often applied to land as a fertilizer to enhance soil fertility and structure. National estimates indicate that 34% of aggregate slurry is from dairy cows, 23% from suckler cows, and 11-13% from younger cows. On average, about 50% of the slurry is applied to lands throughout the year. The data also show that 82% of cattle manure is stored as liquid slurry while 18% is stored as solid manure on farms where the slurry is mostly applied on lands through splash plate method (Buckley, 2023).

In order to prevent pollution of surface waters and ground water from agricultural sources, especially from manure application to lands, and to protect and improve water quality, Ireland has developed a program called Nitrate's Action Programme (Department of Housing, 2020) under which there are 3 nitrate zones based on soil type, rainfall and growing season duration (Irish Farmers Association, 2023). Based on the nitrate zones specified in Ireland, there are three zones as zone A (southern and eastern counties), zone B (south-western and western counties), and zone C (counties bordering Northern Ireland). Regarding the distribution of cattle manure throughout Ireland, recent statistics show that annually the majority of slurry in zone A is from dairy cows at 44%, and in zone B and zone C from suckler cows at 29% and 34% respectively (Buckley, 2023). Figure 51 below depicts the map of Ireland divided based on the nitrate zones.

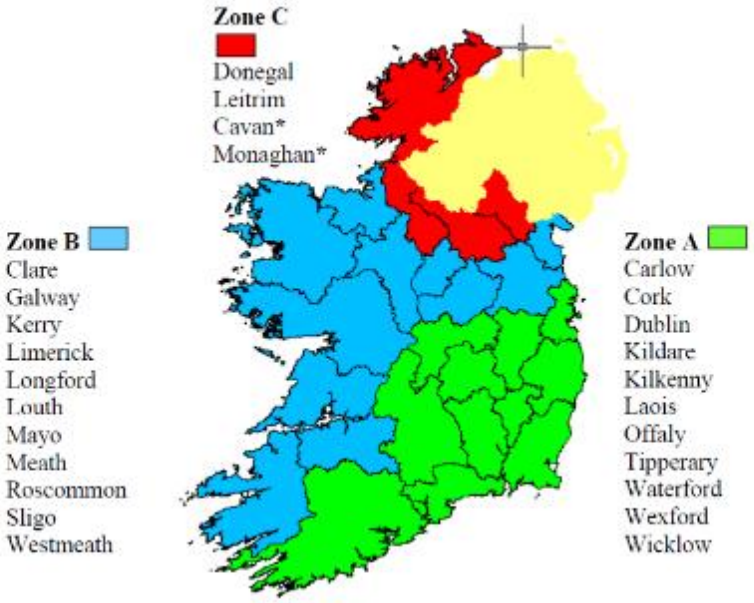

Figure 51: Nitrate zone designations in Ireland (Köninger, 2021).

Agro-industrial biomass

As indicated in previous sections, the agri-food sector in Ireland encompasses about 2,000 food production and drink enterprises of which the dairy industry is a major player with an annual milk output of over 8 billion litres in 2023 (Central Statistics Office, 2024d), providing grounds for milk processing activities throughout the country including skimmed milk, butter and cheese production, and whey is the main by-product of the dairy processing sector with a potential to be turned into value-added products and according to statistics 80-190 million tonnes of salted and acid whey are generated annually in Ireland (Teagasc, 2024). Additionally, it was also mentioned that beef production is of considerable importance in Ireland's economy producing high amounts of biomass as organic waste streams in slaughterhouses with a good potential for energy recovery (Ware, 2016).

Forestry biomass

Forestry biomass in Ireland plays a significant role in the country's renewable energy sector. Biomass from forestry includes materials such as wood chips, logs, and residues from forest management activities where the main product is timber logs made of spruce tree stems consisting 60-75% of total tree volume while the remaining 25-40% residues (about 800,000 m^3/year) including branches, stems and deformed trees are not utilized due to lack of large-scale demand in Irish market (Rai, 2023). Statistics of 2023 indicate that about 1.46 million m^3 of roundwood and wood residues with an energy content of 10 million GJ were produced in Ireland, and it is forecasted that the wood biomass would reach an amount of 1.8 million m^3 with an energy content of 12.5 million GJ by 2040 (*Forest Statistics - Ireland 2023*, 2023). In Ireland, forest residues are usually left on the forest floor after wood harvest which according to studies has ecological benefits like soil fertility and nutrient cycling in forest ecosystem (Titus et al., 2021-04-14), but there should be a balance between that and biomass utilization to avoid underutilization (Rai, 2023) of this bioresource. According to the Sustainable Energy Authority of Ireland 2018 report, 393 combined heat and power (CHP) units used natural gas and oil as primary fuel, producing up to 327 MW_e, whereas only 3 CHP units used biomass including forest residues for heat and electricity generation in 2017, producing 5.5 MW_e (Rai, 2023).

Marine biomass

It should also be noted that Ireland holds a considerable amount of marine and aquaculture biomass including wild fish catch, and aquatic plants/animals. In 2022, the aquaculture sector produced a total of 44,723 tonnes of aquaculture products, including salmon, oyster, mussel, shellfish, trout and seaweed spread over 292 production units. The relatively new segment of seaweed production was at 493 tonnes over 165 ha of inshore area in 2022 (Dennis, 2023). In the same year, a total of 267,202 tonnes (live weight) of fish were landed in Irish ports of which 156,943 tonnes were landings by Irish vessels and 110,259 tonnes were landings by foreign vessels (Central Statistics Office, 2023). Figure 52 below shows the locations of Irish ports with fish landings size in 2022, and according to the map it is evident that northwest, and southwest region ports have the highest number of fish landings in the country.

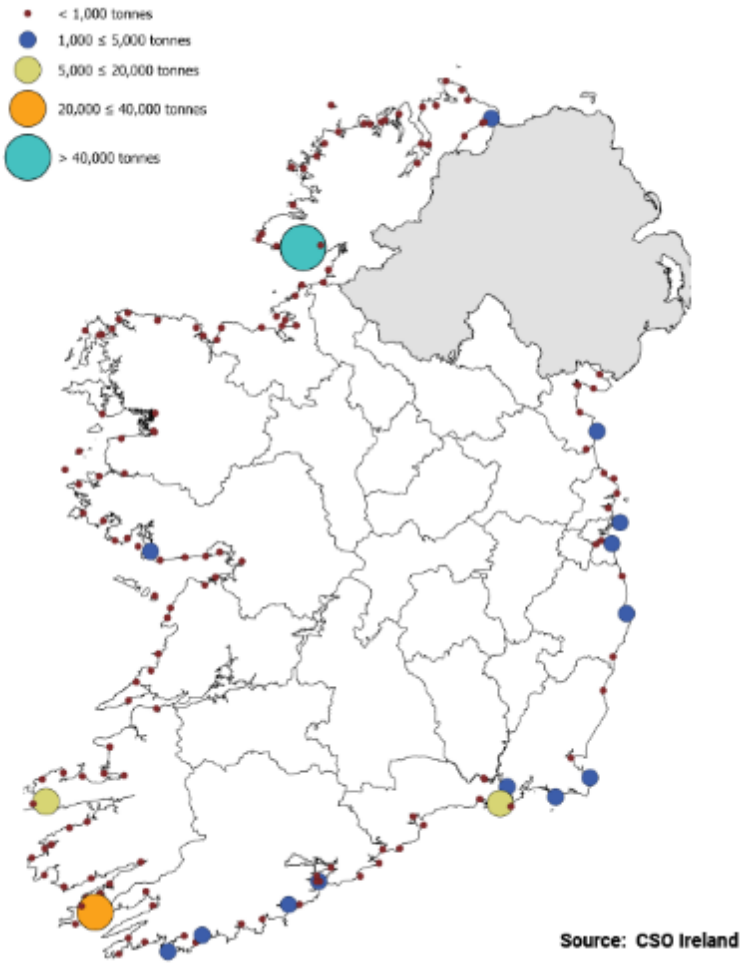

Figure 52: Locations of Irish ports with fish landings, 2022 (Central Statistics Office, 2023).

5.2.2 Management and logistics of biomass resources

Ireland's biomass sector has significant potential, but logistical challenges such as transportation, storage, and supply chain coordination must be addressed to fully realize its benefits. Continued policy support, technological innovation, developing a suitable regulatory regime for the bioeconomy that would encourage private investment; and stimulating market demand for bioeconomy products are

crucial for overcoming these barriers and ensuring the economic viability of biomass resources. As said, market prices for biomass resources affect the availability of the product, as the higher the price, the more resources can be viably grown, harvested and refined. In the case of forest residues, in addition of lack of significant market, due to the low quality and low density of forest residues there are challenges, e.g., difficulty of extraction and wide geographical distribution, in large-scale mobilization of such residues to CHP units. Furthermore, in light of the National Bioeconomy Statement there is an imminent need for developing more advanced conversion technologies beyond the conventional heat and power applications of forest residues (Rai, 2023).

Likewise, energy crops such as grass silage and oil seed rape are widely available, but they need a higher market price to make financial sense. On the other hand, organic waste resources such as municipality waste, waste wood and used cooking oil are typically available at a low or even negative cost for biomass fuel producers because it costs money to dispose of waste at landfills (Sustainable Energy Authority of Ireland, 2024).

5.2.3 Bio-products target market

The Irish Bioeconomy Action Plan identifies agriculture, food, forestry and the marine as a key sector in bioeconomy with high potential for recirculation and upcycling of biobased materials (*Bioeconomy Action Plan 2023-2025*, 2023). With respect to the role of agriculture sector in the Irish economy, as discussed in earlier sections, it is clear that agri-food sector is a key producer of biomass which has great potential for renewable energy production (Sustainable Energy Authority of Ireland, 2024). Additionally, agricultural biomass can undergo digestion, extraction, fermentation, combustion and pyrolysis techniques resulting in building blocks, intermediates and end products for use in the food, chemicals, functional materials and fuel sector. Although, due to their calorific value as well as cost considerations the agricultural biomass is often valorised to food applications. Also, forestry biomass can be treated with extraction, combustion, pyrolysis, chipping and pelletizing techniques to valorise woody side streams into marketable products such as heat, electrical power, fertilizer, biochar, bio-oil and syngas (Hendriks, 2018). In light of this, the following section will review the current status of using biomass sources from Agri-forestry activities.

Bioenergy and biofuels sector

Error! Reference source not found. Figure 53 below illustrates the share of indigenous primary energy production in Ireland and it can be seen that biomass has a share of 8% equal to 2.92 TWh in energy production in 2022 in Ireland. It is worth noting that the use of biomass has mainly increased in the wood-processing industry (Energy in Ireland 2023, 2023).

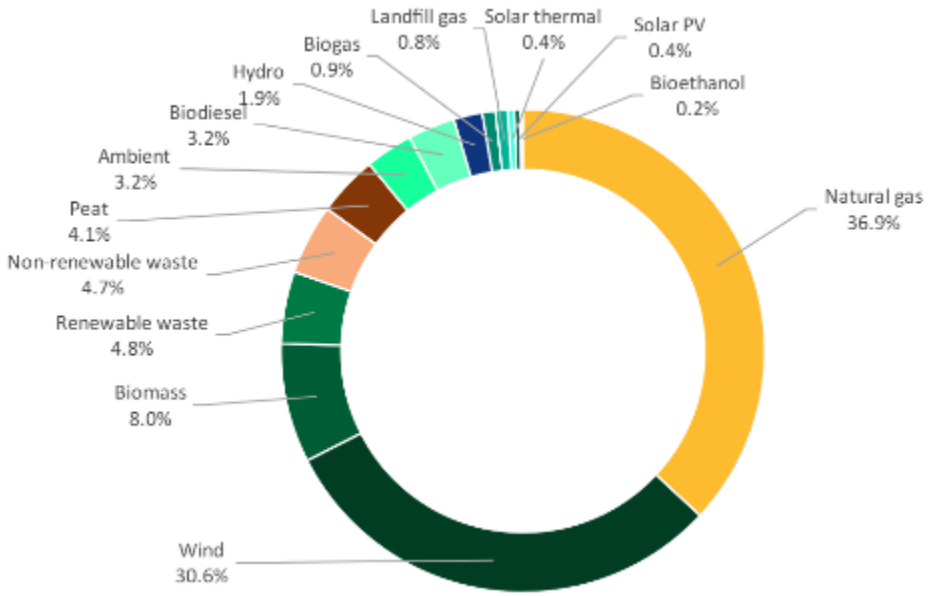

Figure 53: Share of indigenous primary energy production by energy type in Ireland (Energy in Ireland 2023, 2023).

Despite the low share of biogas at 0.9% in energy production in Ireland, there are many suitable feedstocks for biogas production from the agricultural sector, including energy crops, animal slurry and manures, as well as waste and by-products from agro-industries. As such, the potential for a biogas industry derives largely from the abundance of grassland, which can be used to grow feedstock for anaerobic digestion (AD), and the significant number of livestock and hence slurry that can be co-digested with grass and grass silage in the AD process. AD is a multi-step process whereby organic waste, and residues are converted into biogas by a group of microorganisms in an anaerobic environment. In Ireland, the AD sector is relatively underdeveloped despite its potential due to the abundance of grassland and cattle slurry, which can be used to provide feedstock for AD (Teagasc, 2022a).

- Biomass electricity generation

Regarding the potential for biomass to be used as a source of energy, the primary areas of focus are waste, industrial residues, and agricultural residues. In 2022, out of the total electricity generation of 33.6 TWh, only 3.9% came from biomass, which accounted for 11.2% of renewable energy (Biomethane energy report, 2023; IEA Bioenergy, 2021; Sustainable Energy Authority of Ireland (SEAI), 2023).

- Biogas generation

According to latest statistics, there are 43 facilities in Ireland producing 580 GWh of biogas, in addition to the two biomethane facilities (Department of Agriculture and Communications, 2024). In 2022, a total of 0.32 TWh energy representing 0.9% of total domestic primary energy was produced by biogas of which 0.12 TWh was input to electricity generation yielding 0.06 TWh electricity for final consumption (Biomethane energy report, 2023). On the other hand, while biomethane production has been rolled-out over recent decades across Europe at significant scale, biomethane is at a nascent stage of development in Ireland. Biomethane deployment in Ireland has been limited to date, with only a handful of commercial scale AD plants developed and Ireland stands as one of the lowest

biomethane producers in Europe with 487 GWh in 2021 which was increased to 580 GWh by mid-2024. A survey from 2022 reveals that approximately 176 prospective biomethane producers with a total annual production volume of 14.8 TWh (using mainly agricultural feedstock) can operate in Ireland (Biomethane energy report, 2023). Figure 54 below depicts the survey results standing for Ireland counties' capacity of biomethane production and, as it can be seen, counties Cavan, Kildare and Cork have the most potential for up taking biomethane production at 2,791 GWh, 2,527 GWh and 1,442 GWh respectively.

Figure 54: Survey of biomethane production capacity by county in Ireland, 2022 (adapted from Biomethane Energy Report) (Biomethane energy report, 2023).

- Combined heat and power (CHP) generation

CHP is the simultaneous generation of usable heat and electricity in a single process. The efficiency of a CHP plant can be 20-25% higher than the combined efficiency of heat-only boilers and conventional power stations. Meanwhile, the combustion of biomass including logs, wood pellets and wood briquettes accounted for about 1% of residential heat demand (Energy in Ireland 2023, 2023). Table

34**Error! Reference source not found.** below shows the number of operational CHP units and their installed capacity by fuel in 2022. It is clear that biomass utilization for CHP generation in Ireland is at a low level with only 3 CHP plants with 6.6 MWe in operation.

Table 34: Number of operational CHP units and installed capacity by fuel, 2022 (Energy in Ireland 2023, 2023).

	No. of units	Installed capacity (MWe)
Natural gas	275	305.5
Solid fuels	1	2.6
Biomass	3	6.6
Oil fuels	21	1.1
Biogas	18	11.9
Total	318	327.7

- Biofuels

Statistics of 2023 show that only 15% of feedstocks for biofuels were sourced from Ireland itself while the majority (51%) were from Europe followed by imports from China (20%). Also, 47% of all biofuels in the Irish market were produced from used cooking oil, 19% from category 1 tallow, and 14.5% from POME. It is also notable that the majority of the HVO in Ireland was produced from palm oil mill effluent. The 8 major biofuel producers and suppliers in Ireland include Green Biofuels Ireland (GBI), Agri Energy, Calor Teoranta, Carbery Food Ingredients, College Biofuels, Green Gas Generation, Green D Project Ireland, ElectroRoute Energy Trading (Byrne Ó Cléirigh, 2023).

Non-energetic applications of biomass

Ireland has several business models that convert biomass into bioproducts, which fall outside the sector of bioenergy. Some of these enterprises source their biomasses from outside Ireland. Nevertheless, it is worth noting that these enterprises contribute to the Irish bioeconomy. Marine biomasses appear to be the most prevalent among businesses engaged in biomass conversion, with a focus on the production of healthy animal feed, plant bio-stimulants, fertilisers, food supplements, cosmetics packaging and bait and pet food. The preferred feedstock for conversion in Ireland at present is agricultural biomass, which can be used to produce fertilisers, feed, plant, animal and human health products, insulation and biodegradable plastics. Finally, regarding wood biomasses, it is notable that a significant number of sawmills and wood-based products businesses exist in Ireland. However, only a few of these businesses make any mention of the utilisation of their waste materials, and only one business has as its focus on the conversion of wood wastes into valuable products. The following paragraphs provide details about the bioproducts manufactured through biomass processing for non-energy purposes in Ireland (Biomap, 2021).

- Biomaterials/biochemicals

There are several processors in Ireland that source, produce and market a range of biomaterials or biochemicals aimed for applications such as fertilizers, animal nutrition products, bio-stimulants and insulation materials. The utilized biomass sources include sea and terrestrial plants, dairy by-products, and cellulose-dense crops (cotton, straw, sawdust, hemp and corncob).

Grassland Agro has three industrial fertilizer plants in Limerick, Cork and Slane where they process seaweed and other plant extracts to produce biofertilizer and mineral blocks for animal health.

AgriChemWhey converts dairy by-products (whey) into lactic acid which can then be used to manufacture biodegradable plastic.

Sustainable Insulation Products manufactures insulation made of recycled cellulose from cotton, straw, sawdust, hemp and corncob as well as non-biomass resources like newspaper and cardboard.

BioAtlantis uses marine and terrestrial plants to manufacture products for plant, animal and human health specialized in stress reduction.

Corcoran converts a wide range of biomass sources into various biomaterials and biochemical such as food ingredients, animal feed, human nutrition products, raw materials for pharmaceutical and veterinary uses, polymers, cosmetics and insulation.

Arramara, Wild Irish Seaweeds, NutraMara, Brandon Bioscience, Ocean Harvest Technology, Bio marine and Algaran are companies specialized in harvesting and using seaweed to produce a range of pharmaceutical, and nutraceutical products to improve animal, crop and soil health as well as ingredients for cosmetic industries.

- Wood products

Some companies process wood residues and waste including deformed logs, wood chips, sawdust, bark, and shavings into products like moulded door skins and quality timbers. Masonite and Glennon Brothers are two such companies.

In conclusion, the Irish Bioeconomy Action Plan underscores the significant potential of biomass utilization across various sectors including agriculture, food, forestry, and marine as witnessed by diverse biomass sources available in the country especially agriculture biomass which can be converted into renewable energy through digestion, extraction, fermentation, combustion, and pyrolysis techniques. These processes yield valuable products such as biofuels, biochemicals, and organic fertilizers. While there are bioeconomic opportunities in Ireland that could be leveraged for valorisation, there is still considerable scope for improvement in this regard. The biogas and biomethane sector, though currently small, shows promise due to the abundance of grassland and livestock slurry suitable for anaerobic digestion. According to the national biomethane strategy published in May 2024, Ireland has a great potential for biomethane production in Europe and farmers as the key stakeholders can substantially contribute to the development of this sector in the country. In addition of the economic profits, the biomethane production has also the benefit of decarbonising Ireland's energy system contributing to environmental sustainability. Also, biomass utilization in CHP generation is currently low, but the technology presents a significant opportunity for efficiency improvements. Biomass CHP plants could increase overall energy efficiency by 20-25% compared to conventional power stations. Lastly, the biofuel sector in Ireland relies heavily on imported feedstocks, with only 15% sourced domestically. However, there is room for growth, particularly in increasing the use of domestic feedstocks and expanding the production capacity.

In addition of energy applications, the biomass resources in Ireland are also used for producing biomaterials and biochemicals with applications ranging from animal and crop health improvement to human nutrition and cosmetics as well as industrial uses such as packaging and insulation materials. Despite all the advances, there is a need to enhance knowledge and awareness about the alternative uses of biomass and its potential applications across various value chains. Detailed analysis of biomass resources, potential applications, and market demand are crucial in further valorisation of the biomass resources available in Ireland especially for developing BBTs. Additionally, fostering a culture of innovation and technological adaptation is essential for the biomass sector's growth and competitiveness. Investment in facilities and technologies for biomass conversion is necessary to unlock the sector's full potential. And lastly, continued support through favourable policies and financial incentives is needed to encourage investment in biomass technologies and to support small and medium enterprises (SMEs) in the sector.

5.2.4 R&D system associated with biomass valorisation

Ireland hosts several research and development (R&D) groups dedicated to advancing the bioeconomy and biomass valorisation. These groups focus on various aspects of biomass utilization, including bioenergy, bioproducts, and sustainable practices. As an initiative by the Irish state, the Irish Bioeconomy Network is overseen by the Bioeconomy Implementation and Development Group through its co-chairing departments and secretariat. This network comprises prominent organizations, centres, clusters, and programs, including the SFI BiOrbic Bioeconomy Research Centre, Enterprise Ireland's Irish Bioeconomy Foundation, the Circular Bioeconomy Cluster South-west, the Circular Bioeconomy Research Group, Shannon ABC, Teagasc, and the Marine Institute. Collectively, these organizations aim to foster engagement, increase awareness of the bioeconomy, and support its progress among a diverse array of stakeholders (Department of Agriculture, 2023).

Additionally, Bioeconomy Ireland Week is an annual event in October that aims to showcase and promote Ireland's flourishing bioeconomy. This event, which involves various participants such as industry, communities, producers, researchers, and students, is organized by the Irish Bioeconomy Network around a central theme to raise awareness about the bioeconomy in Ireland. The Table 35 shows the list of key Irish Bioeconomy Network members with details of their main research activities.

Table 35: Key Irish Bioeconomy Network members (Department of Agriculture, 2023).

Main research areas and activities	Institution
Research on separating and extracting valued compounds from renewable materials, converting them into novel bio-based products and processes	BiOrbic
To support the conversion of Ireland’s natural land & sea resources to high-value products through design, financing and promotion	Irish Bioeconomy Foundation
To develop and promote the circular bioeconomy using marine, agriculture and waste-to-value thematic areas	Circular Bioeconomy Cluster South-west

Main research areas and activities	Institution
Sustainable circular bioeconomy solutions	Cill Ulta (Northwest Bioeconomy Hub)
Bioresource mapping, bio-based value chain development, biorefining, low carbon economy, new business models, education & outreach	Circular Bioeconomy Research Group
Detection, identification, characterization and valorisation of bioresources	Shannon ABC
Integrated research, advisory and training services to the agriculture and food industry and rural communities	Teagasc (Agriculture and Food Development Authority)
Marine research, technology development and innovation	Marine Institute

The Table 36 provides a list of universities and research centres in Ireland with the goal of developing bioeconomy innovation and technologies in the country.

Table 36: Irish universities and research centres working on bioeconomy (Bioeconomy Factsheet Ireland, 2018).

Institution	Research group/centre
NUI Galway	Ryan Institute for Environment, Marine and Energy Research
University College Cork (UCC)	Sustainable Energy Research Group
University College Dublin (UCD)	Energy Research Group
Dundalk Institute of Technology	Centre for Renewable Energy
Institute of Technology Carlow	-
Galway-Mayo Institute of Technology	-
Science Foundation Ireland, coordinated by UCD	BEACON Bioeconomy Research Centre
Science Foundation Ireland, coordinated by UCC	MaREI Marine and Renewable Energy Research Centre
Coordinated by the University of Limerick	Dairy Processing Technology Centre

Also, “BioConnect Innovation Centre” led by Enterprise Ireland with the mission to engage with local and regional food businesses and agricultural producers, together with entrepreneurs and investors to drive the agri-food sector forward using biotechnology, and “Knowledge transfer Ireland” organization support bioeconomy network and enterprise in the country (*Bioeconomy Factsheet Ireland*, 2018).

5.2.5 Support and financing policies

According to Ireland’s Bioeconomy Action Plan 2023-2025, bioeconomy opportunities will be integrated into national research funding programs and support. Key financiers in Irish bioeconomy include Enterprise Ireland (EI), Science Foundation Ireland (SFI), Sustainable Energy Authority of Ireland (SEAI), Western Development Commission (WDC), Irish Strategic Investment Fund (ISIF), Environmental Protection Agency (EPA), Teagasc, Údarás na Gaeltachta, InterTrade Ireland, Local Enterprise Offices (LEOs), European Investment Bank (EIB) and Accelerate Green (*Bioeconomy Factsheet Ireland*, 2018).

Among all, EI and SFI represent numerous funding schemes to enable businesses throughout Ireland to grow and play their role in bioeconomy. In addition of the equity investments and grants, EI also offers opportunities to connect with international research programs and further funding bodies as well as the possibility of commercialization of academic research and inventions through funds and industry collaboration. It is worth knowing that EI also offers grants for companies based on their stage of development i.e., start-up, high potential start-up, established SME and large company with specific funding ceilings.

There is a co-funded program by the Irish government and the EU Just Transition Fund named “Bioeconomy Demonstration Initiative” which supports close collaboration between stakeholders in the bio-based value chain including SMEs, research bodies, universities, local authorities, primary producers, bioprocessing industries and consumer brands (*2023 Bioeconomy Demonstration Initiative – EU Just Transition Fund*, 2023).

Also, the Shared Island Initiative awards grants for an All-Island Bioeconomy Demonstrator initiative to support the integration of biobased innovation in the agriculture and marine sectors across the island of Ireland. In light of this initiative, DAFM and the Department of Agriculture, Environment and Rural Affairs in Northern Ireland have established the “Shared Island Fund Bioeconomy Demonstration Initiative Scheme” which will support bioeconomy piloting and demonstration actions across Ireland and Northern Ireland. This will enable stakeholders to enhance existing or establish new cross-border collaborations, and formulate initiatives for piloting and showcasing agriculture or marine-based bioeconomy activities on an all-island scale (Irish Bioeconomy Network, 2023).

The Table 37 identifies national funding opportunities to support bioeconomy research, demonstration and commercial initiatives in relation to upcycling of biobased materials in Ireland.

Table 37: Funding programmes for bioeconomy at national level (Irish Bioeconomy Network, 2023).

Programme	Funding organization	Type	Web
Disruptive Technologies	DAFM, manged by EI	Grant fund	https://enterprise.gov.ie/en/what-we-do/innovation-research-

Programme	Funding organization	Type	Web
Innovation Fund (DTIF)			development/disruptive-technologies-innovation-fund/
Green Transition Fund	EI	Grant fund	https://globalambition.ie/green-transition-fund/
Digitalisation Funds			https://globalambition.ie/digital/
Lean Business Offer			https://www.enterprise-ireland.com/en/supports/leanstart
Exploring Innovation Grant			https://www.enterprise-ireland.com/en/supports/exploring-innovation-grant
Innovation Partnership Programme			https://www.enterprise-ireland.com/en/supports/innovation-partnership-programme
Innovation Voucher		Knowledge transfer fund	https://www.enterprise-ireland.com/en/supports/innovation-voucher
	Local Enterprise Office		
Springboard+	Higher Education Authority	(Bioeconomy) Education grant	https://hea.ie/skills-engagement/springboard/
Agri-Food Skillnet	Skillnet Ireland	Skills development fund	https://www.skillnetireland.ie/sectors/agriculture
SFI ARC Hub Programme	SFI	Grant fund	https://www.sfi.ie/funding/

Programme	Funding organization	Type	Web
SFI Industry RD&I Fellowship Programme			
SFI Discover Programme			
Co-Centre Programme			
SFI Spokes programme			
SFI Strategic Partnership Programme			
National Challenge Fund			
Industry Collaboration Fund			
SDG Challenge	SFI & Irish Aid	Grant fund	https://www.sfi.ie/funding/funding-calls/future-innovator-sdg/index.xml
Fisheries, Aquaculture and Seafood Processors Funding Schemes	EU's European Maritime, Fisheries and Aquaculture Fund, co-funded by Ireland's Seafood Development Agency (BIM)	Grant and investment funds	https://bim.ie/fisheries/funding/
Marine Research Programme	Marine Institute	Grant fund	https://www.marine.ie/site-area/research-funding/marine-institute-funding/marine-institute-funding

Programme	Funding organization	Type	Web
Climate Action Fund	Department of the Environment, Climate and Communications	Grant fund	https://www.gov.ie/en/publication/de5d3-climate-action-fund/
EPA Green Enterprise Scheme	EPA	Grant fund	https://www.epa.ie/our-services/research/epa--research-funding/
EPA Research Calls			
National Energy Research Funding Programme	SEAI	Grant fund	https://www.seai.ie/grants/research-funding/
Support Scheme for Renewable Heat			https://www.seai.ie/business-and-public-sector/business-grants-and-supports/support-scheme-renewable-heat/
Rural Regeneration and Development fund	Department of Rural and Community Development	Grant fund	https://www.gov.ie/en/policy-information/c77144-rural-regeneration-and-development-fund/#how-to-apply
LEADER programme			https://www.gov.ie/en/service/87e09-leader-programme-for-rural-development/?referrer=https://www.gov.ie/en/service/c5849b-rural-funding/?section=leader-programme-for-rural-development#how-to-apply
ClimAccelerator	EIT Climate-KIC	Acceleration	https://climaccelerator.climate-kic.org/
Accelerate Green programme	Bord na Móna, Resolve Partners, co-funded by EU	Executive Accelerator	https://accelerategreen.ie/

Programme	Funding organization	Type	Web
EIC Accelerator	European Innovation Council (EIC)	Grants and investments	https://eic.ec.europa.eu/eic-funding-opportunities/eic-accelerator_en
Hatch Fund	Hatch	Venture Capital	https://www.hatch.blue/
The Pearse Lyons Cultivator	AllTech	Acceleration	https://www.pearselyonscultivator.com/
Yield Lab Europe	The Yield Lab	Venture Capital	https://theyieldlab.eu/
New Frontiers programme	EI	Acceleration	https://www.newfrontiers.ie/
NDRC	NDRC	Acceleration	https://www.ndrc.ie/
IndieBio	SOSV	Acceleration	https://sosv.com/
THRIVE	SVG Ventures	Acceleration	https://thriveagrifood.com/

In addition of the public funding mechanisms, there are commercial funding opportunities. The **Strategic Banking Corporation of Ireland (SBCI)** helps SMEs achieve their business plans by providing flexible and lower-cost funding. Some of specific funding schemes of SBCI include "Energy Efficiency Loan Scheme", "Ukraine Credit Guarantee Scheme" (finance facilitation for SMEs and primary producers affected by conflict in Ukraine), "Invoice Financing", and "Leasing and Hire Purchase". Also, **National Treasury Management Agency (NTMA)** offers "Ireland Strategic Investment Fund (ISIF)" and "Agri-Tech Fund" programs to support economic activity and employment in Ireland. Another investment provider is **Resolve Partners** that offers support to leaders in innovation, research and entrepreneurship. Commercial funding opportunities are also available by private financial institutions like the Allied Irish Banks through their dedicated Agri Advisor Team and farm development loans, and the Bank of Ireland supporting the Food and Drink Industry (Irish Bioeconomy Network, 2023).

Other relevant supports are available through the following organizations (Irish Bioeconomy Network, 2023):

1) **Irish Business and Employers Confederation (IBEC)**: the lobby and business representative group in Ireland which provides information and support for businesses, and one of their tools is "climate action toolkit" providing the required information and practical guidance on how to develop an enduring climate action strategy;

2) **Nua na Mara (Marine Innovation Development Centre)**: dedicated to supporting the development of marine start-ups, early-stage companies, and existing businesses, with the mission to bridging the gap of innovation, research, and industry through commercialisation;

3) **Circuléire (The National Platform for Circular Manufacturing)**: a public-private partnership with the mission to demystify, derisk, and deliver circular business model innovation by unlocking the value that resides in an Irish circular economy;

4) **Irish Nutrient Sustainability Platform**: founded on the principle that waste is a valuable resource of nutrients, energy and other high-value products. Its mission is to promote sustainable nutrient management on the island of Ireland in the context of the United Nations Sustainable Development Goals Agenda;

5) **Cré (Composting and Anaerobic Digestion Association of Ireland)**: a non-profit association of public and private organisations, dedicated to growing the biological treatment sector. Cré supports the production of high-quality outputs, assists the delivery of Government waste diversion and bioenergy targets, and promotes the creation of sustainable indigenous jobs;

6) **IrBEA (Irish Bioenergy Association)**: to promote the bioenergy industry and to develop this important sector on the island of Ireland through a self-governing association of voluntary members;

7) **CAP Network Ireland**: to support the networking of a diverse range of stakeholders across the fields of agriculture, rural development and innovation. It is a partnership between Irish Rural Link, ERINN Innovation and MTU;

8) **Regional Assemblies:** to accelerate and optimise effective regional development in Ireland through policy making based on 'Regional Spatial and Economic Strategy', optimising EU policy and funding instruments for regional/local development priorities and engaging with innovative research partnerships and regional based networks. The three regional assemblies are "the Northern and Western Regional Assembly", "the Eastern and Midland Regional Assembly", and "the Southern Regional Assembly".

5.3 Analysis of Operational Groups

5.3.1 Operational groups characterization

The latest indicate that 3,400 EIP-AGRI Operational Groups (OGs) have been funded since 2014 to 2023, and 6,600 projects are planned for 2023-2027 throughout EU. Out of that, 57 OGs have been funded until 2023 in Ireland, and Table 38 below shows the breakdown of these OGs revealing that the majority of OGs have been focused on areas related to biodiversity, farm management and community conservation (EIP-AGRI Operational Group Projects - Ireland). These OGs have been funded by DAFM under the Rural Development Program 2014-2020 which was extended to 2022.

Table 38: OGs breakdown in Ireland 2014-2023.

Type of OG	Quantity
Themed	2
Open call 1 and 2	21
Locally led farm and community biodiversity	24
Farm health, safety and wellbeing	8
Rewetting of farmed peatlands	2
Total	*57*

Based on the information provided by CAP network Ireland, the majority of OG projects in Ireland are about farm management and biodiversity while only 3 projects have worked on biomass valorisation with a BBT development which include "Small Biogas Demonstration Programme" performed from 2019 to 2022 in midlands and Midwest region with a total budget of 994,273 €, "Biomass to Biochar for Farm Bioeconomy" performed from 2018 to 2021 in Midwest region with a total budget of 998,377 €, and "Biorefinery Glas (Small-scale Farmer-led Green Biorefineries)" performed from 2019 to 2020 in southwest region with a total budget of 940,498 €. All three OGs identified have developed technologies for processing agricultural biomass, with outputs being biochar, biogas, and biomaterials such as protein, and fructo-oligosaccharides (EIP-AGRI Operational Group Projects - Ireland; EU CAP Network, 2024). Figure 55 below shows the total number of OGs launched in each year, including the proportion that focused on development of BBTs.

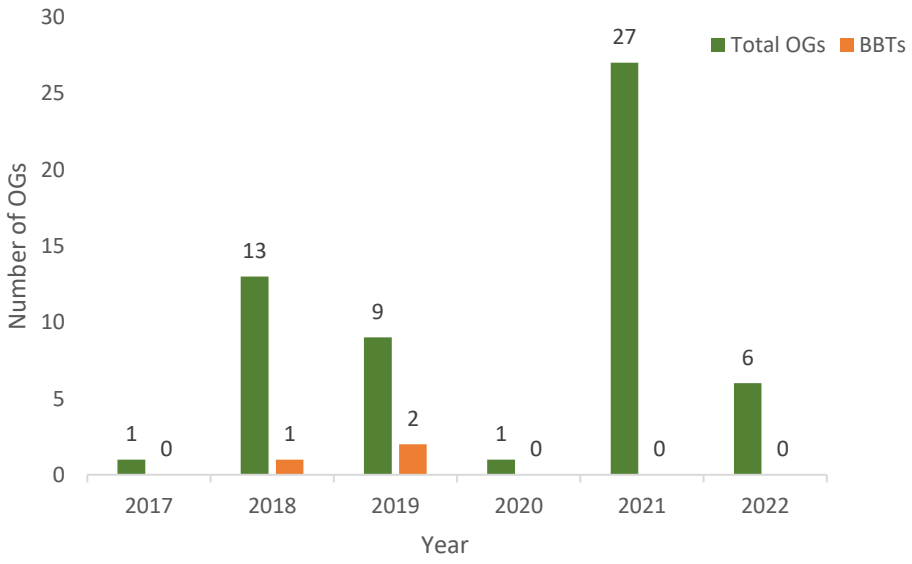

Figure 55: OGs evolution in the period 2017-2022 in Ireland (EIP-AGRI Operational Group Projects - Ireland; EU CAP Network, 2024).

The Figure 56 shows the total budget of OGs projects over the analysis period. It can be seen that this follows a similar trend to the total number of projects funded. The OGs show a diverse funding range from as low as 46.5k€ to as high as 25M€, while the BBT OGs had a rather similar budget range of 977K€ on average.

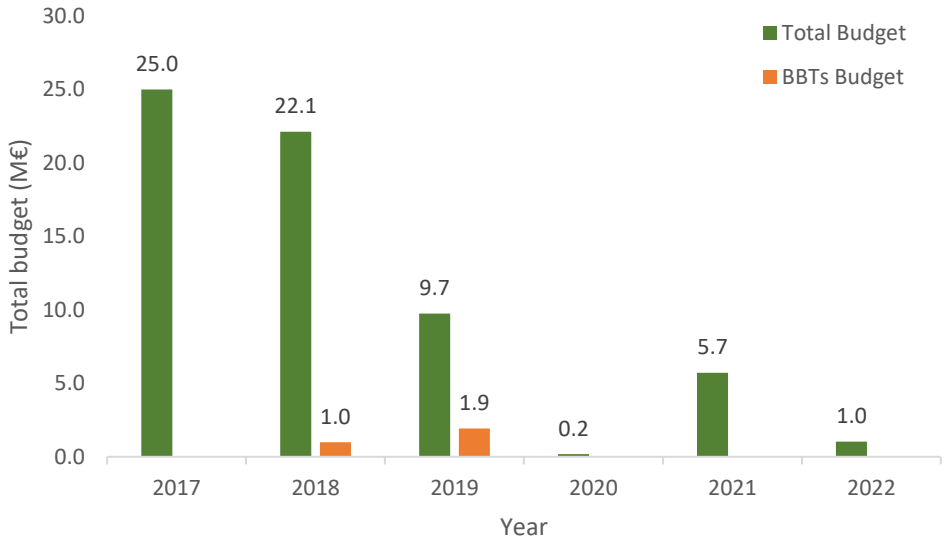

Figure 56: OGs budget evolution over the period 2017-2022 (EIP-AGRI Operational Group Projects - Ireland; EU CAP Network, 2024).

5.3.2 Bio-based Technologies (BBT) developed by OGs

As it was mentioned in previous section, Ireland has had merely three OG projects focused on BBTs which all used green agricultural biomass or livestock waste as the feedstock to produce a range of bioproducts including biochar, biogas, animal feed and biochemicals. It is important to note that, due to novelty of these projects or commercial sensitivities, there is still not much details available about them. The following Table 39 summarizes details on the three BBT-focused OGs in Ireland.

The focus of these BBTs have been developing a farm-scale technology that can be utilized by primary producers to practice a circular economy initiative with benefits to both the environment and economy while diversifying their income sources. These BBTs have previously been practiced in a more industrial level (pyrolysis, AD and grass biorefinery) with established TRLs depending on their type (A review of pyrolysis technologies and feedstock: A blending approach for plastic and biomass towards optimum biochar yield, 2022/10/01) while in their OG form they are more of a small-scale technology with a potentially different TRL.

Table 39: OGs focused on BBT development in Ireland (EIP-AGRI Operational Group Projects - Ireland).

OG project	Technology description	Biomass target	TRL	Output(s)
Biomass to Biochar for Farm Bioeconomy (2018-2021)	Mobile Pyrolysis Unit (chemical)	Rushes, gorse, bracken, hazel, and forest residues	NA	Biochar

OG project	Technology description	Biomass target	TRL	Output(s)
Small Biogas Demonstration Programme (2019-2022)	Farm-scale biogas (AD) plant (microbial)	Farming waste (including livestock manure)	NA	Biogas
Biorefinery Glas (Small-scale Farmer-led Green Biorefineries) (2019-2020)	Small-scale mobile grass biorefinery (physical-chemical)	Grass	7	Cattle fibre feed, Protein concentrate feed for monograstrics, High value prebiotic sugars, grass whey (fertilizer/bioenergy).

5.4 Discussion of previous sections

Ireland has a great potential for utilising the agricultural, forestry and marine biomass especially regarding the availability of research and funding schemes in the country. The government has also prepared several actions plans in support of bioeconomy in the country that foresees great opportunities for bioeconomy development and offers funding mechanisms under European and national programs. Although the focus of OG projects in Ireland has mainly been on biodiversity and conservation of lands, several plans like National Bioeconomy Actions Plan and National Biomethane Strategy pinpoint the pivotal significance of developing research and technologies to utilize the available biomass resources in the country for a sustainable and prosperous future. The OG projects database shows that the number of BBTs developed around biomass sources in Ireland have been very limited and there is room for development of such technologies in the context of available biomass in the country.

Among all biomass categories, grass is the most abundant source which is currently mainly used for feeding purposes while experiences like the grass biorefinery demonstration have shown its potential for valorisation and producing biomaterials/biochemicals and improved feed and protein products for animals. Also, the abundance of livestock manure and slurry is another opportunity to develop technologies for efficient use of them to produce bioenergy or soil improvement products. The forestry sector has a lower biomass prospect but shows potential for utilization of forest residues for green energy solutions and or extracting biomaterials. Additionally, marine sector is a major contributor to biomass resources in Ireland which shows a good potential for developing technologies to utilise it in the bioeconomy.

In conclusion, Ireland stands in a good position to utilise and valorise its bioresources for bioeconomy development with agricultural, forestry and marine biomass holding a great potential for research and development of BBTs that can add value to overall economy. There is a good support environment available nationally and at European level which needs to be explored, but the capacity has not yet been fully used to date. With respect to the current biomass size and the available support both in terms of research facilities and funding programs, Ireland shows a green light to develop BBTs.

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6 Poland

6.1 General description of the region

6.1.1 Geographic description of the region

Poland is located in Central Europe. It borders Russia and Lithuania to the north, Belarus and Ukraine to the east, Slovakia and the Czech Republic to the south, and Germany to the west. Poland's northern border is marked by the Baltic Sea coast. Poland has an administrative area of 312,696 km and a population of 37,636,508 people, which gives population density of 120.36 inhabitants per km². The city with the largest population and, at the same time, the capital of the country is Warsaw. Poland is divided into 16 *voivodeships*[1], 380 *poviats* [2]and 2,477 communes, 60% of which are rural communes.

Stretching over 700 km in latitude and 650 km longitude Polish landscape is very diverse, ranging from the sandy Baltic coast in the north to mountain ranges in the south, from grasslands in the west to forested hills in the east. Approximately 30% of the country's area is covered by forests and about 60% is agricultural land.

Poland is situated in the warm temperate transitional climate zone – it is surrounded by other climate types from the temperate zone: maritime to the west and continental to the east. To the north, it is adjacent to a cool temperate climate zone, while a warm Mediterranean climate predominates in the southern part of Europe.

Figure 57: Location of Poland in Europe (Anon.,s.d).

[1] *Voivodeship* is the highest-level administrative division of Poland, equivalent to province.

[2] *Poviat* is the second-level unit of local government and administration in Poland, equivalent to a county, district or prefecture.

6.1.2 Agriculture and forestry sectors in the region

Agricultural sector

In 2020, Poland had 14,952,885 ha of agricultural land, of which 11,149,636 was arable land. Almost 50% of the agricultural area constitute cereal crops. There are more than 1.3 million agricultural holdings in Poland, 39,000 holdings with an area of more than 50 ha, 106,000 holdings with an area between 20 and 50 ha, 485,000 holdings between 5 and 20 ha, 662,000 holdings between 1 and 5 ha and 26,000 holdings with an area up to and including 1 ha. In 2020, units engaged only in crop production dominated, accounting for 55.8% of the total number of farms, while farms engaged only in livestock production accounted for 0.6%. Farms with mixed production (both crop and animal production) accounted for 43.6% of total number of farms. In 2020, the agricultural sown area amounted to 10,742 thousand hectares, of which 7,411 thousand hectares were cereals and 1,294 thousand hectares were industrial crops. The remaining agricultural land is covered by orchards - 327 thousand ha and permanent grassland – 3,190 kha. The average size of agricultural land per farm in the country in 2023 was 11.42 ha. (Anon., brak daty)

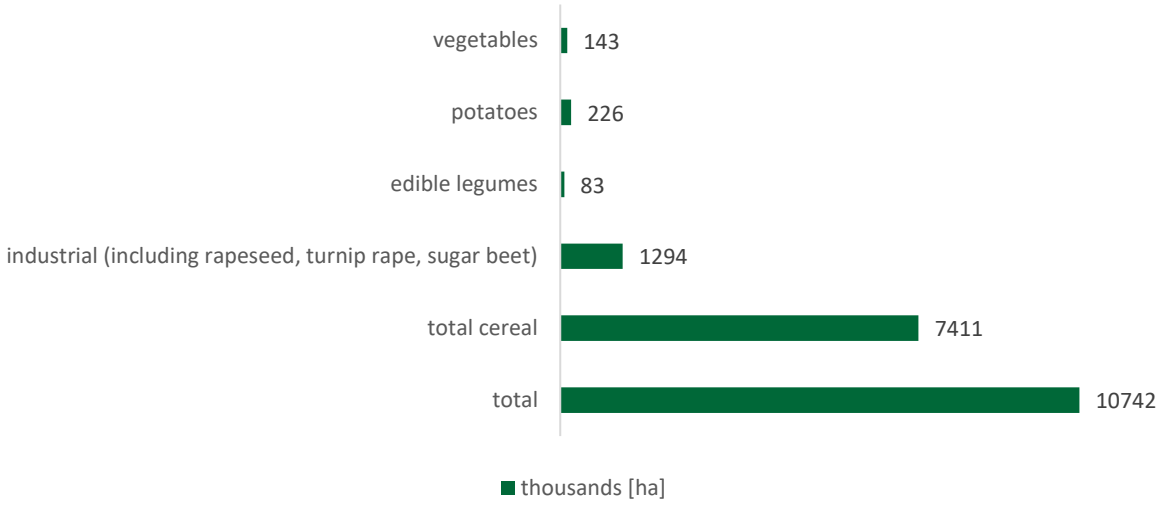

Figure 58: Cultivation of agricultural land in 2020 (Source: Central Statistical Office).

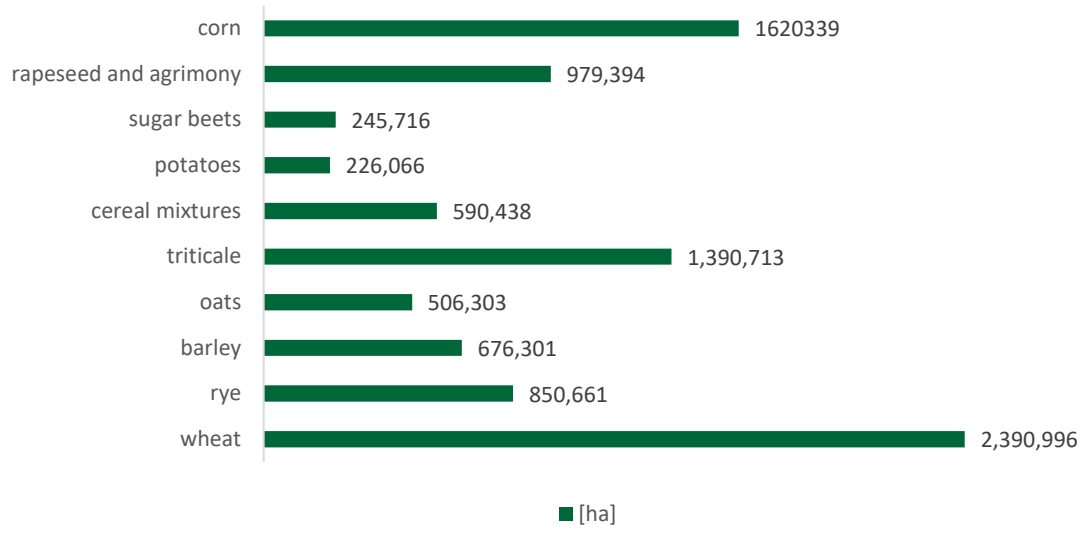

Figure 59: Area of individual crops [ha] (Source: Central Statistical Office).

Animal husbandry sector

The animal husbandry sector in Poland is mostly focused on the breeding of cattle, swine and poultry, but there are also other animals such as goats, sheep, horses and others. The Table 40 shows the population of the main livestock in Poland.

Table 40: Livestock population in 2023 (Source: Central Statistical Office).

Country	Cattle	Swine	Poultry	Sheep	Goats
Poland	6,267,461	9,769,697	218,302,793	270,492	60,897

Forestry sector

Poland is at the forefront of Europe in terms of forested area. Currently, Poland's forests cover 9.2 million hectares, which gives coverage of 29.6%. At the end of 2021, Poland had 0.243 hectares of forest per capita. According to the Central Statistical Office, the area of deciduous forests in Poland in 2020 was 2,928,193 ha, while coniferous forests covered 6,330,650 ha. The ownership structure of forests is dominated by public ownership. At the end of the analysed year, public forests constituted 80.7% of the total forest area, including 76.9% of the total forest area under the management of the State Forests. Private forests occupied the remaining 19.3% of the forests in Poland. Forests and forest land constitute one of the most important and valuable natural objects under legal protection. At the end of 2021, the area of forest land occurring within national parks was 193,200 ha (i.e. 2.0% of the national forest land area) and occupied 61.3% of the total area of the parks. At the end of 2021, the status of protective forests, i.e. forests with non-productive functions, was held by 3,912,600 ha of forests (42.2% of the forest area in the country), 97.6% of which was under the management of the State Forests (3,816,900 ha). (Anon., brak daty)

According to data from the Central Statistical Office, 42.2 million m3 of timber were harvested in Poland in 2021, i.e. by 6.5% more on an annual basis. Timber harvesting in Poland is dominated by

coarse wood (40.7Mm^3) - a share of approximately 96%. Small-sized timber, of which 1.6 Mm^3 was harvested, is of marginal importance (4%). Nearly 97% of the total coarse wood mass was harvested in forests managed by the State Forests (National Forest Holding), and about 3% in private forests. Wood is an important raw material for the Polish economy. Industries related to the processing of this raw material, i.e. the production of wood products, the paper industry and the furniture industry, accounted for approximately 9.5% of the industry's production sold in 2020 (Anon., brak daty).

Table 41: Detailed information in Poland.

Location	Forestry area
Poland	9.2 million hectares
Species	Deciduous and coniferous forests.

Agroindustry

According to data from the National Support Centre for Agriculture (KOWR), the value of Polish food exports abroad in 2021 reached a record 37.4 B€, which gives a 9% year-on-year increase. More than 70% of Polish agri-food exports go to EU markets. Poland is a leading producer of fruit (apples, raspberries, blackcurrants, blueberries), meat (poultry, pork), dairy products and mushrooms. The indigenous processing industry is known for its diversity, including tobacco production as well as alcohol production in the long list of food products. The agri-food products that generated the largest export revenues in 2021 were poultry meat and offal, bakery products, chocolate products, animal feeds and fodder, beef meat, smoked, dried and salted fish, cheese and cottage cheese, wheat, pork meat, or fruit and vegetable juices and mineral waters. Large revenues were also obtained from the export of cigarettes and other tobacco products (Anon., brak daty).

6.1.3 Economic Indicators

Poland positions itself as the third largest economy in Europe with a gross domestic product (GDP) exceeding 747M€. However, GDP per capita is 20,210€. Regarding the production structure in terms of gross value added (GVA), in 2023 the agricultural sector, forestry and fisheries generated 21.91M€. Poland has an employment rate of 77.9%. The number of people employed in activities related to agriculture, forestry and fishing is 1.42 million. Dividing this value by the total population gives this employment rate in this sector at the level of 3.86% (Anon., brak daty).

According to the JRC, in 2021, Poland's bioeconomy generated around 159 B€ in turnover (6% of the EU-27) and 40B€ in value added (5% of the EU-27). The number of people employed in the biomass and processing sectors in Poland was 2.4 million (14 % of the EU-27). The average productivity of the Polish bioeconomy sectors can be described as follows:

- turnover per person employed: approximately 66,000€ (EU27 average: 147,000€).
- value added per person employed: about 16,000€ (EU average: 42,000€).

Among the bioeconomy sectors in Poland, agriculture and the food sector employed the largest number of people, 1.46 million and 475,000 respectively. Electricity bio-products and liquid biofuels employed the lowest numbers, 207,000 and 422,000 people respectively. The highest turnover and

value added to the economy among the bioeconomy sectors in Poland was the food and beverage sector, second was agriculture, third wood products and furniture, and fourth was the paper industry. Fisheries and aquaculture and bio-based energy products had the lowest turnover and value added (Anon., brak daty).

Table 42: Economic indicators by country (Source: European Union, "Rural Observatory").

	Population (M hab)	GDP (M€)	GDP per capita (€)	GVA (M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Poland	36.75	747.75	20,210	21,91	77.9 %	3.86 %

6.1.4 Bioeconomy regulatory framework

In Poland, the EU bioeconomy goals are to some extent covered by national strategies related to agricultural, environmental and energy policies, and regional strategies include smart specialization strategies. At the national level, Poland has several bioeconomy development strategies. **National Energy and Climate Plan for the years 2021-2030**; the main goals of this energy and climate strategy of Poland, representing the future measure of its implementation, are: -a reduction target for Poland in terms of greenhouse gas emissions in non-ETS sectors has been set at -7% in 2030 compared to 2005 levels. The set target is to be achieved through emission reductions in transport, construction and agriculture, taking into account the beneficial effects of CO2 sequestration by ecosystems as well as flexibility in land use, land use change and forestry (LULUCF- an EU-wide target for 2030, in which Poland declares to achieve a 21-23% share of RES in gross final energy consumption by 2030, where the share of RES in heating and cooling is estimated to increase by an average of 1.1% per year, while the share of renewable energy in transportation is expected to reach 14% by 2030, -a national energy efficiency improvement target for 2030 set at a 23% reduction in primary energy consumption compared to the PRIMES 2007 forecast. (Anon., brak daty)

National Smart Specialisation Strategy aims to enable each region to identify and develop its own competitive strengths. The support provided relates to the development of research, development and innovation (https://smart.gov.pl/pl/). In Polish National Smart Specialisation Strategy (KIS), among the 13 found smart specializations, three of them are directly related to the bioeconomy. KIS priorities related to the bioeconomy covering agri-food, forestry and environmental specialization include: (KIS 2) Innovative technologies, processes and products of the agricultural and forest-wood sector; (KIS 3) Biotechnological and chemical processes, bioproducts and special products of chemical and environmental engineering; (KIS 7) Circular economy. (Anon., brak daty)

Roadmap on circular economy, Poland's adopted roadmap for the transition to a circular economy (GOZ). This concept aims to rationally use resources and reduce the negative environmental impact of manufactured goods, which, like products and raw materials, should remain in the economy as long as possible, and waste generation should be minimized as much as possible. (Anon., brak daty)

Polish National Strategy for Adaptation to Climate Change (NAS2020) with the perspective by 2030 the main goal of NAS2020 is to ensure sustainable development and effective functioning of the

economy and society under climate change conditions. The main objective will be achieved through the implementation of specific objectives and the NAS2020 directions of action indicated within these objectives. The specific objectives include: -ensuring energy security and good state of the environment, -effective adaptation to climate change in rural areas, -development of transportation under climate change conditions, -ensuring sustainable regional and local development taking into account climate change, -stimulating innovation for climate change adaptation, -shaping social attitudes towards climate change adaptation. (Anon., brak daty)

Strategy for Sustainable Rural Development, Agriculture and Fisheries 2030 assumes: - maintaining the principle that family farms will be the basis of the agricultural system; - supporting the sustainable development of small, medium and large farms; - making greater use of the potential of the agri-food sector through the development of new skills and competencies of its employees, as well as through the use of the latest technologies in production and the application of digital solutions, and creating favourable conditions for developing innovative products; -building the competitive position of Polish food on foreign markets, the hallmark of which will be high quality and reference to the best Polish traditions, as well as the adaptation of agri-food products to changing consumption patterns (e.g. growing interest in organic food); -conducting agricultural and fish production with respect for environmental protection principles and adapting the agri-food sector to climate change, among other things, in terms of access to water; -dynamic development of rural areas in cooperation with cities, which will result in stable and sustainable economic growth, providing every rural resident with a decent job and urban residents with access to healthy Polish food; -creating conditions for improving the occupational mobility of rural residents and for them to take advantage of opportunities for development and re-skilling, resulting from the emergence of new economic sectors (e.g. bioeconomy). (Anon., brak daty)

The National Environmental Policy 2030 is a strategy for development in the area of environment and water management, designed to ensure Poland's environmental security and high quality of life for all residents. (Anon., brak daty)

Energy Policy of Poland until 2040 (PEP2040) sets the framework for the country's energy transition. It outlines solutions to achieve the EU's climate and energy goals, such as the construction of offshore wind power or the launch of the country's first nuclear power plant planned for 2033. PEP2040 focuses on equitable and inclusive energy transition towards a zero-emissions system based on innovation, sustainable economic growth, increased efficiency and competition. The final key factor is improving air quality nationwide. Achievement of these goals should be measured in the 2030 timeframe by (I) a maximum 56% share of coal-fired generation (with a conservatively estimated 2049 exit date); (II) a minimum of 23% renewable electricity in final consumption (32% in generation, 14% in transportation); (III) nuclear generation included in the mix by 2033; (IV) reduction of greenhouse gas (GHG) emissions by 30% (compared to 1990 levels); (V) reducing primary energy consumption by 23% (in relation to 2007 estimates). (Anon., brak daty)

Table 43: Existing national Bioeconomy related strategy documents in Poland [16]

Name of the strategy	Bioeconomy related goals* addressed				
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
National Energy and Climate Plan for the years 2021-2030		+	+		

Name of the strategy	Bioeconomy related goals* addressed				
	(1)	*(2)*	*(3)*	*(4)*	*(5)*
National Smart Specialisation Strategy	+	+			+
Roadmap on circular economy	+	+		+	+
Polish National Strategy for Adaptation to Climate Change (NAS2020) with the perspective by 2030			+	+	+
Strategy for Sustainable Rural Development, Agriculture and Fisheries 2030 (SZRWRiR 2030)	+	+	+	+	+
National Environmental Policy (PEP2030)	+	+	+		+
Energy Policy of Poland until 2040		+	+		

**Is one of the EU bioeconomy strategy (2018) objectives covered by the bioeconomy related strategy at national level? Creating jobs and maintaining competitiveness in bioeconomy sectors (1); Reducing dependence on non-renewable resources (2); Mitigating and adapting climate change (3); Ensuring food security (4); Managing natural resources sustainably (5).*

6.2 State of the art of biomass valorisation

6.2.1 Biomass resource availability

Agricultural biomass residues

Based on the estimates, it can be calculated that nearly 22 million agricultural biomass residues were produced in 2023. As shown in Figure 60, grass and straw were considered, accounting for more than 90% of total agricultural residues biomass. Figure 61 shows the breakdown of biomass produced by voivodeship.

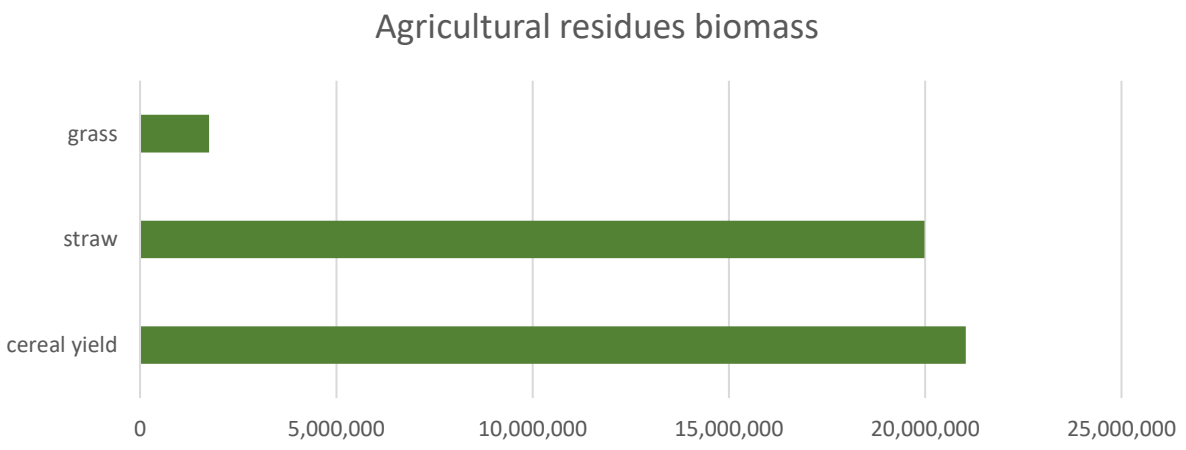

Figure 60: Agricultural biomass residues resources generated in 2023 [17].

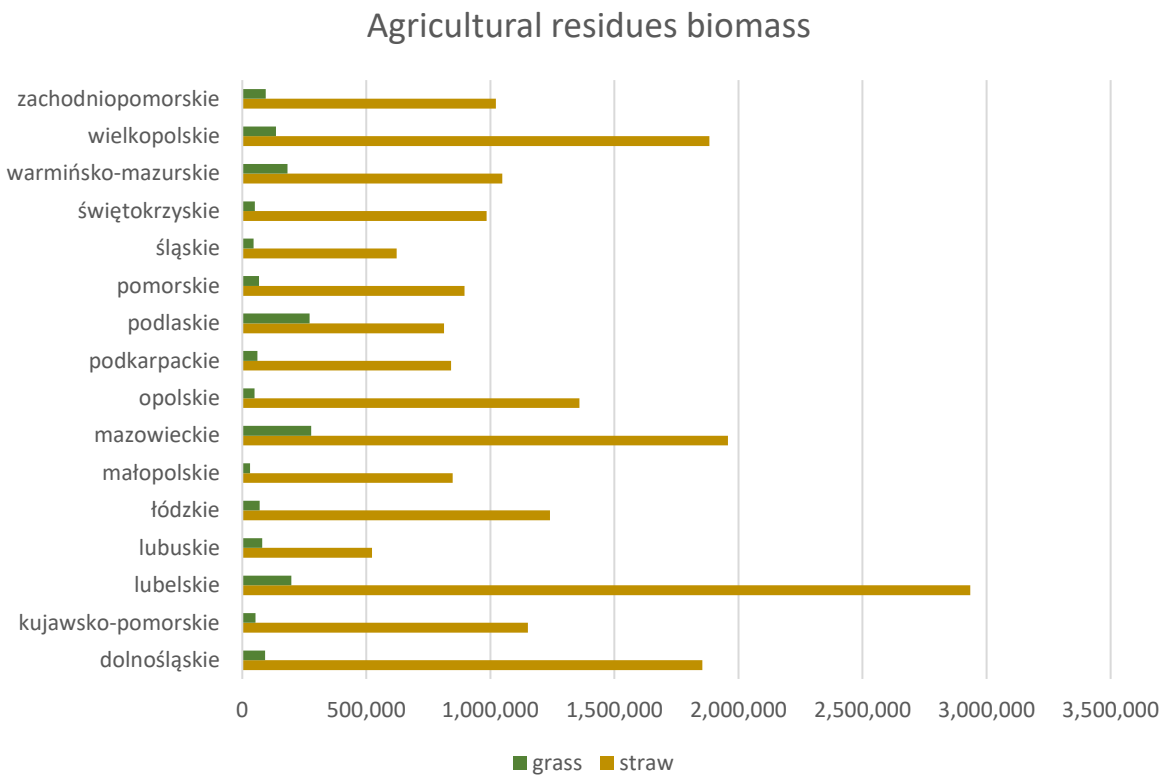

Figure 61: Agricultural biomass residues resources generated in 2023 divided into voivodeships (Source: IUNG's own study based on data from ARiMR).

As can be seen in the graphs, most of the biomass generated comes from straw, with the most important being that from *lubelskie, mazowieckie, wielkopolskie and dolnośląskie*. In terms of the geographical area with the highest concentration of biomass, the east of the country stands out. On the other hand, the south is the area with the lowest biomass generation.

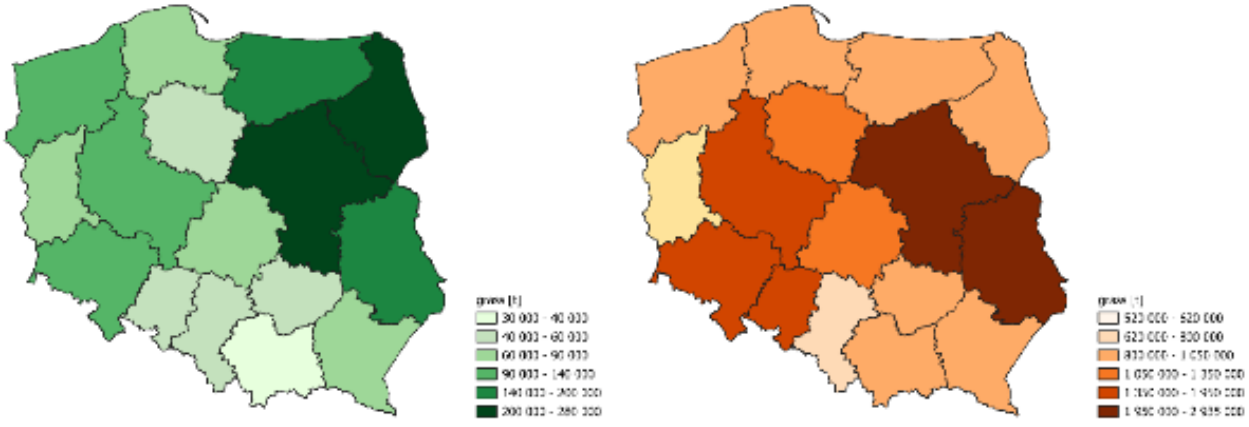

Figure 62: Maps of agricultural biomass residues resources created in 2023 (Source: IUNG's own study based on data from ARiMR).

Livestock biomass

Livestock including cattle and pigs alone are estimated to have generated 63 million tonnes of biomass in 2020, with cattle biomass production dominating in all *voivodeships*, accounting for 90% of total livestock biomass. The largest amount of livestock biomass, i.e. manure and slurry, was produced in Wielkopolska, Podlaskie and Mazowieckie *voivodeships*.

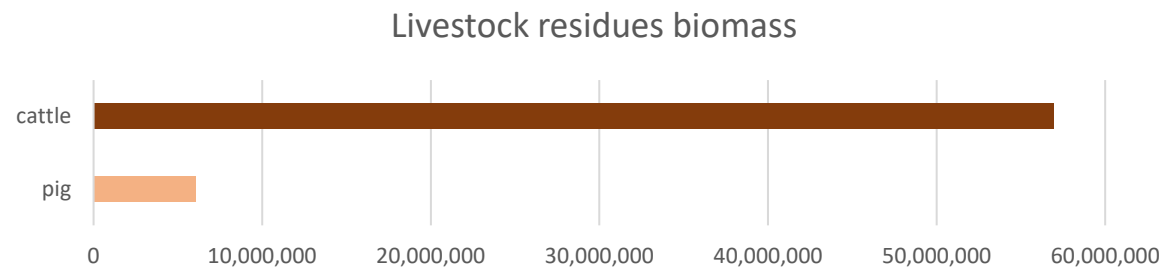

Figure 63: Livestock biomass resources generated in 2020 [17].

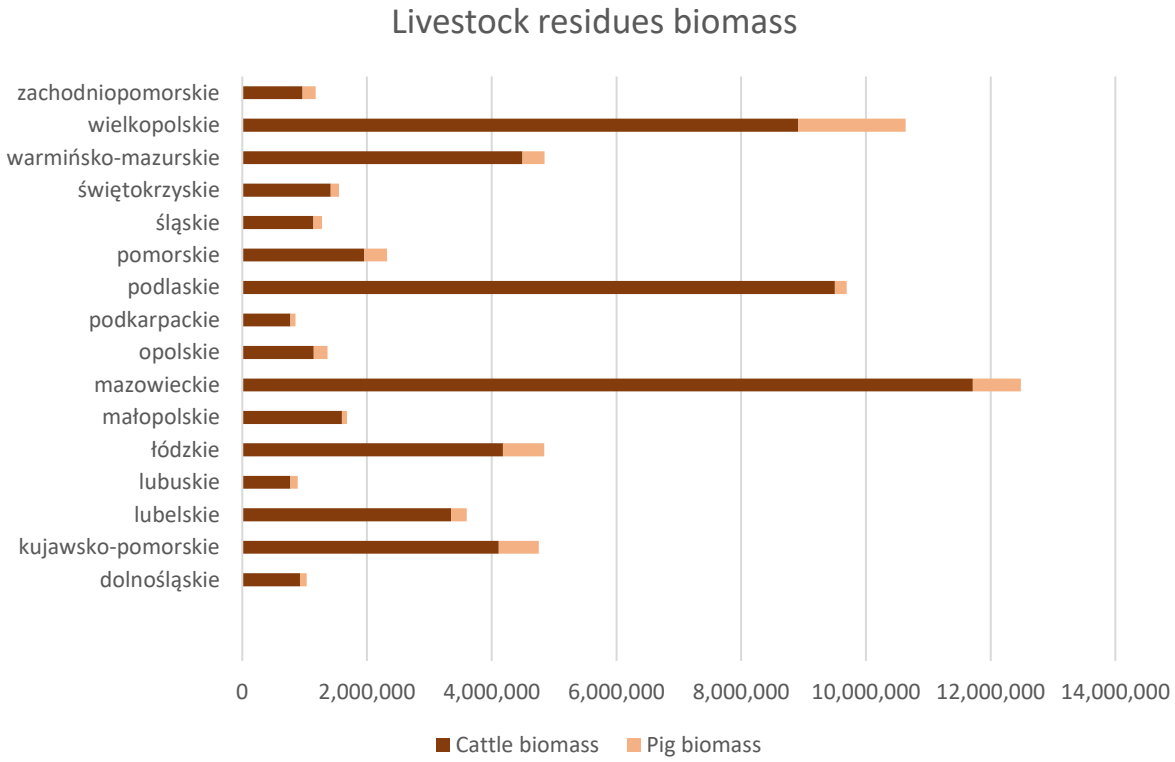

Figure 64: Livestock biomass resources generated in 2020 divided into voivodeships [17],

Agro-industrial residues biomass

The data presented consider the amount of waste in Poland in 2023 generated from agriculture, horticulture, hydroponics, fishing, forestry, hunting and food processing. This group of waste is divided into two subgroups, namely animal by-products and food by-products. The total amount of biomass produced from the agricultural industry is 7.59 tonnes, of which 5 tonnes come from food processing and the remaining 2.59 tonnes from animal by-products.

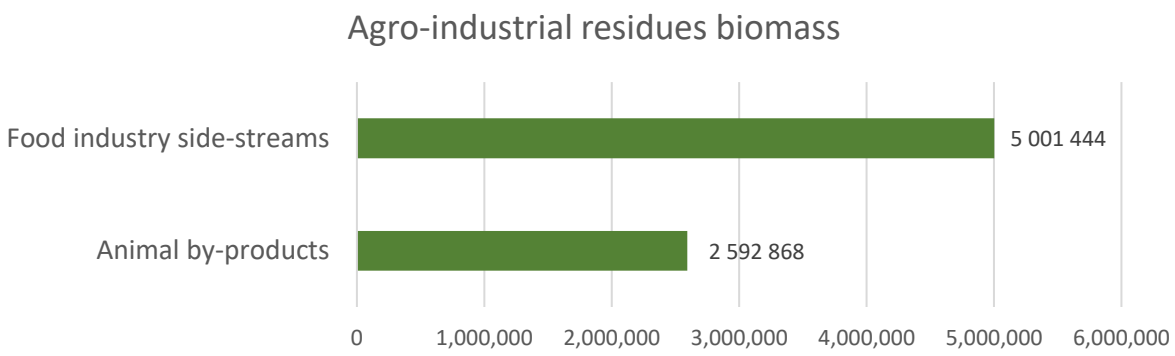

Figure 65: Agro-industrial residues biomass resources generated in 2023 (Source: IUNG's own study based on data from the Database on products, packaging and waste management).

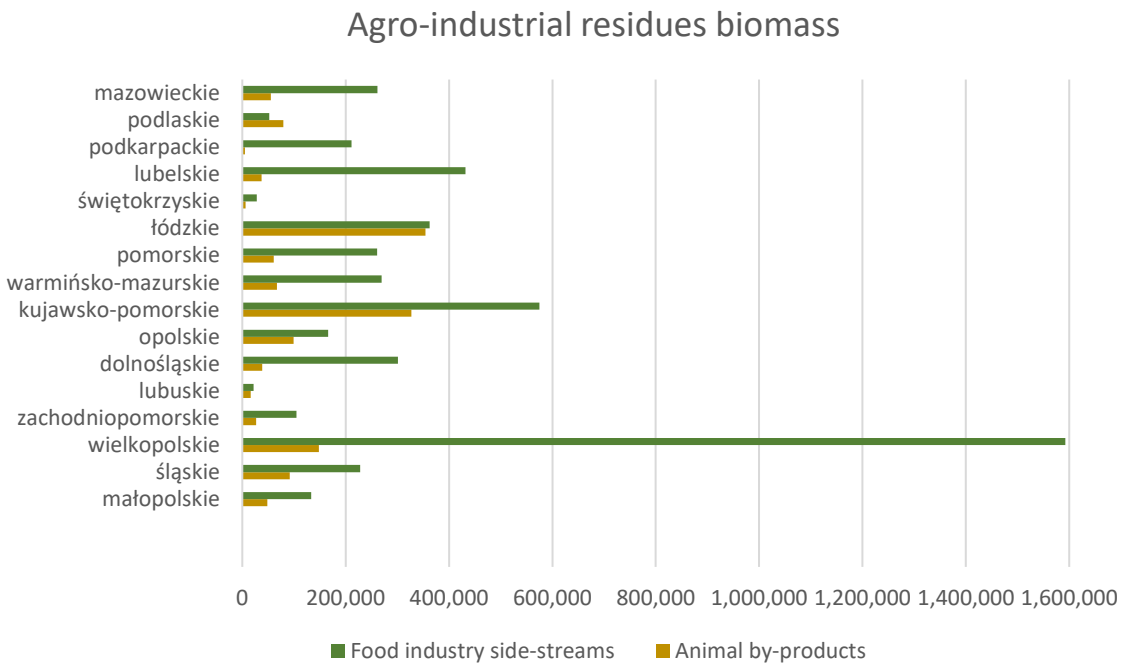

Figure 66: Agro-industrial biomass residues resources generated in 2023 divided into voivodeships (Source: IUNG's own study based on data from the Database on products, packaging and waste management).

Forestry biomass

Timber harvesting comprises activities involved in cutting down trees and obtaining wood material from its various parts (from the trunk, crown and stump/rootstock), and sorting this material into specific wood categories. As a result of these activities, woody biomass is produced, which must be removed from the forest, as it is a serious risk factor for the spread of pests and forest fires. In 2022, a total of 44,647,000 m^3 of timber was harvested, of which 42,703,000 m^3 was coarse wood, while the remaining 1,944 m^3 was small-sized wood, and only 0.8 m^3 was stumpwood.

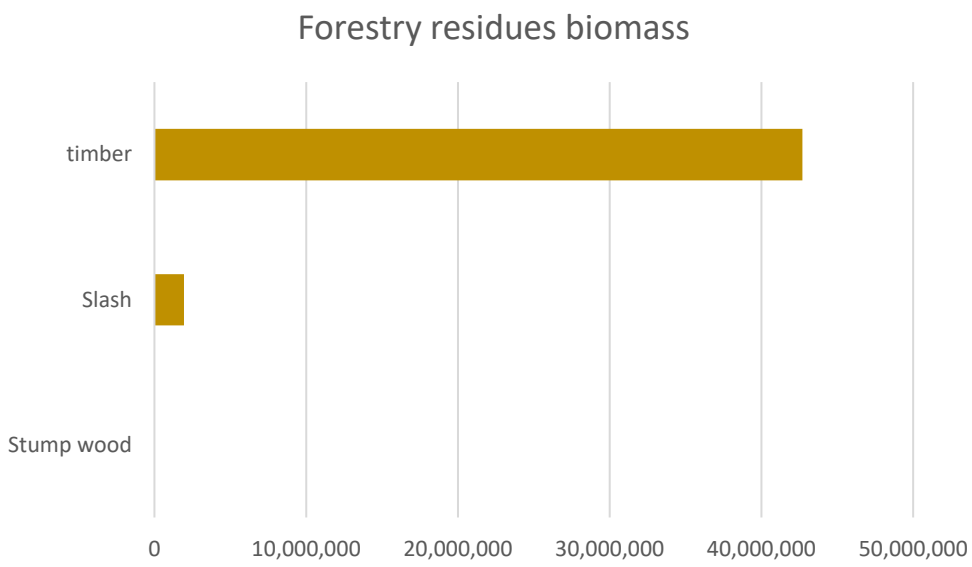

Figure 67: Forestry biomass resources generated in 2022 [4].

6.2.2 Management and logistics of biomass resources

Logistical processes ensure a stable feedstock base for biomass energy producers. In many cases, obtaining biomass is difficult due to dispersed nature of feedstock. For these reasons, large amounts of investment in harvesting, transportation, storage and processing are required. Therefore, an efficient logistics system for the reduction of transportation and further processing costs is so important. Factors to be taken into account in the logistics system are related to the type of biomass, physical-chemical and mechanical characteristics of biomass, availability of raw material, number of suppliers of a given type of biomass, technical possibilities of transportation, storage possibilities, pre-treatment before conversion process, economic, legal, environmental conditions, etc., as well as location of energy production sites. The utilization of biomass requires taking action along the entire supply chain involving: feedstock acquisition, production, distribution and use of biomass, including transportation and storage. Taking the source for energy production as a criterion, we can distinguish the complete supply chain management (CSCM) group with solid and liquid biomass as the energy source. The complete supply chain (CSCM) includes the procurement process, that is, the supply of raw materials and materials for energy production and maintenance, the energy production and the energy distribution. From the point of view of logistical processes, it is important for the raw material to be supplied continuously. Therefore, management refers to all the processes and actors in the chain, which should be interrelated. The goal of supply chain management is to increase efficiency while reducing storage and operating costs and aligning energy production with customer needs.

Safe management should consider the following:

- supply (supply management of raw materials, inventory, supplier relations, supplier base),
- operational control (customer relationship management, production management, supply/distribution network design),
- integration (strategic management, infrastructure, risk, measurement, performance, environmental management).

When considering security issues in biomass supply chain management from a logistics perspective, the following conclusions can be mentioned:

- efforts should be made to optimise organizational and logistical models for stable biomass supply and sustainable rural development;
- to avoid the movement of large masses of biomass over long distances, it is reasonable to create local biomass markets and logistics systems that minimize the costs of biomass procurement, transportation and storage;
- implementation and certification of biomass quality assurance systems can have a significant impact on the security of supply of such a diverse raw material;
- aiming to increase biomass in the balance of electricity production in the country, due to the high cost of investment requires the use of appropriate support systems, which guarantee their systematic development. (Anon., brak daty)

6.2.3 Bio-products target market

Bioenergy and biofuels sector

In Poland, there is a great potential for the development of the biogas sector, including the production of biomethane. Poland has its own feedstock supplies and developed biofuel production chain. Biomass streams from agriculture, forestry and hunting, as well as fishing and aquaculture offer adequate potential for advanced energy use. Biofuel production sectors are mainly related to the agro-food industry, forestry and green energy. The production of biofuel components, i.e. bioethanol or biodiesel, is limited by a percentage cap. Each time the limit is increased, the market grows. Although, even in the current situation in Poland (with a significantly low share of bio-components in biofuels), there are still potential opportunities for the development of the biofuel sector. The challenges are, for instance, technological limitations and improving product quality through the use of innovation.

In Poland's case of biogas production (especially agricultural biogas), there is considerable untapped potential for the development of this sector. A period of growth between 2011 and 2016 was followed by stagnation, which is mainly due to legislative barriers and unstable public support. There are promising innovations in Poland (e.g., in the biogas production) showing that the zero-waste path in the circular bioeconomy can yield favourable results in terms of waste conversion. (Anon., brak daty)

- Biomass electricity generation

According to data from the Energy Regulatory Office (URE) (Anon., brak daty) on the installation of renewable energy sources, at the end of 2023, in Poland, there were 46 biomass-burning power plants with a total installed capacity of 1,250.077 MW and 31 installations with co-incineration of conventional fuels and biomass or biogas with total installed capacity of 13,534.913 MW.

- Biogas generation

  According to the biogas map for 2023/2024, there are 310 biogas plants in Poland with a total installed capacity of 215 MW. Of these, 149 biogas plants use municipal waste, with a total installed capacity of 63.9 MW. The remaining 161 biogas plants use agricultural waste, with a total installed capacity of 151.7 MW. (Anon., brak daty)

On the other hand, data from the Energy Regulatory Office (URE) on renewable energy installations show that at the end of 2023, 388 biogas plants with a total installed capacity of 295.262 MW were registered.

- Thermal use

  According to data from the Energy Regulatory Office (URE) on renewable energy installations, as of the end of 2023 there were 10 registered thermal waste conversion installations with a total installed capacity of 171.461 MW.

Table 44: Thermal waste treatment installations in Poland [21]

Location	Voivodeship	Power (MW)	Type
Zabrze	śląskie	76,500	thermal conversion of waste
Rzeszów	Podkarpackie	8,993	thermal conversion of waste
Poznań	Wielkopolskie	19,635	thermal conversion of waste
Szczecin	Zachodniopomorskie	15,481	thermal conversion of waste
Bydgoszcz	kujawsko-pomorskie	13,800	thermal conversion of waste
Kraków	małopolskie	16,900	thermal conversion of waste
Konin	wielkopolskie	7,300	thermal conversion of waste
Białystok	podlaskie	9,002	thermal conversion of waste
Warszawa	mazowieckie	2,600	thermal conversion of waste
Płock	mazowieckie	1,250	thermal conversion of waste

- Biofuels

Liquid biofuels are a set of products that include biobased, biodiesel and other bio liquid fuels called bioliquids, which are used for energy purposes other than transportation, including electricity generation, heating and cooling. Between 2018 and 2022, there was an increase in the acquisition of liquid biofuels by 19.4% (from 37.9 PJ to 45.3 PJ), in total domestic consumption by 18.3% (from 38.3 PJ to 45.3 PJ) and imports by 22.0% (from 15.7 PJ to 19.1 PJ). There was, however, a decline in exports - 8.6% (from 14.6 PJ to 13.3 PJ). In 2022, biodiesel consumption was 36.7 PJ, accounting for 81.0% of liquid biofuel consumption. From 2018 to 2022, biodiesel consumption grew, while bioethanol and bioliquids consumption remained at similar levels. (Anon., brak daty)

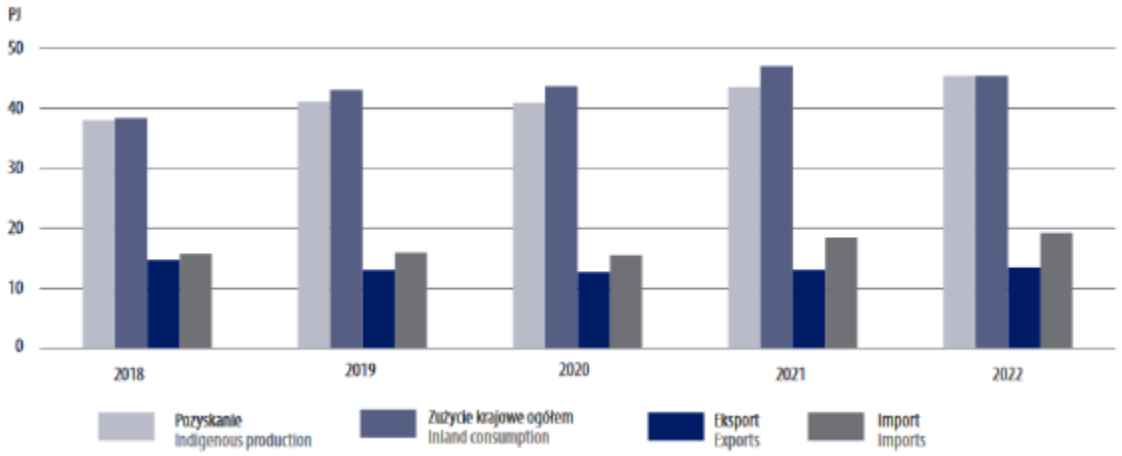

Figure 68: Balance of liquid biofuels in 2018-2022 [23]

In summary, Polish strategy for a circular bioeconomy, the directions adopted are concerned with the management of biomass throughout its life cycle, including processing, production of goods (food, feed, energy, etc.), sale of goods, their use and management of bio-waste. In this sense, the bioeconomy is the basis for the functioning of the first sector of the economy, i.e. agriculture, forestry and fishing, as well as several branches of the second sector (food, feed, forest-wood, pulp and paper, pharmaceutical, textile, furniture, construction, biotechnology, cosmetics, fuel and organic recycling industries). The closed-loop economy (GOZ) stipulates that the key is to keep biomass in the economic cycle for as long as possible, thus maximizing its value. Direct burning of biomass, widely used in Poland, is not part of the GOZ. Instead, the GOZ focuses on two priorities: creating conditions for the development of the bioeconomy in Poland, and measures to foster the creation of local industrial and energy value chains (Anon., brak daty).

6.2.4 R&D system associated with biomass valorisation

In Poland, the Ministry of Agriculture manages 12 research institutes, five of which conduct research on field crops, including organic farming. In addition, there are also institutes conducting research on field horticultural crops, livestock production, and fisheries. Agricultural economic analysis and research, including FADN data, is provided by the Institute of Agricultural and Food Economics. Research in agri-food biotechnology, safe food production and storage is conducted by the Institute of Agriculture and Food Biotechnology of the Polish Academy of Sciences (PAN). Strategic research in rural areas is conducted at the Institute of Rural and Agricultural Development of the Polish Academy of Sciences in Warsaw (IRWiR PAN), while the Institute of Agrophysics in Lublin is involved in the research on soil-plant-atmosphere system interactions, as well as strategic planning and policy. The leading research institution in bioproducts or biomass processing is the Lukasiewicz Research Network, which includes 22 research institutes across Poland. Some of the institutes are included in research roup called Sustainable Economy and Energy, which focuses on bioeconomy and recovery of materials (Anon., brak daty).

Table 45: Research Institutes focused on agriculture and bioproducts biomass processing (Source: Concept Paper For Bioeconomy: Poland).

Group's main research areas	Institution
Field crops, organic farming	Institute of Soil Science and Plant Cultivation (IUNG)
	Plant Breeding and Acclimatization Institute (IHAR)
	Institute of Natural Fibres and Medicinal Plants (IWNiRZ-PIB)
	Institute of Plant Protection (IOR)
	Institute of Technology and Life Science
Horticultural field crops research	Institute of Horticulture (INHORT)
Research on animal production	Institute of Animal Production (IZ)
	National Veterinary Institute (PIWET)
Fishery	Inland Fisheries Institute (IRS) in Olsztyn
	Marine Fisheries Research Institute (MIR)
The agricultural economic analysis and research including FADN	Institute of Agricultural and Food Economics
Research on agri-food biotechnology, safe food production and storage	Institute of Agriculture and Food Biotechnology of the Polish Academy of Sciences (PAN)
Strategic research on rural areas	Agricultural Development of the Polish Academy of Sciences in Warsaw (IRWiR PAN)
Soil-plant-atmosphere related system interaction science and strategic planning and policy	Institute of Agrophysics in Lublin
Consulting activities in the field of establishment of energy crops, the logistics of biomass, economic aspects and processing	Polish Biomass Association (POLBIOM)

In Poland, there are 10 universities with agricultural faculties, 8 with forestry faculties and 2 with fisheries/aquaculture faculties. Bioeconomy is a subject of study at 7 universities. At the secondary

level, the Ministry of Agriculture oversees 61 agricultural technical colleges, while the Ministry of the Environment oversees 11 technical colleges related to forestry and wood processing.

Table 46: Polish universities with the subject of bioeconomy (Source: Concept Paper For Bioeconomy: Poland).

Description CEI
University of Warmia and Mazury in Olsztyn - Centre for Bioeconomy and Renewable Energies
Warsaw University of Life Sciences (SGGW)
University of Agriculture in Krakow
Lodz University of Technology
Warsaw University of Technology
Military University of Technology in Warsaw
Wroclaw University of Environmental and Life Science

6.2.5 Support and financing policies

Funding institutions in Poland are not oriented toward a specific area of the bioeconomy. Activities in this area focus on sectors or elements that can contribute to the bioeconomy. Start-ups seek funding mainly from Venture Capital (VC) funds. Despite the fact that the Venture Capital market in Poland is growing rapidly, existing companies from bioeconomy sectors develop mainly by using funds received from bank loans or grants. European funding for venture capital investments in Poland largely passes through state financial and administrative institutions (PFR, NCBiR). These institutions have built mechanisms for allocating European funds to the private sector and are managed by entities with experience and knowledge in the area of start-up development.

EU funds launched in Poland under the Common Agricultural Policy and the Common Fisheries Policy (2014-2020), mainly supporting bio-economic sectors such as agriculture and fisheries, were distributed in the funding perspective mainly by the Agency for the Restructuring and Modernization of Agriculture (ARiMR). The Agency, as the executor of agricultural policy, works closely with the Ministry of Agriculture and Rural Development and is the implementer of aid instruments financed by the following EU funds: European Agricultural Guarantee Fund (EAGF), European Agricultural Fund for Rural Development (EAFRD), European Maritime and Fisheries Fund (EMFF). (Anon., brak daty)

At the European level, the public funding program "Horizon Europe" can be distinguished. Horizon Europe's program in cluster 6 is entitled "Food, Bioeconomy, Natural Resources, Agriculture and Environment," and is designed to provide opportunities to strengthen and balance environmental, social and economic goals and redirect human economic activity on a path towards sustainable development. (Anon., brak daty)

The Ministry of Funds and Regional Policy is responsible for the implementation of European Funds in Poland. It is its task to coordinate the implementation of the assumptions arising from the most important document describing how and for what European Funds will be allocated in 2021-2027 - the Partnership Agreement. A managing authority has been designated for each program. It is responsible

for the preparation of the program and its management. The managing authority for national programs and territorial cooperation programs is the Ministry of Funds and Regional Policy. (Anon., brak daty)

PFR Ventures is a Development Finance Institution dedicated to investment financing. The institutional company is part of the Polish Development Fund (PFR), which is wholly owned by the government. The sole investor is the Government of the Republic of Poland, either directly or through the Polish Development Fund or the Polish Development Bank (BGK). PFR Ventures distributes funds raised from: European Funds (2014-2020: Intelligent Development and Innovative Economy), Ministry of Economy, Swiss Contribution, and own funds. (Anon., brak daty)

Another institution under the Ministry of Agriculture and Rural Development is the **National Centre for Agricultural Support** (KOWR). It is an executive agency tasked with implementing and applying instruments of support for active agricultural policy and rural development, for the benefit of Polish farmers and other entities operating in the agri-food sector, while providing competent service. (Anon., brak daty)

National Centre for Research and Development (NCBiR) - NCBiR is a centre for the support and development of innovative technological and social solutions, creating an ecosystem of knowledge and information about innovations. One of NCBiR's tasks is the duty to efficiently disburse and account for innovation grants awarded, as well as to provide substantive support to beneficiaries and grantees implementing projects with EU funds. NCBR is an Intermediary Institution for the transfer of funds under operational programs, namely: European Funds for a Modern Economy 2021-2027 (FENG), the Intelligent Development Program 2014-2022 (PO IR), the Knowledge Education Development Program 2014-2020 (PO WER) and the Digital Poland Program (PO PC) Grantee. NCRD finances R&D projects for various sectors, including bioeconomy, e.g. for strategic programs BIOSTRATEG, GOPOSTRATEG. They offer grants for research and innovation activities in biotechnology, agriculture and forestry. (Anon., brak daty)

Table 47: Funding programmes identified in the agri-food sector at national level.

Programme	Funding organization	Type	Web
Rozwój małych gospodarstw	Polska Agencja Pozyskiwania Funduszy Unijnych Sp. z o. o.	Investment fund	https://www.papfu.pl/rozwoj-malych-gospodarstw/
Młody rolnik	Polska Agencja Pozyskiwania Funduszy Unijnych Sp. z o. o.	Investment fund	https://www.papfu.pl/mlodyrolnik/
Inwestycje zwiększające konkurencyjność	Polska Agencja Pozyskiwania Funduszy Unijnych Sp. z o. o.	Investment fund	https://www.papfu.pl/inwestycje-zwiekszajace-konkurencyjnosc-wrzesien-2024/
Inwestycje przyczyniające się do ochrony środowiska	Polska Agencja Pozyskiwania Funduszy Unijnych Sp. z o. o.	Investment fund	https://www.papfu.pl/inwestycje-przyczyniajace-sie-do-ochrony-srodowiska/
Inwestycje poprawiające dobrostan bydła i świń	Polska Agencja Pozyskiwania Funduszy Unijnych Sp. z o. o.	Investment fund	https://www.papfu.pl/inwestycje-poprawiajace-dobrostan-bydla-i-swin/

6.3 Analysis of Operational Groups

6.3.1 Operational groups characterization

The Polish Rural Network + (PRN+) is a partnership network for information exchange and cooperation between public and private organizations. Its goal is to bring together representatives of the agricultural sector, agricultural advisors, researchers, entities involved in implementing innovations and other actors working for the development of agriculture, including increasing its competitiveness and improving the quality of life of the residents of rural areas and small towns.

According to the EPI-AGRI project database from the Polish Rural Network + (PRN+), 420 groups were funded in Poland between 2014 and 2020. The database includes projects whose main source of funding is the 2014-2020 Rural Development programs, but also 9 projects from CAP SP 2023-2027. Of all the groups, 16 fall into the category of "Rational management of natural resources, climate and environment," i.e. the most relevant to BBT.

The National Strategic Plan of the Common Agricultural Policy for 2023-2027 offers Polish farmers, entrepreneurs and advisory units, in addition to the well-known, from previous financial periods, mechanisms of subsiding their activities and development investments, the possibility of help under Intervention 13.5. "Cooperation of EIP Operational Groups", which provides for an allocation of 168,950,000 €. Thanks to this intervention, it is possible to finance the establishment of Operational Groups of the European Innovation Partnership for Efficient and Sustainable Agriculture (OG) and to develop and implement innovative projects as a part of the activity of these groups, with priority consideration of the needs of farmers, combining various partners with relevant knowledge in complementary fields and based on an interactive and adaptive model of innovation. (Anon., brak daty)

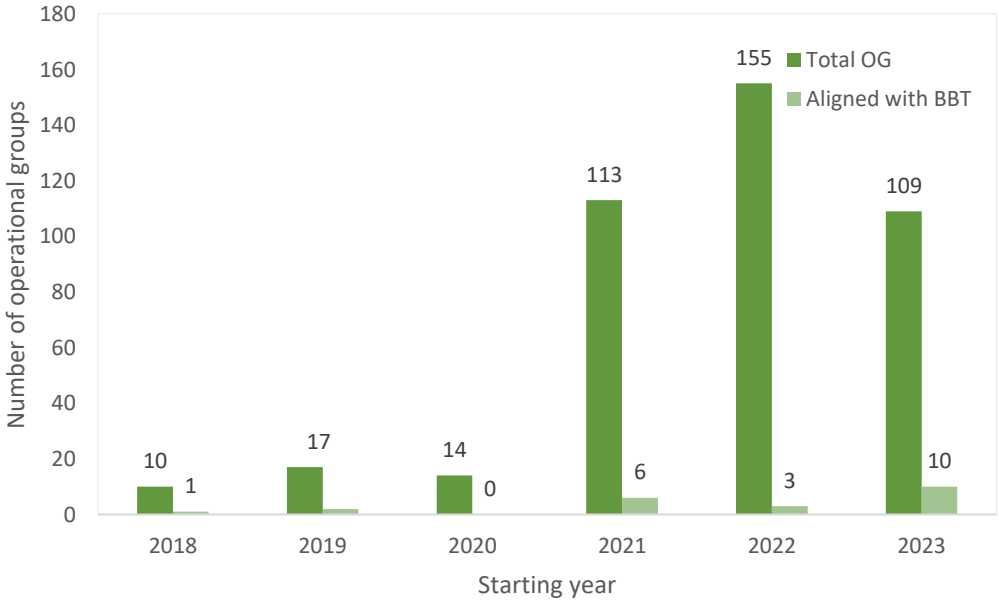

Figure 69: OGs evolution in the period 2015-2024 in Poland (Source: Krajowa Sieć Obszarów Wiejskich).

The Figure 70 below shows the total budget of OG projects in the period under review. It can be seen that it develops similarly for the total number of subsidized projects. The average budget per project is 502,369 €, the maximum and smallest amount of funding is 6,100,555 € and 50,842€ respectively.

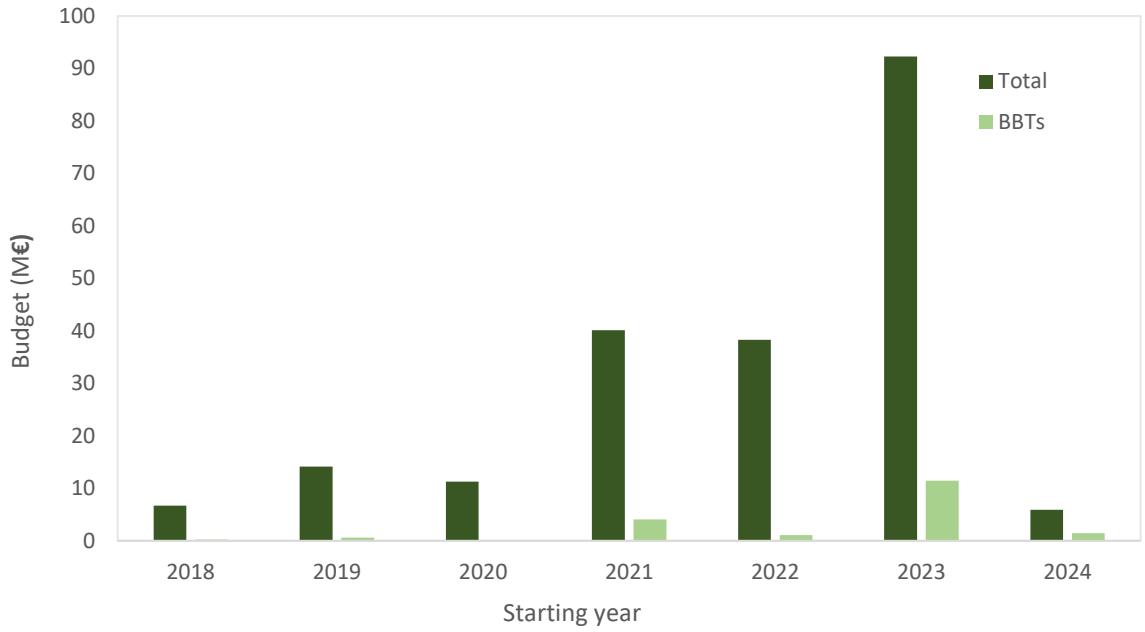

Figure 70: OGs budget evolution over the period 2015-2023 (Source: Krajowa Sieć Obszarów Wiejskich).

6.3.2 Bio-based Technologies (BBT) developed by OG

This section presents in more detail some technological aspects regarding the BBTs developed by OGs mentioned in the above section. It is important to note that, since some OG are relatively new, there is still not much information available in their websites or they do not have a web yet.

First of all, the type of biomass used is analysed. For this analysis, the 22 OGS working in BBTs development were considered. The projects used biomass related to livestock, in the second position the projects that use fruits biomass. Finally, the rest is distributed over different types of biomasses.

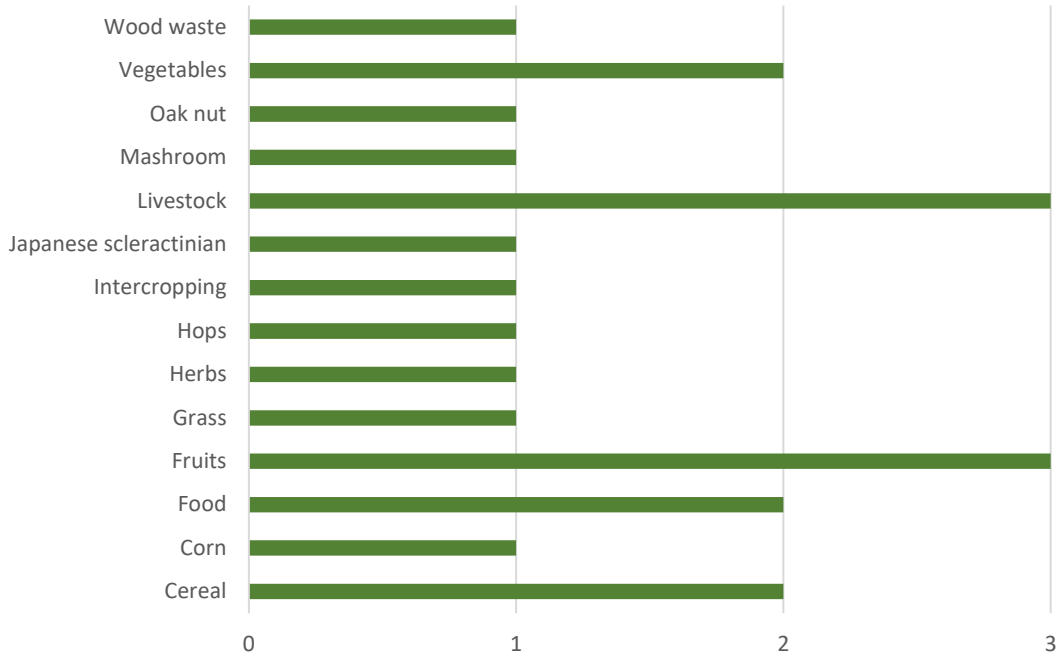

Figure 71: Biomass used in BBTs developed by OGs.

Moreover, it is analysed the bio-products obtain from the processing of the biomasses considering the 22 BBTs identified. 50% of the technologies (11) generates as different kind of food or feed. It is important to note that although some OGs uses the same biomass it generates two different bio-products.

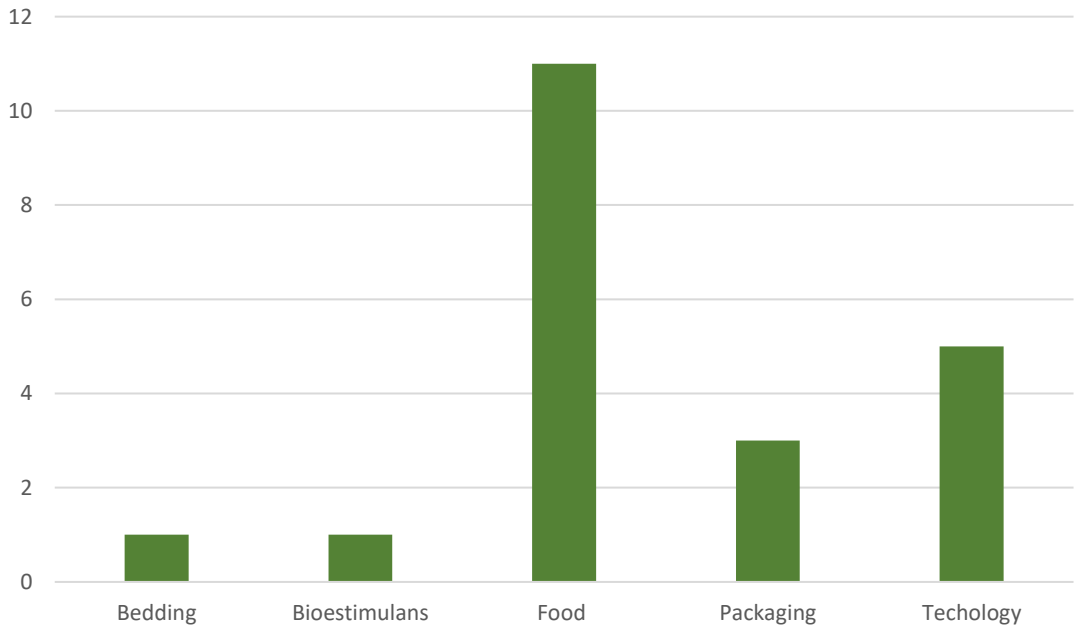

Figure 72: Bio-products generated by BBTs.

Finally, the type of processing methods (physical, chemical, and biological) was analysed. Only 14 BBTs were considered for this analysis, and as can be seen in the Figure 73, most of the technologies developed used biological processing methods.

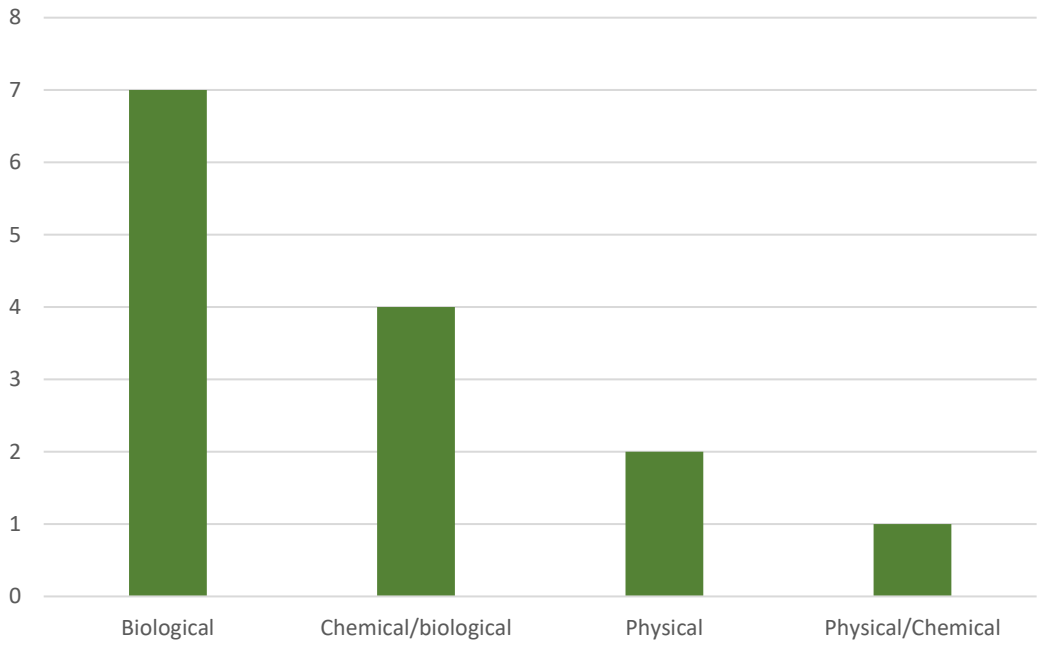

Figure 73: Processing methods.

6.4 Discussion of previous sections

As expressed in the present report, Poland is eighth country in the European Union in terms of the number of OGs, although the number of groups developing BBTs is low. Poland has not yet developed a bioeconomy strategy, only some regions have it in their overall plan. However, over time, a change in the participation of BBTs in the OG is visible.

In terms of available funding and R&D system associated with biomass valorisation, we have highlighted the different programmes available at different levels (European, national, and regional), both public and private, and we can observe the large increase in the recent year.

Most of the OGs, 212, concern the area of "Short food supply chains and local markets", 111 are related to "Plant cultivation", 69 concern Livestock, 19 Agri-food processing, 3 organic farming, 3 Digital solutions, 1 Rational management of natural resources, climate and environment, 1 Rural development.

In conclusion, Poland can be classified as yellow because although the country has potential, there is still a lot of work to be done before it can be considered green.

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7 Spain - Andalusia

7.1 General description of the region

7.1.1 Geographic description of the region

Located in the south of the Iberian Peninsula, Andalusia is the most populated region in Spain with over 8.58 million inhabitants and a population density of 97 hab/km^2. It accounts for the 18% of the country's total population and 1.9% of EU27. The region covers an area of 87,597 km², making up 17% of the Spanish territory (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023). Andalusia has 8 provinces: Almería, Granada, Málaga, Jaén, Córdoba, Sevilla (capital), Cádiz and Huelva. There are 785 municipalities, from which 740 (94.3%) are rural. Slightly above half of the population (51.7%) lives in rural municipalities.

The climate in Andalusia is mainly mediterranean, although the geographical diversity offers a wide variety of climates, from subtropical on the coast to mountain climates in some inland areas, as well as subdesert climates in Almeria and tropical climates in the south of Granada and Malaga. This variety of climates affects the agricultural, livestock and forestry sectors.

Figure 74: Location of Andalusia in Europe.

7.1.2 Agriculture and forestry sectors in the region

Agricultural sector

In Andalusia, there are 267,717 agricultural exploitations which carry out their activity in the 4.78 million hectares of utilised agricultural area (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023), representing the 26% of Spanish and 2.3% of European community exploitations. This accounts for an average establishment size of 17.7 ha (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023), which is below the national average

agricultural establishment size that is 24.5 ha (Instituto Nacional de Estadística (INE), 2017). The Andalusian province with the largest utilised agricultural area per holding is Cádiz, with 42.9 ha, followed by Seville (33.9 ha), Huelva (31.8 ha) and Córdoba (24.4 ha), all of them above the Andalusian average of 17.7 ha. The evolution over the years of utilised agricultural area is shown in the following area, where an upward trend can be observed in recent years.

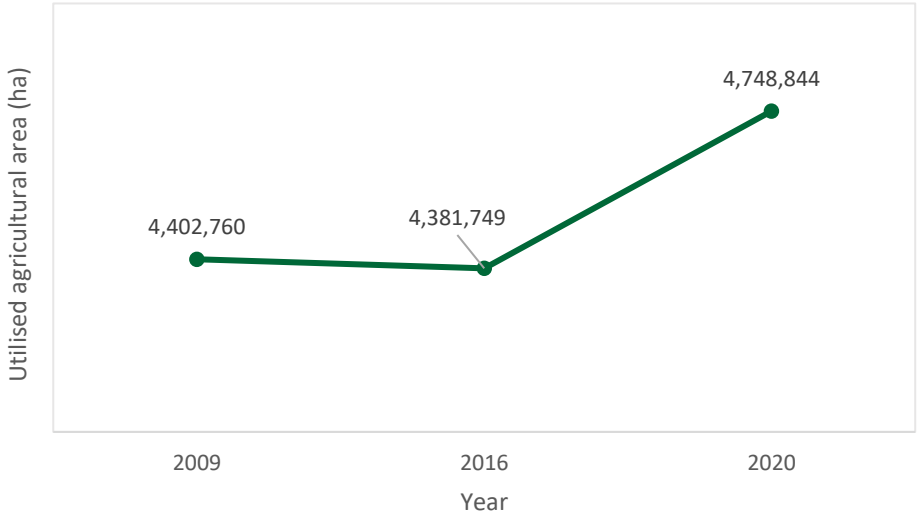

Figure 75: Utilised agricultural area (ha) in Andalusia over the years (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

The standard total production average by exploitation in Andalusia is 41,984€ annually (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023), Huelva has the exploitations with a higher annual average of standard total production (123,108€) and Jaen with the lowest (17,412€). In terms of the active population in the sector, in Andalusia, only 16% of the agricultural exploitation owners have less than 45 and 36.5% has more than 65 years. These figures show an ageing in the agricultural population in Andalusia. Regarding the Andalusian business in the agricultural sector, is mainly made up of small companies (96%).

Furthermore, the distribution between permanent crops (woody) and annual crops (herbaceous) is similar, occupying 39.8% and 35.1% of the available area, respectively. In next figures are shown the ten main crops regarding to occupied area (ha) (Figure 76) and production quantity (t) (Figure 77). The olive oil mill is the most representative crop both in terms of surface area and production quantity (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

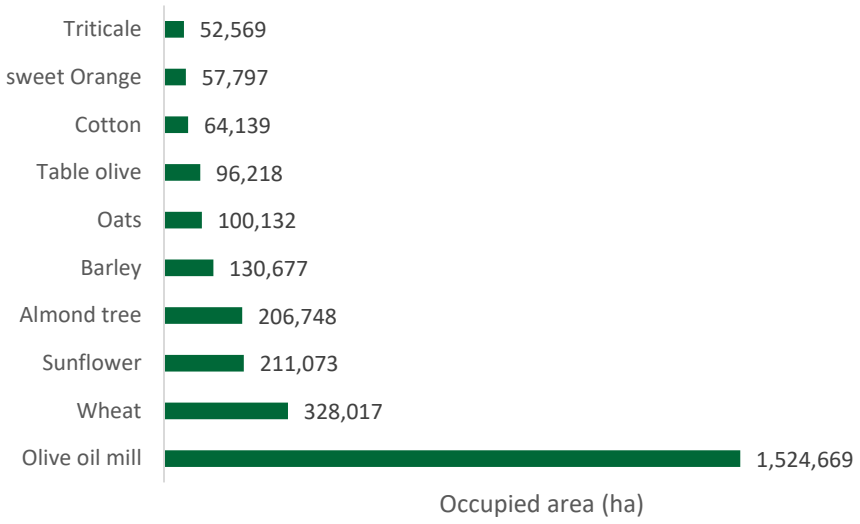

Figure 76: Main crops according to occupied area (ha) (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

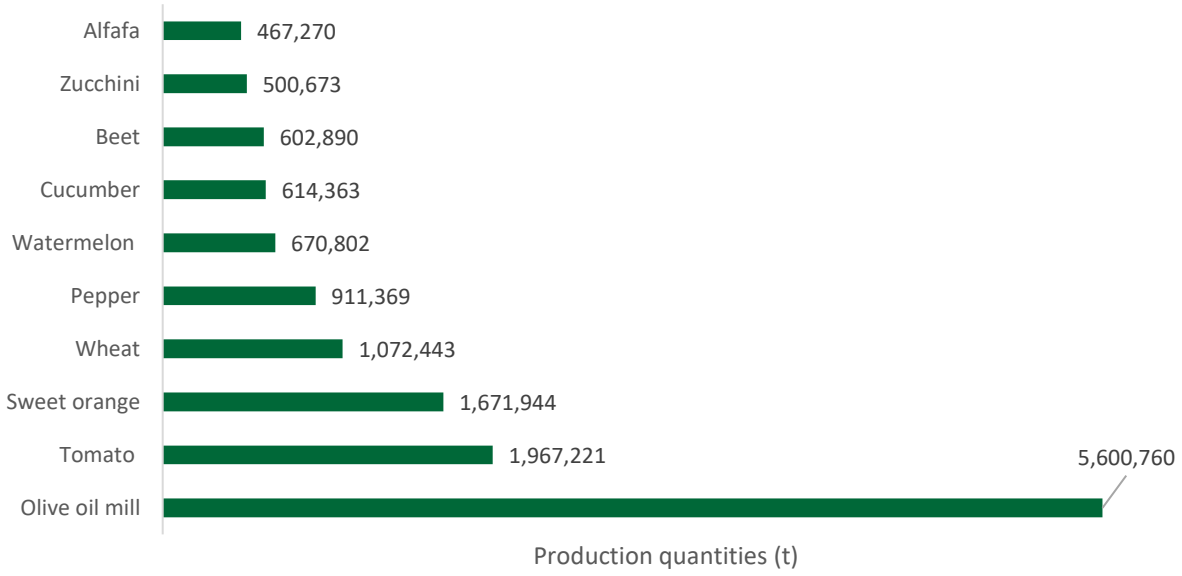

Figure 77: Main crops according to production quantities (t) (Source: Junta de Andalucía) (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023) .

In addition, greenhouse crops are representative of the Andalusian agricultural activity. The total area covered by greenhouses is 40,305 ha (excluding Huelva) with 21,395 greenhouses exploitations (8% of the total exploitations), being 83% of these concentrated in Almeria (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Livestock sector

According to the 2020 Agricultural Survey, Andalusia has 16,534 exploitations which main activity is livestock farming (6.2% from the total agricultural exploitations) and represent the 10,7% of the livestock Spanish establishments (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de

Andalucía, 2023), the majority of these exploitations are dedicated to the production of sheep, goats and other herbivores.

Livestock production in Andalusia is divided into extensive systems, which focus on the use of local natural resources, and intensive systems, which are based on the controlled feeding of livestock with cultivated fodder. The type of management (extensive or intensive) for each exploitation is shown in Figure 78. Extensive production is highest in sheep, cattle meat, goats and swine, while intensive production is highest in equine and cattle milk production. As in the case of agriculture, the livestock sector in Andalusia is mainly made up of small companies.

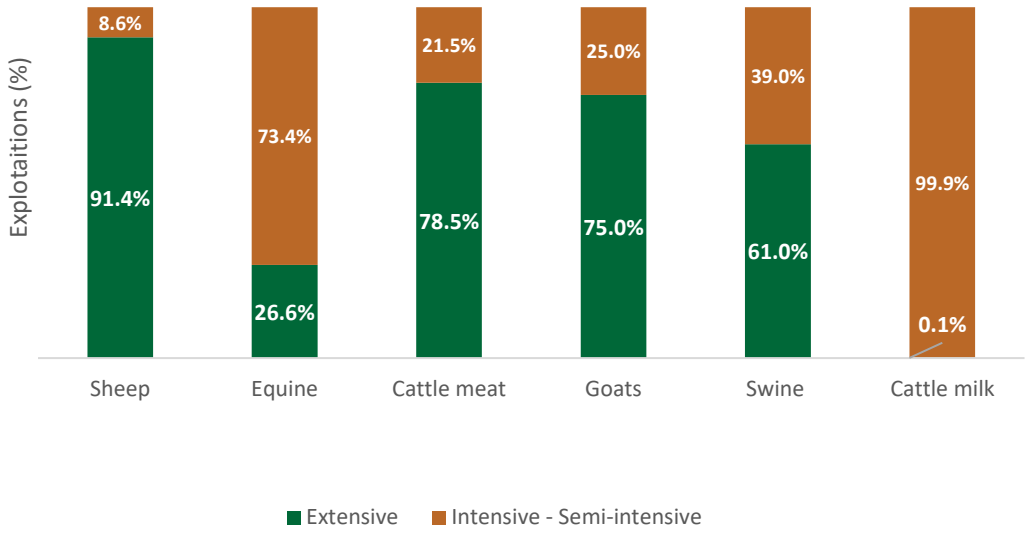

Figure 78: Andalusian livestock farms (%) by type of management in 2022 (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Without taking poultry into account, the livestock species in Andalusia with the largest census in 2020 were pigs and sheep, with the livestock units generated by sheep being larger than those of pigs. The Andalusian livestock with the highest representation in the national livestock is goats, with 39.6%, while the lowest representation is cattle, with 8.4%.

Forestry sector

The forest area covers 34.3% of Andalusia total area (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023). According to SIOSE (Information System of Land Occupation of Spain in Andalusia) 2020, the forest area is 44,434 km^2. The provinces with the largest public forest area are Granada (22.2%) and Jaen (21.3%); followed by Huelva (16.7%), Almería (15.2%) and Málaga (9.6%); and finally, Cádiz (5.8%), Seville (4.6%) and Córdoba (4.5%).

The "Dehesa" is a unique ecosystem in the southwest of the Iberian Peninsula, characterised by holm oaks and cork oaks, which produce acorns for livestock feed, so it is common for different animal species such as Iberian pigs, sheep, goats, cows and horses to graze there. In addition to livestock, the "Dehesas" are also used for forestry, hunting and agricultural activities. In Andalusia, the "Dehesa" is closely linked to the Andalusia´s identity and economy. In 2021, the Andalusian surface area of

"Dehesas" amounted to 1.07 million hectares, of which 32.7% were located in the province of Córdoba, 21.4% in Huelva, 18.1% in Seville and 10% in Jaén. In terms of the number of farms, this amounted to 10,956, with the province of Cordoba accounting for 37.9% of these. The main forestry use of Andalusian "Dehesa" farms is cork, with an average production between 2006 and 2014 of 36,000 tonnes, 59% of national production and 18% of world production, which highlights the importance of this activity in the region.

Figure 79: "Dehesa".

In Andalusia, the cork oaks groves form part of the "Dehesa" landscape that is closely linked to the Andalusia´s identity and economy. Cork oaks have a close relationship with cork production, with a average annual cork production in Andalusia of 33,645 tonnes per year from almost 320,000 ha, which highlights the importance of this activity in the region.

Regarding livestock in "Dehesas", the system of livestock is fundamentally extensive and is based on the simultaneous and combined production of different types of livestock, so that the resources are used more efficiently. The most common types of livestock on the "Dehesas" are pigs, sheep, cattle and goats. The distribution of pigs within Andalusia, the province of Huelva, which has 49% of the extensive pigs in the whole of the Community, followed by Cordoba and Seville, with 19%.

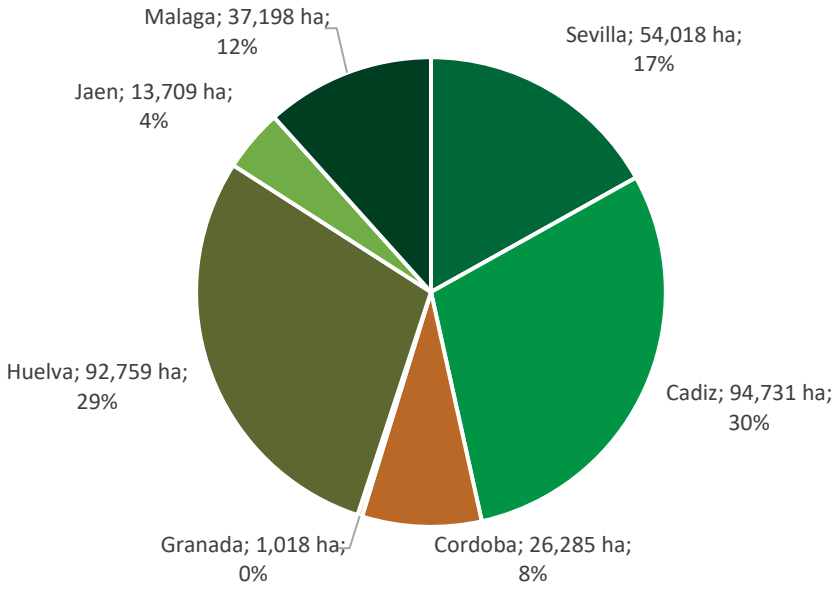

Figure 80: Distribution of cork oak groves in Andalusia in ha. (Source: Strategic Plan for cork oak in Andalusia 2017).

In general, the main forest formations are holm oak forest (23.5%), pine forest (14.8%) and cork oak groves (4.33%). In Andalusia, 74.4% of the forest land is private property, while the remaining 25.6% is public.

Table 48: Detailed information in Andalusia

Location	Forestry area
Andalusia	4,443,400 hectares
Species	Holm oak forest, pine forest, cork oak groves.

Agroindustry

The agri-food sector in Andalusia is the most important industrial sector, with more than 6,000 companies belonging to over 2,900 industries. In fact, it is the region with the highest number of agri-food companies in Spain, with 18.4% of the total, according to the Ministry´s Annual Indicators Report: Agriculture, Fisheries, Food and Environment, published in 2017. In 2020, the value of Andalusian agro-industrial production accounted for 12.4% of the value of national agro-industrial production.

The most important agroindustry in Andalusia are the oil and fat industries, with largest production of olive oil; the meat industry, the second most important in the Andalusian agri-food industry in terms of turnover; and the horticultural industry.

7.1.3 Economic Indicators

Andalusia positions itself as the third largest economy in Spain with a gross domestic product (GDP) of over 195 M€ (13.4% of the Spanish total). Nevertheless, the GDP per capita its only 22,670 €, 25% below the Spanish mean and the second lowest in the country (European Union, s.f.). In 2022, the

Andalusian GDP registered a real growth of 5.2%. Although it is 1.7 points above the euro zone value, it is still 0.3 points below the Spanish one (5.5%) (Consejería de Economía, Hacienda y Fondos Europeos. Junta de Andalucía, 2023). Regarding its productive structure, in terms of gross value added (GVA), in 2023, the agriculture, forestry and fishing sector accounted for 12 M€ which represents 6.2% of the total.

Andalusia has an employment rate of 62.9% below the Spanish total (70.5%) and rural areas (69.3%) mean. Agricultural activity is the main source of employment in half of municipalities, 7.2% of the population works in activities related to agriculture (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023; European Union, s.f.). The employment generated by the bioeconomy amounts to more than 353,000 people (2020), of which 75% is attributed to agriculture, followed by the agro-industrial sector with 16%. The number of people employed by bioeconomy has increased by 7.1% in the last five years, reflected in the GVA of the bioeconomy, which was €13,040 million in 2020, and in the turnover attributed to the bioeconomy in 2020, which was €33,050 million, mainly attributed to the agro-industrial sector (47%) and agriculture (43%) (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Table 49: Economic indicators (European Union, s.f.).

Region/Country	Population (M hab)	GDP (M€)	GDP per capita (€)	GVA (M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Andalusia, Spain	8.58	195k	22,670	11k	62.9	7.2

7.1.4 Bioeconomy regulatory framework

At national level, Spain has a national Bioeconomy Strategy Horizon 2030, which was approved at the end of 2015 following a political agreement between the Ministry of Economy, Industry and Competitiveness and the Ministry of Agriculture, Food and Environment (Secretaría de Estado de Investigación, Desarrollo e Innovación. Ministerio de Economía y Competitividad, 2015). The application fields are the agri-food, forestry, fishing, aquaculture and exploitation of marine resources, chemical industry, bioenergy, and water. This strategy develops its activity in annual action plans. The first of these created the "Spanish Bioeconomy Observatory for Bioeconomy" which plays an important role as an instrument of support and cooperation for the fulfilment of the national strategy. Two Andalusian representatives integrate this observatory (Junta de Andalucía, 2018).

At regional level, there are only four autonomous communities which have a specific strategy or plan related to bioeconomy, and Andalusia is one of them. The "Andalusian Circular Bioeconomy Strategy" was approved in 2018 with 2030 as the time horizon. It is important to highlight that in this way, the Regional Government (Junta de Andalucía) promotes the development and expansion of an economic model based on renewable biological resources and their transformation into products and services. The strategic aims are to: i) increase the biomass availability for its valorisation through innovative treatments, ii) raise the number of bioindustries and biorefineries, iii) boost markets and consumption

of bioproducts and bioenergy (Junta de Andalucía, 2018). The action plan for the achievement of these objectives is organized in 4 strategic lines. The strategic line 1 is focused on the sustainable generation and availability of biomass resources. Specifically, the measure 1.2 is oriented towards improving the biomass availability and sustainable practices in the sectors which generates biomass resources associated to the bioeconomy. Furthermore, the strategic line 2 addresses the distribution and logistics from generation points to the bioindustries that use them as raw material. The line 3 aims to foster and support bio-based industries that improve the use of biomass resources, especially, the biorefineries. Finally, line 4 goal is to promote and support the value chains development of bioproducts and bioenergy, as well as to consolidate already existing markets (Junta de Andalucía, 2018).

Furthermore, in March 2023, the Circular Economy Law was approved in Andalusia, whose main objective is to promote a new model of environmental protection based on the circular economy. This law seeks to contribute to sustainable economic growth, the generation of employment, the preservation of natural resources and the promotion of responsible consumption in Andalusia.

7.2 State of the art of biomass valorisation

7.2.1 Biomass resource availability

Agricultural biomass

In 2023, it is estimated that 7.5 M tonnes of agricultural biomass were generated in Andalusia. In the Figure 81 it can be seen the distribution of biomass resources generated by crop type and by province. As it can be observed, the largest number of resources corresponds to olive groves, with more than 2.6 million tonnes, representing 35% of the total. It is followed in importance by greenhouse crops, which represents 19% of the total (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

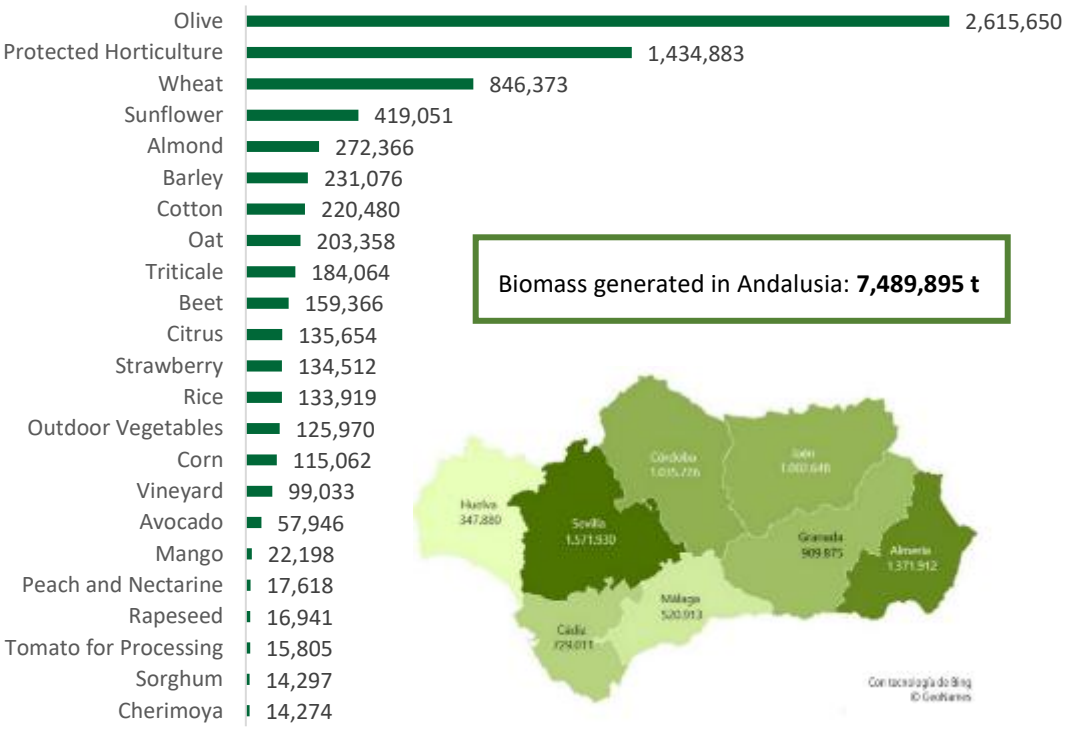

Figure 81: Biomass resources generated in 2021 distribution by crop and by province. Adapted from (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

The biomass resources that are utilised amounts to 6,471,984 tonnes annually (value calculated for 2019). From this total, almost 35% corresponds to olive groves, 26% to cereals and 21% to greenhouse horticultural crops. The destination of this resources classified if in non and horticultural crops are shown in Figure 82 and Figure 83, respectively. For the non-horticultural crops, the main destination is the incorporation on the soil or the distribution in the plot (74%), regardless of whether they have been chopped before or not. In protected horticultural crops, almost 70% are delivered to waste treatment plants (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023). It means that 1,017,911 tonnes of agricultural biomass are still not being valorised.

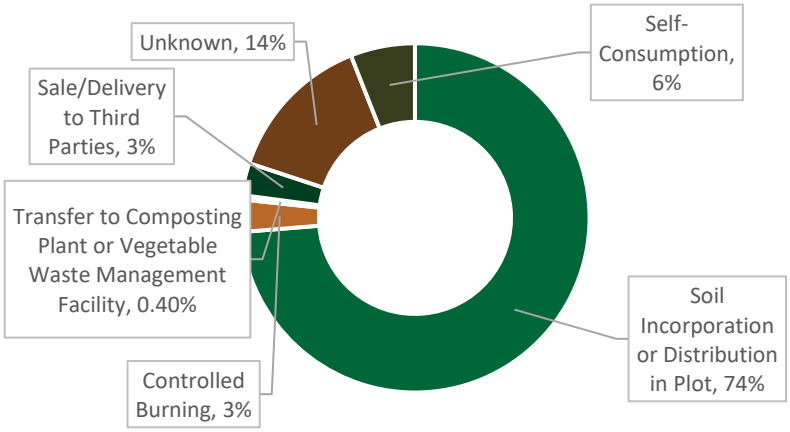

Figure 82: Destination of biomass resources generated by studied crops (without horticultural crops). Adapted from (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

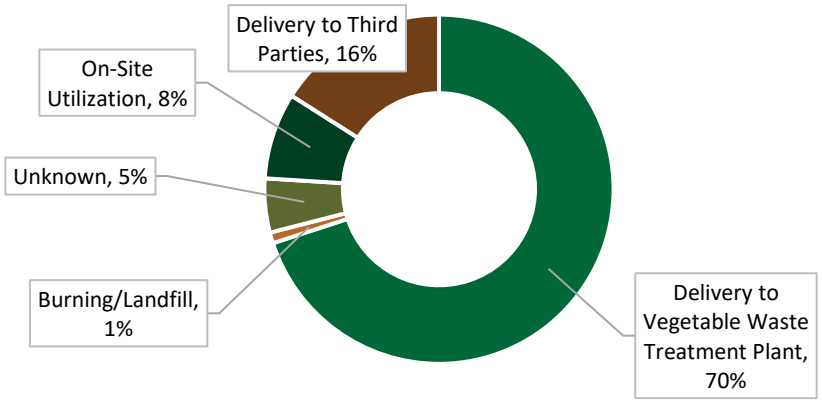

Figure 83: Destination of biomass generated by protected horticultural crops. Adapted from (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Overall, the rate of use of agricultural biomass resources rises to 89.2% with all provinces exceeding 80%, with Malaga and Granada being those with the lowest use of resources (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Livestock biomass

It is estimated that livestock activity generates annually 5.54 million tonnes of biomass annually, with porcine production dominating in all provinces with 63% of the total, in the second place is bovine production. As for the use of resources from livestock activity in the region, the figure reaches 4.82M tonnes per year, reaching a utilization rate of 90.5%. Almost all of these resources (4.8 M tonnes) are directly recovered, while the remaining 18,000 tonnes are processed in biogas or composting plants. Figure 84 shows the amount of biomass generated according to production, and the amount according to each province, with Almeria producing the most, followed by Seville.

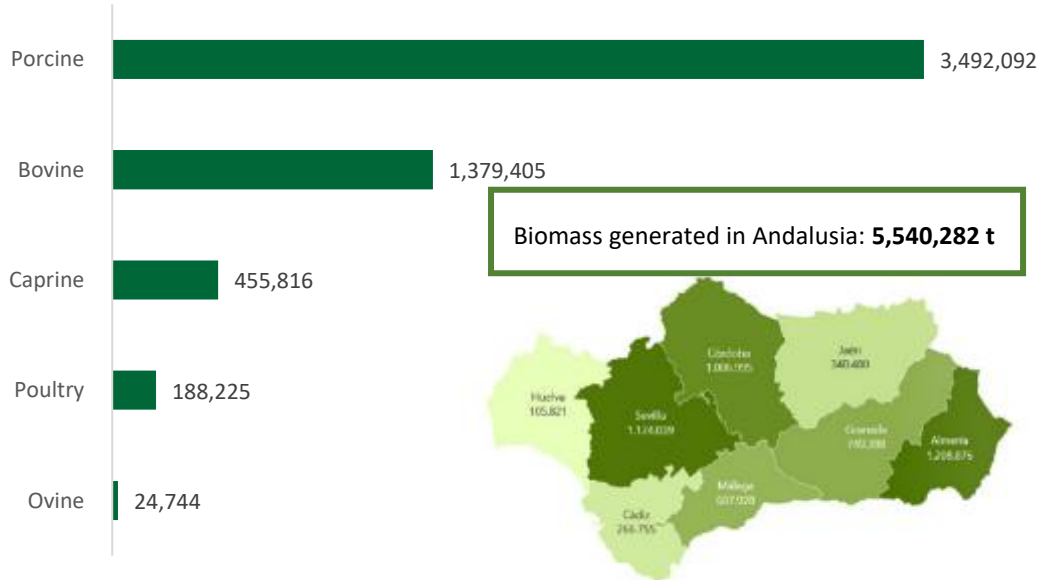

Figure 84: Livestock biomass generation by activity and province. Adaptation from (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Agro-industrial biomass

The data reported is considering the following agro-industries, which are the most relevant in Andalusia regarding biomass production: wineries and breweries, olive related agro-industries (olive mills, olive pomace oil extraction plants and canning factories), rice mills, vegetables processing, industrial tomato processing, slaughterhouses. The total of generated biomass from the analysed agro-industries amount to 5.1 M tonnes annually in 2020. Of the total resources, 3,258,675 tonnes are utilized, representing a utilization rate of 66.6% (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

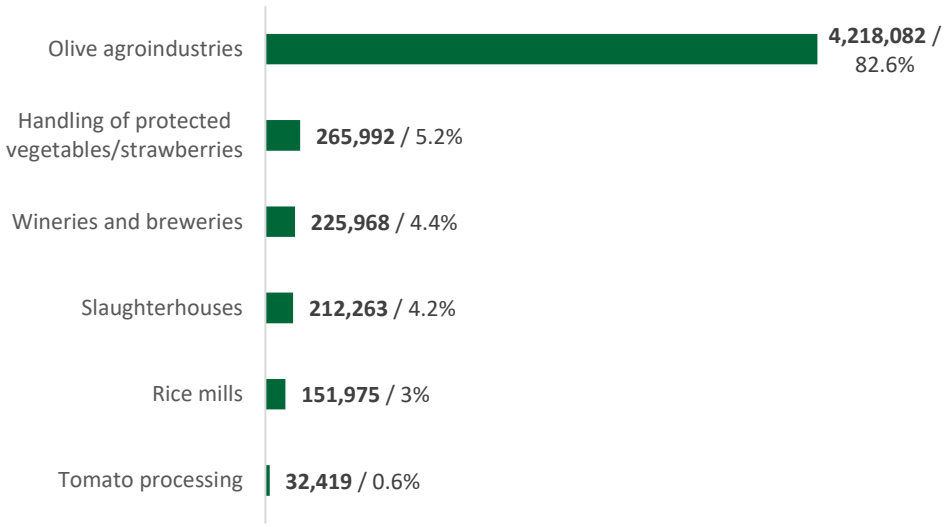

Figure 85: Agro-industrial generated biomass. Adaptation from (Consejería de Agricultura, Pesca, Agua y Desarrollo Rural. Junta de Andalucía, 2023).

Forestry biomass

Forestry biomass comes from the need to carry out silvicultural treatments for the maintenance and improvement of forests and woodlands through felling, pruning, clearing of scrub, etc. These generate woody biomass (firewood, branches and bushes) that must be removed from the forest, since they are a serious risk factor for the spread of pests and forest fires.

The use of biomass depends to a large extent on the costs associated with the procedures for obtaining, extracting, and transporting biomass to the centres of consumption. It is therefore essential to have good knowledge of the economics parameters of biomass use viability.

In 2018 it was estimated that the forest biomass waste generated annually, which is potentially exploitable, is around 320,960 tonnes. From this total, 92% corresponds to wood and the remaining 8% to scrub (Junta de Andalucía, 2018). The calorific value of forestry biomass in Andalusia is between 4.13-5.1 kcal/kg (Agencia Andaluza de la Energía., 2020).

7.2.2 Management and logistics of biomass resources

Biomass resources must be extracted, pre-treated and transported to processing plants for use, so management and logistics must ensure that they are available in processing plants at the time and under the required conditions. One of the main problems affecting the successful use of biomass is the difficulty and high costs involved in the logistics of its supply. The impact on the cost and profitability

of the installation depends on the type of processing industry and the bioproduct. For example, in the case of biodiesel or bioethanol production, the impact of this factor is greater than in the case of pellet production, a product with higher added value (Junta de Andalucía, 2018).

Another example is lignocellulosic biomass, both of agricultural and forestry origin, which has low density and high humidity. These two characteristics have a direct impact on their transport, requiring densification, homogenization and drying processes necessary before their production into logistics circuits (Junta de Andalucía, 2018).

An important issue to take into account is strongly linked to the cultivation calendars of each vegetable production. Seasonality must be considered when designing logistics circuits. In addition to this, it is necessary to analyse the distribution in the Andalusian territory (Junta de Andalucía, 2018).

In the first meeting of the Andalusian FAN, the members commented the problems of storing agricultural biomass, for example the particular case of olive oil mills, with logistics problems due to seasonal biomass generation, and regarding the forest biomass, the risk of fire, the need for large storage spaces, or the problem of humidity in biomass.

7.2.3 Bio-products target market

The Andalusian Circular Bioeconomy Strategy, identify the following as main target markets for bio-products: bioenergy and biofuels, chemical industry, pharmaceutical industry, agriculture and aquaculture, food and beverage industry, cosmetic industry, construction, and plastic industry (Junta de Andalucía, 2018). This section focuses on the first target market, as it is the main consolidated market due to an already established demand for the use of certain bioproducts such as compost or organic amendments.

Bioenergy and biofuels sector

Currently, in Andalusia, the most developed and mature sector for bio-products is the bioenergy and biofuels industry. In the last years, the region has witnessed a continuous expansion of this sector, foresting a dynamic business ecosystem based on the use of biomass for thermal and electrical purposes, as well as the production of biofuels (Junta de Andalucía, 2018). In this way, Andalusia has positioned itself as a leader in the biomass energy generation sector in Spain, thanks to the significant potential offered by the cultivation of olive groves and their processing industries. The companies involved in this sector are very diverse. In 2020, it was estimated that there were 1240 companies working in the biomass sector in Andalusia, most of which are micro, small or medium-sized enterprises (Agencia Andaluza de la Energía., 2020). Below are some stocks from the bioenergy and biofuels sectors.

- Biomass electricity generation

The installed capacity of biomass in Andalusia represents 33.7% of the total. There are 17 biomass power plants and biomass cogeneration plants with an installed capacity of 274 MW (Junta de Andalucía, 2023).

Table 50: Biomass electricity generation installed capacity (Junta de Andalucía, 2023).

Plant name	Power (MW)	Biomass	Province	Year of commissioning	Type
Albaida Recursos Naturales 1	1.7	Greenhouse biomass	Almería	2004 (closed)	Generation
Agroenergética Baena	25	Orujillo, chip	Córdoba	2002	Cogeneration with biomass
Bioenergética Egabrense	8	Orujillo, chip	Córdoba	2006	Generation
Severaes	0.1	Olive pruning	Córdoba	2009	Generation
Bioenergía Santamaría	14.3	Orujillo, chip	Córdoba	2006	Generation
Agroenergética de Palenciana	5.37	Orujillo, chip	Córdoba	2007	Cogeneration with biomass
El Tejar Autogeneración	5.65	Orujillo	Córdoba	1999	Cogeneration with biomass
Vetejar	12.9	Orujillo, chip	Córdoba	2000	Generation
Biomasa Puente Genil	9.82	Orujillo, chip	Córdoba	2006	Generation
Ence I	40.95	Chip	Huelva	2009	Generation
ENCE Biomasa	50	Chip	Huelva	2012	Generation
Ence Huelva II	46	Wood biomass	Huelva	2019	Generation
Bioenergética de Linares	15	Orujillo, chip	Jaén	2009	Generation
La Loma	16	Orujillo, chip	Jaén	2002	Generation
Aldebarán Energía del Gualdalquivir	6	Olive pruning	Jaén	2010	Generation
Fuente de Piedra	8.04	Orujillo, chip	Málaga	2004	Generation
Extrago	9.15	Orujillo, chip	Málaga	2003	Generation

Plant name	Power (MW)	Biomass	Province	Year of commissioning	Type
Total	273.98				

- Biogas generation

There are 21 biogas plants in operation with an installed capacity of 33.45 MW. Most of them use urban sewage sludge or municipal solid waste, only one uses slurry, which has an installed capacity of 0.3 MW (Agencia Andaluza de la Energía., 2020).

- Thermal use

Andalusia is positioned as the first region in Spain in terms of biomass consumption to generate thermal energy. The Andalusian region has a very significant tradition of industrial use, mainly associated with the olive oil industry, which has been able to take advantage of the residues from the extraction of the oil. Consequently, the consumption of thermal biomass varies greatly from one year for the next depending on the olive growing season and, therefore on the activity of the extractive and processing industry (Junta de Andalucía, 2023). At the end of 2023, Andalusia had more than 28.300 facilities for the thermal use of biomass, representing an installed capacity of 1,836 MW. The Table 51 shows the consumption by year:

Table 51: Biomass and biogas thermal consumption (kteo/year). Anual evolution (Junta de Andalucía, 2023).

	2014	2015	2016	2017	2018	2019	2020	2021	2022
Andalusia (ktep)	875.1	518.2	685.8	665.0	567.4	716.2	488.9	711.7	688.7

- Pellets manufacturing

Andalusia has 13 pellet manufacturing plants that use raw material waste from forest industries, with a total production capacity of 59,52 kteo (Junta de Andalucía, 2023).

Table 52: Production of pellets from biomass resources (Junta de Andalucía, 2023).

Name	Province	Production capacity (kteo/year)
Alcolea Biomass Center	Córdoba	10.80
Reciclados Lucena	Córdoba	7.20
Sunwood Biomasa Energía	Jaén	6.00
Sunwood Biomasa Energía (Surpellet)	Jaén	4.00
Maderas Doñana	Huelva	4.00
Tubocas S.L.	Granada	2.69
Maderas Campos	Jaén	2.00

Name	Province	Production capacity (kteo/year)
Futurpelet	Jaén	1.00
Biomasa Córdoba	Córdoba	10.80
Biomasa Tristante	Granada	3.60
Planta Euroil Biomasa	Jaén	5.40
Envafres	Huelva	0.45
Pelet BioGenil	Córdoba	1.58
Total		59.52

- Olive bone and chip production for thermal use

In 2019, Andalusia had 19 operational plants for the preparation of olive stones and 3 in the preparation of chips for use in thermal applications (Agencia Andaluza de la Energía., 2020).

- Biofuels

Andalusia has 10 biofuel plants in operation. Of this total, 6 are for biodiesel, 2 ETBE and 2 HVO. The installed production capacity is 1,273.7 kteo annually (Junta de Andalucía, 2023).

Table 53: Biofuels production installed capacity (Junta de Andalucía, 2023).

Plant	Province	Biofuel	Production capacity (kteo/año)
Biodiesel carboneras	Almería	Biodiesel	186.9
Cepsa bioenergía san roque	Cádiz	Biodiesel	180
Cepsa san roque	Cádiz	ETBE	22.11
Compañía española de petróleos (CEPSA)	Cádiz	HVO	36.9
Biooils	Huelva	Biodiesel	450
Cepsa la rábida	Huelva	ETBE	9.89
Linares biodiésel technology	Jaén	Biodiesel	90
Compañía española de petróleos (CEPSA)	Huelva	HVO	36.9
Biotrading	Sevilla	Biodiesel	45
Biosur (gunvos)	Huelva	Biodiesel	216
Total			**1273.7**

By way of conclusion, the Andalusian Circular Bioeconomy Strategy identifies two main elements that promote the development of bioproduct markets in the region. This is the consolidated market for

bioenergy and biofuels and an established demand for the use of certain bioproducts such as compost or organic amendments. In addition, its experience in the sustainable chemistry sector and its active participation in the "Bioindustries Consortium", places Andalusia in a favourable position for the development of markets related to the bioeconomy (Junta de Andalucía, 2018).

On the other hand, the strategy identifies some weaknesses regarding the development of bioproduct markets. First, the limited knowledge of the alternative uses of different raw material and their introduction into alternative value chains. Second, the lack of detailed analysis of the potential application of by-products and biomass resources and companies potentially interested in them. Regarding the business sector, it is detected that there is a deficient culture of innovation to face technological adaptation to new products and manufacturing processes as well as the low number of medium and big companies in the sector.

7.2.4 R&D system associated with biomass valorisation

In turnover terms, Andalusia is the third Spanish region that invest more in research and development in absolute terms and position itself as the 5th with respect to the regional GDP (Junta de Andalucía, 2018).

Andalusia has several public institutions researching on bioeconomy. Some of these are "Natural Resources and Agrobiology of Seville" (IRNAS) which depends of "International Council of Scientific Research" (CSIC), "Andalusian Research and Training Agricultural, Fisheries, Food and Organic Production" (IFAPA) and 8 out of 10 Andalusian universities (Junta de Andalucía, 2018). In Table 54 are shown the Andalusian research groups working on bioeconomy projects.

Table 54: Andalusian investigation groups working on bioeconomy. Adapted from (Junta de Andalucía, 2018) and results from ATRESBIO project.

Group's main research areas	Institution
Integrated studies of soil-water-plant relationships and the use of organic residues as fertilizers or amendments.	Natural Resources and Agrobiology of Seville, IRNAS (CSIC)
Chemical characterization and valorisation of non-food plant biomass.	
Technical, energetic, and economic feasibility studies of biorefinery systems based on the valorisation of residual biomass from agri-food processes.	Institute of Fat (CSIC)
Conservation and sustainable use of soil, water, and biodiversity in agricultural systems.	Andalusian Research and Training Agricultural, Fisheries, Food and Organic Production (IFAPA)
Nano chemistry and valorisation of biomass and wastes.	University of Córdoba
Chemical Engineering. Analysis of lignocellulosic raw materials. Separation and valorisation processes.	
Biofuels and Energy Saving Systems.	

Group's main research areas	Institution
Hydrogen bioproduction in algae.	
Viticulture and Oenology. Characterization and utilization of by-products of the wine industry.	
Valorisation of biomass into chemical products and energy through heterogeneous (photo)catalysis.	
Valorisation of agro-food by-products or wastes as components of rechargeable batteries.	
Bioproducts and Process Engineering.	
Ecology, evolution and conservation of Mediterranean vegetation. Biofuels and environment.	University of Jaén
Electrical research and technology. Works on the optimal location of power stations based on harnessing agricultural and forestry residues.	
Chemical and environmental engineering. Biorefineries. valorisation of forest biomass, agricultural and urban waste and agro-food lignocellulosic raw materials.	
Bioprocesses. Use of by-products and wastes from the olive industry.	
Applied biological chemistry: new pharmaceuticals and bioremediation.	University of Granada
Chemical and biochemical process technology.	
Environmental, Biochemical and Food Analytical Control. Obtaining functional ingredients through new environmentally friendly technologies.	
Natural products: Chemical biotransformation.	
Bioactive ingredients.	
Pilot or industrial scale application of adsorption processes for the purification of liquid industrial effluents, using biosorbents prepared from agro-industrial by-products or wastes.	
Renewable resource technologies and environnemental pollution.	University of Huelva
Technologies for biomass and organic materials.	
New inorganic materials. Development and optimization of biomass waste valorisation processes to produce biofuels and higher value-added products..	University of Málaga

Group's main research areas	Institution
Ecophysiology of aquatic systems	
Use of lignocellulosic wastes as raw material for carbonaceous materials production by thermochemical processes. Development of catalyst of biomass origin.	
Biofuel production.	University of Sevilla
Surface chemistry and catalysis.	
Environmental and process engineering.	
Production of Compounds of Industrial Interest by Microalgae and Plants.	
Extraction of cellulose from different species of macroalgae using clean technology.	University Pablo de Olavide
Biological and enzymatic reactors.	University of Cádiz
Food Engineering and Technology.	
Isolation, Structural Determination and Synthesis of Natural Products.	
Instrumentation and Environmental Sciences.	
Plant production in Mediterranean Cropping Systems. Circular Economy In Agriculture.	University of Almeria
Biodegradation and reuse of agricultural wastes.	
Research Applied to the Aquaculture and Seafood Sector.	CTAqua

In addition to this, Andalusia has six “International Campus of Excellence” (CEI) in which the ten public university have participation in different modalities. Three of them, are working on investigation and transfer of knowledge in areas related to bioeconomy.

Table 55: CEI description working on bioeconomy related fields (Junta de Andalucía, 2018).

Description	CEI
Integrated by universities of Almería, Cádiz, Huelva and Jaén and led by University of Córdoba. It has more than 200 investigations teams with special interest in agri-food sector and bioeconomy.	ceiA3

Description	CEI
Integrated by universities of Seville and Malaga. It is specialized in 6 areas, in which includes biotechnology and energy and environment.	Andalucía TECH
It is coordinated by the University Pablo de Olavide from Seville. Its investigation areas are environment, biodiversity, and climate change.	CAMBIO
It includes both teaching and research in marine subjects included in the sciences, engineering and humanities, channelling solutions to the challenges of society that arise in the marine field.	CEI-MAR
Based on the fields of Bio-Health, Information and Communication Technologies (ICT), Earth System and Heritage and Culture.	BioTIC
Its aim is to highlight the cultural and heritage wealth of Ansalusia.	CEI Patrimonio

Furthermore, Andalusia has different technology centres that develop activities related to bioeconomy. These are: ADESVA, TECNOVA, CICAP, CTAQUA, CIDAF, CITOLIVA and CITGARUM.

7.2.5 Support and financing policies

Regarding initiatives and projects of interest related to the bioeconomy, it is worth highlighting the innovation projects developed in the bioeconomy, both those financed within the line of aid to national and regional operational groups. Furthermore, the bioeconomy is addressed in different support lines of the national "Recovery, Transformation and Resilience Plan" (Ministerio de Agricultura, Pesca y Alimentación., n.d.).

At national level, some OG stand out, the Spanish Bioeconomy Strategy, mentioned above, some calls from the Ministry for Ecological Transition and the Demographic Challenge, or the financing calls from the Centre for Industrial Technological Development (CDTI). Finally, at the regional level: some regional OGs, financing from the "Junta de Andalucía", or financing from CTA stand out.

In addition, in the Smart Specialisation Strategy for the Sustainability of Andalusia, "S4Andalucía 2021-2027", the Catalogue of Opportunity Areas and the Battery of Demonstrator Projects is available, specifically: E2, Agrotechnology.

- **E2.S1: Green and blue economy**: Linked to the agricultural, forestry, livestock and fisheries sectors, as well as the bioeconomy, the following areas have been identified:
    - E2.S1.O1: Organic, integrated and differentiated quality production.

        - E2.S1.O1.F1: Local food, local value chain.
        - E2.S1.O1.F2: Farm-to-table strategy.
        - E2.S1.O1.F3: Organic production in the Mediterranean diet.
    - **E2.S1.O2: Bioeconomy in agricultural, livestock and fisheries systems.** Through this opportunity area, the aim is to create the conditions for an increase in the added value produced throughout the food system, including new bio-products, such as insect farming as pesticides or as an alternative for waste management.
        - **E2.S1.O2.F1: Bioproducts and biotechnology for the bioeconomy, green economy, blue economy and biomass.**
        - **E2.S1.O2.F2: Bioeconomy and food genetics.**
    - **E2.S1.O3: New models of waste management in the agri-food system.** The aim is to encourage waste recovery processes in the system by moving towards greater circularity through the recycling, replacement, reuse and recovery of waste through new procedures or improved processes.
        - E2.S1.O3.F1: Reduce food waste in all links of the value chain, especially in households.
        - E2.S1.O3.F2: Promoting innovative and sustainable packaging solutions.
- E2.S2: Agri-food industry – functional food

The following are key funding programmes identified in the agri-food sector at the national level.

Table 56: Funding programmes identified in the agri-food sector at national level.

Programme	Funding organization	Type	Web
Food technology grants & procurements	European Institute of Innovation and Technology	Mixed (grant + loan); Recruitment	https://www.eitfood.eu/
Europe Foodtech Acceleration Fund I SCSp	EATable adventures	Investment fund	https://eatableadventures.com/fund/
Tech transfer Agrifood (TTAF	Tech transfer Agrifood (TTAF	Investment fund	https://techtransferagrifood.com/
Swanlaab Ag-FoodTech FCR	Swanlaab Ag-FoodTech FCR	Business Angels & Venture Capital	https://swanlaab.com/
Creas	Creas	Business Angels & Venture Capital	https://creas.es/
clave capital	clave capital	Business Angels & Venture Capital	https://clave.capital/
BeAble Capital	BeAble Capital	Business Angels & Venture Capital	https://beablecapital.com/
Faraday venture Partners	Faraday venture Partners	Business Angels & Venture Capital	https://es.faradayvp.com/portfolio
Ship 2B	Ship 2B	Business Angels & Venture Capital	https://www.ship2b.org/
SPAIN FOODTECH	European Institute of Innovation and Technology	Acceleration and Incubation	https://www.spainfoodtech.es/
StartBEC	MAPA and AINIA	Technological accompaniment	https://startbec.com/
Austral Venture Gestión	Austral Venture Gestión	Venture Capital	https://www.australventures.eu/es/

Programme	Funding organization	Type	Web
Banco Santander	Banco Santander	Private Investment	https://app.santanderx.com/calls?acceptedCountries=ES
CDTI	CDTI	Public Investment	https://www.cdti.es/

7.3 Analysis of Operational Groups

7.3.1 Operational groups characterization

According to the EPI-AGRI project database from EU CAP network in Europe, 2,892 OGs funded between 2015 and 2023, with Spain having the most operational groups with 638 in the period mentioned (EU CAP NETWORK, n.d.).

Of this total, 62 OGs belong to Andalusia. It is important to mention that this database only includes projects whose main source of funding is Rural Development programmes 2014-2020. In an effort to complement this information and thus have a more representative picture of the region, 21 OGs were added to this database, most of them extracted from the resolution of the 2022 call of the Regional Government of Andalusia, whose funding source is included within the Rural Development programme 2021-2027. For the analysis, it was assumed that the 2022 call projects started in 2023. Therefore, the analysis presented is for a total of 83 OGs in Andalusia.

From the 83 OGs analysed, 25 focused their work on the development of BBTs. The Figure 86 below shows the total number of operational groups that were launched in each year and how many of them focused on development of BBTs.

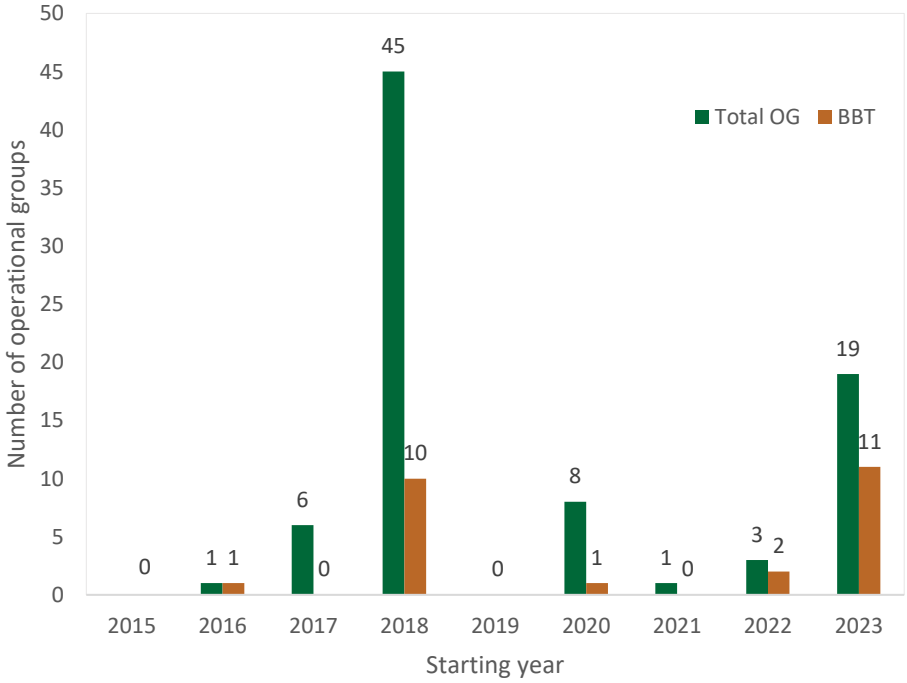

Figure 86: OGs evolution in the period 2015-2023 in Andalusia.

The Figure 87 below shows the total budget of OGs projects over the analysis period. It can be seen that it follows a similar trend to the total number of projects funded. The average budget per project is 88,352€, the maximum and minimum funded is 654,402€ and 95,234€, respectively. For BBT projects the average budget was slightly above from the total being 308,985 €.

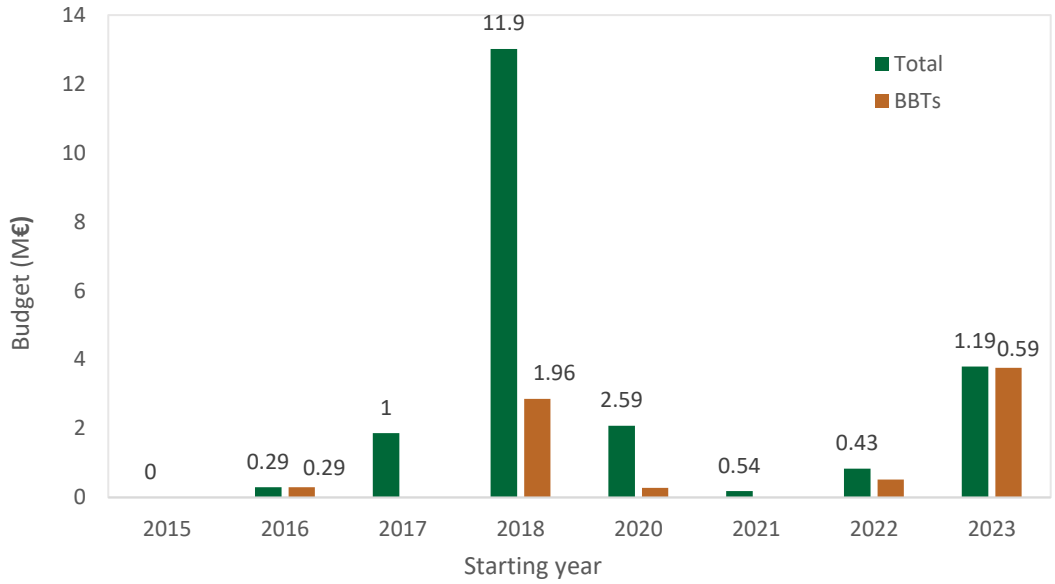

Figure 87: OGs budget evolution over the period 2015-2023.

The Figure 88 shows the distribution of OG projects by different sectors (agriculture, agro-industry, livestock, forestry, and algae). In green is presented the total number of OGs for each sector, and in brown the ones that develop a BBT. Most OGs focused on agriculture sector (64%) followed by agro-industry (16%) and livestock (12%). Only 6% of the OG worked on forestry related projects. The BBTs related projects have a similar trend.

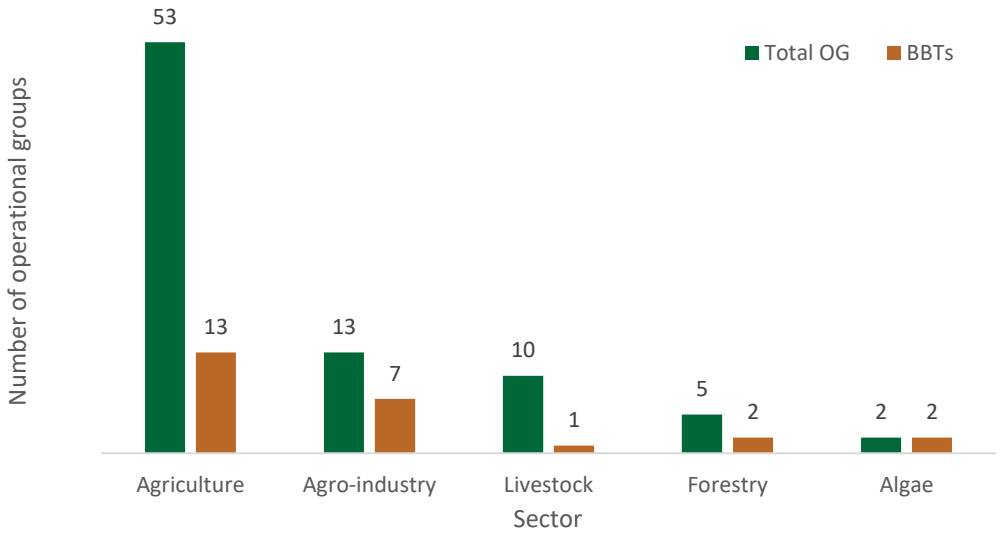

Figure 88: OG by sector in Andalusia.

7.3.2 Bio-based Technologies (BBT) developed by OGs

This section presents in more detail some technological aspects regarding the BBTs developed by OGs mentioned in the above section. It is important to note that, since some OG are relatively new, there is still not much information available in their websites or they do not have a web yet.

First of all, the type of biomass used is analysed. For this analysis, the 25 OGs working in BBTs development were considered. Six of the projects (24%) used biomass related to olive cultivation or industry, in the second position the projects that use forestry biomass, tomato, and algae each of them with 2 projects. Finally, the rest is distributed over different types of biomasses.

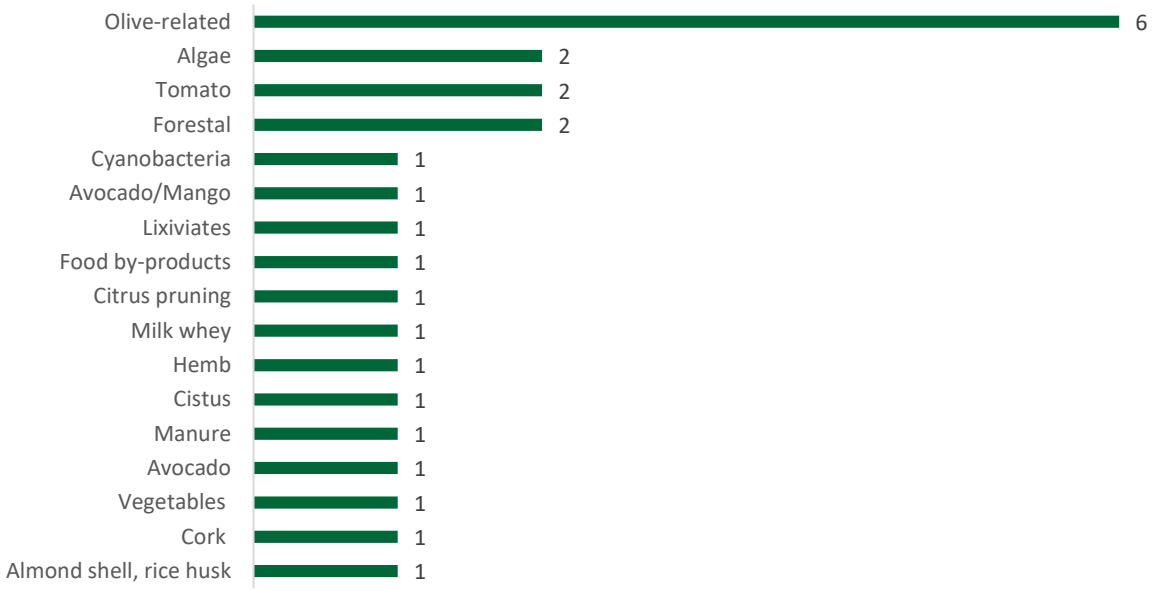

Figure 89: Biomass used in BBTs developed by OGs.

Moreover, it is analysed the bio-products obtain from the processing of the biomasses considering the 25 BBTs identified. 32% of the technologies (8) generates as bioproduct compost, bio stimulants or biofertilizers, followed by feed for animals with 3 projects. It is important to note that although some OGs uses the same biomass it generates two different bio-products.

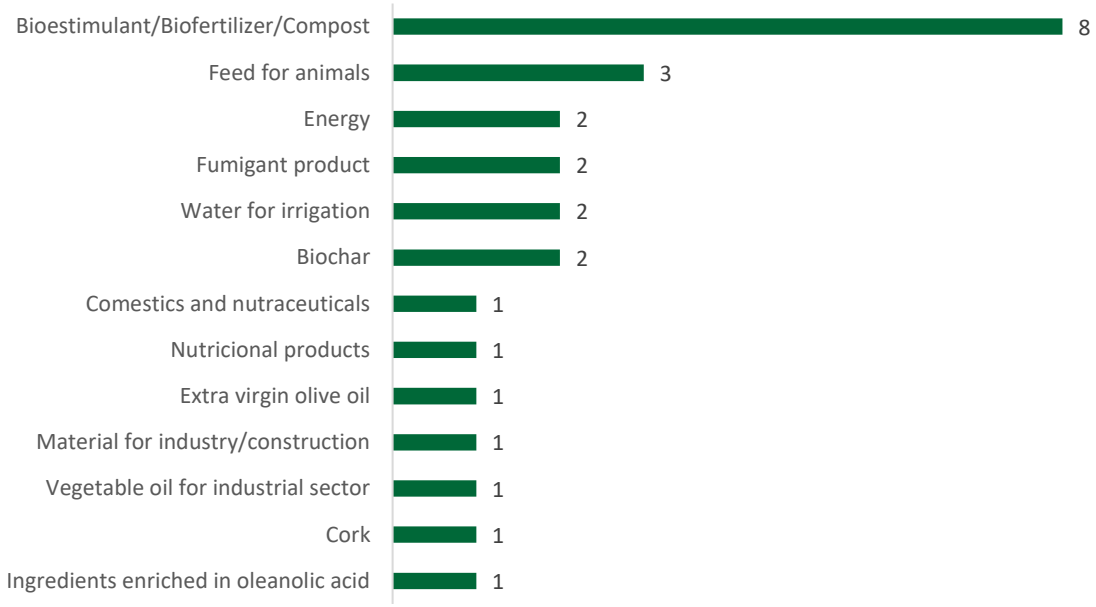

Figure 90: Bio-products generated by BBTs.

In terms of technological maturity, information is only available for 17 projects and most of the technologies developed correspond to TRL 5, validated in relevant environment.

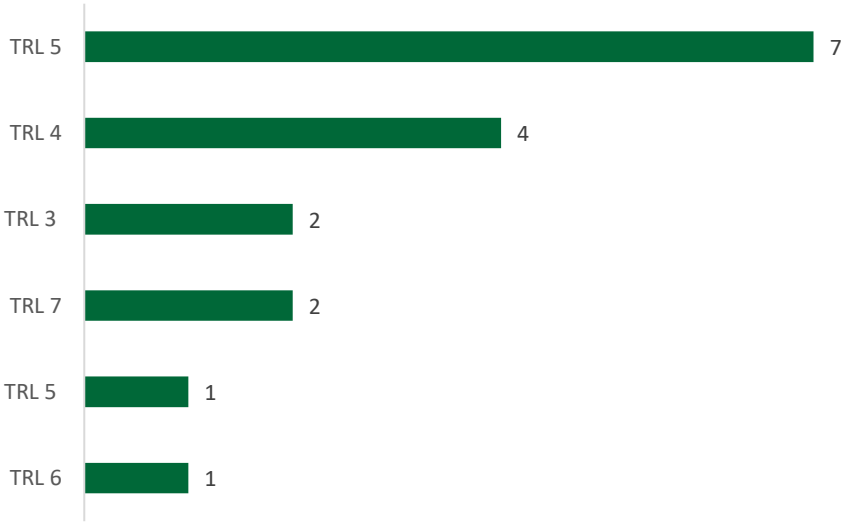

Figure 91: TRLs for each BBTs.

Finally, the type of processing methods (physical, chemical, and biological) was analysed. Only 14 BBTs were considered for this analysis, and as can be seen in the Figure 92, most of the technologies developed used biological processing methods.

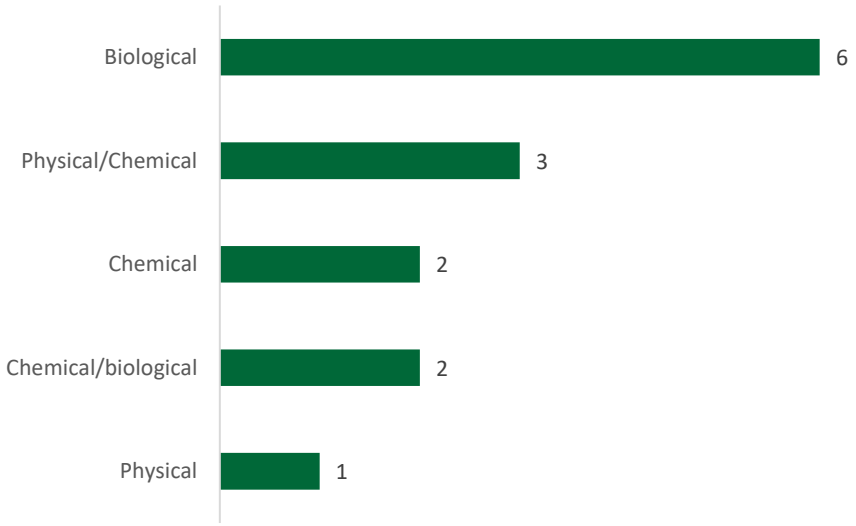

Figure 92: Processing methods.

7.4 Discussion of previous sections

As expressed in the present report, Spain is the largest country in the European Union in terms of the number of OGs. From the total number of OGs analysed, almost 1/3 (33% of them) is or will dedicate its work to the development of BBTs, therefore demonstrating a strong commitment of stakeholders in supporting bioeconomy in the region. In addition, Andalusia is one of the few regions in Spain with a developed Bioeconomy Strategy as well as the Circular Bioeconomy Law, so the regulatory context is also favourable.

In terms of available funding and R&D system associated with biomass valorisation, we have highlighted the different programmes available at different levels (European, national, and regional), both public and private.

Regarding the search for information, there is no up-to-date and easily accessible database on the OGs in the region. Furthermore, the information from the forestry sector in comparison to the agricultural sector is very limited in terms of the amount of biomass available, as well as the number of forest-based OGs. In the analysis carried out in the OGs, it can be observed that in the years 2020-2022 there was a decrease in the number of OGs as well as in the budget, perhaps influenced by the global pandemic, but an upward trend can be observed after this year. In addition, it has been particularly difficult to find economic information on the development of BBTs in the OGs.

Therefore, considering the geographical, regulatory and technical point of view, and looking at the amount of biomass as well as knowledge available in the region, we can conclude that Andalusia have a green light in terms of BBTs implementation.

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8 Conclusions

This report has provided an overview of each region, and an in-depth analysis of the economic situation and resources available in each region. In addition, an analysis of the OGs targeting the use of BBTs in each region is detailed. As mentioned above in each of the findings for the regions/countries, the information available and the situation in each of these regions/countries is different, highlighting in each of them one aspect or another, such as the capacity to implement BBTs or the activity of the OGs.

Regarding the economic situations, the Table 57 shows a summary of the economic indicators of the different regions. Some comparative percentage data is the employment rate, where Ireland, Poland and Italy stand out. However, some of the highest employment rates in the agricultural, forestry and fisheries sector are found in Greece or Andalusia. **Please consider that some indicators refer to the entire countries while others only to the FAN regions.**

Table 57: Economic indicators summary by region/country.

Country - Region	Population (M hab)	GDP (k M€)	GDP per capita (€)	GVA (k M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Czech Republic - South Moravian	1.22	33.6	27,730	0.79	51.2	1.5
Vysočina Region/ Highlands - Czech Republic	0.518	9.83	19,306	0.8678	57.7	6.9
Greece – Central Macedonia	1.78	30.3	16,990	1.69	65.6	12
Greece – Crete	0.62	11.01	14,302	0.75	69.4	14
Greece - Peloponnese	0.53	10.37	17,400	0.84	70.5	27
Ireland	5.27	504.62	94,320	4.43	79.1	4
Italy - Piemonte	4.25	156.33	36,780	2.24	72.2	2.4
Italy - Valle d'Aosta	0.123	5.79	47,070	0.063	77.3	3.5
Italy - Liguria	1.51	57.7	38,300	0.54	72.2	1.4
Poland	36.75	747.75	20,210	21.91	77.9	3.86

Country - Region	Population (M hab)	GDP (k M€)	GDP per capita (€)	GVA (k M€) Agriculture, Forestry and Fishing	Employment rate (%)	Employment by sector (%) Agriculture, forestry, and fishing
Spain - Andalusia	8.58	195	22,670	11	62.9	7.2

It was presented a comprehensive description of **current state of OG-identified** and locally applied **BBTs**. The main results are:

- Czech Republic identified 10 OGs in the period 2017-2023 that focused their research on BBTs. Nearly all of them use crop residues and perennial plant.
- Greece identified 7 OGs that focused on the development of BBTs, being 6 of them in Central Macedonia and the other 2 in Peloponnese. There are no OG of Crete documented at the moment. The biomass resources used are oregano, agricultural biomass, rice residues, residue sheep wool, Hippophage and olive leave. Most of the bioproducts are for soil improvement as anti-fungi or fertilizer, feed and high nutrition additives for food.
- Italy identified 5 OGs in the period 2014-2022 that focused their research in BBTs, being two of them in Piemonte and three in Liguria. The biomass used by the project identified come from the forestry sectors (2), the flower production and plant nursery (2) and breeding sector. For the outcomes, the biomass is utilised to increase energy efficiency and one to produce fertilizers.
- Ireland identified 3 OGs focused on the development of BBTs in the period 2014-2023. The biomass used in these technologies are farming waste (including livestock manure), forest residues and grass. Regarding the outputs, they produce biochar, biogas, and feed.
- Poland identified 22 OGs focused on the development of BBTs in the period 2014-2023. According to the analysis done, 6 projects utilized biomass form livestock (3) and fruits residues (3), the others are distributed over different types. Respect to the outcomes, 50% of the developed technologies produces food or feed.
- Andalusia identified 25 OGs in the period 2015-2023 focused on the development of BBTs. The main biomass used is from olive groves or the olive oil industry. The majority of projects (8) produce bio-stimulants, biofertilizer or compost, followed by feed for animals (3).

It can be noted that there are differences in the number of operational groups that are funded depending on the country or region, but in all cases, there is a general trend in the low percentage of OGs dedicated to the development of BBTs compared to the total number of OGs.

Regarding the regulatory framework, differences can be observed between regions that are more developed in this respect, such as Andalusia, which has developed a Bioeconomy Strategy, and Poland, which does not yet have one, or Greece, where the concepts of bioeconomy and circular economy are being integrated into society.

Finally, the Table 58 shows the classification of the different regions according to the following criteria:

- Green light means that the country has the necessary economic resources and financial support to implement BBTs and, in addition, its action plans include valorisation as an action that contributes to mitigate carbon emissions.
- Yellow light means that the country has only one of the above aspects.
- Red light means that the region has none of the above.

Table 58: Assessment of the capability of implementing BBTS in each region/country.

Country – Region	Capability of implementing BBTs
Czech Republic - South Moravian	Yellow
Greece – Central Macedonia	Green
Greece – Crete & Peloponnese	Yellow
Ireland	Green
Italy - Piemonte, Valle d'Aosta & Liguria	Green
Poland	Yellow
Spain - Andalusia	Green

BBioNets

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Document information

Title	BBioNets - Creation and promotion of Forest and Agriculture Networks to boost Bio-Based Technologies adoption and Value Chain development (GA No 101133904)
Start - end date	1/11/2023 – 31/10/2026 (36 months)
Project type	Coordination and Support Action
Programme	Horizon Europe – Cluster 6
Funding	1,998,636.20 €
Coordinator	Munster Technological University Ms. Carmen Girón Domínguez (carmen.dominguez@mtu.ie)
Project overview	**BBioNets** will constitute a thematic network that will rely on, promote, and further advance the work carried out by EIP AGRI Operational Groups (OGs) with respect to **management and/or processing of agricultural and forest biomass with Bio-Based Technologies (BBTs).** The project will set up 6 regional Forest and Agriculture Networks - FANs (IE, ES, IT, GR, PL, CZ) that will identify local needs, prioritise specific BBTs and share BBT knowledge ready for practice to farmers and foresters, boosting the (re)definition of value chains, stimulating cross-fertilisation beyond borders, and bringing Europe to the forefront of farming, forestry, and bioeconomy with economically viable and sustainable practices.
Consortium	MTU Ollscoil Teicneolaíochta na Mumhan Munster Technological University cagasc iung Institute of Soil Science and Plant Cultivation State Research Institute TEPRO Consultores Agrícolas, S.L. CTA crea American Farm School Thessaloniki - Greece FOCUS Bio East

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