BIO CIRCULAR CITIES

Exploring the circular bioeconomy potential in cities

Regulatory gap and opportunity analysis for a circular bioeconomy

Deliverable D3.2 of WP3

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EXECUTIVE SUMMARY

This report (D3.2) is the second deliverable of Work Package 3 "Circular bioeconomy regulatory framework analysis and set of policy recommendations for the selected urban areas" of the BioCircularCities (BCC) project. WP3 is divided into three phases: The first phase aims to provide an overview of the current regulatory framework and best practices in the field of circular bioeconomy (CBE) and biowaste management at European, national and regional level in the three pilot areas; the second phase analyses in depth the selected regulatory framework and identifies drivers and barriers for the CBE; the last part formulates policy recommendations that could help to overcome the identified gaps or regulatory deficiencies that hinder the collection of biowaste as a feedstock and the valorisation of biowaste at local level.

The objective of D3.2 is to identify the legal/administrative, technical, economic, environmental, and social drivers and barriers that favour or hinder the transition to a more biocircular system for biowaste management. A more sustainable management of biowaste requires improving the quantity and quality of source-separated biowaste so that it can be used as feedstock for bio-based products, as well as the successful market introduction of bio-based alternatives compared to fossil-based solutions in the legal framework at EU level and in each target country.

For the analysis of legal opportunities and gaps in the policy framework, 23 documents on CBE at EU level and 49 at national, regional, and local level for Pazardzhik Province (PP), the Metropolitan City of Naples (MCN) and the Metropolitan Area of Barcelona (MAB) were examined. Key passages of legislation were selected and analysed in depth to identify relevant drivers and barriers that promote or hinder the implementation of new biocircular value chains.

Moreover, with the support of local stakeholders and international reviewers, potential opportunities and existing shortcomings that promote or limit biocircular products/processes at each specific stage of the selected local bio-based value chains were identified. The involvement of numerous stakeholders in Living Laboratories and Peer Review Sessions allowed for understanding their approaches and interests and clarifying what they see as opportunities and shortcomings in the current regulatory framework for CBE and potential recommendations for the adoption of bio-based solutions. The collective knowledge built in the participatory processes ensures that the decisions taken by the project partners are in line with local priorities and existing international practices.

At the European level, support is mainly given to biorefineries that – according to the "cascading use of biomass principle" – process secondary raw materials into a range of marketable bio-based products, including biochemicals, bioplastics, (novel) food and feed, and bioenergy. This approach also applies to the selected streams of the pilot project, i.e., forestry residues, organic waste from the agro-industrial sector and municipal biowaste for the pilot regions PP, MCN and MAB respectively.

In the discussion of the results, the identified legal drivers and barriers to CBE implementation were structured according to the stages of biowaste management, i.e., biowaste prevention, separate collection and biowaste valorisation into bio-based products relevant to the three project pilots.

Among the most important **drivers** grouped per category were:

- **Legal/Administrative:** Strong EU policies with binding targets for Member States on municipal solid waste (incl. biowaste) include limiting landfilling, preparing for reuse and recycling targets, and introducing mandatory separate collection systems for biowaste. Equally important are legal incentives for new bio-based products.
- **Technical:** Door-to-door collection and smart bin collection systems to improve the quality and quantity of municipal biowaste in order to use biowaste as feedstock for bio-based products; best available techniques (BAT) implementation; construction of decentralised valorisation plants (e.g., micro-scale anaerobic digestion or community composting); and conversion of MBT plants treating residual waste into composting or anaerobic digestion plants for source separated biowaste.
- **Economic:** Taxes and restrictions on landfilling and incineration; reduction of waste charges/fees and pay-as-you-throw (PAYT) schemes to encourage separate collection of biowaste; specific and differentiated waste fees covering all waste management costs; taxes on fossil fuels to allow fair competition with bio-based products; EU funding for using BAT; and sustainable public procurement of biobased products.
- **Environmental:** (Food) waste prevention measures; biowaste valorisation schemes instead of landfilling and incineration; decoupling products from fossil resources; using biowaste instead of primary biomass.
- **Social:** Communication campaigns to raise social awareness on the positive effects of the CBE in relation to food waste prevention, biowaste separate collection and bio-based products.
- **Stakeholder Involvement:** Involve stakeholders with different knowledge and interests to facilitate exchange and cooperation and find sustainable CBE solutions tailored to the local context.

Among the most important **barriers** grouped per category were:

- **Legal/Administrative:** Lack of binding targets and consequences for non-compliance with targets and measures; lack of a clear definition between “end of waste” and “by-products”; lengthy and cumbersome authorisation procedures.
- **Economic:** Too high investments for the implementation of innovative infrastructures and lack of planning security for long-term investments; large disparity between the current high cost of collecting and valorising biowaste compared to the income from the sale of bio-based products (unstable market demand).
- **Technical:** Lengthy and cumbersome permits for new biorefineries and organic waste treatment plants; lack of biowaste collection and treatment infrastructure; limited implementation of BAT and feedstock availability.

- **Environment/Health:** Lack of comprehensive environmental and health risk analyses to assess the performance of innovative biowaste collection systems and recovery technologies for the use of biowaste as feedstock for the production of new bio-based products.
- **Social:** Lack of knowledge and will for (food) waste prevention and separate collection; reluctance of using products made from biowaste.
- **Stakeholder Involvement:** Lack of best-practices exchange.

The results of this report are aligned with the literature review on CBE carried out in D4.1 and will support the formulation of policy recommendations to overcome the barriers for the implementation of CBE in the selected pilot areas, that will be addressed in the deliverable D.3.3.

List of acronyms

ACRONYM	Description
(Bio)PE	(bio)polyethylene
(Bio)PP	(bio)polypropylene
(Bio)PET	(bio)polyethylene terephthalate
BAT	Best Available Technique
BCC	BioCircularCities project
CBE	Circular Bioeconomy
CHP	Combined Heat and Power
DtD	Door-to-Door
DBPF	Database on Policy Framework
EC	European Commission
EFSA	European Food Safety Authority
EPR	Extended Producer Responsibility
EU	European Union
GHG	Green House Gas
LL	Living Lab
MAB	Metropolitan Area of Barcelona
MBT	Mechanical Biological Treatment
MCN	Metropolitan City of Naples
MS, MSs	Member State, Member States
MSW	Municipal Solid Waste
PAYT	Pay As You Throw
PLA	Polylactic acid or polylactide
PP	Pazardzhik Province
PRS	Peer Review Session
SDGs	Sustainable Development Goals
SMEs	Small and medium-sized enterprises (2003/361/EC, Annex, Art.2)
UN	United Nations
WP	Work Package

1. PREFACE

The BioCircularCities (BCC) project aims to unlock the potential of unexploited bio-based waste streams for the circular economy by investigating the development of economically and environmentally efficient organic waste valorisation models through three pilot regional case studies on municipal organic waste (Metropolitan Area of Barcelona, MAB), agro-industrial biowaste (Metropolitan City of Naples, MCN), and forest residues (Province of Pazardzhik, PP).

This report (D3.2) is the second deliverable of Work Package 3 "Circular bioeconomy regulatory framework analysis and set of policy recommendations for the selected urban areas" of the BCC project. For the analysis of legal opportunities and gaps, a selection of the updated version of the legal framework documents on circular bioeconomy (CBE) identified in D3.1 (summary) was used. Drivers and barriers that favour or hinder the improvement of biowaste quantity and quality for becoming a feedstock for bio-based products as well as the successful market introduction of bio-based alternatives compared to fossil-based solutions were identified in the legal framework at EU level and in each target country. Moreover, the involvement of stakeholders from the three pilot areas was crucial to get a real picture of the situation based on the experiences on the ground. Indeed, during the second round of Living Labs, local stakeholders operating along the three selected biowaste chains identified in WP2 supported this task. They were highlighting the opportunities for valorisation of biowaste or the gaps hindering the optimal use of biowaste in line with the CBE principles along the different stages of the identified value chains. The results were validated and optimised with the support and advice of external international experts (advisory board and peer reviewers). Shortcomings and recommendations to the CBE implementation identified during the 2nd Living Lab and the 2nd Peer Review Session are also included in this report. *All Living Labs and Peer Review Sessions minutes and conclusions will be reported in a separate deliverable (D5.4) by June 2023.*

2. AIM OF THE DELIVERABLE

The aim of D3.2 is to summarise the results of Task 3.2. "Legislative gaps and opportunities analysis for implementing CBE in the pilot areas". On the one hand, this deliverable analyses in depth the documents collected in D3.1 to identify drivers and barriers for the implementation of the CBE from bio-based waste (biowaste) in the pilot areas and across Europe. On the other hand, potential recommendations and existing shortcomings that promote or limit biocircular products/processes at each specific stage of the selected local bio-based value chains were identified with the support of local stakeholders and international experts. The three targeted biobased value chains are: (i) forestry residues in the province of Pazardzhik (PP), (ii) bio-waste from agro-industries (coffee industry) in the Metropolitan City of Naples (MCN) and (iii) municipal bio-waste in the Metropolitan Area of Barcelona (MAB). For each value chain, alternative scenarios to current waste management practices were defined, in line with the CBE principles, in order to better identify the specific barriers and drivers that could arise in the implementation of these scenarios. The identification of gaps and opportunities at pilot level will then aim to analyse which supporting measures could help to address the identified shortcomings and contribute to a more efficient and sustainable implementation of the CBE. The results of this deliverable will support the development of the third and last task of WP3: T3.3 "Policy recommendations for implementing circular bioeconomy in the pilot areas" and will also complement the first deliverable of WP4: D4.1 "Definition of the Scope of Circular Bioeconomy for biowaste management in urban areas".

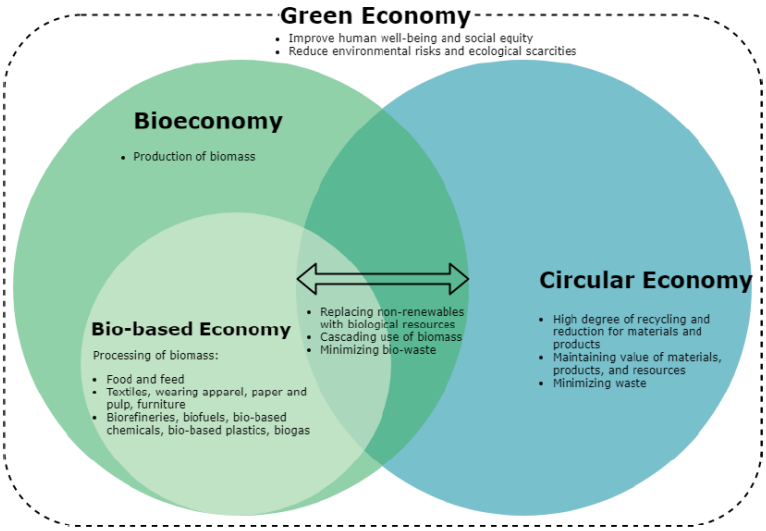
3. INTRODUCTION

Over the past two decades, European Union (EU) policy makers have given high priority to a sustainable and circular (bio)economy in order to cut the use of petrochemicals, mitigate climate change, decrease dependence on imports of natural resources and boost local economies. The EU Bioeconomy Strategy[1] is a core part of the European Green Deal[2], along with the Circular Economy Strategy[3], the Industrial Strategy for a Competitive, Green, Digital Europe [4] and the Clean Energy and Innovation Strategy[5].

Bioeconomy encompasses several related concepts (e.g., bio-based economy, green economy and circular economy) and there are clear linkages between these concepts, in particular between the bioeconomy and circular economy concepts (Figure 1), but there is much potential to make bio-based and bioeconomy strategies more circular. While circular economy aims at increasing the resource efficiency of processes and the use of recycled materials to reduce material consumption, bioeconomy aims at promoting sustainable production of natural resources from biomass rather than fossil and mineral-based resources (Kardung et al. 2021). The bioeconomy is based on primary production sectors that use and produce biological resources (including by-products, residues, and waste), i.e., agriculture, forestry, fisheries, and aquaculture. The biogenic resources can in turn become feedstock for the economic and industrial sectors that use biological resources and processes to produce 1) food and feed, 2) fibres, 3) chemical and materials that later on will be transformed into bio-based products, 4) bioenergy and biofuels substituting fossil feedstock (COM/2018/673 final). As far as the risk of a linear bioeconomy is concerned (competition of land uses, damage to soils, energy, fertiliser consumption, etc.), the bioeconomy offers many promising alternatives for replacing fossil products and services, but it also has many limitations. Circular economy and the bioeconomy are therefore complementary concepts that can reinforce each other.

[1] https://research-and-innovation.ec.europa.eu/research-area/environment/bioeconomy/bioeconomy-strategy_en
[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en
[3] https://research-and-innovation.ec.europa.eu/research-area/environment/circular-economy/circular-economy-strategy_en
[4] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/industry-and-green-deal_en
[5] https://research-and-innovation.ec.europa.eu/research-area/energy/strategy_en

Figure 1 : Relations between bioeconomy, bio-based economy, green economy, and circular economy (Kardung et al. 2021)



Biowaste and bio-based by-products play a key role in circular economy strategies and, in line with the waste hierarchy, they can be reduced and, in the case of unavoidable biowaste, they can be considered as a resource that can be reused, recovered, or recycled. In fact, through waste prevention measures and mechanisms of industrial symbiosis, the volume of biowaste to be disposed of can be reduced, the problem of biomass losses can be resized, the bio-based waste streams can be used again in cascading and organic recycling as feedstock for the bio-based industry.

There is still a large untapped potential of biowaste, by-products and residues valorisation from municipal solid waste (MSW) as well as from the agro-industrial and forestry sector. The **EU Biorefinery Forecast to 2030** (EC 2021a) supports the EU Bioeconomy Action Plan (EC 2019a) to promote the development and use of new resource-efficient and sustainable biorefineries in Europe. Biorefining can be broadly defined as the processing of biomass - and thus also by-products, organic residues and biowaste - into a range of marketable bio-based products through thermochemical, physicochemical, biochemical and thermochemical processes, which may also involve the co-production of food and feed, chemicals and materials, and bioenergy (Figure 2); Zuin & Ramin 2018, EC 2021a). Chemical and material biorefineries increasingly complement biomass processing in biorefineries for bioenergy and biofuels as well as other production pathways to obtain bio-based chemicals and materials, but could also co-produce food, feed and bioenergy. So far, more than 300 chemical- and material-based biorefineries are in operation in the EU, with a strong tendency to expand in order to make an even more important contribution to the CBE and the EU's transition to a climate-neutral economy in the future (Figure 3)[6]. Especially in rural areas, small-scale biorefineries can help farmers, foresters and fishermen to better diversify their income sources and manage market risks, while replacing fossil products and creating additional jobs and business opportunities (EC 2021a).

[6] https://datam.jrc.ec.europa.eu/datam/mashup/CHEMICAL_BIOREFINERIES_EU/index.html

Figure 2 : Holistic biorefinery model incorporating biomass, bioenergy and biomaterials, built on green and sustainable technologies within the framework of the CBE (Zuin & Ramin 2018).

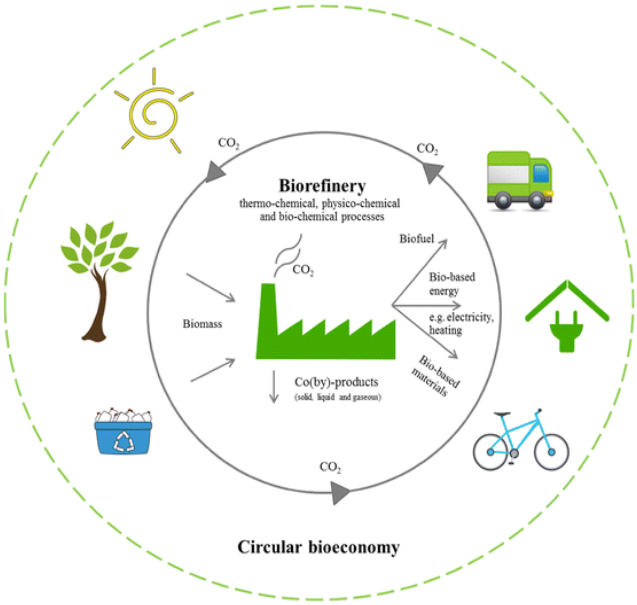
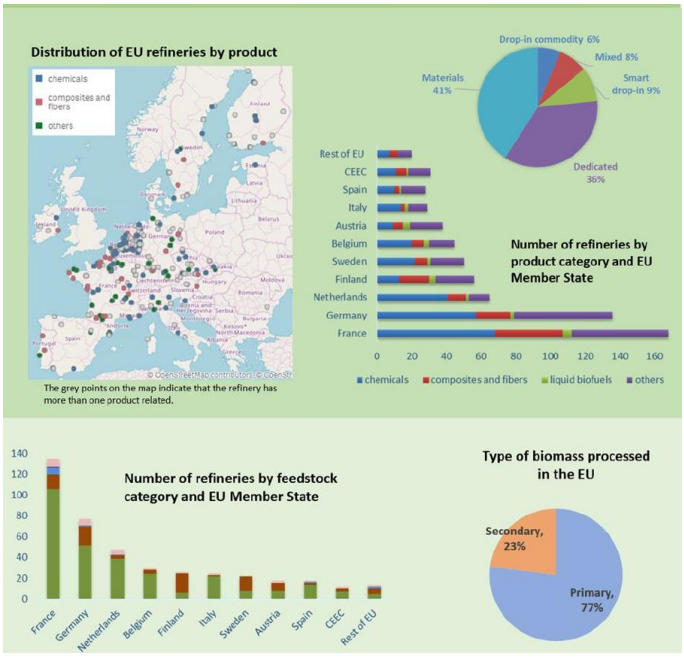


Figure 3 : Distribution of the chemical and material biorefineries in the EU by their feedstock and product categories (EC 2022c).[7]



[7] https://datam.jrc.ec.europa.eu/datam/mashup/CHEMICAL_BIOREFINERIES_EU/index.html

One of the key outcomes of the 2012 EU Bioeconomy Strategy (COM/2012/60), alongside with many EU policy initiatives, to strengthen and expand EU bio-based sectors and unlock investments and markets at all stages of the innovation cycle, was the launch of research and development programmes, such as the Bio-based Industries Joint Undertaking (BBI JU, 2014-2021)[8], and – with the **2018 EC Bioeconomy Strategy update** (COM/2018/673) and its Action Plan (EC 2019a) including the three main action areas bio-based sectors, rural development, and ecological boundaries – the new Circular Bio-based Europe Joint Undertaking (CBE, 2021-2031)[9].

Together with bioeconomy policies, the exchange and implementation of best practices enable the strongest progress in developing bio-based solutions that demonstrate industrial modernisation and sustainable value chains for sustainable food and bio-based products, bio-based and bio-derived chemicals, advanced biofuels, and bioenergy. Transitioning the economy to the bioeconomy requires an understanding of both the drivers that can enhance the development and implementation of sustainable biocircular solutions and the barriers that hinder this development.

This report aims to provide insights into existing CBE regulations and policy instruments to identify potential opportunities and gaps, complemented by the experiences of relevant stakeholders involved in biowaste chains and knowledgeable about the circular economy in local contexts. Building this collaborative knowledge is crucial for developing recommendations for the development of the CBE at EU, national, regional, and local levels.

[8] https://wayback.archive-it.org/12090/20221125105151/https://www.bbi.europa.eu/

[9] https://www.cbe.europa.eu/

4. METHODOLOGY

4.1. Identification of drivers and barriers

4.1.1. Definitions of drivers, barriers and categories

Before explaining how the drivers/opportunities and barriers/shortcomings to the implementation of circular bioeconomy were identified both at EU and pilot level, it is relevant to introduce the following definitions:

Drivers/ opportunities/recommendations favour the implementation of the CBE in the biowaste value chain.
Barriers/gaps/shortcomings hinder the implementation of the CBE in the biowaste value chain.

Implementation of the CBE means utilising secondary biomass (organic waste, residues and by-products) to produce food, materials, and energy. This can be done either by changing or improving current treatment systems in a circular perspective: 1) by introducing preventive measures (reduction of biowaste generated), 2) by improving biowaste separate collection (quantity and quality); 3) by producing new products from biowaste.

Categories (Cat) of barriers and drivers with examples:

- **Legal/Administrative (L/A):** EU-wide, national, regional, and local legislation and its implementation, e.g., through binding targets, administrative penalties for non-compliance.
- **Technical (Tec):** Technological innovations, best available techniques (BAT), available infrastructure and equipment, waste quality requirements, etc.
- **Economic (Ec):** Capacity for investment in innovation, BAT and new product chains, profitability threshold, market situation of raw materials and bio-based products, economic incentives such as tax reductions, waste charges/fees and subsidies.
- **Environment/Health (E/H):** Greenhouse gas emissions, possible impacts on environment and health.
- **Social (Soc):** Public acceptance of new waste collection systems and bio-based products, awareness raising campaigns on biowaste separate collection or biowaste-based products.
- **Stakeholder involvement (SI):** Involvement of various stakeholders from science, industry, politics, citizens, and NGOs in decision-making processes.

4.1.2. Definitions of waste streams, by-products, and relevant waste concepts

This section includes some definitions related to waste streams or products obtained from waste and concepts that are used in the description of barriers and drivers. They have been taken from the current European guidelines or the bibliography and reproduced to clarify the sense in which these terms are used in the text.
Municipal biowaste, agro-industrial organic waste and forestry residues are the focus of this study as they are the selected streams of the BCC project pilots for the MAB, MCN and PP respectively. Bioplastics are likewise relevant as

bio-based chemicals since different types of organic residues, such as agro-industrial biowaste or forestry residues can be used as potential feedstock thanks to the new biowaste routes explored in the project pilots.

Waste, biowaste, agro-industrial organic waste and forestry residues

Waste (Directive 2008/98/EC) means any substance or object which the holder discards or intends or is required to discard.

Municipal waste (Directive EU/2018/851) means: a) mixed waste and separately collected waste from households, including paper and cardboard, glass, metals, plastics, biowaste, wood, textiles, packaging, waste electrical and electronic equipment, waste batteries and accumulators, and bulky waste, including mattresses and furniture, b) mixed waste and separately collected waste from other sources, where such waste is similar in nature and composition to waste from households. Municipal waste is referred to as Municipal Solid Waste (MSW) in this report.

Biodegradable waste (Directive 99/31/EC) means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard.

Biowaste (Directive EU/2018/851) means biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises and comparable waste from food processing plants. According to the European Commission website[10], biowaste does not include forestry or agricultural residues, manure, sewage sludge, or other biodegradable waste such as natural textiles, paper, or processed wood. It also excludes those by-products of food production that never become waste.

Food waste (Directive EU/2018/851) means all food - as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council - that has become waste. Within the FAO's definitional framework (FAO, 2013), the concept of food waste is substituted by the notion of "food wastage" referring to any food loss or food lost by deterioration. The food loss refers to a decrease in mass (dry matter) or nutritional value (quality) of food that was originally intended for human consumption. These losses are mainly caused by inefficiencies in the food supply chains, such as poor infrastructure and logistics, lack of technology, insufficient skills, knowledge and management capacity of supply chain actors, and lack of access to markets. In addition, natural disasters play a role. While the food lost per deterioration refers to the food appropriate for human consumption being discarded, whether or not after it is kept beyond its expiry date or left to spoil. Often this is because food has spoiled but it can be for other reasons such as oversupply due to markets, or individual consumer shopping/eating habits.

Agro-industrial organic waste refers to residues coming from industry activities which include the by-products of the agrifood industry such as coffee dregs, bagasse, degummed fruits and legumes, milk serum, sludge from wool, cellulose (Yusuf 2017).

[10] https://ec.europa.eu/environment/topics/waste-and-recycling/biodegradable-waste_en

Forestry residues (acc. EC 2021b) consist of fine woody debris (FWD) (including slash, i.e., tops and branches), coarse woody debris (including snags, standing dead trees, and high stumps) and low-stumps.

Waste management stages

Waste prevention (Directive 2008/98/EC) means measures taken before a substance, material or product has become waste, that reduce:
(a) the quantity of waste, including through the re-use of products or the extension of the life span of products;
(b) the adverse impacts of the generated waste on the environment and human health; or
(c) the content of hazardous substances in materials and products.

Waste management (Directive EU/2018/851) means the collection, transport, recovery (including sorting), and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker.

Separate collection (Directive 2008/98/EC) means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment.

Recycling (Directive 2008/98/EC) means any recovery operation by which waste materials are reprocessed into products, materials, or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations.

Organic recycling (biological treatment of biowaste; Directive 94/62/EC) means the aerobic (industrial composting) or anaerobic (biomethanisation) treatment, under controlled conditions and using microorganisms, which produce stabilized organic residues or methane. The EU Directive refers to the harmonised European standard for the industrial compostability of plastic packaging: EN 13432. An equivalent standard has been approved by the European standardisation organisation CEN for the testing of compostability of plastics: EN 14995. In order to be recovered by means of organic recycling (composting) a material or product needs to be biodegradable.

Biorefinery can be broadly defined as the processing of biomass - and thus also by-products, residues and biowaste - into a range of marketable bio-based products through thermochemical, physicochemical, biochemical, and thermochemical processes, which may also involve the co-production of food and feed, chemicals and materials, and bioenergy (acc. to Zuin & Ramin 2018; EC 2021a).

Treatment (Directive 2008/98/EC) means recovery or disposal operations, including preparation prior to recovery or disposal.

Recovery (Directive 2008/98/EC) means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being

prepared to fulfil that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations.

Disposal (Directive 2008/98/EC) means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. The list of disposal operations includes among others deposit into or the land (e.g. landfill), incineration (on land or at sea), permanent storage (Annex I of Directive 2008/98/EC).

By-products

By-product (Directive 2008/98/EC): A substance or object resulting from a production process whose primary aim is not the production of that substance or object can only be regarded as a by-product rather than as waste (see definition) if the following conditions are met:

a) further use of the substance or object is certain;
b) the substance or object can be used directly without any further processing other than normal industrial practice;
c) the substance or object is produced as an integral part of a production process; and
d) further use is lawful, i.e., the substance or object fulfils all relevant product, environmental and health protection requirements for the specific use and will not lead to overall adverse environmental or human health impacts.

Agro-industrial by-product means discarded organic materials produced from the raising of plants and animals as part of agronomic, floricultural, horticultural, silvicultural, vinicultural, or viticultural operations including, but not limited to, animal manure, bedding materials, plant stalk, leaves, other vegetative matter and discarded by-product from the on-farm processing of fruits and vegetables.[11]

Animal by-products (Regulation (EC) 1069/2009) means entire bodies or parts of animals, products of animal origin or other products obtained from animals, which are not intended for human consumption, including oocytes, embryos, and semen.

Bioenergy, biogas and biomethane

Bioenergy is the general term for the energy produced from **biomass**, i.e., the biodegradable fraction of products, waste and residues from biological origin from agriculture, including vegetal and animal substances, from forestry and related industries, including fisheries and aquaculture, as well as the biodegradable fraction of waste, including industrial and municipal waste of biological origin as defined in Directive EU/2018/2001.

Biogas and biomethane are a form of bioenergy. **Biogas** is a mixture of methane (CH_4), carbon dioxide CO_2 and small quantities of other gases produced by anaerobic digestion of organic matter in an oxygen-free environment. The

[11] https://www.lawinsider.com/dictionary/agricultural-byproduct

methane content of biogas typically ranges from 45% to 75% by volume, with most of the remainder being CO_2. This variation means that the energy content of biogas can vary. **Biomethane** (also known as "renewable natural gas") is a near-pure source of methane produced either by "upgrading" biogas (a process that removes any CO_2 and other contaminants present in the biogas) or through the gasification of solid biomass followed by methanation.[12] Biomethane is hence the purified form of raw biogas and can be used as a natural gas substitute. It is one of the main renewable gases of the future and available today to decarbonise the EU's energy system.[13]

Bio-based and biodegradable and compostable and oxo-degradable plastics

Referring to plastics as **'bio-based'** (COM/2022/682 final) points to the raw materials, or feedstock, used for their production. While conventional plastics are made from fossil resources (oil and natural gas), bio-based plastics are made from biomass. The biomass currently originates mainly from plants grown specifically to be used as feedstock to substitute fossil resources, such as sugarcane, cereal crops, oil crops or non-food sources like wood. Other sources are organic waste and by-products, such as used cooking oil, bagasse, and tall oil. Bio-based plastics can be fully or partially made from bio-based feedstock and can be both biodegradable and non-biodegradable.

While conventional plastics do not decompose at the end of their life, plastics referred to as **'biodegradable'** (COM/2022/ 682 final) are designed to **decompose** at the end of their life by the conversion of all their organic constituents (polymers and organic additives) mainly into carbon dioxide and water, new microbial biomass, mineral salts and, in the absence of oxygen, methane. For that to happen, in addition to the characteristics of the plastic material, suitable conditions (e.g., location, temperature, humidity, presence of microorganisms, etc.) in the receiving environment (industrial composting plant, garden compost, soil, water, etc.) and sufficient time are necessary. Plastics designed to biodegrade can be both bio-based and fossil-based.

Compostable plastics (COM/2022/682 final) are a subset of biodegradable plastics designed to biodegrade under controlled conditions, typically through industrial composting in special facilities for composting or anaerobic digestion. The biodegradable plastics waste sent for industrial composting first needs to be collected. There is a European standard (EN 13432:2000) for industrially compostable packaging, but not for home composting as the conditions for the latter can differ significantly. EN 13432 requires for the compostable plastics to disintegrate after 12 weeks and completely biodegrade after 6 months during a composting process. That means that 90% or more of the plastic material will have been converted to CO_2. The remaining share is converted into water and the product of the degradation process (compost).

Concerning the anaerobic mesophilic degradation of biodegradable plastics together with food waste, Zhang et al. (2018) concluded that of the 9 bioplastics certified according to EN13432 tested, only 4 showed substantial

[12] https://www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth/an-introduction-to-biogas-and-biomethane

[13] https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomethane_en

biodegradability under anaerobic conditions and that even the most degradable materials would not break down sufficiently to meet the physical contaminant criteria of the UK PAS110 specification for anaerobically digested material, if fed to a digester at 2.0%of the input load on a volatile solids basis.

Oxo-degradable plastics (Directive EU/2019/904)) means plastic materials that include additives which, through oxidation, lead to the fragmentation of the plastic material into micro-fragments or to chemical decomposition.

Novel Food

Novel food means any food that was not used for human consumption to a significant degree within the European Union before 15 May 1997, irrespective of the dates of accession of Member States to the Union, and that falls under at least one of the lists of categories defined in Article 3(2)(a) of Regulation EU/2015/2283. They are foods or ingredients considered "new" compared to those traditionally intended. This concept was introduced to differentiate them from the products consumed before 1997. These foods are therefore not new to consumers, in fact this diversification was made in order to provide greater protection to European citizens. The safety of novel food is guaranteed by the application of European Food Safety Authority (EFSA) procedure for the scientific risk assessment.

End-of-waste

End-of-waste (Directive 2008/98/EC): when certain waste ceases to be waste and becomes a product, or a secondary raw material when it has undergone a recovery operation (including recycling) and complies with:

a) the substance or object is commonly used for specific purposes;
b) a market or demand exists for such a substance or object;
c) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and
d) the use of the substance or object will not lead to overall adverse environmental or human health impacts.

Achieving end-of-waste status for recovered waste materials can support the recycling of waste and the beneficial use of the waste without harm to human health and the environment. This in turn diverts waste from landfill disposal, keeping it in the economy as a resource, which can reduce the environmental impacts arising from waste management.

End-of-waste criteria represent the specific requirements that need to be fulfilled by a material to cease to be regulated as waste. These criteria will be specific for the defined use(s) of the material. The criteria ensure that the use of the material will not have overall adverse effects and that it is of sufficient quality to support a sustainable market. End-of-waste criteria are material specific, as each material will have different characteristics, risks and intended uses. End-of-waste criteria have been set at EU level for glass cullet, and copper, iron, steel and aluminium scrap. Where no EU-level end-of-waste criteria have been set, applications for case-specific end-of-waste criteria can be made by specific national bodies that each MS shall notify to European Commission and the other Member States for the third-party conformity assessment of proposed criteria. According to EC (2022b), the current priority list for defining new end-of-waste criteria includes the following waste/by-product categories and streams in the top tercile:

1) Plastics; 2) Textiles; 3) Rubber; 4) Mineral fractions of construction and demolition wastes and 5) Paper and cardboard.

Policy instruments

Policy instrument (acc. to the European Environment Agency): When European environmental policies were first developed, many policy instruments focused on specific environmental problems. Since no single policy instrument can provide solutions to all problems, the spectrum of policies has broadened gradually to address increasingly complex environmental and health related problems. Today, many environmental policy interventions combine:

a) Traditional regulatory approaches, sometimes labelled 'command-and-control measures' (for example emission standards, bans of toxic substances, and land planning instruments)
b) Market based instruments (such as environmental taxes and greenhouse gas emission trading)
c) Awareness raising (including for example energy efficiency labels and communication campaigns).[14]

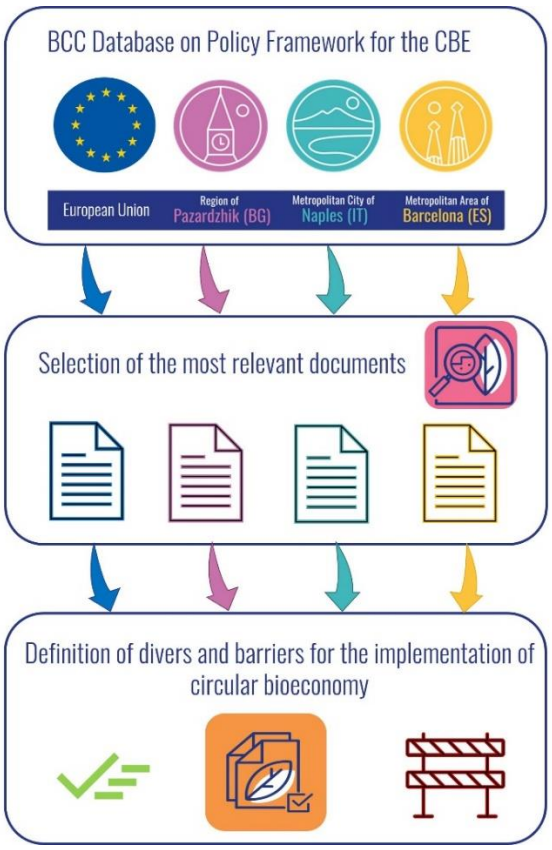
4.1.3. Identification of drivers and barriers in the Database on Policy Framework

For the analysis of legal, environmental, economic, technical, and social drivers and barriers, a selection of the most relevant documents from the updated Database on Policy Framework (from D3.1) was made at EU level and for the three pilot areas Pazardzhik Province (PP), Metropolitan City of Naples (MCN) and Metropolitan Area of Barcelona (MAB) at national, regional, and local level.

The identification of drivers and barriers in the legal framework for the implementation of biocircular biowaste management was carried out in collaboration of LIST at EU-Level and the local partners REAP, CMNA and AMB for the pilot areas. The most important laws and documents were selected and analysed in depth to select relevant passages to identify legal opportunities and limitations that foster or hinder the implementation of new biocircular value chains (Figure 4). Focus was set on the parts related to biowaste and bio-based products, and barriers and drivers were classified into the categories reported in 4.1.1. In the Annexes (Chapter 9.1 to 9.4) there are links to the respective tables of the selected policy frameworks, which contain relevant text passages from the legal documents and a detailed analysis of drivers and barriers identified in this context. The content of the Annexes are discussed in detail in chapters 6.1 and 6.2.

[14] https://www.eea.europa.eu/themes/policy/intro

Figure 4 : Methodology for the analysis of opportunities and shortcomings for the implementation of CBE at EU level and for the selected value chains in the three pilot areas.



The reference documents were analysed by using the following classification:

Scope	Sectors
EU	Administration (Admin)
National (Bulgaria, Italy, Spain)	Agriculture and fertiliser products (Agri)
Regional (Bulgarian South-Central Region, Campania, Catalonia)	Biocircular Products (BP)
Local (Pazardzhik Province, Metropolitan City of Naples, Metropolitan Area of Barcelona)	Circular Bioeconomy (CBE)
	Environmental Protection (EP)
	Energy
	Waste management (WM)

4.1.4. Identification of drivers and barriers along the selected pilot value chains

Shortcomings and opportunities that may limit or foster biocircular products/processes at each specific stage of the selected biowaste chain in the pilot areas were identified during the 2nd Living Labs (LL#2), taking advantage of the experience of the local stakeholders. The local stakeholders of the three pilot regions, representing different sectors playing a role in the analysed value chain, were involved in the different steps for defining and planning the alternative scenarios for biowaste management: (i) the selection of the biowaste of concern; (ii) the development of the concept of the new value chain; (iii) the identification of the related existing challenges and the potential solutions in the current biowaste management system; and (iv) the validation of alternative scenarios.

In order to achieve better results from the Living Labs, preparatory guidelines with a detailed description of the respective value chain and with examples of categories, drivers and barriers in the pilot context were prepared and translated into the local languages to facilitate accessibility to the local stakeholders. They discussed about the legal/administrative, technological, economic, environmental, and social drivers and barriers to CBE implementation for the local value chains: i) the forestry value chain of PP; ii) the agro-industrial and municipal biowaste chains of the MCN and iii) the municipal biowaste chain of the MAB. The LL#2 of MAB took place on-site on 16/09/2022, the LL#2 of PP and MCN were held online on 22 and 30/09/2022.

In addition to the LL#2, six external experts from across Europe were invited to share their experience and perspective with the consortium during a project meeting called "2nd Peer Review Session" (PRS#2). To be well prepared for the PRS#2, the international reviewers were sent in advance a guideline with the main shortcomings and potential opportunities per pilot value chain previously identified by the consortium members and stakeholders during the LL#2. The PRS#2 was held online on 27/10/2022. During this session, open questions for each identified value chain in the pilot areas were discussed and the experts added further drivers and barriers per category to the ones already identified in the 2nd Living Labs.

The involvement of numerous actors in the 2nd Living Labs and Peer Review Session made it possible to understand their approaches and interests, and to clarify what gaps and inadequacies they see in the current regulatory framework that hinder the uptake of bio-based solutions (Figure 5). The collective knowledge generated thanks to the support of local stakeholders and international experts ensures that the decisions taken by the project partners are in line with local priorities and existing international practices.

Figure 5 : Methodology for obtaining data on "Regulatory and market bottlenecks and sustainable drivers to circular bioeconomy implementation" from the three pilot areas during the three 2nd Local Living Labs and the 2nd Peer Review Session

5. RESULTS

5.1. Drivers and barriers identified in the analysis of the current CBE Policy Framework

This section includes the main legal drivers and barriers to the implementation of circular bioeconomy identified from the analysis of the Database on Policy Framework (DBPF) first at EU level and then at pilot level (national, regional, and local).

The updated and complete Database on Policy Framework can be found here.

5.1.1. Drivers and barriers in the CBE Policy Framework of the European Union

The selection of relevant EU documents from the DBPF for the implementation of bio-based value chains can be found in Table 1, identified legal drivers and barriers per category are listed in Annex 9.1 and discussed in the chapters 6.1 and 6.2.

Table 1 : Selection of relevant CBE documents for the analysis of drivers and barriers at EU level.

Year	Code	Title of the document
2011	2011/142/EC	Commission Regulation (EU) No 142/2011 of 25 February 2011 implementing Regulation (EC) No 1069/2009 of the European Parliament and of the Council laying down health rules as regards animal by-products and derived products not intended for human consumption and implementing Council Directive 97/78/EC as regards certain samples and items exempt from veterinary checks at the border under that Directive Text with EEA relevance
2013	2013/727/EU	Commission Implementing Decision of 6 December 2013 establishing a format for notifying the information on the adoption and substantial revisions of the waste management plans and the waste prevention programmes (notified under document C(2013) 8641)
2015	2015/2119/EU	Commission Implementing Decision (EU) 2015/2119 of 20 November 2015 establishing best available techniques (BAT) conclusions, under Directive 2010/75/EU of the European Parliament and of the Council, for the production of wood-based panels
2015	2015/720/EU	Directive (EU) 2015/720 of the European Parliament and of the Council of 29 April 2015 amending Directive 94/62/EC as regards reducing the consumption of lightweight plastic carrier bags

Year	Code	Title of the document
2015	2015/2283/EU	Regulation (EU) 2015/2283 of the European Parliament and the Council of 25 November 2015 on novel foods, amending Regulation (EU) No 1169/2011 of the European Parliament and of the Council and repealing Regulation (EC) No 258/97 of the European Parliament and of the Council and Commission Regulation (EC) No 1852/2001
2018	2018/1147/EU	Commission Implementing Decision (EU) 2018/1147 of 10 August 2018 establishing best available techniques (BAT) conclusions for waste treatment, under Directive 2010/75/EU of the European Parliament and of the Council (notified under document C(2018) 5070)
2018	2018/2001/EU	Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast)
2018	COM/2018/673 final	COM/2018/673 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society, and the environment
2018	2018/850/EU	Directive (EU) 2018/850 of the European Parliament and of the Council of 30 May 2018 amending Directive 1999/31/EC on the landfill of waste
2018	2018/851/EU	Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste
2018	2018/852/EU	Directive (EU) 2018/852 of the European Parliament and of the Council of 30 May 2018 amending Directive 94/62/EC on packaging and packaging waste
2019	COM/2019/640 final	COM/2019/640 final. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal
2019	2019/2031/EU	Commission Implementing Decision (EU) 2019/2031 of 12 November 2019 establishing best available techniques (BAT) conclusions for the food, drink and milk industries, under Directive 2010/75/EU of the European Parliament and of the Council (notified under document C(2019) 7989
2019	2019/1597/EU	Commission delegated decision (EU) 2019/1597 of 3 May 2019 supplementing Directive 2008/98/EC of the European Parliament and of the Council as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste

Year	Code	Title of the document
2019	2019/1004/EU	Commission Implementing Decision (EU) 2019/1004 of 7 June 2019 laying down rules for the calculation, verification and reporting of data on waste in accordance with Directive 2008/98/EC of the European Parliament and of the Council and repealing Commission Implementing Decision C(2012) 2384 (notified under document C(2019) 4114)
2019	2019/904/EU	Directive (EU) 2019/904 of the European Parliament and of the Council of 5 June 2019 on the reduction of the impact of certain plastic products on the environment
2019	2019/1009/EU	Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003
2019	2019/2000/EU	Commission Implementing Decision (EU) 2019/2000 of 28 November 2019 laying down a format for reporting of data on food waste and for submission of the quality check report in accordance with Directive 2008/98/EC of the European Parliament and of the Council
2020	COM/2020/98 final	COM2020/98/final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A new Circular Economy Action Plan for a cleaner and more competitive Europe
2021	COM/2021/572 final	Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: New EU Forest Strategy for 2030
2022	2022/1616/EC	Commission Regulation (EU) 2022/1616 of 15 September 2022 on recycled plastic materials and articles intended to come into contact with foods, and repealing Regulation (EC) No 282/2008
2022	COM/2022/230 final	Commission staff working document implementing the repower EU action plan: investment needs, hydrogen accelerator and achieving the biomethane targets
2022	COM/2022/682 final	COM/2022/682 final. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: EU policy framework on bio-based, biodegradable, and compostable plastics

5.1.2. Drivers and barriers in the CBE Policy Framework of Pazardzhik Province

The selection of relevant documents from the DBPF for the implementation of bio-based value chains in the PP pilot can be found in Table 2, identified legal drivers and barriers per category are listed and analysed in detail in Annex 9.2. and discussed in the chapters 6.1 and 6.2.

Table 2 : Selection of relevant CBE documents for the analysis of drivers and barriers in PP at national and local level.

Scope	Year	Title of the document (English translation)
National	2012	Waste Management Act (WMA) 2012 (amend. SG 100 of 16 December 2022)
National	2013	Regulation No 6 of 27 August 2013 on the conditions and requirements for construction and operation of landfills and other facilities and installations for recovery and disposal of waste (amend. SG 36 of 1 May 2021)
Local	2014	Regulation on the disposal, (separate) collection, transport and shipment of construction waste and household waste, including biowaste and household hazardous waste in the municipality of Pazardzhik
National	2017	Regulation for Separate Collection and Treatment of Biowaste (amend. Dz. ART.2 of 8 January 2021)
National	2018	National action plan for energy from forest biomass 2018-2027
National	2021	National Waste Management Plan 2021-2028
Local	2021	Ordinance on Determination and Administration of Local Fees and Prices of Services on the Territory of Pazardzhik Municipality as of December 2021

5.1.3. Drivers and barriers CBE Policy Framework of the Metropolitan City of Naples

The selection of relevant documents from the DBPF for the implementation of bio-based value chains in the MCN pilot can be found in Table 3, identified legal drivers and barriers per category are listed and analysed in detail in Annex 9.3 and discussed in the chapters 6.1 and 6.2.

Table 3 : Selection of relevant CBE documents for the analysis of drivers and barriers in the MCN at national, regional and local level.

Scope	Year	Title of the document (English translation)
National	1995	Ecotax (Ecotassa): Law n. 549 of 28th of December 1995
National	2006	Legislative Decree 3 April 2006, n. 152 Environmental regulations (Official Gazette No. 88 of 14 April 2006). National law for the implementation of the Waste Framework Directive, provides for measures aimed at protecting the environment and human health
National	2012	Ministerial Decree of July 6, 2012, Incentives for energy from non-photovoltaic renewable electric sources
National	2013	Directorial Decree 7-10-2013. Italy's National Programme for Waste Prevention
National	2013	Decree 358/2013, 13-10-2013. "Task Force no .5 - Analysis and elaboration of food waste reduction models" within the framework of the "Study group for the identification of political strategies and priorities"
National	2013	Law no. 147 of December 27, 2013. Provisions for the formation of the annual and multi-year state budget (Stability Law 2014)
National	2015	Law no. 221 of December 28, 2015. Environmental provisions to promote green economy measures and to contain the excessive use of natural resources (Environmental Annex to the Stability Law 2014)
National	2016	Law 19 August 2016, n. 166, Provisions concerning the donation and distribution of food and pharmaceutical products for the purposes of social solidarity and waste reduction
Regional	2016	Resolution no. 685 of 6 December 2016, published in the B.U.R.C. no. 85 of 12 December 2016 updating acts of the Regional Plan for the Management of Urban Waste (PRGRU)
National	2016	The Ministerial Decree No 264 of 13 October 2016 on indicative criteria to facilitate the demonstration of the existence of the requirements for qualifying process wastes as by-products and not as waste
National	2017	Towards a Model of Circular Economy for Italy. Overview and Strategic Framework. November 2017
National	2019	1-1-2019. Strategy plan. Bioeconomy in Italy. A unique opportunity to reconnect Economy, Society, and the Environment"
National	2020	Government act 168, 5th March 2020. Scheme of legislative decree implementing Directive (EU) 2018/850, amending Directive 1999/31 / EC on the landfill of waste (168)

Scope	Year	Title of the document (English translation)
National	2020	Decree 16-10-2020. Approval of the National Consortium for the organic recycling of composting and biodegradable plastic packaging
Local	2020	Deliberation of Municipal Council n. 27, 15-4-2020. Regulation "TARI" for the disciplines of waste taxes
National	2021	Decree no. 261 of 23 June 2021. Approval of the "General program for the prevention and management of packaging and packaging waste 2019-2023"
National	2021	Resolution no. 105/2021. Waste classification guidelines
National	2022	Decree n. 240 of 15 September 2022. Development of biomethane, according to criteria to promote the circular economy - Biomethane production
Regional	2022	Resolution of the Regional Council n. 364 of 07/07/2022. Update of the Regional Plan for the Management of Special Waste in Campania

5.1.4. Drivers and barriers identified in the Legal Framework of the Metropolitan Area of Barcelona

The selection of relevant documents from the DBPF for the implementation of bio-based value chains in the MAB pilot can be found in Table 4, identified drivers and barriers per category are listed and analysed in detail in Annex 9.4. and discussed in the chapters 6.1 and 6.2.

Table 4 : Selection of relevant CBE documents for the analysis of drivers and barriers in the MAB at national, regional and local level.

Scope	Year	Title of the document (English translation)
Regional	2008	Law 8/2008, of July 10, on the financing of waste management infrastructures and the fees for the disposal of waste
Regional	2009	Legislative Decree 1/2009, of July 21, approving the revised text of the Waste Regulatory Law
National	2010	Royal Decree 865/2010 of 2 July 2010 on cultivation substrates
National	2012	Royal Decree 1528/2012 of 8 November 2012 laying down rules on animal by-products and derived products not intended for human consumption
National	2013	Royal Decree 506/2013 of 28 June 2013 on fertiliser products. Last amendment: 18 February 2022
Regional	2014	Law 2/2014 of 27 January 2014 on fiscal, administrative, financial, and public sector measures

Scope	Year	Title of the document (English translation)
National	2014	Royal Decree 413/2014, of 6 June, which regulates the activity of electricity production from renewable energy sources, cogeneration and waste
National	2015	Spanish Strategy on Bioeconomy. Horizon 2030
National	2015	National Waste Management Framework Plan (PEMAR) 2016-2022
Regional	2018	Royal Decree 209/2018, of 6 April, approving the Territorial Sectoral Plan for Municipal Waste Management Infrastructures in Catalonia (PINFRECAT20)
Regional	2018	Royal Decree 210/2018, of 6 April, approving the Programme for the Prevention and Management of Waste and Resources in Catalonia (PRECAT20)
National	2018	Decree APM/189/2018 of 20 February, which determines when production waste from the agri-food industry destined for animal feed is a by-product within the meaning of Law 22/2011 of 28 July on Waste and Contaminated Soil.
Local	2019	PREMET25. Metropolitan Program on Prevention and Use of Resources and Municipal Waste 2019-2025, including the Metropolitan Zero Waste Agreement
National	2020	Royal Decree 646/2020 of 7 July regulating the disposal of waste by landfill
Regional	2020	Law 3/2020, of March 11, on the prevention of food loss and waste
Regional	2020	Law 5/2020, of April 29, on fiscal, financial, administrative and public sector measures and the creation of the tax on facilities that affect the environment
National	2020	España Circular 2030. Spanish Strategy on Circular Economy
Regional	2021	Agreement GOV/141/2021, of 14 September, approving the Bioeconomy Strategy of Catalonia 2021-2030
National	2021	Circular Economy Action Plan 2021-2023
Local	2021	Fiscal ordinance regulating metropolitan fees for the treatment and disposal of municipal waste
National	2022	Law 7/2022, of April 8, on waste and contaminated soil for a circular economy
National	2022	Law 34/2022 of 13 December on the regime for the assignment of taxes from the State to the Autonomous Community of Catalonia and setting the scope and conditions of said assignment
Regional	2022	Decree Law 17/2022 of 20 December by which measures are established to adapt to the tax on the deposit of waste in controlled deposits, incineration and co-incineration

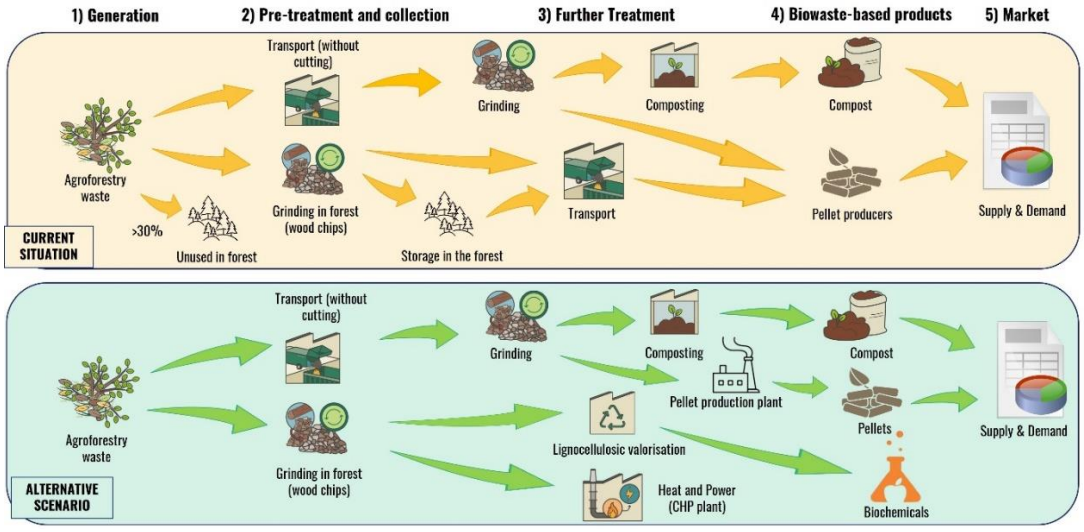
5.2. Opportunities and shortcomings identified through the analysis of the selected pilot bio-based value chains

This section presents the opportunities/ recommendations and the shortcomings identified for each selected bio-based value chain at pilot level with the feedback from the stakeholders and experts in the 2nd local Living Labs and the 2nd Peer Review Session. Each chain is explained in detail. The results have been reported per pilot and an introduction of the chain has been explained. Opportunities and limitations were defined according to the different stages of the state-of-the art and innovative value chains.

5.2.1. Opportunities and shortcomings in the forest residues value chain in Pazardzhik Province

In the case study of Pazardzhik Province (PP), the value chain of forest wood biomass residues is analysed. Currently, forestry residues are mainly used for wood pellet production, although more than 30%of the forestry residues remain unused in the forest. Increased collection of this type of waste may lead to new business opportunities with positive environmental impacts. Two alternative scenarios for the sustainable use of this little-used residues stream were considered: (i) generation of thermal energy and/or cogeneration and (ii) valorisation of lignocelluloses for the production of biochemicals from forest wood residues (Figure 6).

Figure 6 : Forestry residues chain in PP - Current situation and alternative scenario.



The full lists of the identified opportunities/recommendations and shortcomings in the implementation of the circular bioeconomy in PP are presented in Table 5 and Table 6 respectively. The results presented in the tables are the outcome of the elaboration of the inputs obtained during the 2nd local Living Lab and the 2nd Peer Review Session for the PP pilot.

Table 5 : Overview of all collected potential opportunities/recommendations for a biocircular value chain in PP. The drivers were classified into the following categories: Legal/Administrative (L/A); Technical (Tec), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

PP – Potential opportunities/recommendations to implement CBE in the forest residues value chain

	ALL STAGES	PRE-TREATMENT & COLLECTION	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
Potential opportunities/ recommendations proposed by the BCC consortium and the local stakeholders in LL#2	• ***Ec:*** Granting of funding for research in the field of forestry residues. • **SI:** Strengthening the industrial awareness of the benefits resulting from the sustainable use of forestry residues. • ***Tec:*** Elaboration and sharing of a good database on forest residues (type, quantity, quality) for the evaluation of new treatment methods.	• ***Tec:*** Improving the efficiency of existing collection and transport facilities for forestry residues. • ***Tec:*** Introducing new, more efficient technologies for the collection, storage, and transport of forestry residues. • ***E/H:*** Collecting forestry residues to reduce the risk of forest fires, which severely affect flora, fauna and human health and increase GHG emissions. • ***Ec:*** Collecting forestry residues to reduce firefighting and reforestation costs after fires.	• ***Ec:*** Introducing financial incentives for investments in new plants for the valorisation of forestry residues, e.g., CHP units. • ***L/A:*** Extending the tender-intervals (giving more planning security).	• ***L/A, Ec:*** Introducing legal incentives to produce renewable energies (feed-in tariffs) and biochemicals (e.g., tax reduction) from forestry residues. • ***E/H:*** Reducing GHG emissions using renewable fuels or biochemicals coming from forestry residues instead of fossil-based products.	• ***L/A:*** Introducing EU quality certifications for bio-based products (e.g., biochemicals from forestry residues). • ***Soc:*** Fostering campaigns for the sustainable use of wood biomass (restriction of the use of moist raw wood as firewood).
Potential opportunities/ recommendations proposed by the international peer-reviewers in PRS#2	• **SI:** Elaboration of a detailed, comprehensive waste management plan involving all stakeholders along the entire value chain and including a central provider for all information.	• ***Ec:*** Promoting new jobs and start-ups. • ***Tec:*** Looking at existing technologies to collect wood to check the applicability and the potential obstacles already experimented elsewhere (e.g., banana harvesting in Brazil).	• ***Ec, Tec:*** Extending the fields of biowaste application by adding biowaste-based products to the conventional fossil-based products. • **Soc:** Sharing best practices and experiences among adjacent communities at	**SI:** Encourage collaboration between policymakers, researchers, and market players to incentivise new start-ups that address all relevant aspects of value chain.	• **SI:** Clarify and make visible the benefits of biowaste value chains for stakeholders and businesses at all levels. • ***Soc:*** Educating people (of all ages) about the benefits of using products made from biowaste.

	ALL STAGES	PRE-TREATMENT & COLLECTION	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
		• ***Ec:*** Testing a fee and incentive programme to foster pre-treatment and collection of forest residues.	different levels (from streets to neighbourhoods to urban areas) to work towards integrated and harmonised planning. • ***L/A:*** With the introduction of the obligation to collect municipal biowaste separately, it would make sense to compost forest residues (as structural material) as a new recycling route. • ***Ec:*** Introduction of financial support for innovative treatment technologies (R&D, pilots, demos).		• **SI:** Providing State interventions – also in form of incentives to support a profit-driven free market that may not be ready for new strategies in this field. • ***Soc:*** Raising awareness (among young people) to promote behavioural change. • ***Ec:*** Promoting taxes on fossil fuels for fair competition with bio-based products.

Table 6 : Overview of all collected shortcomings for a biocircular value chain in PP. The barriers were classified into the following categories: Legal/Administrative (L/A); Technical (Tec), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

PP – Shortcomings to implement CBE in the forest residues value chain					
	ALL STAGES	**PRE-TREATMENT & COLLECTION**	**TREATMENT**	**BIOWASTE-BASED PRODUCTS**	**MARKET**
Shortcomings proposed by the BCC consortium and the local stakeholders in LL#2	• ***L/A***: Lack of political will to change the current situation. • ***L/A***: Lack of appropriate regulations for forestry residues valorisation. • ***L/A***: Uncertainty of forest administration and management (state, municipal, and private). • **SI**: Lack of best practices' exchange in the forest sector from other remote EU regions.	• ***E/H***: Lack of environmental impact analysis for forestry residues collection (soil erosion, biodiversity losses, additional transport compared to fire risk reduction). • ***Ec:*** Inaccessibility of forestry terrain making forestry residues collection difficult and expensive. • ***Tec***: Lack of a regional biomass logistics centre for collection and distribution. • ***Ec:*** Leaving the forest residues in the forest is a cheaper solution than collecting them in poorly accessible areas.	• ***L/A***: Lack of policy incentives for the sustainable use of forestry residues. • ***Ec:*** Lack of planning security for long-term, tender-bound investments for new infrastructure. • ***Ec:*** Too high investments for SMEs to implement a sustainable treatment of forestry residues.	• **SI**: Strong lobby of fossil fuel companies against the use of forestry residues as an alternative fuel. • ***Ec:*** Conflict of interest between different biowaste products (e.g., pellets vs. biochemicals). • ***L/A***: Lack of regulations to define the status "from biowaste to product" (e.g., biochemicals production).	• ***Ec:*** Fluctuations in market demand for products from forestry residues (pellets and biochemicals). • ***Soc***: Lack of willingness to change the current situation (use of individual GPL boiler heating instead of district heating systems).
Shortcomings proposed by the international peer-reviewers in PRS#2	• ***Ec:*** Limited competitiveness of innovative options compared to other forms of energy and materials already available on the market.	• ***E/H:*** Limitation for collecting 100% of forest residues to maintain the nutrient cycle within forest soil and use controlled fire as part of natural cycle in a forest.	• ***E/H***: Limited and often difficult to access environmental assessment of the new processes. Lack of clarity about the tools to be used to assess environmental performance (e.g., LCA,	• ***Tec:*** Limited knowledge about appropriate technologies for extracting new products from forest residues.	• ***L/A***: Limited promotion of the innovative products and their benefits compared with old products (for example products from fossil fuels).

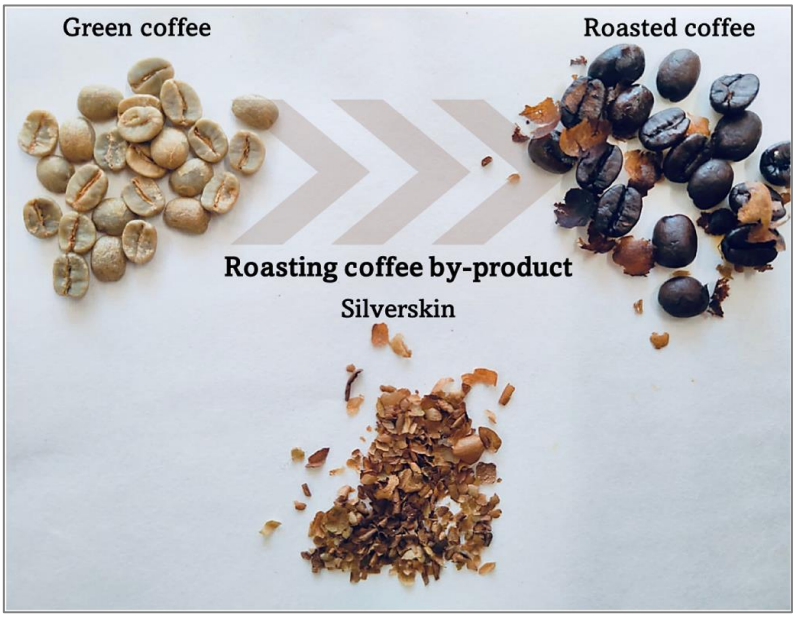
	ALL STAGES	PRE-TREATMENT & COLLECTION	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
	• **Tec:** Lack of clarity on the relative benefits of the forestry residues treatment options. • ***L/A:*** Difficulty in developing a general tool appropriate for all policymakers since all steps of the value chain may turn out to be quite site dependent. • ***Ec:*** Lack of compensation schemes (e.g., feed-in tariffs) for CHP. • ***E/H:*** Lack of biodiversity impact analysis (forest residues collection may harm species).	• ***Ec:*** Expensive transport for low-density biomass combined with the increase in fuel costs due to the current energy crisis.	carbon emission assessment, etc.). • ***E/H:*** Identification of potential environmental impacts of lignocellulosic valorisation needed.	• ***Ec:*** Potentially high dependence of bio-based products on fluctuating market demand. • ***L/A:*** Unlevel playing field: while bio-based products must prove sustainability (certifications), fossil products do not have to prove anything.	• ***Ec:*** Lack of incentives to make a market profitable, which may not be ready for new strategies in this field.

5.2.2. Opportunities and shortcomings in the agro-industrial biowaste value chain in the Metropolitan City of Naples

The selected biowaste stream for the Metropolitan City of Naples (MCN) is coffee silverskin, a thin tegument, which is located directly around the two beans of the coffee cherry and is accumulating in large amounts during coffee roasting activities (Figure 7). This chain was chosen as an example of biowaste from the agro-industrial sector because the alternative value chain is new and there is the possibility of using primary data from existing local industries. Currently, this type of waste is treated in the same plants that receive municipal biowaste: anaerobic digestion or composting plants (Figure 8). It is important to underline that, although biowaste is separated at source and collected door-to-door in most municipalities of the MCN, the current limited capacity of biological treatment plants makes it necessary to export biowaste also outside the Campania region. Therefore, it is important to find alternative solutions for the treatment of biowaste from the municipal and agro-industrial sectors.

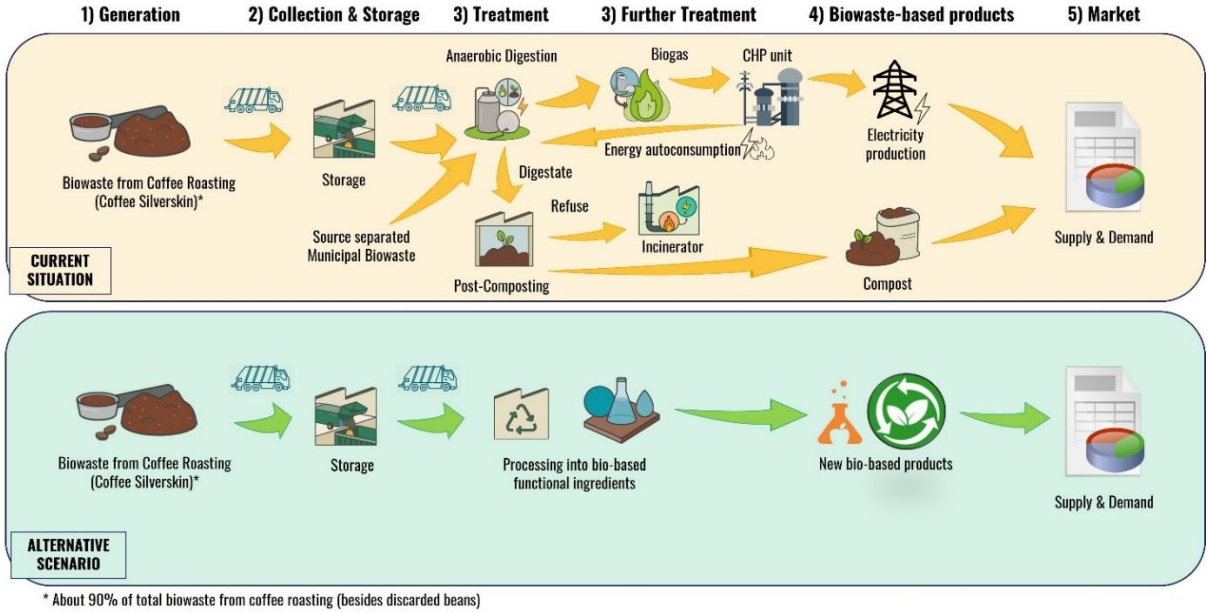
In the alternative scenario, coffee silverskin, which accounts for about 90% (by weight) of the total residues from coffee roasting (besides broken and unsuitable coffee beans), is stored and then transported for treatment to extract functional ingredients that are used to produce new bio-based products. According to Nolasco et al. (2022 a, 2022b), coffee silverskin has a great potential for use in the food sector due to its nutritional profile, as it contains 18.9% protein and 34.7% fibre, and has a low-fat content (3.0%). Coffee silverskin is suggested to be used as dietary fibre source, in bakery products (breads, biscuits), beverages (tea) or as a smoke flavour additive (Klingel et al. 2020). In addition to that it could be used as filler for biocomposite (Nolasco et al. 202 2a) or for the production of biodegradable packaging (Garcia & Young-Teck 2021).

Figure 7 : Coffee silverskin: the only waste material from the roasting phase of the green coffee beans (Nolasco 2022a).



The case study under investigation is already running at pilot scale in the MCN: it is based on 20 tonnes of coffee silverskin recovered from an industry that roasted around 2,600 tonnes of coffee in 2021. This corresponds to around 3% of 95,700 tonnes of total coffee roasted in the MCN.

Figure 8 : Agro-industrial biowaste (biowaste from the coffee chain) in the MCN - Current situation and alternative scenario.



The full lists of identified opportunities/recommendations and shortcomings in the implementation of the circular bioeconomy in the agro-industrial biowaste chain in the MCN are presented in Table 7 and Table 8 respectively. The results shown in the tables are the outcome of the elaboration of the inputs obtained during the 2nd local Living Lab and the 2nd Peer Review Session for the pilot of the MCN.

Table 7 : Overview of all collected potential opportunities/recommendations for a biocircular value chain in the MCN. The drivers were classified into the following categories: Legal/Administrative (L/A); Technical (Tec), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

MCN - Potential opportunities/recommendations to implement CBE in the agro-industrial biowaste value chain

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
Potential opportunities/ recommendations proposed by the BCC consortium and the local stakeholders in LL#2	• ***L/A***: Simplification of the bureaucratic burden for the introduction of biowaste chains for SMEs. • **SI**: Promoting local agro-industrial symbiosis for the use of biowaste and by-products. • **SI**: Increasing industrial awareness of the benefits of a circular biowaste management. • ***Ec:*** Granting of funding for research in the field of agro-industrial biowaste.	• ***Tec***: Providing an updated and comprehensive database on the generation of agro-industrial waste streams (quantity, quality, destination). • ***Tec, L/A, Soc***: Reduction of food losses in agro-industrial processes due to overly strict product standards (e.g., size of coffee beans, shape of carrots).	• ***E/H***: Reduction of GHG emissions by improving the quality and quantity of separate biowaste collection.	• ***L/A***: Introduction of (higher) landfill and incineration taxes to promote new biowaste valorisation. • **SI**: Provide easily accessible information for the valorisation of agro-industrial waste. • **Tec**: Increasing the number of decentralised anaerobic digestion and composting plants for municipal biowaste treatment. • ***L/A:*** Simplifying the licensing and administrative procedures for new treatment plants.	• ***L/A, Ec***: Legal and/or economic incentives for new local value chains within the agro-industrial sector (e.g., tax reductions). • ***L/A***: Having access to a comprehensive and clear list of biowaste-based products/ agro-industrial by-products and end-of-waste criteria.	• ***L/A***: Establish lower costs for biowaste-based compared to fossil-based products, e.g., by reducing VAT. • ***L/A***: Introduce EU quality certification for biowaste-based products from the agro-industrial sector. • ***Soc:*** Higher demand for biocircular-oriented products due to growing social awareness of the positive effects.

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
Potential opportunities/ recommendations proposed by the international peer-reviewers in PRS#2	• ***Tec*** **& SI:** Use synergies between industries (e.g., energy from recycling). • ***Soc:*** Awareness raising about the importance of effective biowaste management to human health and the environment. • ***Ec:*** It is very important that the proposed solutions generate income and jobs. This applies to all phases and should be clearly advertised.		• ***Ec:*** Economic or political incentives to promote the financial interest of industry in recycling or collecting their by-products. • ***E/H:*** Development of a new collection chain (e.g., spent coffee grounds) with "soft" transport in urban areas, e.g., with bicycles, to limit the impact of transport.	• **SI**: Incentives for new areas of research, business, and the promotion of start-ups. • ***L/A:*** New taxes on landfilling and incineration should be transferred to CBE sectors. • ***Tec:*** The providers of new product ideas need to be informed by the national authorities about the latest treatment technologies in order for the proposal to be successful.	**SI, *L/A, Ec:*** Incentives for start-ups dedicated to all aspects of the value chain should be created through collaboration between policy makers, researchers, and market participants.	• ***Soc:*** It is important to provide clear information on the absence of contamination or potential harm from waste-derived products to prevent reluctance to use them.

Table 8 : Overview of all collected shortcomings for a biocircular value chain in the MCN. The barriers were classified into the following categories: Legal/Administrative (L/A); Technical (Tech), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

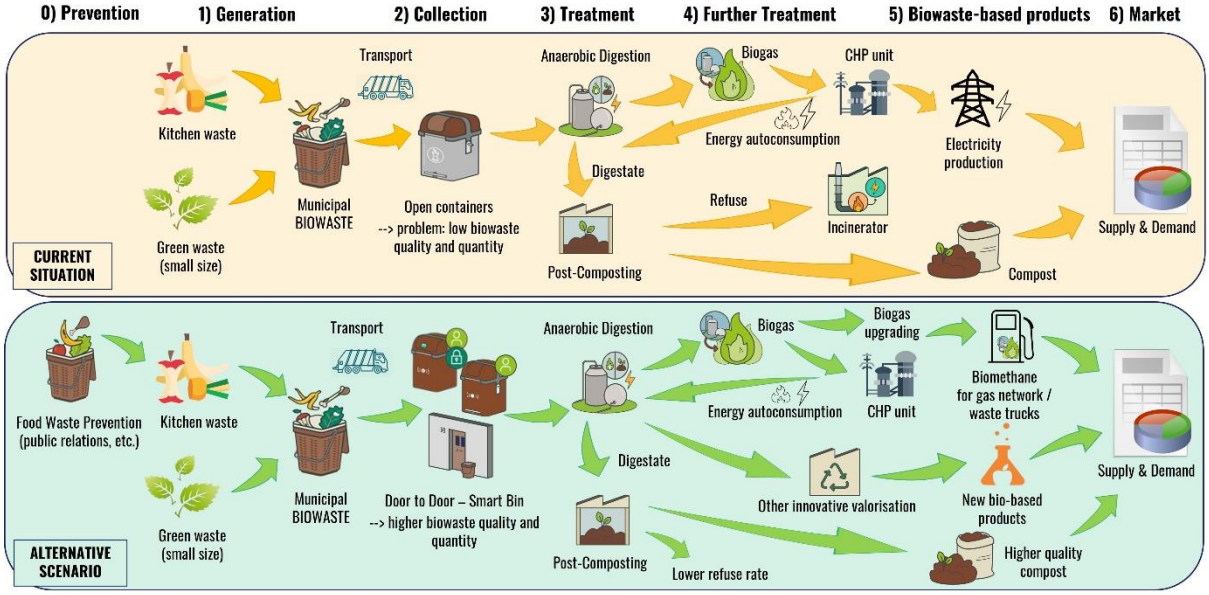
MCN - Shortcomings to implement CBE in the agro-industrial biowaste value chain						
	ALL STAGES	**GENERATION**	**COLLECTION & STORAGE**	**TREATMENT**	**BIOWASTE-BASED PRODUCTS**	**MARKET**
Shortcomings proposed by the BCC consortium and the local stakeholders in LL#2	• ***L/A***: Lack of political will to change the current situation. • **SI**: Lack of exchange of experience and good practice. • ***L/A***: Too complex/ contradictory regulations • ***L/A***: Administrative shortcomings in the implementation of research results, which can consequently be more easily implemented abroad on an industrial scale.	• ***L/A***: Lack of clarity on the definition of "by-products", "products" and "wastes" and how to achieve "end of waste" status.	• ***Tec:*** Specific agro-industrial waste streams are currently not separately collected and/or stored. • ***E/H***: Lack of a thorough analysis of the environmental impacts of different waste collection and treatment systems.	• ***L/A***: Permits for the construction of valorisation plants are too long and cumbersome. • ***L/A***: Lack of planning security for long-term investments in innovative infrastructure. • ***Tec:*** Lack of decentralised innovative biowaste valorisation. • ***Ec:*** Too high investments for SMEs. • ***L/A***: Difficulty in upgrading biowaste if it is not defined as a by-product (classification as "end of waste").	• ***L/A***: Lack of comprehensive regulations on the status "from biowaste to product". • ***Ec:*** Conflict of interest between different products (e.g., compost vs. bio-based ingredients). • ***E/H:*** Lack of in-depth environmental analysis for the use of biowaste from agro-industrial sector as food ingredients.	• ***Soc:*** People's reluctance to use products made from biowaste (especially food such as functional ingredients). • ***Ec:*** Fluctuations in market demand for products from biowaste.

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
Shortcomings proposed by the international peer-reviewers in PRS#2	• ***E/H:*** Lack of clear health risk assessment and risk distribution along the value chain. • ***SI:*** The topic of products made of coffee residues is new for almost all the stakeholders at all levels and needs awareness raising.	• ***Tec:*** Depending on the technological path chosen, a very specific and continuous type (quality) of biowaste is required throughout the year, but the range of agricultural products depends largely on the season and climatic changes. • ***Ec:*** There are often some competing uses for agro-industrial waste. Therefore, in all proposed cases, we should be careful not to create unnecessary competition.	• ***E/H:*** Partial incorporation of crop residues into the soil must be maintained. Example: In Brazil, 40% of the leaves (biomass) or sugar cane must remain in the soil to maintain the nutrient cycle and reduce the amount of industrial fertiliser. • ***L/A:*** Unclear and yet untested strategies. • **Tec:** Possibility of feedstock contamination- LCAs required for new products. • ***Ec:*** If waste is collected (e.g., spent coffee grounds): Giving financial incentives to cafeterias for collection and storage. • ***E/H:*** Risk of new urban traffic by collection a new waste stream (e.g., spent coffee grounds) in urban areas.	• ***Tec:*** Lack of data to assess the environmental impact of the valorisation process (e.g., extraction process). • ***Tec:*** Need for specific and possibly not directly available technologies.	• ***L/A:*** Since coffee waste is only a case study: There is still a lack of selected pattern for other waste streams that could be included in an urban strategy to avoid overlap and misunderstanding. • ***Ec:*** Lack of incentives from municipalities for new start-ups.	• ***L/A:*** Legal constraints for biowaste-based products: In Brazil, it is completely forbidden by law to produce food from residues (incl. the agri-food sector). • ***Soc:*** Citizen's aversion to anything made from "residues" that has passed through a production chain - perhaps a higher acceptance could be achieved through local production. • ***Ec:*** A profit-driven free market may not be ready for new strategies in this field. State interventions – also in form of incentives - may be appropriate.

5.2.3. Opportunities and shortcomings in the municipal biowaste value chain in the Metropolitan Area of Barcelona

The case study of Metropolitan Area of Barcelona (MAB) analyses the separately collected biowaste treated in one of the MAB´s Ecoparcs. The alternative scenario to be studied foresees (i) the introduction of prevention measures to reduce the generation of food waste, (ii) a change in the separate collection of biowaste from open street containers to door-to-door collection and/or smart bins to increase the quality and quantity of biowaste collected, and (iii) the upgrading of the biogas produced from anaerobic digestion into biomethane to be injected into the local gas grid or used as biofuel (Figure 9). At present, most of the energy produced from the biogas delivered to the CHP unit is used for the plant's own consumption. An increase in the amount of high quality biowaste collected would also lead to an increase in usable biogas production: Keeping the total amount of biowaste treated, the amount of organic fraction to be fermented is higher in the alternative scenario and produces more biogas, as the impurities are lower compared to the BAU situation. With the planned improvement of the biowaste collection system, the quantity and quality of compost from post-composting of digestate would also increase.

Figure 9 : Municipal biowaste value chain in the MAB - Current situation and alternative scenario



The full list of the identified opportunities/recommendations and shortcomings in the implementation of the circular bioeconomy in the MAB pilot are presented in Table 9 and Table 10 respectively. The results shown in the tables are the outcome of the elaboration of the inputs obtained during the 2nd local Living Lab held on-site in Barcelona and the 2nd Peer Review Session for the pilot of the MAB

Table 9 : Overview of all collected potential opportunities/recommendations for a biocircular value chain in the MAB. The drivers were classified into the following categories: Legal/Administrative (L/A); Technical (Tech), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

MAB – Potential opportunities/recommendations to implement CBE in the municipal biowaste value chain

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
Potential opportunities/ recommendations proposed by the BCC consortium and the local stakeholders in LL#2	• ***Ec:*** Granting of funding for research in the field of municipal biowaste. • ***Soc:*** Successful public awareness campaigns on food waste prevention, separate collection, and biowaste-based products. • ***L/A:*** Easily accessible and understandable information on "how to achieve product status (end of waste) from a biowaste stream". • ***Tec:*** Updated and comprehensive database on the generation of municipal biowaste (quantity, quality, destination).	• ***Tec:*** Available updated database on municipal biowaste flows (quantity, quality, destination). • ***L/A, Soc:*** Well-elaborated local food waste prevention plans and awareness campaigns, e.g., the Catalan law against food waste. • ***L/A:*** Changing the existing local waste taxation towards PAYT systems. • ***Ec/Soc:*** The current increase in food prices leads to less food waste. • ***Soc:*** Buying in small local markets vs. large retailers (less transport and food waste).	• ***L/A:*** Policy incentives for DtD and PAYT. • ***E/H:*** Reduction of GHG emissions through better municipal biowaste collection (less incineration and landfilling). • ***L/A:*** New legislation for municipal biowaste quality improvement. • ***L/A:*** Legal enforcement of efficient separate collection systems. • ***Tec:*** Creation of a separate collection and recycling stream for animal waste.	• ***Ec:*** Financial incentives for investments coming from e.g., landfill/ incineration taxes. • ***Ec:*** Planning security for long-term investments, especially for SMEs. • ***L/A:*** Ban on incineration of biowaste to promote new recycling methods. • ***Tec:*** Improving the efficiency of existing municipal biowaste treatment facilities. • ***E/H:*** Reduction of GHG emissions through better municipal biowaste treatment. • ***Tec:*** Improving quality and quantity of separately collected MSW biowaste can create new treatment options.	• ***E/H:*** Less GHG emissions through replacing fossil fuels with renewable biomethane. • ***Tec:*** Higher quality of source separated municipal biowaste to produce higher quality compost. • ***L/A:*** Policy incentives for the biomethane production for injecting in the local gas grid.	• ***L/A:*** The introduction of an EU quality certification could enhance the official recognition of products from municipal biowaste. • ***L/A:*** Taxes on fossil-based materials would increase the market shares of bio-based products. • ***Ec:*** Higher revenues for compost could at least cover the costs of collection and composting.

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
		• ***Tec:*** Reducing the collection frequency for residual waste.		• ***L/A:*** Financial incentives such as tax reductions for innovative technologies to valorise municipal biowaste. • ***Ec:*** Cheaper and simpler treatment through better quality of waste separation; less sorting/treatment technology required.		
Potential opportunities/ recommendations proposed by the international peer-reviewers in PRS#2	• ***Soc:*** Local decentralised valorisation could be a pedagogic tool to increase municipal biowaste sorting but also prevention (see DECISIVE project) • ***L/A, SI:*** Creating a comprehensive narrative supporting both the specific intervention lines and the general policy-making procedures. This should be directed at policymakers and media representatives	• ***L/A:*** Promoting less biowaste generation through lower waste fees for those who produce less waste.	• ***L/A:*** A fees and incentives programme on municipal biowaste source separation should be carefully designed and tested, helping also to disseminate the right messages. • ***Tec, Soc:*** Smart bins generate big data that can be used to improve citizens' habits by communicating with them (Know-As-You-Throw) • ***L/A:*** Strict fines for the misuse or non-use of collection systems	• ***SI, Soc:*** Adjacent communities at different levels (from streets to neighbourhoods to urban areas) can share best practices and experiences and work towards integrated and harmonised planning on MSW biowaste treatment in line with CBE principles. • ***SI:*** Local authorities should create a specific framework for collaboration with the academic community or, more generally, with	• ***Ec, E/H:*** Assigning a real value to recycled carbon (e.g., compost). • ***SI:*** Through collaboration between policymakers, researchers and market players, new start-ups should be incentivised to address all aspects of the MSW biowaste value chain.	• ***SI:*** Having a good connection with local agriculture. • ***SI:*** Creating regular opportunities to talk to stakeholders and ensure that common strategies are followed in purchasing food and disposing of food waste.

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
	who are responsible for shaping public opinion. • ***Soc:*** Presenting MSW biowaste management in a quantitative perspective that is easily understood by the public so that people can see the potential improvement in their well-being or health status. • ***L/A:*** Administrations should incentivise food products with less packaging that could lead to less impurities in collected MSW biowaste.		demand a real commitment from the authorities.	stakeholders involved in the study of CBE aspects of the local economy. • ***L/A:*** The new EU targets for net recycling (excluding rejects) will foster the improvement of the quality of collected biowaste.		

Table 10 : Overview of all collected shortcomings for a biocircular value chain in the MAB. The barriers were classified into the following categories: Legal/Administrative (L/A); Technical (Tec), Economic (Ec), Environment/Health (E/H), Social (Soc); Stakeholder involvement (SI)

MAB - Barriers to implement CBE in the municipal biowaste value chain						
	ALL STAGES	**GENERATION**	**COLLECTION & STORAGE**	**TREATMENT**	**BIOWASTE-BASED PRODUCTS**	**MARKET**
Shortcomings proposed by the BCC consortium and the local stakeholders in LL#2	• ***L/A:*** Too high bureaucracy for SMEs and slow transposition of laws. • ***L/A:*** Bureaucracy, regulatory inconsistencies, and different implementation timeframes in different federal states. • **SI:** Limited exchange of best practices for innovative municipal biowaste chains from other EU cities. • ***L/A:*** Political unwillingness to	• ***Soc:*** Lack of awareness of food waste generation and prevention. • ***Soc:*** Difficulty in changing personal habits (planning for shopping, sharing food etc.).	• ***Tec:*** Lack of experience with smarts bins. • ***Ec:*** High costs of new collection systems (door-to-door or smart bins): transport, premises, and personnel. • ***Soc:*** Citizen's acceptance of (new) biowaste collection systems. • ***Soc:*** Lack of knowledge on correct source separation. • ***Soc:*** Low acceptance of smart bins (e.g., because of personal data protection, feeling of being controlled). • ***Tec:*** Lack of experience in how to deal with big data (smart bins). • ***Soc:*** Confusion in source separating bioplastics (biowaste or light-weight packaging bin?).	• ***Tec:*** High heterogeneity and impurities of input material for specific treatment processes. • ***Tec:*** Seasonal fluctuations of the amounts of separately collected biowaste. • ***Tec:*** Need to increase the capacity of existing AD plants to have enough biogas to upgrade. • ***Ec:*** Lack of planning security for long-term investments, especially for SMEs. • ***Ec:*** In most countries landfilling and incineration are cheaper (and often	• **L/A:** Lack of appropriate regulations for the injection of biomethane. • ***Ec:*** Conflict of interest between different biowaste value chains (compost vs. bioplastics). • ***E/H, Ec:*** New biowaste-based products will need to undergo an extensive evaluation of possible environmental impacts (e.g., accumulation of heavy metals). • ***E/H, Ec:*** Possibly higher energy consumption in the manufacture of new products.	• ***Ec:*** Lack of long-term security for revenue from sales (market demand for compost, biomethane). • ***L/A:*** Slow legal procedures for obtaining product status for an innovative technology. • ***Ec:*** Higher costs of biowaste-based products compared to fossil-based products (e.g., bioplastics vs. conventional plastics). • ***Soc:*** Potential health consequences from using insect protein (e.g., accumulation of heavy metals). • ***Soc:*** Consumers' reluctance to use

	ALL STAGES	GENERATION	COLLECTION & STORAGE	TREATMENT	BIOWASTE-BASED PRODUCTS	MARKET
	change the current situation in MSW biowaste management.		• ***E/H:*** Lack of environmental impact analyses about the pros and cons of changing the collection system.	unique) solutions compared to more innovative and sustainable treatments. • ***L/A, Tec:*** Difficulties in collecting and recycling bioplastics.		products derived from biowaste.
Shortcomings proposed by the international peer-reviewers in PRS#2	• ***E/H:*** The hygiene risk must be carefully assessed along the entire biowaste value chain. • ***Soc, SI:*** People in general do not have easily available information about what they are required to do and why, and there is a general sense of detachment from policymaking.	• ***Soc:*** Basic awareness raising of people (education at all levels) on the importance of reducing waste generation and on the importance of sorting waste before disposal.	***Soc:*** Door-to-door collection: Especially in summer, leaving perishable waste indoors for a long time can lead to disturbances or even potential hygiene problems. ***Soc, Tec:*** PAYT and smart bins do not necessarily lead to an increase in the quality of the collected biowaste. Sensibilisation campaigns are needed. ***Soc, SI:*** Uncontrolled tourism flows in the MAB are an important barrier to smart bins. Full cooperation of the population and responsible tourism would be needed.	• ***Tec:*** Carefully consider the risk of conflict between waste prevention and "oversized" higher valorisation treatment plants.	• ***Tec, E/H:*** The energy required to transport the compost to the farmland must be planned logistically. • ***L/A:*** Regulatory aspects for the sale of biomethane. E.g., in Brazil, the fuel market is exclusively controlled by a state-owned company.	• ***Ec:*** A profit-driven free market may not be ready for new strategies in this field. Public interventions – also in form of incentives - may be appropriate. • ***Tec:*** Lack of biomethane distribution infrastructure. • ***E/H, Tec, Soc:*** It is more advantageous for supermarkets and suppliers to sell products with a lot of packaging, as they can be safer transported. This barrier should be turned into a driving force by promoting local products.

6. DISCUSSION ON IDENTIFIED DRIVERS AND BARRIERS TOWARDS A SUSTAINABLE CIRCULAR BIOECONOMY

The discussion reported in this section is carried out structuring the identified drivers and barriers to CBE implementation according to the different biowaste management stages and bio-based products relevant to the three project pilots. A final discussion addresses the different categories of drivers and barriers (social, administrative, economic etc.) that emerged during the local Living Labs and the Peer Review Session for the selected pilot bio-based value chains.

6.1. Biowaste management stages

6.1.1. Biowaste prevention

Legal drivers and barriers to biowaste prevention in the EU/Spain/Italy/Bulgaria

In line with the first priority of the waste hierarchy (prevention) from **Directive 2008/98/EC on waste** (amended by Directive (EU) 2018/851), the European Commission specifies that Member States shall take **waste prevention measures** by using appropriate qualitative or quantitative indicators and targets, notably on the quantity of waste that is generated. Member States shall employ economic instruments and other measures to provide incentives for the application of the waste hierarchy. In addition, relevant stakeholders and authorities and the general public shall have the opportunity to participate in the elaboration of the waste management plans and waste prevention programmes and have access to them once they have been drawn up.

Special emphasis is posed on the **prevention of food waste** as it constitutes an important part of biowaste. The **EU Communication on a new Circular Economy Action Plan for a cleaner and more competitive Europe** (COM/2020/98 final) includes the **United Nations Sustainable Development Goal (SDG) 12.3**[15]**, targeting responsible consumption and production** to halve the per capita global food waste at the retail and consumer levels, and to reduce food losses along production processes and supply chains by 2030. In this context, the Commission will introduce waste reduction targets for specific streams and ask Member States to take measures to prevent food waste generation. Food waste reduction shall be measured separately for the different stages of the food supply chain: in primary production, in processing and manufacturing, in retail and other distribution of food, in restaurants and food services as well as in households. As established in the **EU Farm-to-Fork Strategy**[16], one major part of the **European Green Deal (COM/2019/640 final)**[17], and as part of the review of Directive 2008/98/EC, Member States are requested, to adopt specific food waste prevention programmes within their waste prevention programmes, to monitor and assess the implementation of their food waste prevention measures by measuring the levels of food waste on the basis of a standard methodology. Moreover, each MS shall take

[15] https://sdg12hub.org/sdg-12-hub/see-progress-on-sdg-12-by-target/123-food-loss-waste
[16] https://food.ec.europa.eu/horizontal-topics/farm-fork-strategy_en
[17] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

appropriate measures to ensure the reliability and accuracy of the measurements of food waste, report the data and submit the quality check report.

According to the European Green Deal (COM/2019/640 final), EU businesses should also benefit from a robust and integrated **single market for secondary raw materials and by-products**. The Farm to Fork strategy will also aim to reduce the environmental impacts of food processing and retailing through measures on transport, storage, packaging and food waste. This will also strengthen the enforcement and investigation capacities at EU level, and **launching a process to identify new innovative food and feed products**.

As a driver for food waste data, **Commission Delegated Decision (EU) 2019/1597 as regards a common methodology and minimum quality requirements for the uniform measurement of levels of food waste**, defines that the amounts of food waste shall be measured annually separately for the different stages of the food supply chain, i.e., primary production, processing and manufacturing, retail and other distribution of food, restaurants and food services and household, and defines specifications for the measurement.

Among the most important drivers it has been identified that the implementation of a standard methodology and common specifications can make more reliable food waste data sets at EU level and more comparable food waste prevention measures between MSs providing the basis for the exchange of appropriate good practices. Moreover, pushing the MSs to elaborate food waste prevention programmes can foster the definition of specific measurable food waste prevention targets covering the entire food value chain, measures to achieve these targets and comprehensible information on how those prevention measures are monitored. However, it is often a long process until such plans/programmes are fully completed at national or regional level. Financial support for investment in new ways to collect and recycle food before it becomes waste can be a further driver especially in food manufacturing and processing, where new investments in technologies are needed to secure cooling chains or redistribute food that is still edible.

As another barrier it has to be taken into account that there are probably large differences in data availability and quality on food waste across the EU Member States. Data on food waste generation at national/ regional/ local level is limited or difficult to access in order to assess inter-annual variations, which also makes it difficult to obtain data on food waste prevention. Moreover, food waste at different stages of the food supply chain is often difficult to measure/estimate and the lack of data on food waste makes it difficult to verify compliance with the targets. On the other hand, the lack of awareness of food waste generation and prevention and the difficulty in changing personal habits (planning for shopping, sharing food etc.) makes it even more urgent to increase the awareness-raising campaigns for the general public and the food industry (e.g., food producers and processors, retailers, etc.) to promote more sustainable consumption patterns. Continue and participative communication actions generate costs that have only recently been recognised as part of waste management costs.

The **Bulgarian Waste Management Act (WMA) of 2012** (amended by SG 100 of 16 December 2022) is a driver for food waste prevention, by developing a **Food Waste Prevention Sub-Program" (FWPSP)**, which is part of the "National Waste Management Plan 2021-2028" and includes communication campaigns and awareness raising activities. However, there are major obstacles such as the lack of a coordinated national food waste prevention

policy and the need to establish a national platform that brings together all stakeholders to work together on measures and actions to reduce food waste. Other barriers include the low level of awareness and engagement of citizens on the problem of food waste, legal and logistical difficulties in donating food, and a very low number of businesses currently donating food. Furthermore, there is currently no methodology in Bulgaria to measure food waste from sources other than households. Also, there is no effective strategic food waste prevention framework at national level with appropriate measures and actions covering all stages of the food chain - primary production, food processing, wholesale and retail, public catering and households.

In **Italy**, the **National Programme for Waste Prevention** (Directorial Decree 7-10-2013) identifies biowaste (especially the food waste fraction) as one of the main waste streams to be addressed. A key factor for the agri-food sector is that it specifically addresses waste generation along the entire food supply chain and provides specific measures for the recovery of agro-industrial by-products. In addition, it promotes a short food supply chain that also favours the donation of surplus products. This programme also provides incentives for the reduction of food waste in households and the application of environmental certification for catering companies. As a main obstacle, the programme does not include a specific target for food waste reduction or consequences if the measures are not implemented.

The **Italian Ecotax Law (Ecotassa) No. 549 of 28 December 1995** introduced a landfill tax (Ecotassa) in 1996, which goes into a "regional environmental fund" to promote, among other things, waste prevention, including, though not explicitly, food waste prevention measures. As a barrier, it can be said that there is no mandatory enforcement, only the promotion of market-based instruments that limit (food) waste, and that the share of ecotax revenues allocated by law to "environmental initiatives", including waste prevention measures, is usually used by regions for other purposes, as already pointed out by the NWPP Technical Scientific Committee on Implementation in 2014.

As a driving force, **Decree-Law No. 152 of 3 April 2006 on environmental regulations, the national law transposing the Waste Framework Directive**, promotes the use of by-products and thus the reduction of waste. As a barrier, there remains considerable room for interpretation in the distinction between waste and by-products, and there is a lack of clear information about the by-product from the perspective of producers and end-users. For the re-use of waste in a new production process, companies have to pay higher fees and costs for both the requalification of the waste and the administrative procedures.

An important driver is the **Italian Environmental Law for the Promotion of Environmentally Friendly Economic Measures and the Curbing of the Excessive Consumption of Natural Resources** (Law No. 221 of 28 December 2015), which allows local councils to grant a reduction in the municipal waste fee to private and commercial users who implement waste prevention measures, without making them subject to general taxation again. It also incentivises food donations by granting a reduction in waste charges to non-household users.

Decree 358/2013 established the "**Task Force no.5 - Analysis and elaboration of food waste reduction models**" within the framework of the "Study group for the identification of political strategies and priorities". A driving force resulting from the Task Force is the information contained in the document "Italy - Country Report on National Food Waste

Policy"[18], prepared by the Technical and Scientific Secretariat of the National Food Waste Prevention Plan (PINPAS) in 2016, which identifies the main measures to be taken at national level to combat food waste. The measures described in the document are the result of an extensive consultation with the main stakeholders of the Italian food industry.

A very important Italian document on food waste prevention is the **national Law No. 166 of 19 August 2016 on the donation and distribution of food and pharmaceutical products for the purposes of social solidarity and waste prevention**, with the aim of reducing waste at every stage of the production, processing, distribution and management of food, pharmaceuticals and other products. It contains many drivers for waste reduction, such as (i) promotion of reuse systems and new production chains for value-added products; (ii) environmental and economic benefits of enterprises implementing waste reduction (upstream) and waste recovery (downstream) processes with benefits for the corresponding specific reuse and/or recycling activities; (iii) in the agri-food sector, waste and residues may be considered as by-products with end-of-waste status if they fulfil all the conditions provided for in the applicable legislation and are used in innovative process chains; (iv) promoting and facilitating solidarity-based donations of food surpluses with priority for human consumption; and (v) transparency and full involvement of stakeholders in the decision-making process. It also includes simplifications to the bureaucratic procedures required for the donation of surplus food, such as the possibility of donating food with expired best-before dates, the possibility of donating bakery products that do not need to be thermally conditioned 24 hours after production, the possibility of donating food with labelling errors and the easing of liability issues in the case of gleaning. Also, the circle of potential recipient organisations is expanded to include public and private entities established as non-profit organisations to pursue civic and social goals, provided that the preservation, transport, storage and use of food is secured.

The limited commitment of the Italian Ministry of Environment, Land and Sea (MELS) must be highlighted as the main obstacle: The problem of food waste is mainly seen as an option for social food donation, instead of being contextualised within resource efficiency and waste prevention strategies. Furthermore, there are still no national food waste prevention targets and no reference framework for establishing and implementing voluntary agreements at local, regional, and national levels. There is also a lack of financial resources for the implementation of food waste prevention policies/strategies at local and regional level, for monitoring food waste data and for scientific research. Another obstacle is the lack of instruments/measures to facilitate the dissemination and exchange of good practices and the networking of stakeholders.

An example of drivers for food waste prevention in **Spain** is the **national Law 7/2022 of 8 April on Waste and Contaminated Soil for a Circular Economy**, which provides **incentives** for companies in primary production, the food industry and the hospitality sector **to donate food or process products** that have not been sold but are still fit for consumption, in this order: (i) animal feed and the production of animal feed, (ii) their use as by-products in another industry, and (iii) finally, as waste for recycling and, in particular, for the production of compost and digestate of the highest quality for use in soils and, if this is not possible, (iv) for the production of fuel. As a

[18] https://www.eu-fusions.org/phocadownload/country-report/FUSIONS_IT%20Country%20Report%2030.06.16.pdf

barrier, the implementation of this prioritisation is difficult to verify and there are no sanctions for non-implementation.

At **regional** level, **Law 3/2020 of 11 March on the Prevention of Food Losses and Waste in Catalonia** aims to promote the implementation of a hierarchy of priorities for the food chain that puts the prevention of food waste first, but also the use of food waste in industrial processes before composting and biogas production. Food businesses, social initiatives and other non-profit organisations involved in food distribution need to ensure that their employees are trained to actively participate in food waste reduction and involve them in these actions. Other drivers to prevent food waste include (i) measures to promote the sale of products with a best before date or a near expiry date; (ii) promoting waste prevention through informing consumers about more responsible consumption habits; (iii) promoting the sale lines of products with defects or damage; (iv) facilitating the creation of spaces and systems for the distribution of surplus food; (v) providing funding for food waste reduction and job creation projects for disadvantaged groups; (vi) allowing consumers to take their own containers; (vii) promoting educational programmes to reduce food waste in school canteens, hospitals, nursing homes, etc. and (viii) promoting and improving the practice of harvest crop residues. Law 3/2020 also requires the public administration to draw up a **food waste prevention plan**, to **report annually on the quantification of food losses and waste**, and to carry out the control and inspection activities provided for in this law. Reliable data helps to define more detailed prevention measures. As an obstacle, quantifying food waste along the value chain could be difficult, as seasonal variations have to be taken into account and the implementation of measures can be difficult to evaluate.

The **Spanish National Strategy on Circular Economy 2030** includes the following objectives as a contribution to the UN **SDG goal 12** for responsible consumption and production **by 2030**: 1) the reduction of **the national consumption of materials by 30%** in relation to the GDP; 2) the **Reduction of waste generation by 15%** and 3) a reduction of the **generation of food waste in the entire food chain of 50%** per capita at the level of household and retail consumption and 20% in the production and supply chains with 2010 as the reference year. The UN **SDG target 12. 3 for a reduction of food waste** in the retail, restaurant, food service or catering sectors and in the domestic sector by 50% by weight by 2030 is introduced at the **regional** level through Royal Regional Decree 210/2018, which approves the **Programme for the Prevention and Management of Waste and Resources in Catalonia (PRECAT20)**, and at the **local** level for the MAB through the **Metropolitan Programme for the Prevention and Use of Resources and Municipal Waste 2019-2025 (PREMET25**;), including the metropolitan zero waste agreement – but in both cases for 2020 with 2010 as the reference year, 10 years earlier than the UN SDG target for 2030. PREMET25 also includes a target to reduce municipal waste generation by 15% by weight by 2020, with 2010 as the reference year. One obstacle is that there are no consequences for not meeting these targets and the food waste database is not sufficient to measure actual waste generation and reduction.

6.1.2. Biowaste Separate Collection

Legal drivers and barriers to biowaste separate collection in EU/Spain/Italy/Bulgaria

Directive 2008/98/EC on waste (as amended by Directive (EU) 2018/851) establishes important rules such as the **'polluter pays' principle**', which helps to recover the costs of waste management, which are ultimately passed on to citizens (producers of household biowaste) through waste taxes. It also encourages the recycling, including (home) composting and anaerobic digestion of biowaste in a way that fulfils a high level of environment protection and results in output which meets relevant high-quality standards. As the main driver for separate collection, the amending Directive 2018/851 introduced new EU waste preparing reuse and recycling targets for municipal waste, including biowaste: 55%, 60% and 65% (by weight) by 2025, 2030 and 2035. One of the main barriers to implementation is the frequent lack of equipment and/or infrastructure for separate collection and recycling, the lack of financial resources (especially for SMEs) and the lack of controls at national, regional, and local level.

As a driver for separate (bio)waste collection, the **European Green Deal** (COM/2019/640 final) and the **Communication on a new Circular Economy Action Plan for a cleaner and more competitive Europe** (COM/2020/98 final) include the plan to develop an EU-wide harmonised model for separate collection of waste and labelling to facilitate separate collection.

Directive 1999/31/EC on the landfill of waste (amendment: Directive (EU) 2018/850) encourages Member States to further restrict the landfilling of biodegradable waste by prohibiting the landfilling of biodegradable waste collected separately for recycling. Moreover, it includes a maximum target of 10% of municipal waste (by weight) to be landfilled by 2035, hence promoting separate biowaste collection and the construction of new biowaste treatment plants. Higher quantities of separately collected municipal biowaste also potentially enable the development of new biocircular biowaste value chains and the production of added-value products. As a barrier it can be emphasised that Member States still face challenges in implementing national strategies and further restrictions on the landfilling of separately collected biodegradable waste. Furthermore, illegal landfills are often difficult to address. There is also still a lack of investment in new equipment and/or infrastructure (new composting and anaerobic digestion plants and adapting existing MBT plants currently treating residual waste including a high share of organic fraction).

Directive 1999/31/EC further states that "In order to contribute to the objectives laid down in this Directive, Member States shall make use of **economic instruments** and other measures to provide incentives for the application of the waste hierarchy. Such instruments and measures may include those indicated in Annex IVa to Directive 2008/98/EC or other appropriate instruments and measures." The following economic instruments and measures can be seen as crucial drivers **for biowaste prevention, separate collection and bio-based products**: "1. **Charges and restrictions for the landfilling and incineration** of waste which incentivise waste prevention and recycling, while keeping landfilling the least preferred waste management option; 2. '**Pay-as-you-throw' schemes** that charge waste producers on the basis of the actual amount of waste generated and provide incentives for separation at source of recyclable waste and for reduction of mixed waste; 3. **Fiscal incentives for donation of** products, in particular **food**; [...] 6. Sound planning of investments in waste management infrastructure, including through EU funds; 7. **Sustainable public procurement** to encourage better waste management and the use of recycled products and materials; 8. Phasing out of subsidies which are not consistent with the waste hierarchy;

9. Use of fiscal measures or other means to promote the uptake of products and materials that are prepared for re-use or recycled; 10. **Support to research and innovation** in advanced recycling technologies and remanufacturing; 11. Use of best available techniques for waste treatment; 12. **Economic incentives for regional and local authorities, in particular to promote waste prevention and intensify separate collection schemes**, while avoiding support to landfilling and incineration; 13. **Public awareness campaigns**, in particular on separate collection, waste prevention and litter reduction, and mainstreaming these issues in education and training; 14. **Systems for coordination**, including by digital means, between all competent public authorities involved in waste management and 15. Promoting continuous dialogue and cooperation between all stakeholders in waste management and encouraging voluntary agreements and company reporting on waste."

The Implementing Decision (EU) 2019/1004 laying down rules for the calculation, verification, and reporting of data on waste in accordance with Directive 2008/98/EC introduces a standardised calculation method for the collection and recycling of biowaste at source and stricter calculation criteria for the recovery rate of biowaste in anaerobic digestion and composting processes, thus providing an additional incentive for the separate collection of biowaste. However, one main obstacle is the harmonisation of the calculation methods between the Member States.

The **Bulgarian national Regulation No 6 of 27 August 2013** (amend. SG 36 of 1 May 2021) **on the conditions and requirements for construction and operation of landfills and other facilities and installations for recovery and disposal of waste** includes drivers such as limiting the landfilling of separately collected household waste, including biowaste, and all household waste suitable for recycling or other recovery. In addition to promoting the separate collection of municipal (bio)waste, the use of appropriate technologies for the treatment of biowaste, such as anaerobic digestion and composting, as well as the collection of landfill gas, is encouraged where economically feasible.

As drivers, the **Bulgarian national Regulation for Separate Collection of Biowaste and Treatment of Biodegradable Waste** (PMS20/ 25.01.2017) defines and regulates the requirements for separate collection of biowaste and prohibits uncontrolled incineration of biowaste, landfilling and/or incineration of green waste and biowaste when it can be recycled or recovered, as well as mixing of separately collected biowaste with other types of waste.

The **local Regulation on the disposal, (separate) collection, transport and shipment of construction waste and household waste, including biowaste and household hazardous waste in the municipality of Pazardzhik** (147/30.07.2014) requires separate collection and treatment (composting or anaerobic digestion) of green waste (leaves, branches, etc.) generated from the maintenance of communal areas, parks and gardens, as well as green waste from households, and also prohibits the burning of green waste. However, as a barrier, there is no obligation for separate collection of biowaste from households at the local level.

A major barrier to the MSW source separation has been identified in the local **Ordinance on Determination and Administration of Local Fees and Prices of Services on the Territory of Pazardzhik Municipality as of December 2021**: When calculating the municipal waste fee, the local administration only considers the surface of a property

and its location – the closer to the city centre, the higher the fee. The actual generation of municipal waste and whether or not this municipal waste is collected separately are not taken into account.

The **Bulgarian national Waste Management Act** (WMA) of 2012 (amended by SG 100 of 16 December 2022) is the normative law that regulates all major obligations of municipalities, producers, and operators of waste activities. It contains many drivers, such as ambitious targets for separate collection and achieving the Directive (EU) 2018/851 waste recovery targets for preparing for reuse and recycling of household waste, including biowaste: 55%, 60% and 65% by 2025, 2030 and 2035, respectively, as well as the Directive (EU) 2018/850 requirement to reduce landfilling of household waste (by weight) to 10% by 2035. These targets can also be seen as an incentive for the creation of new jobs in the (bio)waste management sector. Other drivers are the obligation to raise citizens' awareness of separate biowaste collection, the promotion of separate collection of biowaste for the purpose of composting and anaerobic digestion, and the promotion of the use of environmentally sound materials produced from biowaste, potentially generating new added-value products from biowaste valorisation. In addition, the Bulgarian WMA (Art. 151) provides for various sanctions and fines that can be imposed on local administrations and mayors if they do not implement the measures provided for in the local waste management programmes or do not provide containers for the collection of household waste.

A main barrier to the implementation of waste separate collection in Bulgaria is the fact that enforcement of laws, controls, fines, and sanctions for non-implementation of legislation by municipalities is still lacking in many regions, or sometimes municipalities even prefer to pay fines instead of introducing new waste management systems to improve separate collection at source. As a result, the percentage of separately collected waste is still very low and large amounts of municipal waste are landfilled.

Separate collection of municipal waste, including biowaste, is still at a rather early stage in Bulgaria. There are some good examples of Bulgarian municipalities trying to collect municipal waste separately, but the general case shows that municipal waste is collected unsorted, and a separation process is initiated at the landfills rather than at source, where it requires much more effort and the efficiency of the process is low. The collection of landfill gas has yet to be introduced at many sites and the incineration of biowaste at an incineration plant if the collection of landfill gas is not economically feasible is not a good and realistic alternative, especially as there is hardly any separate collection so far and municipal waste is still more likely to be landfilled (approx. 90%, Eurostat 2020[19]) than incinerated. Numerous local, unregulated illegal landfills cause major environmental problems, but control lies with the mayors, who have great difficulty in solving this problem.

Regarding the Bulgarian infrastructure for biowaste collection, there is still a great lack of street containers compared to containers for separate collection of plastic, glass, metal, and paper. Significant investments are needed to develop the infrastructure for waste collection and treatment, especially for successful but cost-intensive collection systems such as door-to-door collection or smart bins. A major barrier is that landfilling is

[19] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Waste_treatment_by_type_of_recovery_and_disposal,_2020_(%25_of_total_treatment)_12-01-2023.png

still the most convenient and cheapest option in Bulgaria, and there are still many uncontrolled landfills, making investment in more sustainable options even rarer.

Furthermore, there is a lack of adequate Bulgarian communication campaigns targeting citizens. According to recent studies (p. 17 of the STCE), only less than 1/4 of the citizens of the municipalities that have introduced separate collection use these systems. In most cases, citizens are not aware of the existence of separate collection points in the municipality and do not take action to use this option to dispose of bulky waste and biowaste. In order to achieve the objectives of separate collection, clear guidelines, and measures to promote the separation of (bio)waste at source are needed – especially since separate collection is not yet or hardly introduced in many parts of the country.

The **Italian Ecotax Law No. 549 of 28 December 1995** introduced a national landfill tax (Ecotassa) in 1996 to discourage landfilling and promote more environmentally friendly waste management methods. However, as a barrier, the landfill tax should be higher to create a stronger incentive for separate collection and hence recycling. **Italian national Legislative Decree No. 152 of 3 April 2006 on the implementation of the Waste Framework Directive** provides for measures to protect the environment and human health by implementing the EU waste hierarchy, rehabilitating polluted sites and reducing waste in production by promoting the use of by-products.

National Law 168 of the Italian Government of 5 March 2020 reformulates the system of acceptance criteria for landfills under Regulation (EU) 2018/850 and adapts the criteria for the construction and closure of landfills to technical progress. Reducing the amount of municipal solid waste, including biowaste, going to landfills and limiting the environmental impact of landfills can be considered as driving forces.

Regional Resolution No. 685 of 6 December 2016 provides for an increase in separate waste collection of MSW to 65% by 2019 as the main driver for the Campania region and finances the construction of anaerobic treatment plants for the organic fraction on behalf of municipal consortia.

Local Council Regulation No. 27 of 15 April 2020 for MCN defines the Tax on Waste (TARI) for the collection, transport and disposal of municipal waste to be paid by anyone who owns properties, which is used for any purpose, and which may generate municipal and similar waste, with a solidarity relationship between members of the family unit or between those who share the premises or land. A major obstacle is that it does not provide an incentive for separate collection of biowaste as a PAYT system would.

Regional Council Decision No. 364 of 7 July 2022. Update of the Regional Plan for the Management of Special Waste in Campania contains the following strategic objectives: (i) to promote the reduction of the quantity and hazardousness of waste generated; (ii) to promote the reuse of waste generated in different production cycles; (iii) to promote the maximisation of recycling and other forms of recovery and the minimisation of the use of disposal; (iv) to promote the principle of proximity of installations to waste generation sites, respecting environmental sustainability criteria; (v) to promote the fight against the illegal management of hazardous waste and construction and demolition waste. This regulation is relevant to biowaste from agro-industrial sector since they are classified as special waste. However, for their organic nature and characteristics often this kind of waste can be treated or valorised together with municipal biowaste.

In **Spain, National Law 7/2022 on Waste and Contaminated Soil for a Circular Economy** introduces the mandatory separate collection of households biowaste for all cities with more than 5,000 inhabitants and for commercial and industrial activities from 30 June 2022, and from 31 December 2023 for all others. In **Catalonia**, the promotion of separate (bio)waste collection including municipalities with more than 5,000 inhabitants was already introduced in 1993[20] and for less than 5,000 inhabitants through the **regional Legislative Decree 1/2009 approving the revised text of the Law regulating waste**. This decree also states that municipalities must provide the separate collection systems that have proven to be the most efficient.

In order to increase not only the quantity but also the quality of biowaste, acc. to Law 7/2022 priority should be given to door-to-door collection or smart bio-bins, and **the maximum percentage of impurities in the collected biowaste must be 20% from 2022 and 15% from 2027**. If the percentage of contamination is higher, this is considered an administrative offence and can be punished with fines. As an obstacle, a contamination level of 15% is still quite high, which does not sufficiently promote the recommended door-to-door collection and makes certain biowaste recycling options more difficult.

Another driver of Law 7/2022 is that **by 2025**, local authorities shall introduce a charge or, where appropriate, a fee, which shall be specific, differentiated, and cover all waste management costs, and allow the introduction of **pay-as-you-throw schemes**. The introduction/reform of these charges could be a challenge for local authorities and politicians. Currently, at local level, the separate collection and treatment of (bio)waste from households and the private sector in the MAB is financed acc. to the **Fiscal ordinance regulating metropolitan fees for the treatment and disposal of municipal waste** (2021/904671), which establishes a charge covers the large majority of the cost of waste management (but still not 100%). The fact that the introduction of PAYT is still not mandatory is seen as an obstacle.

The **EU targets** of 55%, 60% and 65% (by weight) **for the reuse and recycling of municipal waste**, including biowaste, by 2025, 2030 and 2035 (Directive 2018/851) are being introduced in different timeframes at national, regional and local levels: The **National** State Waste Management Framework **(PEMAR) 2016-2022** (approval date 16 November 2015) includes a target of **50% by 2020**, compared to the **Regional** Programme for the Prevention and Management of Waste and Resources in Catalonia (**PRECAT20**) and the Metropolitan **Local** Programme for the Prevention and Use of Resources and Municipal Waste 2019-2025 (**PREMET25**; Exp. 9000350/19) of **55% by 2020** respectively.

PREMET25 also defines a **more ambitious local target** for improving the quality of separate collection of organic fractions with a contamination level of **less than 8% by 2020** (compared to 20% at the national level by 2022 according to National Law 7/2022). In addition, collection systems such as pay-as-you-throw systems and individual collection systems will be introduced in the municipalities of the MAB to facilitate and improve the separate collection of biowaste.

[20] Ley 6/1993, de 15 de julio, reguladora de los Residuos (repealed regulation). https://www.boe.es/eli/es-ct/l/1993/07/15/6

PRECAT25 foresees **climate change targets**, including biological treatment – reducing the carbon footprint and greenhouse gas emissions related to landfilling, biological treatment, and combustion of municipal waste, including biowaste, and resource use in Catalonia by 30% in 2020 compared to 2012.

What the national, regional, and local plans have in common is that measuring target achievement is sometimes difficult due to a lack of data and that there are no consequences for non-compliance.

National Royal Decree 646/2020 regulating waste disposal by landfill limits the total amount (by weight) of municipal waste landfilled to 40% by 2025, 20% by 2030 and 10% by 2035 in accordance with Directive (EU) 2018/850. The national PEMAR framework for state waste management also includes the old target to landfill no more than 35 % of total municipal waste by 2020, to gradually introduce separate collection of all types of green waste and biowaste at national level, and to promote the construction of new biological treatment facilities and/or the adaptation of existing facilities to increase the treatment capacity of separately collected biowaste. The lack of support for decentralised treatment facilities (e.g., for agro-industrial waste), the financing of the application of BAT and the promotion of innovative value chains for biowaste prove to be obstacles.

As a driving force, **Regional Law 5/2020 on Fiscal, Financial, Administrative and Public Measures and the Creation of the Polluting Facilities Tax** aims to create and regulate the polluting facilities tax. It provides for the gradual increase of the **types of fees for the controlled deposit and incineration of municipal waste over four years**. In addition, at least 50% of the revenues from taxes must be used for the treatment of the selectively collected organic fraction and the financing of the infrastructures foreseen in the **Sectoral Spatial Plan for Municipal Waste Management Infrastructures**. The rest of the revenues must be used for the separate collection of organic materials at source, for the separate collection and recycling of other waste fractions, for other forms of recycling, for the promotion of awareness campaigns, dissemination, and environmental education, and it must be ensured that in any case 2% of the fees are allocated to green infrastructure and environmental improvement measures in the areas.

The **regional Law 8/2008 on the financing of waste management infrastructures and the taxes on the disposal of waste** (and modifications introduced by the **Law 2/2014 of 27 January 2014** on fiscal, administrative, financial, and public sector measures) introduced incineration and landfill taxes in Catalonia providing incentives for more sustainable treatment of biowaste and rules for financing waste management infrastructures, including biowaste management. The new national waste law 7/2022 of 8 April on waste and contaminated soil for a circular economy, has established new national taxes for all Spanish regions for the delivery of waste to landfills and incinerators, so that the differences between regions and the convenience of sending waste to landfills or incinerators in regions, where no fees are charged, will decrease. Nevertheless, this new law does not make it compulsory for the revenue from the taxes to be used only for measures and investments to improve waste management. **National Law 34/2022** gave Catalonia the right to set taxes on landfilling and incineration of waste at regional level which will apply from the 1 January 2023. At the same time, the Generalitat, through the regional **Decree 17/2022**, established the adjustment measures for these taxes and stipulated that the revenues collected from this tax may only be used for measures and investments related to the improvement of waste management.

6.1.3. Biowaste treatment

The discussion is not centred on the definition of drivers and barriers related to the different technologies for biowaste valorisation and treatment according to the CBE principles. An extensive study on biocircular technologies (for example, municipal biowaste composting and anaerobic digestion, bioenergy from residual waste from forestry, production of biochemicals from lignocellulosic valorisation, novel food production from agro-industrial biowaste) will be reported in D.4.2, which intends to describe the guidelines developed based on the outcomes of the BCC project presented in D4.1, D3.2, D2.1 and D2.2, to support the identification of the most suitable technological options (bio-circular technologies).

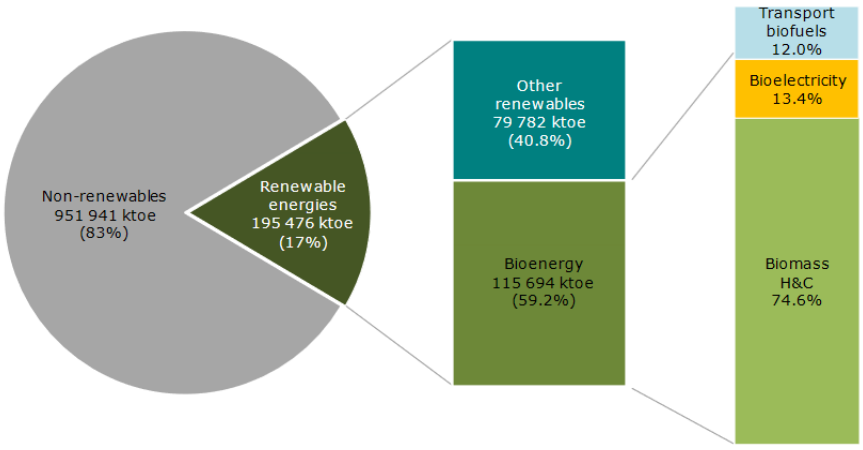
The purpose of this study is to draw attention to the type of bio-based products that can be obtained from biowaste treatment and valorisation relevant to the BCC pilots, as well as the potential legal, technical, economic, environmental, and social barriers and drivers that could hinder or facilitate their market introduction. Chapter 6.2 discusses the bio-based products that are relevant to the scope of the BCC regional pilots.

6.2. Bio-based-products

6.2.1. Bioenergy from forest residues

According to the EC (2019b), biomass for energy (bioenergy) continues to be the main source of renewable energy in the EU, with a share of almost 60%. The largest end-user appears to be the heating and cooling sector, which consumes about 75% of the total bioenergy (Figure 10). Forestry is the most important source of biomass for energy production (logging, wood processing residues, firewood, etc.). Wood pellets, primarily used for heating and electricity generation, are an important source of energy. Germany, France, Italy, Sweden and the United Kingdom represent the largest bioenergy consumers in absolute terms, while the Scandinavian and Baltic countries and Austria have the highest per capita consumption of bioenergy.

Figure 10 : Contribution of renewable energies to the EU's gross final energy consumption in 2016 and breakdown of the bioenergy contribution. (EC 2019b, based on Eurostat 2018 and NREAP Progress Reports).



EC (2021b) analysed EU data on primary woody biomass used from 2009 to 2015 and concluded that about 20% of all wood used for energy production is stem wood and 17% is other woody components (treetops, branches, etc.). However, there appears to be a significant gap in the data required for sustainable and resilient resource use, i.e., there is a growing trend for the origin of wood used for energy production to be unknown. It is therefore crucial to improve the availability and quality of data on the forest-based sector and in particular on the use of wood for energy.

When forestry residues, food and feed crops are used for energy purpose, the sustainability aspect has been identified as the most important issue to be clarified before a decision is made on collection and use for alternative value chains. The **EU Biodiversity Strategy for 2030**[21] (COM/2020/380 final) gives relevant indications to be taken into account in this field. Moreover, the European Commission (EC 2021b) recognised the increased removal of logging residues (fine and coarse woody debris and low stumps) as one of the main reactions to enhanced production of wood from forests for bioenergy. Main results of the EC analysis report 2021b are the following risks of forest residues removal: (i) removal of nutrients may lead to productivity losses in the long term, while reducing nitrate leaching; (ii) removal of carbon sources could lead to a decrease in soil organic carbon in the long term (with all the associated impacts on the forest ecosystem), while removing a CO_2 source through respiration and decomposition; (iii) substrates on which all saproxylic species depend are removed. In addition, logging residues collection and removal practices carry risks such as the removal or damage of other deadwood with high ecological value (e.g., older stumps/logs or other coarse woody debris) and the creation of ecological traps when logging piles are left in the forest and then removed and burned.

Legal drivers and barriers for bioenergy in the EU/Spain/Italy/Bulgaria

The **EU Forest Strategy for 2030** (COM/2021/572 final), as part of the revision of the **Renewable Energy Directive (REDIII)** of July 2022, is a driver for all MSs to integrate in national supporting schemes the **'cascading use of biomass principle'**. Indeed, "Member States shall design their support schemes for the use of biomass for energy in a way that minimises undue distortive effects on the biomass raw material market and harmful impacts on biodiversity. To specify how to apply the cascading principle for biomass, in particular on how to minimise the use of quality roundwood for energy production, the Commission will adopt a delegated act" (COM/2021/572). In line with this principle, "biomass should be preferably used to produce materials, including plastics, and only in subsidiary order, as a source of bioenergy. Furthermore, priority should be given to long-lived products over short-lived products, including single-use products. This priority order applies to waste, to by-products and to primary biomass coming, for instance, from agriculture, forestry, or aquaculture. Organic waste and by-products should be preferred over primary biomass, especially for short-lived products." (COM/2022/682)

In **Communication on a sustainable bioeconomy for Europe** (COM/2018/673 final), a key driver for bio-based products is to reduce dependence on non-renewable, unsustainable resources by promoting bioenergy to meet the EU's 2030 energy and climate targets. Another opportunity is the promotion of industrial symbioses and innovative industrial bio-based processes to contribute to the greening of industry and the development of circular economies and products, for example through the innovative ways in which cities recycle their significant share of biowaste.

[21] https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

Potential barriers are the competition between fossil and renewable energy producers, as well as the lack of knowledge of industrial symbiosis practices and potential benefits on the part of managers, as well as the unwillingness to establish cooperatives.

Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources contains important environmental drivers as it aims at ensuring that despite the growing demand for forest biomass, harvesting is carried out in a sustainable manner in forests where regeneration is ensured, and that special attention is given to areas explicitly designated for the protection of biodiversity. In order to minimise the risk of the operator using unsustainable forest biomass for bioenergy production, a risk-based approach needs to be introduced. This Directive further contains main drivers such as the 32% target for energy from renewable sources in EU Member States by 2030 and the promotion of separate collection by prohibiting subsidies for renewable energy from waste incineration in cases where the separate collection obligation has not been met. Furthermore, this Directive promotes the use of economic incentives (e.g., investment aid, tax exemptions or reductions, tax rebates, renewable energy support schemes) for the use of renewable energy by a Member State or a group of Member States. However, the renewable energy quota should be more ambitious for certain EU Member States that have already reached this target. An obstacle is the lack of mandatory enforcement, as support schemes for renewable energy are only encouraged.

The **Bulgarian National Action Plan for Energy from Forest Biomass 2018-2027 (NAPEFB)** aims to increase the collection of wood residues from logging and use them for energy production by providing financial support and concrete measures. According to the **Bulgarian Strategy for Transition to a Circular Economy 2021-2027 (STCE)**, forest wood biomass has great potential for energy production, but at the same time priority should be given to its further processing and use by other industries. As a main barrier the lack of a **platform for the exchange of information and best practices**, especially for remote regions, makes it impossible to establish a link between the sources of biomass formation in Bulgaria and the producers and processors who wish to use the available biomass for the production of various products. One of the main objectives of the STCE is to develop such a platform for the exchange of information related to the demand and supply of secondary raw materials, recycled building materials and biomass in order to strengthen the exchange of information within the sector to promote the demand and facilitate the supply of secondary raw materials in the country.

In Italy, the Ministerial Decree of 6 July 2012 lists all types of waste/by-products eligible for incentives and used for energy production in biomass/biogas plants. Moreover, the **Law No. 221 of 28 December 2015** provides incentives for energy production in biomass and biogas plants for by-products from sugar and vegetable oil processing. From 2021, the costs related to **CIP6/92**[22] (incentives for energy produced in incinerators from inorganic and organic waste) will be reduced until they are removed due to the phasing out of the incentive period from the Convention. This could foster the source separation of biowaste and diverting its treatment from

[22] https://www.gazzettaufficiale.it/eli/id/1992/05/12/092A2173/sg

incineration towards other more circular biological treatments. However, an important obstacle is the lack of incentives for more innovative value chains for these by-products.

The **Spanish Royal Decree 413/2014, which regulates electricity generation from renewable energy sources, cogeneration, and waste,** is a driver for the bioenergy implementation, since it sets legal and economic criteria for electricity generation from renewable energy sources using liquid biofuels, e.g., from biomass or biogas from anaerobic digestion, as the main fuel.

The Regional **Bioeconomy Strategy of Catalonia 2021-2030 (GOV/141/2021)** includes further drivers such as (i) improving the use of Catalonia's biomass through characterisation, quantification, optimisation of management and distribution, (ii) promoting the use and consumption of bioenergy, together with bioproducts and biomaterials, (iil) strengthening the role of the administration and adapting the regulatory and legal framework to promote the CBE in Catalonia. No consequences for non-implementation of the objectives can be mentioned as the main obstacle.

6.2.2. Biomethane

Legal drivers and barriers for biomethane in the EU/Spain/Italy/Bulgaria

Biomethane legislation was analysed not only for Spain in relation to the MAB pilot project, but also for the other pilot countries, as the aim of this report is also to share best practices. This means that the MAB value chain for biomethane production could theoretically also be implemented for MCN in the near future. For PP, this is more likely in the distant future due to the current lack of separate collection and recycling of biowaste.

Biogas and biomethane are a form of bioenergy. Biogas can be upgraded into biomethane, which has a higher and more stable energy content than biogas. Biomethane has the potential to be a key contributor to the **REPowerEU plan**'s[23] objectives of diversifying gas supply and reducing the EU's dependence on Russian fossil fuels, while at the same time decreasing dependence on fluctuating natural gas prices. Since biomethane is a renewable energy source, expanding the production and use of biomethane also contributes to tackling the climate crisis[24].

In 2022, the European Commission published the Staff working document **"Implementing the Repower EU Action Plan: Investment Needs, Hydrogen Accelerator and Achieving the Biomethane Targets"** (SWD/2022/230 final), which aims to increase biomethane production to 35 billion cubic metres (bcm) per year by 2030 and set the stage for further increasing the potential by 2050. This document is containing several possible actions to unlock the potential of biogas and biomethane across all EU countries. Closer stakeholder engagement (EC, MS, industry representatives, NGOs, ETIP Bioenergy[25], representatives of primary producers) and public acceptance will be promoted through the **Biomethane Industrial Partnership**[26]**,** encouraging participatory multi-stakeholder involvement between the

[23] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

[24] https://energy.ec.europa.eu/topics/renewable-energy/bioenergy/biomethane_en

[25] https://www.etipbioenergy.eu/

[26] https://bip-europe.eu/

Commission, EU countries, industry representatives, feedstock producers, academia and NGOs through conferences, workshops, and training with technical support.

Other important drivers of SWD/2022/230final are actions to promote the sustainable production and use of biogas and biomethane at EU and national/regional level from separately collected organic waste and at regional level from secondary feedstock (crop residues, manure, organic waste), while discouraging the use of food and feed for biomethane production (land use issues). An important driver for the expansion of sustainable biomethane production and income generation is the fact that Member States have to separately collect recyclable organic waste that can be recovered in anaerobic digestion plants by 2024. However, it has to be taken into account that separate collection of biowaste and anaerobic digestion plants have different degrees of implementation in the EU Member States, which can be a barrier to the enforcement of SWD/2022/230final. To overcome those barriers, the Commission will support Member States in developing national strategies for the production and use of biogas and biomethane, integrating them into national energy and climate plans and strengthening cooperation with neighbouring and candidate countries, including Ukraine, on biomethane. Innovative technologies for the sustainable production of biogas and biomethane based on the gasification of biogenic waste and the safe injection of biomethane into the gas grid are promoted, as well as the connection of decentralised generation plants with consumption centres over large distances (for example, dispersed settlements). The reduction of the current delay in permitting procedures is also incentivized by increasing the capacity in municipalities responsible for issuing permits and streamlining best practices such as the establishment of one-stop shops for biomethane-related permits and setting a maximum processing time.

To facilitate new investments in biogas and biomethane, the European Commission also offers extended access to grants and loans from existing EU funds, such as the Common Agricultural Policy Rural Development Funds, Structural and Cohesion Funds, National Resilience and Recovery Plans, Horizon Europe, Innovation and Modernisation Funds, LIFE funds and other national funds, as well as access to innovation funds for innovative production and use of biomethane and biogas projects. Nevertheless, there is a lack of awareness of these grants as well as administrative challenges in applying for them, especially for SMEs and small municipalities. In order to speed up the approval process, capacity building is needed in municipalities, as human and financial resources are currently insufficient. There is also still a lack of coordination between the different sectors producing biogenic waste.

This situation leads to insufficient infrastructure for the production of biogas from biowaste from the food, forestry and agricultural sectors, its conversion into biomethane and the adaptation of the existing gas grid. In this context, **Directive (EU) 2018/2001 on the promotion of the use of energy from renewable source** aims to ensure a good data overview by including biomethane production and use, its injection into a natural gas network and cross-border trade in a mass balance system as part of the bioenergy sustainability review and the new EU database. This can be seen as a major driver for the integration of biomethane into European gas grids.

In **Bulgaria**, no specific legislation was found that covers the production and use of biomethane.

In **Italy**, the reference legislation for biomethane support was the **Decree of 2 March 2018** on incentives for producers of biomethane and advanced biofuels other than biomethane, but thanks to the National Recovery and Resilience Plan (Pnrr), the provision undergoes important changes with the new Biomethane Decree (**Decree n. 240 of 15 September 2022 "Development of biomethane, according to criteria to promote the circular economy - Biomethane production"**). This new decree aims to support the production of biomethane injected into the natural gas network in compliance with the sustainability requirements established by Directive 2018/2001/EU. Two types of actions are supported: On the one hand, the conversion of existing agricultural biogas plants that can produce biomethane in whole or in part. The biomethane produced can be used in industry, private households, the tertiary sector, and transport. The other action line concerns incentives for the construction of new biomethane production plants. A capital subsidy of up to 40 %of the investment costs for the new plants is foreseen. The total incentives available for this decree amount to 1.7 billion from the Pnrr.

In **Spain**, as a main driver fostering biogas and biomethane generation, the recent National Law 7/2022 of 8 April **on Waste and Contaminated Soil for a Circular Economy** provides that, where appropriate, the competent authorities shall promote the use of biogas from anaerobic digestion for energy purposes, for direct use in the plants themselves, as a fuel for transport, as a raw material for industrial processes and for injection into the natural gas grid in the form of biomethane, where technically and economically feasible. Another driver is the reduction of GHG emissions through replacing fossil fuels with renewable biomethane.

Moreover, in response to the REPowerEU plan, the Ministry for Ecological Transition and the Demographic Challenge (MITERD) has recently published the **Spanish Biogas Roadmap**[27], which sets a minimum target of 10.41 TWh per year in 2030 for biogas production based on the available potential of agro-industrial waste, the organic fraction from municipal waste and sewage sludge, and manure. This minimum production target for 2030 (set in the PNIEC 2021-2030) means multiplying the national biogas production in 2020 by 3.8 times. Additionally, it also foresees that in 2030 at least 1%of the gas consumed through the natural gas grid should be biomethane.

Although the Spanish Institute for Energy Diversification and Saving (IDAE) estimates a current available potential of about 34 TWh/year (3 times more than the production target set by the PNIEC 2021-2030), other recent reports[28] raise this potential to 137 TWh/year (10 times more than the production target set by the PNIEC 2021-2030). Thus, the target set at the national level for biomethane injected into the grid, not only seems very unambitious but also not aligned with the REPowerEU[27].

Spain currently has only 5 operational biomethane production plants, reaching 95 GWh in 2020, which represents only 1.2%of the total national biogas production. Despite the current capacity, the country is potentially positioned as one of the major biomethane powerhouses at a European level and key to achieving the production targets

[27] https://energia.gob.es/es-es/Novedades/Documents/OOHR_Biogas_V6.pdf

[28] https://estudio-biometano.sedigas.es/wp-content/uploads/2023/01/sedigas-informe-potencial-biometano-2023.pdf

established by the REPowerEU strategy. A production potential of 4 bcm in 2030 and up to 20 bcm in 2050 has been estimated, which would place Spain behind only France and Germany[29].

Several barriers to biomethane production in Spain have been identified. First of all, the number of Spanish biogas plants (146 biogas installations in 2020[27]) is lower compared to other countries such as Germany, France and Italy (> 1,700 biogas plants in 2020)[30], even though Spain is a country with such an important agri-food sector and hence potentially usable biowaste resources for anaerobic digestion. A lack of biogas plants also means that there are few biomethane upgrading plants. Another obstacle could be that the financial feasibility of biogas upgrading to biomethane depends on the amount of biomethane produced, as this affects the performance of the cogeneration system and the balance between the costs and revenues. When large amounts of biogas are upgraded to biomethane, the heat provided by CHP during the winter season could be not sufficient to keep the digesters at the desired temperature, requiring the integration of natural gas. Moreover, the amount of electrical energy drawn from the grid increases with the size of the treatment plant (Baccioli et al. 2021). The optimal upgrading system size also strongly depends on the biomethane selling price, the biowaste supply (larger quantities and quality of separately collected biowaste), the energy demand of the anaerobic digestion and the grid infrastructure, as well the demand of the end-user. In addition, the development of a system to guarantee the origin of biomethane and the simplification and standardisation of administrative procedures for processing biogas and biomethane production projects could facilitate their development.

Other barriers include the need to increase the capacity of existing anaerobic digestion plants to have enough biogas available for upgrading to biomethane and the fact that this type of investment lacks financial incentives and planning security for long-term investments, especially for SMEs. Revenues from sales can also be an obstacle, as biomethane should have a lower market price (lower taxation) than fossil gas. Furthermore, fossil gas companies may not be willing to change the status quo of energy supply.

Subsidy and support mechanisms, as well as a regulatory and fiscal framework that regulates the non-electric applications of biogas, are fundamental driving forces: Mechanisms such as tax exemption to support biogas and biomethane when used as fuel for vehicles or discounts on tolls for injecting biomethane into the natural gas grid can be key to the development of the biomethane market. To attract investors, the business model for biomethane production needs to be guaranteed, and without a real and stable biomethane market, this is complicated.

Large-scale expansion also requires a stable regulatory framework and support from local institutions. The Spanish framework to support biogas and biomethane production is still young: only in 2022 was the biogas regulatory framework updated with the publication of the Biogas Roadmap, with the aim of developing a national guide for biogas and biomethane. However, the regulatory bases for subsidies to be charged to the European funds of the "Recovery, Transformation and Resilience Plan" amounting to a total of €150 million in sunk funds for projects to

[29] RETEMA Revista Técnica de Medio Ambiente. Revista digital Especial Bioenergía 2022. nº241 Energia. https://www.retema.es/revista-digital/especial-bioenergia-8

[30] https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Italy_final.pdf

be implemented before 31 October 2025 will be published.[31] In addition, Spain plans to introduce a guarantee of origin system for renewable gases in the first half of 2023 to facilitate the market introduction of biomethane.

6.2.3. Biochemicals from lignocellulosic valorisation

The valorisation of lignocellulose from forestry waste for the production of biochemicals – a technology selected as one alternative scenario in the PP pilot – will be explained in detailed in deliverable D2.2 and reported among the technologies analysed in the deliverable D4.2, while it is not discussed further in this report as no specific drivers and barriers can be found in the regulatory framework.

6.2.4. Bioplastics

The analysis of bioplastics as bio-based chemicals is also relevant to this report, even though they are not on the list of bio-based products studied in the pilot projects. Indeed, different types of organic residues, such as agro-industrial biowaste or forestry residues, can be used as potential feedstocks for the production of bio-based plastics. In addition, some plastics, even if classified as "biodegradable" (not EN 13432 compliant), could prevent the proper degradation of biowaste during biological treatment and reduce the quality of the compost obtained. Bioplastics are also an important part of legislation at EU and national level, which is why they have been included into the chapter 6.2, Bio-based products.

According to European Bioplastics (2022), bioplastics represent a broad family of materials that can be either bio-based, biodegradable or both. They are applied in an expanding range of applications, from packaging and consumer goods to automotive, electronics, and textiles. However, packaging represented the largest market segment for bioplastics in 2022 with 48%. Globally, bioplastics still account for <1% of the >390 million tonnes of plastic produced annually, with 41% produced in Asia (27% in Europe). Global production capacity for bioplastics is predicted to increase significantly from around 2.2 million tonnes in 2022 to around 6.3 million tonnes in 2027.[32]

As the market share of bioplastics is expected to continue to grow, a stakeholder consultation in the EU highlighted the need for a coherent policy framework for bio-based, biodegradable, and compostable plastics. On the one hand, innovation of bio-based plastics and the reduction of dependence on fossil fuels for plastics should be supported, on the other hand, bioplastics that are placed on the market must meet strict guidelines to be more sustainable than fossil-based plastics, including clear labelling based on certification standards to promote correct use and disposal and reduce negative environmental impacts (EC 2022a).

According to European Bioplastics (2022), there is currently no competition between renewable raw materials for food and feed and the production of bioplastics, with bioplastics taking up 0.015% of global agricultural land.

[31] RETEMA Revista Técnica de Medio Ambiente. Revista digital Especial Bioenergía 2022. nº241 Energia. https://www.retema.es/revista-digital/especial-bioenergia-8

[32] https://www.european-bioplastics.org/market/

Concerning recycling routes for bioplastics, the question of whether bioplastics can be integrated into the established recycling and recovery systems and thus have a circular rather than a linear life cycle is still controversial. According to European Bioplastics (2022), a potential integration depends primarily on the material and the application (Figure 11):

a) Mechanical recycling

In 2022, bio-based, non-biodegradable plastics accounted for 48% of global bioplastics production capacity.[33]

Drop-in bioplastics are "bio-like" copies of petrochemical plastics, but made from biomass instead of fossil oil, and have chemically and physically identical properties: bio-polyethylene terephthalate (**BioPET**), bio-polyethylene (**BioPE**), and biopolypropylene (**BioPP**) can be easily integrated into existing fossil-based PET, PE, and PP collection ('yellow bin') and recycling streams.

New materials such as **PLA** (Polylactic Acid or Polylactide) could also be easily mechanically sorted (using near infrared technologies) and recycled but are not yet produced and sold on the market in sufficient quantities to make the introduction of separate recycling streams economically viable for recyclers. It is expected that new separate recycling streams (e.g., for PLA) will be feasible and implemented in the short to medium term.

b) Industrial composting

In 2022, biodegradable plastics accounted for 52% of global bioplastics production capacity.[33]

Biodegradable plastic products that comply with EN 13432 (for packaging) or EN 14995 (for plastic materials in general) are suitable for industrial composting, i.e. they can be decomposed by microorganisms into CO_2, water and biomass, depending on the material or application and the conditions (e.g. location, temperature, humidity, presence of microorganisms, etc.) of the specific environment (industrial composting plant, garden compost, soil, water, etc.). Since the decomposition process can vary greatly depending on the abiotic and biotic conditions, controlled conditions prevail in industrial composting facilities, i.e., controlled temperatures, humidity, aeration, etc. for a fast and safe composting process. EN 13432 demands that compostable plastics decompose after 12 weeks and are completely biodegraded after six months i.e., that ≥ 90% of the plastic material has been converted into CO_2. The remaining proportion is converted into water and biomass - i.e., compost, which is used as a soil conditioner and can partially replace mineral fertiliser. EN 13432 also comprises tests for ecotoxicity and heavy metal content to assure that no harmful substances remain.

Even though biodegradable and compostable plastics are technically recyclable, they are at present not recycled back into plastics. Future increases in market share could exacerbate the situation, but also make the recycling of certain biodegradable or compostable plastics economically profitable (EC 2019 c).

[33] https://www.european-bioplastics.org/market/

Figure 11 : Bioplastics – Closing the loop (European Bioplastics)[34]

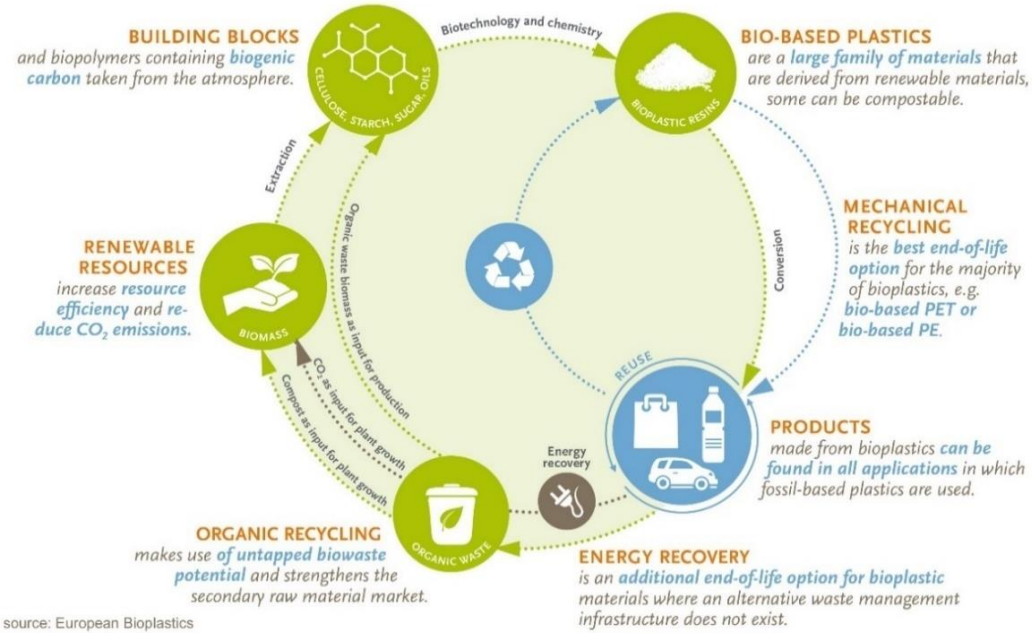


Figure 12 : Schematic display of the options for separate bioplastics collection by the consumer and the resulting recycling routes.[34]

[34] https://www.european-bioplastics.org/bioplastics/waste-management/#

As far as the labelling of bioplastics is concerned, there is currently no European standard specifying the conditions for home composting of biodegradable plastics, but there are several national standards and labels (e.g., the 'OK compost' from the Belgian certifier TŰV Austria[35] or the French standard NF T 51-800[36]. In addition, a series of standardisation projects are underway at ISO and ASTM level to measure marine biodegradation.[37]

In order to be recognisable for consumers, biodegradable plastics should be labelled with the "Seedling" logo via TÜV AUSTRIA Belgium or DIN CERTCO, OK compost label via TÜV AUSTRIA Belgium (Figure 13).[38]

Figure 13 : Logos for compostable packaging: 'Seedling' logo via TÜV AUSTRIA Belgium or DIN CERTCO, 'OK compost' label via TÜV AUSTRIA Belgium[38]

At present there is neither a standard for a minimum content of bio-based materials nor an agreed certification scheme or labelling for a plastic product to be labelled as bio-based. However, CEN/TC411 provides guidance on issues such as measurement methods for the bio-based content, business-to-business, and business-to-consumer communication (COM/2022/682 final).

Legal drivers for bioplastics in the EU/ Spain/ Italy/ Bulgaria

The cascade principle of the **EU Forestry Strategy 2030** (COM/2021/572 final) promotes the use of biomass for the production of materials, including bioplastics, over bioenergy. It also gives clear preference to organic waste and by-products over primary biomass, especially for short-lived products.

The **EU policy framework on bio-based, biodegradable and compostable plastics** (COM/2022/682 final) raises awareness of the sustainability challenges associated with the sourcing, labelling and use of bio-based plastics. Manufacturers should prioritise organic waste and by-products as feedstock to minimise the use of primary biomass - which requires the use of land, water, fertilisers, and pesticides - and thus avoid significant environmental impacts such as biodiversity loss, ecosystem degradation, deforestation, and water scarcity. Furthermore, a competition with crops intended for human consumption should be avoided. According to European Bioplastics (2022), there is currently no competition between renewable raw materials for food and feed and the

[35] https://www.tuv-at.be/green-marks/
[36] https://norminfo.afnor.org/norme/nf-t51-800/plastiques-specifications-pour-les-plastiques-aptes-au-compostage-domestique/108638
[37] https://www.european-bioplastics.org/bioplastics/waste-management/#
[38] https://www.european-bioplastics.org/bioplastics/materials/biodegradable/

production of bioplastics, with bioplastics accounting for 0.015% of global agricultural land.[39] The EU bioplastics framework also promotes longer life and the use of recycled material for bio-based plastics by establishing a strict definition for beneficial carbon storage. In addition, competition with crops for human consumption should be avoided. The EU bioplastics framework also promotes longer life and the use of recycled material for bio-based plastics by setting a strict definition for useful carbon storage. Compostable plastics, however, provide new possibilities beyond replacing fossil-based plastics, e.g., new functions or facilitating organic waste collection (EC 2019c).

Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment stipulates that PET bottles placed on the market in a Member State should contain at least 25% recycled plastic from 2025 and at least 30% by 2030. As the drop-in bioplastic BioPET has chemically and physically identical properties to conventional PET, it can be included in recycling processes (European Bioplastics 2022). In addition, the directive sets restrictions on the placing on the market of oxo-degradable plastics to prevent microplastic pollution and promotes the assessment of criteria for standards for the complete biodegradation of single-use bioplastics in the marine environment, including a short period of time to avoid accumulation and damage to the marine environment. The exchange and public dissemination of best practice examples in the EU, including deposit refund schemes for PET bottles to be recycled, including BioPET is identified as a clear driver to foster the use of bioplastics.

Extended producer responsibility (EPR) schemes are established for all packaging in accordance with Articles 8 and 8a of **Directive 2008/98/EC on waste**, which promotes economic instruments and other measures to incentivise the application of the waste hierarchy and thus also incentivise the reduction of packaging. There is an option pf ecomodulation of fees, i.e., the introduction of specific incentives for the use of bio-based materials. Some packaging EPR schemes (e.g., Altstoff Recycling Austria[40]) have some fee modulation based on biodegradability (Watkins et al. 2017). Through EPR schemes, there is the possibility to finance the separate collection and recycling of bioplastics.

Directive 1994/62/EC on packaging and packaging waste (amended: Directive (EU) 2018/852) provides a clear definition of the criteria that degradable plastics must meet in order to be classified as such. In addition, oxo-degradable plastics are systematically excluded from being labelled as "degradable", reducing potential microplastics in compost. As a driver for bioplastics, the aerobic or anaerobic treatment of biodegradable packaging waste with compost or digestate as feedstock is clearly encouraged as it can be counted as "recycled" for the recycling rate.

Directive (EU) 2015/720 on reducing the consumption of lightweight plastic carrier bags promotes EU-wide recognition of biodegradable and compostable plastic carrier bags through labels or marks and consumer awareness of the correct composting properties of biodegradable and compostable plastic carrier bags.

Given the growing market for non-biodegradable bio-based drop-in plastics (BioPET, BioPP, BioPE), mechanical recycling and reuse as food contact packaging material according to **Regulation (EU) 2022/1616 on recycled**

[39] https://www.european-bioplastics.org/market/

[40] https://www.ara.at/uploads/Dokumente/Tarifbl%C3%A4tter/ARA-tariff-rates-2022.pdf

plastic materials and articles intended to come into contact with foods will also become more important. In addition to that, this regulation promotes the separate collection of household plastic waste (including bioplastics) in order to obtain high quantities and qualities for recycling. One important driver for innovation is that novel (bio)plastics recycling technologies must be approved by the European Food Safety Authority (EFSA) within one year (publication in the form of an assessment report).

No specific legislation for the production and recycling of bioplastics was investigated in **Bulgaria**.

The **Italian national Decree 16-10-2020. Approval of National Consortium for the organic recycling of composting and biodegradable plastic packaging (Biorepack)** is promoting the public participation in a consortium for organic recycling biodegradable plastic packaging. This consortium deals with organizing, guaranteeing, promote and encourage i) the collection and organic recycling of packaging waste in compostable plastic together with household waste; ii) the appropriate labelling of biodegradable plastic packaging to facilitate an easy recognition by citizens and operators; iii) the implementation of information/communication campaigns on the correct methods of use, transfer and recycling of biodegradable and compostable plastic packaging and iv) the fight against illegality (false environmental declarations, false certifications).

The **Spanish national Law 7/2022 on waste and contaminated soil for a circular economy** states that "local entities **may collect together with biowaste, packaging waste and other compostable plastic waste** that meets the requirements of the European standard EN 13432:2000 as well as other European and national standards on compostability of plastics, and in their successive updates, **as long as local entities can ensure** that the biological treatment facility where these wastes are treated complies with the conditions indicated in the previous standards to achieve their **proper treatment**." In addition, biowaste must be collected in compostable bags that comply with the European standard EN 13432:2000 or other European and national standards on the compostability of plastics, resulting in less contamination from non-degradable plastic bags. This law can thus be a potential driver for the production and use of bioplastics that can be produced using different types of biowaste as a feedstock. Furthermore, the authorities should use the best available technologies for the treatment of biowaste together with bioplastics waste.

General barriers for bioplastics

Bio-based, biodegradable, and compostable plastics are being widely seen as more environmentally friendly than conventional plastics that are based on fossil raw materials and are not biodegradable. But simply replacing conventional plastics with bioplastics does not necessarily solve the problems of resource depletion and plastic waste accumulation (Fredi & Dorigato 2021). In order to be more environmentally friendly, bioplastics must be designed to be reusable or recyclable, produced safely and from sustainably sourced raw materials, giving priority to the efficient use of secondary biomass, and comply with relevant standards.

With biodegradable plastics, there are still problems in ensuring their advantageous use on a commercial scale. This could be one reason why the market breakthrough has not yet been achieved, even though compostable and biodegradable plastics started to appear on the market more than 25 years ago (EC 2019c).

A frequent conflict between different value chains for biowaste and residues can be mentioned as an obstacle (e.g., bioplastics vs. biochemicals or functional food ingredients). The conflict of interest between producers using fossil carbon and those using renewable carbon feedstocks can also be mentioned as a barrier, as well as the limited environmental impact assessment of the use of bio-based feedstocks.

For consumers, there is still confusion about the labelling (certified labels and self-declared labels) of the different types of bioplastics (bio-based and/or biodegradable) and the correct sorting of bioplastics (biowaste bin or 'yellow bin'), different sorting instructions for biodegradable and non-biodegradable bioplastics might even be more confusing. Public awareness campaigns are needed, e.g., to promote the "seedling" logo and prevent littering. Littering relates to the thoughtless throwing away of waste and is not a legitimate way to dispose of it - even biodegradable plastics should not be subject to littering, especially considering that the environmental conditions (especially in water bodies) are very different from those of industrial composting.[41]

The life cycles of bioplastics are currently mostly linear. Many different types of bioplastics further complicate mechanical sorting and recycling. There still seems to be a lack of clear collection and recycling routes for bio-based plastics: While drop-in solutions such as BioPET, BioPP and BioPE can be collected with conventional plastics ('yellow bin'), biodegradable or compostable plastics collected together with conventional plastics ('yellow bin') lead to potential cross-contamination with recycling streams (EC (2019c).

Mechanical recycling of new bio-based plastics (e.g., PLA), which would have to be collected separately from fossil plastics (not in the bio bin) and then sorted into a special category for mechanical recycling in the sorting plant, is also hardly available so far. The main obstacle in this case is the lack of economies of scale for mechanical recycling of bioplastics (European Bioplastics 2022).

EN 13432 requires for the compostable plastics to disintegrate after 12 weeks and completely biodegrade after 6 months during a composting process. That means that 90% or more of the plastic material will have been converted to CO_2. The remaining share is converted into water and biomass (i.e., compost). However, concerning the anaerobic mesophilic degradation of biodegradable plastics together with food waste, Zhang et al. (2018) concluded that of the 9 bioplastics certified acc. to EN13432 tested, only 4 showed substantial biodegradability under anaerobic conditions and that even the most degradable materials would not break down sufficiently to meet the physical contaminant criteria of the UK PAS110 specification for anaerobically digested material, if fed to a digester at 2.0% of the input load on a volatile solids basis. Another problem is that biodegradable plastic bags not accepted by composting facilities in certain regions (EC 2019c) and are often sorted out and consequently incinerated together with non-biodegradable bags, as they are indistinguishable before entering the composting process.[42] Furthermore, compostable, and biodegradable plastic packaging may need special sorting and separation technologies. (Taneepanichskul et al. 2022). Home composting can also be an obstacle, as the conditions (e.g., location, temperature, moisture, presence of microorganisms, etc.) differ significantly from those in industrial composting facilities.

[41] https://www.european-bioplastics.org/bioplastics/waste-management/

[42] https://www.vdi.de/news/detail/sind-biokunststoffe-im-bioabfall-ein-problem

To make the life cycle of their products sustainable, all types of bioplastics, including biodegradable plastics, should aim to keep the value of resources, materials and products in the loop for as long as possible and avoid waste. In a closed-loop economy, all plastics in the first instance should go for recycling into new plastics. Compostable plastics that can be treated with biowaste offer environmental benefits for certain uses and situations, provided their use is adapted to the biowaste treatment infrastructure.[43] When composting biodegradable plastics, it must be taken into account that bioplastic monomers, in contrast to chemical or mechanical recycling, cannot be reintroduced into the life cycle of plastic products, but are largely converted into the greenhouse gas CO_2 (Fredi & Dorigato 2021). In order to achieve a truly sustainable plastics economy, the growing production of bioplastics must be accompanied by sound bioplastics waste management strategies for each of the most common types of bioplastics (Fredi & Dorigato 2021).

6.2.5. Novel Food (Coffee Silverskin)

The novel foods legislation was analysed for its relevance to the MCN pilot project, in which the alternative scenario aims to investigate the production of functional ingredients from coffee silverskin (a type of organic waste from the agro-industry).

Legal drivers and barriers for novel foods in the EU/Italy

In order to be included in the list of novel foods, any food which corresponds to one of the categories defined in Article 3(2)(a) of **Regulation (EU) No 2015/2283 on novel foods** and which was not used for human consumption to a significant degree within the EU before 15 May 1997 must undergo an authorisation procedure. In this context, novel technologies in food production processes that may have an impact on food and thus on food safety, i.e., production processes that were not used for food production in the EU before 15 May 1997 and that lead to significant changes in the composition or structure of a food affecting its nutritional value, metabolism, or level of undesirable substances, shall also be assessed.

Since the new EU Novel Food Regulation came into force in January 2018, the procedure for the scientific risk assessment of a novel food application has been centralised. The **European Food Safety Authority (EFSA)** carries out risk assessments on the safety of a novel food at the request of the European Commission.[44]

In addition, requirements for the use and labelling of novel foods to avoid harm to (human) health and the environment have to be met. Furthermore, foods may not be replaced by novel foods if they are nutritionally less beneficial, hence protecting the health of consumers. Furthermore, the requirements for the use and labelling of novel foods must be met in order to avoid harm to (human) health and the environment. Moreover, foods must not be substituted by novel foods if they are nutritionally less beneficial, in order to protect consumer health.

The fear and/or aversion of consumers towards novel foods can be mentioned as a barrier to market entry.

[43] https://www.eea.europa.eu/publications/biodegradable-and-compostable-plastics

[44] https://www.efsa.europa.eu/en/topics/topic/novel-food

With regard to the use of **coffee silverskin** (relevant to the Italian pilot) as potential novel food, the reference law is the **Regulation (EU) 2015/2283 on novel foods "Foodstuffs from plants or parts of plants"**. Indeed, coffee silverskin, the main biowaste generated during coffee roasting, has the potential to be used as a food ingredient and falls under the category referred to in Article 3 (2) (a) (iv) of the mentioned regulation: i.e. "food from plants obtained by non-traditional propagating practices where those practices give rise to significant changes in the composition or structure of the food affecting its nutritional value, metabolism or level of undesirable substances".

Coffee silverskin is currently being assessed for the absence of heavy metals, pesticides, rare earth elements (REEs), polycyclic aromatic hydrocarbons (PAHs), and biological contaminants in this product and is thus subject to a risk assessment by EFSA as a novel food requiring pre-market authorisation.[45] As a reference, dried coffee husk (cascara) has already been approved by EFSA as a novel food in 2021 (Turck et al. 2021).

According to Nolasco et al. (2022 a, 2022b), coffee silverskin has a great potential for use in the food sector due to its nutritional profile, as it contains 18.9% protein and 34.7% fibre, and has a low-fat content (3.0%). In addition, the food safety criteria were met (e.g., low levels of contaminants such as ochratoxin A (OTA) and acrylamide (A), heavy metals and polycyclic aromatic hydrocarbons (PAH) and microbial contamination). Both studies conclude that this by-product poses neither a non-carcinogenic nor a carcinogenic risk and therefore has the potential for safe use in functional foods.

The **Italian national Law for the implementation of the Waste Framework Directive** that provides for measures aimed at protecting the environment and human health (Legislative Decree 3 April 2006, n. 152) promotes the use of by-products and thus reduces the amount of waste. One obstacle that can be identified is that there remains considerable room for interpretation in the distinction between waste and by-products and there is a lack of clear information about the by-product from the perspective of producers and end-users, laws in this field need to be clarified and streamlined. Another barrier is that companies face higher fees and costs when reusing waste in a new production process, both in terms of waste requalification and administrative procedures.

The **Ministerial Decree 264/2016** contains **indicative criteria to facilitate the demonstration of the existence of the requirements for qualifying process wastes as by-products and not as waste**, but they are not exhaustive. The decree does not contain either a "list" of materials that can certainly be qualified as by-products either a list of permitted treatments on the same as undoubtedly constituting "normal industrial practice". The barrier is the lack of clarity in the legislation for both those who generate the by-product and those who reuse it. With the objective of clarify and better apply this provision, an **explanatory circular for the application of this ministerial decree**[46] was integrated in a technical-legal Annex proving some clarifications and useful interpretations concerning the use of by-products, and the absence of long-established interpretative practices. For example, a waste can never acquire the classification of by-product in a time after its generation, since a material initially qualified as waste cannot then become a by-product; in other words, possession of the requisites must therefore exist from the

[45] https://food.ec.europa.eu/system/files/2022-06/novel-food_consult-status_2022-4778355.pdf

[46] https://www.cisambiente.it/circolare-esplicativa-lapplicazione-del-decreto-ministeriale-13-ottobre-2016-n-264-le-principali-evidenze/

moment in which the residue is generated. Moreover, the circular contains a representative table with indications on residual biomass intended for use for energy purposes; treatments which, under the conditions described, may fall within normal industrial practice; the specification of which materials, among those mainly listed in the financing legislation for renewable energy sources, can be used as fuel biomass.

6.2.6. Compost and digestate

A general driver for obtaining high quality compost and digestate is reducing the impurities content in source separated biowaste delivered to biological treatments. That strictly depends by the biowaste collection system, and the quality of source separated municipal biowaste (see subchapter 6.1.2).

The drivers and barriers for the treatment of biodegradable plastics in composting facilities at EU and pilot level are discussed in subchapter 6.2.4.

Legal drivers and barriers to compost and digestate in the EU/Spain/Italy/Bulgaria

According to **Regulation (EU) 2019/1009 laying down on rules on the making available on the market of EU fertilising products**, Article 19, Criteria for reaching the **End-of-waste status** are set: "in accordance with which material that constitutes waste, as defined in Directive 2008/98/EC on waste, can cease to be waste, if it is contained in a compliant EU fertilising product. In such cases, the recovery operation under this Regulation shall be performed before the material ceases to be waste, and the material shall be considered to comply with the conditions laid down in Article 6 of that Directive and therefore to have ceased to be waste from the moment that the EU declaration of conformity was drawn up." The Annex II of regulation, chapter "**Component Material Categories (CMCs)**, includes Compost (CMC 3), Fresh crop digestate (CMC 4) and Digestate other than fresh crop digestate (CMC 5) within the list of EU fertilising products and further states that "An EU fertilising product shall consist solely of component materials complying with the requirements for one or more of the CMCs listed in this Annex. The component materials, and the input materials used to produce them, shall not contain any of the substances for which maximum limit values are indicated in Annex I in such quantities as to jeopardise the EU fertilising product's compliance with the applicable requirements of that Annex." As a main driver, these end-of-waste criteria and Component Material Categories ensure the prevention of risks to human, animal, or plant health, safety or the environment. The main obstacle that can be mentioned is the cost of biowaste treatment in composting and anaerobic digestion plants compared to the revenue from compost sales.

Commission Implementing Decision (EU) 2018/1147 establishing best available techniques (BAT) conclusions for waste treatment under IED Directive (2010/75/EU) is also including BAT conclusions for the biological (composting and anaerobic digestion) treatment of waste (Section 3) and hence promoting the reduction of the environmental impact of biowaste treatment. As a barrier, it can be noted that awareness of BAT is often limited among treatment plant managers and that a lack of financial resources can further limit the implementation of the most sustainable techniques.

Directive 2008/98/EC on waste (amendment: Directive (EU) 2018/851) aims at encouraging the recycling, including composting and digestion, of biowaste in a way that fulfils a high level of environment protection and results in output which meets relevant high-quality standards. The Directive also encourages **home composting** and the use of materials produced from bio-waste. Home composting can be a driving force as it reduces the

amount and therefore the cost of biowaste to be collected and recycled and can also help citizens to build a closer relationship with their own food waste. Another clear driver is to promote the biocircular use of biowaste and its transformation into high value products (such as compost and digestate).
Barriers include the fact that not all households have sufficient space for home composting and that the use of materials or products from biowaste requires economies of scale, environmental impact assessments and public acceptance.

Commission Regulation (EU) No 142/2011 implementing Regulation (EC) No 1069/2009 laying down **health rules as regards animal by-products and derived products not intended for human consumption,** sets **standards for the conversion of animal by-products and derived products into biogas or for composting,** including standards for biogas and composting plants, hygiene, digestate and compost (Chapter III, Section 3 (Art. 10(1)). Annex V also sets out requirements for biogas and composting plants to be approved by the competent authority (Art. 10(2)). As a barrier, it can be noted that the requirements for the use of animal by-products in anaerobic digestion and/or composting require further investments and that the lack of legal and economic incentives may limit the use of animal by-products in biological waste treatment.

As a driving force, the **Bulgarian National Ordinance on the Separate Collection of Biowaste and the Treatment of Biodegradable Waste** (PMS20/ 25.01.2017) defines and regulates i) the conditions under which compost and digestate generated during the recycling of biowaste are no longer considered waste in the sense of § 1, item 17 of the additional provisions of the Waste Management Act (AWG) and ii) the requirements for the use of the composts, digestates, organic soil improvers and stabilised organic fractions obtained. In addition to that, the **Bulgarian National Waste Management Plan 2021-2028 (NWMP)** foresees certain measures to promote green waste composting by providing free composters to 100 000 households.

As a driver, **Italy's National Programme for Waste Prevention** (Directorial Decree 7-10-2013) foresees that Regions and Autonomous Provinces shall favour their anaerobic digestion and composting, to guarantee a high level of protection of the environment, in line with the European standards.

The **Italian national law on Environmental provisions to promote green economy measures and to contain the excessive use of natural resources** (Law no. 221 of December 28, 2015) contains drivers aimed at incentivising home-composting by waste tax reductions, both at individual and community level. An inconsistency within the text of the law can be seen as an obstacle: In the text of the law, the reduction on the waste fee to those who do "home-composting" is listed once as mandatory (Art. 37) and once as optional (Art. 38).

In Spain, among the legal drivers for using compost there is the **national Royal Decree 506/2013 of 28 June 2013 on fertiliser products** (last amendment: 18 February 2022) that defines the quality criteria for the use of compost from biowaste in agriculture and horticulture. In addition to that, the **national Royal Decree 865/2010 of 2 July 2010 on cultivation substrates** defines biodegradable organic waste or by-products suitable for composting, quality criteria for composting processes and compost suitable for growing media. As a further driving force, the **Spanish national Law 7/2022, of April 8, on waste and contaminated soil for a circular economy** establishes that

the competent authorities shall encourage the use of compost and digested compost that meet the end of waste status for compost and digestate laid down in Regulation (EU) No 2019/1009, in the agricultural sector, gardening or the regeneration of degraded areas in place of other organic amendments and as a contribution to the saving of mineral fertilizers prioritizing as far as possible the use of compost over digested compost. By promoting the use of compost as a contribution to reducing the use of mineral fertilisers, greenhouse gas emissions are reduced. The law gives a clear preference to compost over digestate to ensure a higher quality of compost applied to the environment and prohibits the establishment of end-of-waste criteria for the use of biostabilised material as fertilizer. However, the fact that, according to Regulation (EU) No 2019/1009, the bodies authorised to carry out third-party conformity assessment tasks to certify the end of waste status of compost and digestate have to be defined, the conformity procedures are new, and certification may therefore take some time, were identified as obstacles.

As from 1 January 2027, municipal biowaste that undergoes aerobic or anaerobic treatment can only be considered recycled if it has been separately collected. This incentivises the separate collection of biowaste. According to the Law 7/2022, local authorities shall adopt required measures for the separation and recycling of biowaste at source through domestic and municipal composting, especially in municipalities with less than 1,000 inhabitants. As the biostabilised outputs produced in MBT plants will no longer contribute to the national recycling quota, a conversion of existing MBT plants into anaerobic digestion and composting plants treating only source-separated biowaste or the construction of new biological treatment plants is clearly required. This could be seen as a barrier as it requires significant investment.

The new waste landfill and incineration taxes established in the law 7/2022, of April 8, are also an important driver for compost and digestate production since they provide incentives for biowaste separate collection and reduction through household or community composting.

The **Spanish national State Waste Management Framework Plan (PEMAR) 2016-2022** aims at strengthening home-composting in those places where it is easily practicable (domestic composting in horizontal dwellings in urban and rural environments, community composting, self-composting). An increase in composting in households and municipalities further leads to a reduction in the amount of biowaste to be disposed of and thus in the costs of biowaste management. In addition, community composting creates a better sense of community and raises awareness about food waste and ultimately its reduction. Barriers also include the fact that not all households have sufficient space for promoted home composting.

The **Spanish national Royal Decree 1528/2012 laying down rules on animal by-products and derived products not intended for human consumption** establishes hygiene standards for the treatment of animal by-products not intended for human consumption and for the treatment of kitchen waste containing animal products in anaerobic digestion and composting plants. The lack of incentives for new recovery chains for animal by-products can be mentioned as an obstacle.

6.3. Selected pilot bio-based value chains

In this subchapter, the different aspects hindering or fostering the implementation of the CBE in the selected bio-based value chain that were mentioned during the participative processes (2nd Living labs and the 2nd Peer Review Session) are discussed for each project pilot.

6.3.1. Drivers and barriers for implementing the forestry residues pilot in PP

In the case of pilot area Pazardzhik Province, the collection of forestry residues is discussed as a potential measure to reduce the risk of forest fires, which severely affect flora, fauna and human health and increase greenhouse gas emissions, and to reduce the costs of firefighting and reforestation after fires. Currently, there is a lack of local data on the biodiversity impacts of collection, – how much wood waste can be collected without severely harming local biodiversity or soil erosion – additional transport and the potential environmental impacts of lignocellulosic or CHP valorisation, while also including the issue of potential forest fire prevention. In this context, research grants would be an important driver to improve data collection and analysis. For the industry sector, good databases on the quantity and location of forest residues (type, quantity, quality) would be a driving force for creating incentives for new sustainable value chains.

Depending on the terrain, forest residue collection can be challenging in PP as the mountainous landscape makes collection difficult and expensive. The technical improvement of existing collection, storage, and transport facilities for forestry residues on the one hand and the introduction of new, more efficient technologies on the other would be important incentives.

Financial support from the government was mentioned as the main driver for technical improvements and investments in new valorisation plants such as CHP plants or lignocellulosic valorisation plants and thus for the creation and promotion of new jobs. Other important incentives for new industrial investments are the extension of tender intervals with regard to the currently frequently changing forest management, ownership, and management at municipal, national or private level to create more planning security, and cooperation between policy makers, researchers, and market players.

Important barriers are the lack of compensation schemes (e.g., no, or too low feed-in tariffs) for CHP and, more generally, the current uneven playing field between bio-based and fossil-based products. General tax cuts for bio-based products or alternatively higher taxes for fossil products could be important drivers. Another challenge is that a lot of educational work still needs to be done to promote behavioural changes (limiting the use of wet raw wood as firewood) and the use of biowaste-based products. Another obstacle is the general lack of local treatment options: In relation to wood biomass, REAP has developed some initial assessments showing that the distance between the place of wood biomass processing and the place of extraction should not be more than 20 km, otherwise the transport of the raw material is not economically feasible.

6.3.2. Drivers and barriers for implementing the agro-industrial biowaste pilot in the MCN

Among the main limitations to the CBE implementation in the MCN selected chain, local stakeholders mentioned problems with administrative shortcomings in the regulations and the application of the regulations, which also have an impact on research projects that are consequently more easily applied abroad. Competition for different types of waste is also an obstacle: for example, oil-processing companies in Italy compete for the collection of cooking oils, and collection is not well regulated. Biocircularity needs a functioning market and functioning infrastructures.

From a legal point of view, the main obstacles of the sector are the clear definition between final waste and by-product and the contradictory administrative and regulatory contexts. To overcome this limitation, it has been suggested that legislators establish a more comprehensive list of by-products. In addition, permits for the construction of treatment facilities are too lengthy and cumbersome. One driving force would be to simplify the licensing and administrative procedures.

Technologically, there is a lack of innovative structures and exchange of experience and knowledge on best practices. Currently, agro-industrial organic waste and by-products are often treated together with biowaste separated from MSW in composting and anaerobic treatment plants in the MCN. However, the regional capacity of biological treatment is insufficient, forcing biowaste to be treated outside the region, with high environmental costs. The main driving factors for biowaste from MSW are the increase in the number of decentralised anaerobic digestion and composting plants and the improvement of separate waste collection.

Financial incentives from the government to guarantee income generation and job creation were identified as the main drivers to encourage a financial interest from industry to recycle or collect their biowaste. From an economic point of view, the main barriers are too much investment for the implementation of innovative infrastructures and lack of planning; the main driving factors are planning security for long-term investments and the introduction of taxes for landfill disposal.

In terms of environmental safety, the obstacle is the lack of a thorough analysis of the environmental impact of the current organic waste management system, while the driving factors are the reduction of greenhouse gases by improving the quality and quantity of organic waste from separate collection and increasing the production of added value products from biowaste, according to the principles of the circular economy.

In the social sphere, the obstacles are the lack of political will to change the state of the art and the reluctance to use products made from biowaste, while the main driving factor is the growing social awareness of the positive effects of the circular economy implementation in relation to the biowaste management.

In addition, collaboration between policy makers, researchers and market players should incentivise local start-ups dedicated to all aspects of the value chain, and providers of new product ideas should have easy access to BAT for new treatment technologies.

Furthermore, possible new coffee value chains were discussed, such as the use of separately collected coffee grounds from cafeterias (using 'soft' transport in urban areas, e.g., bicycles) for the production of value-added products.

The need for clear risk assessments of health and environmental impacts, including potential contamination of feedstock and risk distribution along the value chain, and the challenge of addressing public concerns about biowaste-based products in advertising were cited as the main barriers to biowaste-based products. In addition, the risk of unnecessary competition for agro-industrial waste (different product ideas) and the challenges of dealing with the seasonal availability of agricultural waste and by-products were mentioned. Part of the crop residues should also remain on the fields as soil fertiliser.

6.3.3. Drivers and barriers for implementing the municipal biowaste pilot in the MAB

The main drivers identified for "food waste prevention" included the promotion of local food supply (small local markets vs. large retailers), change in personal habits planning shopping, sharing leftovers/soon expiring food with others, cooking large vs. small portions) and the current increase in food prices (people waste less food in order to save money, which may also draw attention to reducing food waste in general). Among the main barriers to consider are the lack of financing of (local) waste prevention measures and therefore the lack of food waste awareness among citizens, the challenge of changing personal habits and the different challenges according to the personal living situation (large families may find it more difficult to plan adequate food portions, while supermarkets usually do not offer adequate portions for single households and also their storage space may be smaller). Another mentioned barrier was a so far missing regulation on animal waste.

One driver for "biowaste prevention" reducing biowaste generation would be to mobilise citizens for home composting and community composting, as these are important tools to reduce the volumes to be collected and managed, and thus the costs, and also help to create a better sense of community and raise citizens' awareness of their own food waste. The lack of space for home composting and community composting in densely populated areas was mentioned as an obstacle, as well as the lack of knowledge and will to do so.

For the "separate collection of biowaste", increasing biowaste quality and quantity through door-to-door collection or, technological innovation (smart waste bins) is an important driver. Economic incentives such as waste charge reductions and pay-as-you-throw schemes are also effective tools to promote separate collection, as well as sorting obligations or reducing the collection frequency for residual waste. Obstacles are the citizen's acceptance of new collection systems, higher cost of new collection systems, lack of knowledge in dealing with Big Data from smart bins and the increase of waste charges, as they are unpopular among the population.

Policy incentives such as taxes on landfilling and incineration (strict regulation and enforcement) and improving the quality of inputs to have better treatment options are considered the main drivers for "biowaste treatment". The promotion of by-products in agro-industrial processes can also be seen as a driver that encourages cooperation with potential local end-users. Lack of long-term security for subsidies, investment in new technologies/upscaling of pilot plants and revenue from sales, problems with the valorisation of new bio-based products such as bioplastics were identified as the main barriers.

As a barrier, a certain scale is required for the upgrading of biogas to biomethane to be financially viable. The financial feasibility depends on several factors, e.g., the amount of biomethane produced (i.e., the size of the biogas upgrading plant), the energy demand for anaerobic digestion and the selling price of the biomethane. In addition,

appropriate regulations for the injection of biogas or district heating as well as political and financial incentives for investments in green energy (especially for SMEs) are required.

Drivers for "new innovative biowaste-based products and markets" include potential new market niches and more local production of normally imported products. The main barriers are lack of vision for market potential, lack of legal clarity and EU certifications of new bio-products and low revenues from sales compared to production costs (this is true even for standard products such as compost). There are also uncertainties about the environmental benefits of certain biowaste products such as bioplastics, which currently mostly have a linear life cycle (incineration instead of recycling).

A carefully designed and tested taxation and incentive programme, as well as strict fines for the misuse or non-use of collection systems, are important drivers for increasing municipal biowaste collection. Another driver is the exchange of best practices in biowaste collection and treatment between neighbouring municipalities at different levels (from streets to neighbourhoods to urban areas). The quality of biowaste could be improved by incentivising the commercialization of food products with less/compostable packaging. Smart biowaste bins with identification system generate large amounts of data that can be used to improve citizens' habits by communicating the obtained results (Know-As-You-Throw), but at the same time pose a challenge in dealing with Big Data and in dealing with the large amounts of tourists in the MAB. Mention was also made to supporting start-ups in introducing new biowaste-based products into the municipal biowaste value chain through collaboration between policy makers, researchers, and market players. Minimum food waste prevention targets are needed to avoid excessive demand for new biowaste valorisation technologies.
Citizens' feeling of being disconnected from policy and their lack of knowledge about what they have to do (waste prevention and separation) and why were highlighted as barriers to increasing the quality and quantity of collected biowaste. The seasonal challenges of organic waste collection (particularly, odour in summer) were also mentioned. Hygiene risk assessment needs to be carried out along the entire biowaste value chain. For PAYT and smart waste collection systems to work successfully, they need to be supported by awareness-raising campaigns not only for residents but also for tourists. Legal and financial incentives are needed for the introduction of a biomethane value chain.

7. CONCLUSIONS

Although bioeconomy relies on renewable resources, there is still much potential to adopt a Circular Bioeconomy approach for the sustainable exploitation of biological resources. This implies a profound change in the waste hierarchy and opens new options that have to be weighed beforehand and for which more collaboration between the different stakeholder involved in the value-chains of bio-based products is required. Biomass producers, processors, wholesalers, retailers, restaurants, supermarkets, consumers, biowaste management companies, companies that recycle biowaste, innovative SMEs, researchers, investors, and policy makers are the targeted actors involved in participatory processes in each pilot territory to gather their input and ensure that the frameworks created are in line with the local context and challenges. Stakeholders' involvement is also needed to assess whether the proposed biowaste management strategies will lead to changes that improve the circularity and environmental impacts compared to the current situation and create potential markets and demand for the new bio-based products. One objective is to use the results of previous research and projects as a starting point for expanding the range of available circular solutions. There is a need to create opportunities for industrial symbiosis to enhance local cooperation along with the implementation of new transformation processes to produce value-added products.

Transforming the economy towards CBE requires understanding both the driving forces potentially pushing forward the development and implementation of sustainable biocircular solutions and the constraints hindering this development. In this report, insights have been gained into existing CBE regulations and policy instruments that identify potential opportunities and barriers, complemented and validated by the experiences of relevant stakeholders involved in biowaste chains and knowledgeable about CBE in local contexts, as well as by external experts presenting exemplary international policy instruments that can be used as best practices in the pilots.

The identified shortcomings and drivers can be grouped according to the following measures, which focus on changing or improving the current biowaste management systems from a circular perspective: 1) introducing preventive measures (reducing biowaste generation), 2) improving separate collection (quantity and quality), 3) producing new products from biowaste (products with high added value of organic origin).

Waste prevention is the most important step in the EU waste hierarchy. A key driver to promote **food waste** prevention at European level is the adoption of UN SDG 12.3, which aims to halve global per capita food waste at retail and consumer levels and reduce food losses along production processes and supply chains by 2030. As set out in the EU Farm-to-Fork Strategy, an important part of the European Green Deal, and as part of the revision of Directive 2008/98/EC, Member States are required to adopt specific food waste prevention programmes as part of their waste prevention programmes. In addition to binding food waste prevention targets for Member States, one of the key drivers is the introduction of a standard methodology and common specifications that can lead to more reliable food waste data sets at EU level and more comparable food waste prevention measures between Member States, as well as providing the basis for the exchange of appropriate best practices. However, it is often a long process before such plans/programmes are fully completed at national or regional level and even if they

include communication campaigns and initiatives to reduce food waste in households, catering companies and markets, often no specific targets are established.

In all pilot regions, there is a general lack of financial resources for the implementation of food waste prevention policies/strategies, for monitoring food waste data and for scientific research. On the other hand, the lack of awareness about the generation and prevention of food waste and the difficulty to change personal habits (planning purchases, sharing food, etc.) makes it even more urgent to strengthen awareness-raising campaigns to promote more sustainable consumption patterns. Another obstacle is the lack of tools/measures to facilitate the dissemination and exchange of good practices (e.g., donation of surplus food) and the networking of actors. Furthermore, there are no sanctions for non-implementation of food waste prevention measures.

Improving the quality and quantity of organic waste from **separate collection** would bring important benefits, such as the reduction of greenhouse gases by reducing the amount of biowaste sent to incinerators and landfills and the possible production of value-added products from biowaste, which demand for a stable feedstock supply. The main driving force for separate collection at European level is the new maximum target of 10% of municipal waste (by weight) to be landfilled by 2035 (EU/2018/850), as well as the new EU targets for preparing for reuse and recycling of municipal waste, including biowaste of 55%, 60% and 65% (by weight) by 2025, 2030 and 2035 respectively (Directive EU/2018/851). In addition, the introduction of mandatory separate collection schemes in all Member States by 2024 (SWD/2022/230) is an important driver. Member States are encouraged to use economic instruments and other measures to incentivise biowaste prevention, separate collection and valorisation into bio-based products: (i) Taxes and restrictions on landfilling and incineration, (ii) Pay-as-you-throw schemes that charge waste producers on the basis of the actual amount of waste generated and provide incentives for separation at source of recyclable waste and for reduction of mixed waste, (iii) Sound planning of investments and usage of BAT in waste management infrastructure, including EU funding; (iv) Sustainable public procurement to encourage better waste management and the use of recycled products and materials; (v) The use of fiscal measures or other means to promote the uptake of products and materials that are prepared for re-use or recycled; and (vi) Public awareness campaigns and multi-stakeholder processes (acc. to Directive 2008/98/EC).

However, so far, a couple of barriers for separate collection have been encountered in the pilot countries. Separate collection of municipal waste, including biowaste, is still at a rather early stage in Bulgaria. At a local level in PP, the current waste taxation gives no incentives for separate collection and the collection infrastructure and public awareness raising campaigns are insufficient. In Italy, a nationwide landfill and incineration tax is incentivising separate collection. However, this tax is still too low to make a sufficient contribution to separate collection. The local waste tax TARI at the MCN does not incentivise separate collection of biowaste as a PAYT system would, but the fact that mostly door-to-door collection is introduced does. In Spain the obligation of separate biowaste collection in cites with more than 5,000 inhabitants came into force in July 2022 and for the remaining municipalities from 2024. In Catalonia, by contrast, the separate collection of biowaste was introduced as early as 1993 for municipalities with more than 5,000 inhabitants and was extended to all municipalities in 2009. Moreover, door-to-door or smart bin collection has priority over collection in open containers, and the percentage of impurities in the collected biowaste in Spain is limited to a maximum of 20% from 2022 and 15% from 2027 (as comparison in Catalonia: 8% by 2020). Nevertheless, those values are still too high for high quality biowaste

separated at source. All Spanish municipalities must introduce a compulsory fee designed to cover the full cost of waste management and encourage the introduction of PAYT systems. However, the fact that the implementation of PAYT systems is not compulsory is seen as an obstacle to increasing the rates of separate biowaste collection. At the local level, the current system of open containers in MAB is leading to a high level of impurities, which makes certain recycling options more difficult.

In the EU both Spain and Italy – as countries of the MAB and MCN pilots – have national bioeconomy strategies. In addition to the European Green Deal, government support for the development and expansion of **biorefineries** is seen as a key incentive for investment decisions by private companies in biorefineries. Biorefineries relevant for the BCC project are those processing secondary raw materials, i.e., municipal, and agro-industrial organic waste and forestry residues into a range of marketable bio-based products, including biochemicals, bioplastics, (novel) food and feed, and bioenergy.

The EU holds a great potential for biomass from primary crops, agricultural and process residues, and wastes, as well as post-consumer waste. However, there are strong ethical concerns about using primary biomass for biorefineries, making a focus on biowaste, residues and by-products as feedstock all the more important. Even with by-products, residues and wastes, there is the risk of competition for certified sustainable feedstocks between different sectors with different product ideas (e.g., compost vs. bioplastics) and the challenge of medium- to long-term planning certainty for these feedstocks. For agricultural waste, biorefineries should be decentralised to facilitate biomass transport and designed to be flexible with feedstocks, considering seasonal variations in quality and quantity of certain crops. However, what is still clearly missing in the pilot areas is a comprehensive regulatory approach supporting new biorefinery processes to enter the market, including financial incentives for small-scale biorefineries in rural areas. Stable European and national policy and regulatory frameworks (timeframe 10-25 years) and biorefinery roadmaps at national, regional, and local level would further strengthen the bio-based industrial sector.

When forestry biomass (incl. **forestry residues**), food and feed crops are used for energy purpose, the sustainability aspect has been identified as the most important issue to be clarified before a decision is made on collection and use for alternative value chains. At EU level, the "cascading use of biomass principle" was introduced in 2021, i.e., biomass should preferably be used to produce materials, including plastics, and only in subsidiary order, as a source of bioenergy. Furthermore, priority should be given to long-lived products over short-lived products, including single-use products. This priority order applies to waste, by-products and primary biomass coming, for instance, from agriculture, forestry, or aquaculture. Organic waste and by-products should be preferred over primary biomass, especially for short-lived products". In accordance with that, at national level, forest residual biomass in Bulgaria is identified to have a great potential for energy production, but at the same time priority should be given to its further processing and use by other industries (PP pilot). Also in Italy, the usage of all types of biowaste and organic by-products is incentivised for energy production in biomass and biogas plants. In Spain, legal and economic criteria for electricity generation from renewable energy sources are established with focus on liquid biofuels, e.g., from biomass or biogas from anaerobic digestion, as the main fuel. However, the number

of biogas facilities in Spain is significantly lower than in Italy. A limited number of biogas plants also means less potential for biomethane upgrading plants.

Expanding the biomethane production and use was identified as a key to diversify gas supply, reducing the EU's dependence on Russian fossil fuels and decreasing dependence on fluctuating natural gas prices. REPowerEU plan is a clear driving force to foster biomethane production. MSs are called to fix their own minimum targets for biomethane to contribute to the achievement of 35 billion cubic metres per year by 2030 and set the stage for further increasing the potential by 2050.

A certain scale is required for the upgrading of biogas from the anaerobic digestion of separated biowaste to biomethane to be financially viable. Indeed, the financial feasibility depends on several factors, e.g., the amount of biomethane produced (i.e., the size of the biogas upgrading plant), the energy demand for anaerobic digestion, the selling price of biomethane and the availability of biowaste during the year. In addition, appropriate regulations for the injection of biogas or district heating as well as political and financial incentives for investments in green energy (especially for SMEs) are required. The development of a system to guarantee the origin of biomethane and the simplification and homogenization of administrative procedures for the processing of projects biogas and biomethane production can facilitate their construction.

From a **legal** point of view, the main obstacles for the industry producing new bio-based products are the clear definition between "end of waste" and "by-product", and the contradictory administrative and legal frameworks. To overcome this limitation, it has been suggested that legislators establish a more comprehensive list of by-products and the related requirements to achieve the "end of waste" status. Novel foods such as functional ingredients from coffee silverskin (MCN pilot) need to undergo a lengthy authorisation procedure by EFSA to avoid harm to (human) health and the environment. Another barrier is that companies face higher fees and costs when reusing waste in a new production process, both in terms of waste requalification and administrative procedures. In addition, permits for the construction of treatment facilities are too lengthy and cumbersome. One driving force would be to simplify the licensing and administrative procedures.

Building new **production capacities** for bio-based products is challenging, as the required investments are high and financing is complicated by often lengthy and cumbersome construction permits, market risks and available technologies. The number of composting, anaerobic digestion or other production plants of bio-based materials should be increased, especially where an important potential for biowaste valorisation exists but the local treatment capacity is insufficient. Moreover, as the biostabilised outputs produced in MBT plants will no longer contribute to the national recycling quota, this is a driver to the conversion of existing MBT plants into anaerobic digestion and composting plants treating only source-separated biowaste or the construction of new biological treatment plants. From a technological point of view, there is a lack of development of collection and recovery structures for biowaste, residues and by-products, as well as progress in the development of new innovative methods that can also be applied in rural areas and in the exchange of experience and knowledge. When it comes to treatment, the increasing amounts of bioplastics are still lacking clear recycling routes. The life cycles of bioplastics are currently mostly linear. Many different types of bioplastics further complicate mechanical sorting and recycling. While drop-in solutions such as BioPET, BioPP and BioPE can be collected and treated together with conventional plastics ('yellow bin'), biodegradable or compostable plastics collected together with biowaste may

cause problems and need to be sorted out, depending on the composting plant. In addition, a mixing between non-degradable and biodegradable bioplastics together with conventional plastics may lead to potential cross-contamination with recycling streams. Therefore, clear labelling rules and public awareness campaigns on bioplastics are needed, as well as consultation with regional plant operators on the recyclability and, if necessary, conversion of plants.

From an **economic** point of view, the main barriers to the introduction of new biowaste collection and recycling methods are too high investments for the implementation of innovative infrastructures and a lack of planning certainty for long-term investments. These investments could be partly made by the bio-based private sector, together with financial incentives from the government to ensure income and job creation. However, stable, and long-term strategies and allocation periods are needed for investments in "high-risk" projects. Furthermore, some biorefineries in the EU are less competitive than biorefineries in other parts of the world due to higher energy and labour costs as well as higher taxes and the limited availability of low-cost feedstock materials. In addition, collaboration between policy makers, researchers and market players should create incentives for local start-ups to engage with all aspects of the value chain, and providers of new product ideas should have easy access to BAT for new treatment technologies.

There are still challenges not only on the supply side (secondary raw materials), but also on the demand side (market for bio-based products). **Market access** for bio-based products remains a significant barrier due to the large disparity between the current high cost of collecting and valorising biowaste compared to the income from the sale of bio-based products. In addition, market demand can fluctuate strongly. Given the low cost of fossil equivalents, consumers' willingness to pay more for bio-based alternatives is low. Nowadays, the pull of policy on the bio-based products market is very limited. Therefore, it is a key priority to support the market up-take for bio-based products. A mandatory inclusion of the ecological footprint in the price of all products, including fossil products, would be a powerful driver. Another effective tool to stimulate market demand for new biowaste-based involves sustainable public procurement.

The proven environmental performances of bio-based chemicals and materials constitute one of the main opportunities for their further development. In particular, the use of separately collected organic waste and by-products to produce bio-based products such as biochemicals, bioplastics or bioenergy - including **biomethane** (MAB pilot) - can offer partial decoupling from fossil resources and help achieving the climate neutrality targets of the European Green Deal, while reducing the use of primary biological resources and avoiding harm to biodiversity. However, sustainability benefits need to be quantified through the development and application of standardised biomass-to-product life-cycle methodologies that take into account aspects such as greenhouse gas emissions, biodegradability (e.g., for bioplastics), biodiversity and soil quality.

In addition, there is enormous potential for the use of agri-food by-products to produce **novel foods**, such as functional ingredients from coffee silverskin, which have high human **health** benefits and lower environmental impacts. Nevertheless, new foods and feeds must be assessed by EFSA for health risks, including potential contamination of raw materials, before being placed on the market, which can take a reasonable amount of time.

In the **social** sphere, reluctance to use products made from biowaste was identified as the main barrier, while the main driving factor is the development of concepts and communication campaigns to raise social awareness on the positive impacts of the CBE in relation to biowaste management.

Stakeholders with different areas of knowledge and interests should be involved to facilitate exchange and cooperation along the CBE value chains and to find alternatives that could benefit everyone. There should be more alignment, dialogue, and cooperation between the different industrial sectors, not only to link their material flows, but also to develop a common strategy.

The conclusions of D3.2 are aligned with the outcomes of D4.1, highlighting driving forces and limitations to the implementation of biocircular solutions for biowaste treatment, based on a literature review of publications available from European technical institutions and from scientific journals. The identified drivers and barriers also form the basis for the formulation of policy recommendations for the implementation of the CBE in the selected pilot areas, which will be addressed in the next deliverable D.3.3.

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9. ANNEX I: ANALYSIS OF THE CBE POLICY FRAMEWORK FOR DRIVERS AND BARRIERS AT EU AND PILOT LEVEL

9.1. Legal drivers and barriers analysis at EU level

The drivers and barriers found in selected legal passages of the 23 relevant CBE EU documents listed in 5.1.1 are available here.

9.2. Legal drivers and barriers analysis for the PP pilot area

The drivers and barriers found in selected legal passages of the seven relevant CBE documents chosen for the PP pilot and listed in 5.1.2 are available here.

9.3. Legal drivers and barriers analysis for the MCN pilot area

The drivers and barriers found in selected legal passages of the seven 19 relevant CBE documents chosen for the MCN pilot and listed in 5.1.3 are available here.

9.4. Legal drivers and barriers analysis for the MAB pilot area

The drivers and barriers found in selected legal passages of the seven relevant CBE documents chosen for the MAB pilot and listed in 5.1.4 are available here.

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