Biological Resources Certifications Schemes

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Publishable Executive Summary

The present deliverable 2.2 (*Modified Assessment Methodologies*) will focus on the identification of environmental and circularity criteria required to evaluate biological feedstocks, considering the specificities of each bio-based sector. The study will be conducted at micro level to be suitable for all biomasses and to try to expand the results at meso and macro levels (Task 2.2 or *Identification of Environmental and Circularity Criteria*). Besides, this report will also focus on the investigation of existing environmental impact assessment methodologies in the different applicable biobased sustainability standards. Their adequacy to cover the required criteria needs to be measured and fulfilled (T2.2). T2.3 (*Environmental Impact Assessment Methodology*) will enhance the existing environmental assessment methodologies to holistically analyse and define their practicality of integration in existing biobased certification schemes. The proposed framework was based on the systematic collection of information from documents available in the literature. To verify the adequacy of the requirements determined, BioReCer has also been involved in the selection and enhancement of a methodology that could be used inside certification schemes. Due to their practicality of integration and their mono-dimensional nature, sustainability indicators were associated with each of the requirements and criteria of the framework. The objective is to be able to use them to quantitatively evaluate the certification system.

An initial step in identifying the criteria was the collection of data on certification schemes, which were chosen on the basis of five predefined filtering precepts and a systematic literature review of the Standards Map database. Since some sectors are underrepresented in terms of certification schemes, legislation, standards and initiatives were incorporated into the analysis. This was especially important for circularity criteria, which today can be found mainly in initiatives and other reports. Taking into account the diversity of documents under study, some concepts such as principle, criterion, requirement and indicators were defined. This is due to the lack of consensus in the use of these terms, even among certification systems. A total of 17 and 16 criteria for sustainability and circularity were identified in a complete framework of 10 principles. Once the theoretical framework was created, each of its items was studied to determine where they can be found among the documents and their respective importance for the construction of the framework. Their suitability was studied taking into account on the one hand the previous analysis of documents but also with the participation of BioReCer case studies answering questions associated to each one of the requirements.

Apart from being associated to questions, the indicators (both quantitative and qualitative) were proposed for each one of them. They could be used when approaching certification schemes with a reductionist (weighting and aggregating them) or holistic (uncondensed)

approach. In this regard, BioReCer provides a dataset for four sectors (wastewater, agriculture, fisheries and forestry).

1 Background and project introduction

In response to the global population rise and the associated rapid industrialization, there has been a subsequent increment of resource depletion and pollution (Wang & Azam, 2024). The accelerated development endangered the possibilities of supply for future generations and also led to the escalation of the environmental risks. In order to prevent this, there has been a call for a sustainable development on which both society and industry joint efforts. As a result, the manufacturing sector has driven a transformation of the current production and distribution routes for products in order to achieve a greener, more sustainable and decarbonized industry (Mehmood et al., 2024). Apart from this, society has become more aware of how its consumption habits influence on market, which results in an increased willingness of companies to go green (Gomes et al., 2023). Led by these changes, many companies have entered environmental certification schemes and communicated how they have been trying to pursuit sustainable (social, environmental and economic) precepts (Flagstad et al., 2022). However, and in order to defend the sustainable legitimacy of companies, the certification schemes must ensure that their goals and requirements under assessment are in line with regulations and are able to safeguard and promote that the products manufactured are sustainable throughout their life cycle (Pavlovskaia, 2014).

Alongside sustainability, two other concepts have recently gained attention: the circular economy and the bioeconomy. While the circular economy seeks to extend the life of resources and products by closing loops within life cycles, the bioeconomy aims to replace fossil resources with biogenic ones (Stephenson & Damerell, 2022). Indeed, organic waste materials can be categorised inside this group, and they can be considered one of the potential resources to be used in valorisation processes for the generation of added-value marketable products (Mahjoub & Domscheit, 2020). However, the end-of-life processes are not fully covered by certification schemes, which hinders the possibility of companies to transmit information about their operation in terms of waste management (Majer et al., 2018). Therefore, it is urgent to update the criteria that certification systems must uphold in order for a company to be self-proclaimed green.

In addition to being able to communicate and renew the level of environmentalism, there is intense pressure to offer certification systems that reduce bureaucracy, costs and green washing (Flagstad et al., 2022). The use of qualitative requirements, despite the auditors' expertise, can lead to a certain degree of subjectivity. It is recommended to develop a rigorous and systematic tool that can provide objective qualitative and quantitative information. The digitalization of the conformity assessment using mathematical equations from quantitative data is a feasible option to achieve some of the previously mentioned goals.

In line with this context, the BioReCer (Biological Resources Certification Schemes) project tries to investigate the adaptation of the available certification schemes for the certification of bio-based industries and related products with sustainable and circular perspectives. To do that, the project is composed of a total of 8 work packages. Among them, WP2 has a total of five activities aimed at developing a specification framework that can be incorporated into and validated for certification schemes. The first task is the mapping of biomass flows of industrial systems. Secondly, the identification, definition and adaptation of criteria to assess bio-based feedstocks according to legal requirements. The third and fourth activities are about the collection and proposal of environmental and circularity indicators for the development of assessment methodologies. Finally, the last proposed activity of this WP was created for the integration of the previous four activities between each other and with other WPs. This report provides an overview of the work carried out in two of the BioReCer project tasks: 2.2 (*Identification of Environmental and Circularity Criteria*) and 2.3 (*Environmental Impact Assessment Methodology*). The objective is to provide a list of principle, criteria and requirements that any certification system focused on bio-based products must include. In addition, and in order to meet these requirements, evaluation methodologies could be used. One of the most appropriate approaches to verify compliance with requirements is the use of qualitative and quantitative indicators. Although they often provide information in relation to one-dimensional aspects, a methodological procedure can be proposed to aggregate them and give single scores that can be interpreted for the criteria and principles.

2 Selection of documentation

A previous deliverable of WP2 (**D2.1**, also named *Main Biological feedstocks*), related to **Task 2.1** (*Material Flow Analysis of main biological feedstock flows*) of BioReCer, analysed the Material Flow Analysis (MFA) of the biological European feedstocks. This research pointed out the limitation of information regarding the fate of by-products due to the generation of small amounts compared to their fossil fuel counterparts. More specifically, the study was applied to the four case studies (more information on deliverable **D6.1**, or *Mid-report about case studies*) of the BioReCer project and narrowed the focus of the research going on bottom (sector-specific information) and top (to be potentially applicable to all biomasses). Also, and in line with this, **Task 2.2** (*Identification of Environmental and Circularity Criteria*) has identified some gaps related to the revised documentation to collect requirements and criteria for the creation of a sustainability and circularity framework that could be integrated to certification schemes. The documents found could not provide a complete overview of the key aspects of sustainability issues (environmental, economic and social) and circularity one by one. Therefore, four types of documents (certification schemes, directives, standards and initiative reports) were considered. First, the research conducted provides a review of the requirements within existing certification schemes. These collect detailed information taking into account legislation and other more advanced topics in order to differentiate their applicants from competitors. However, they are usually targeted at a specific sector and not all sectors have yet certification schemes that can be used by different stakeholders. More information will be provided regarding this aspect in **section 2.1**. For this reason, directives, standards and initiative reports were selected to fill the gaps in the BioReCer certification framework. European directives were mainly used to identify specific sectoral characteristics, while the objective of the reports was to provide a generic overview. Although standards can also be generic, some of them were selected based on the feasibility of their use in the BioReCer case studies and were therefore applied to a particular sector. Other types of documents, such as government reports, results of other projects and monitoring plans, were considered outside the scope of BioReCer. Based on this, the collection and the initial analysis of the documents were following two pathways: (1) the type of document and (2) based on its sectorial specificities. This section of the present **deliverable 2.2** (*Modified Assessment Methodologies*) has been organized per document type but the reader should note that both approaches have been addressed interchangeably.

2.1 The initial stage: certification schemes

The selection of the certification schemes was supported by the use of the Standards Maps ITC tool (International Trade Center, 2023). There, more than 341 (November 2023) standards can be found, and they can be classified in accordance different aspects: by sustainability topic or pillar, sector, product type, origin, destination, value chain stage, sustainable development goals, typology of certification scheme (private or public), objective of the certification scheme (verification, certification, evaluation or guidelines), recognition and use of a label for the consumer. The database was used within the BioReCer project to perform a systematic review, as is usually done using SCOPUS, Web of Science or RefWorks within scientific publications. The difference between the bibliographic database and the Standards Map tool is that the advanced keyword string is not used. It is necessary to complete the different filters provided for each of the key aspects mentioned above. Therefore, filtering criteria were developed to adapt the collection of certification schemes according to the objectives of the BioReCer project (**section 2.1.1**). Subsequently, a preliminary analysis was carried out to create a mapping based on the selection possibilities for each of the selected selection criteria (**section 2.1.2**). Certification schemes that met all the filters were grouped, compiled and analyzed. A review of each of them was carried out to check their suitability. Key aspects related to the filtering criteria of the certification schemes were studied and described in **section 2.1.3**.

2.1.1 Filtering criteria for selection of certification schemes

A total of five constraints were defined, in coordination with WP4 (also indicated on deliverable 4.3 or *Integrated environmental and traceability assessment framework into certification schemes*), for the appropriate selection of certification schemes based on project objectives and desirable quality. Apart from these criteria, it was also considered necessary to consider only certification schemes whose documents were publicly available and in English. The specific criteria are described below:

- **01.Schemes comply with European regulations:** All certification schemes certifying products that should be commercialized in Europe must consider European legislation. Therefore, the filter selected for this case was the destination of the production of the services provided.
- **02.Match with the sectors of wastewater/sewage treatment, forestry, agriculture, and fisheries:** The BioReCer project addresses 4 case studies in different contexts and locations: Galicia (Spain), Lombardy (Italy), Central Macedonia (Greece) and Västernorrland (Sweden) corresponding to the fisheries sector, the sewage and wastewater treatment sector, the agricultural sector and the forestry industry, respectively. The biomass to be recovered includes by-products and wastewater from the canning industry, sewage sludge, algae, municipal solid waste, agricultural waste, non-hazardous organic liquid waste, waste from the food processing industry, forestry and wood sectors.

03. The certification scheme must be credible with a robust third-party attestation: Regardless of whether it is voluntary or used for certification accreditation, good management of certification systems and compliance with their requirements must be carried out by external auditors.

Table 1: Recognised certification schemes by other institutions or bodies (European Commission, 2024; ISEAL Alliance, 2024)

European Union (RED Directive compliant)	ISEAL community members(1)	FEFAC compliant
Biomass Biofuels voluntary scheme (2BSvs)	Roundtable on Sustainable Biomaterials (RSB)	ADM Responsible Soy standard
Better Biomass	Roundtable on Sustainable Palm Oil (RSPO)	Amaggi Responsible Soy
Bonsucro EU	Rainforest Alliance	ASC from Aapresid
International Sustainability and Carbon Certification (ISCC EU)	Marine Stewardship Council (MSC)	PROFARM Production Standard from Food Chain ID
KZR INiG system	Forest Stewardship Council (FSC)	ProTerra Europe
REDCert	Bonsucro	Agricultura Sustentable Certificada + Module on Non-conversion
Red Tractor Farm Assurance Combinable Crops & Sugar Beet Scheme (Red Tractor)	Alliance for water stewardship (AWS)	Bunge Pro-S Assuring Sustainable Sourcing
Roundtable of Sustainable Biofuels (RSB)	Aquaculture Stewardship Council (ASC)	COFCO International Responsible Agriculture Standard
Round Table on Responsible Soy (RTRS)	International Sustainability and Carbon Certification (ISCC EU)	Sustainable Cereal and Oilseed Standard (C**SQA**)
Scottish Quality Farm Assured Combinable Crops (SQC)	International Sustainability and Carbon Certification PLUS (ISCC PLUS)	Caramuru Sustentar Programme
Trade Assurance Scheme for Combinable Crops		Cargill Triple S Soya Products
Universal Feed Assurance Scheme (UFAS)		Cefetra Certified Responsible Soya Standard
Sustainable Resources voluntary scheme (SURE)		Donau Soja
Sustainable Biomass Program (SBP)		Europe Soya
Austrian Agricultural Certification Scheme (AACS)		FEMAS Responsible Sourcing Module 2021
		International Sustainability and Carbon Certification (ISCC EU)
		International Sustainability and Carbon Certification PLUS (ISCC PLUS)

(1) Only those for the BioReCer sectors were included.

04. The certification schemes have Governmental and/or market recognition: So far, the European Commission has formally distinguished 15 voluntary national certification schemes (European Commission, 2024). However, most of these certification schemes focus on the bioenergy sector, including biofuels, bioliquids and biomass for fuel production. Therefore, the manufacture of other bioproducts is considered outside their scope, with the drawback that not all recognized certification schemes are suitable for other types of materials. Despite this, there are other institutions or bodies able to recognise the certification schemes such as ISEAL Alliance (through membership), the Global Food Safety Initiative (GFSI), Global Sustainable Seafood Initiative (GSSI) and FEFAC (European Compound Feed Manufacturers Federation). Therefore, any certification system that is established in accordance with the guidelines and recommendations of any of these organizations is assumed to have quality aspects such as measurable progress, stakeholder engagement, transparency, fairness, reliability and continual improvement. **Table 1** lists all the certification systems that comply with the RED directive, the ISEAL members and the FEFAC.

05. **Excluding schemes and labels specific for food/feed, biofuel/bioenergy and recreation sectors:** The HORIZON-CL6-2021-ZEROPOLLUTION-01-05 call aimed to improve the environmental performance of industrial processes in bio-based sectors including primary biomass resources and secondary raw materials. Biofuels and food products are not included in the call, except when they are used for the production of other non-energy biochemical products.

2.1.2 Mapping the certification schemes and possibilities

Out of the 341 certification schemes of Standards Map, 72.1% are considering products commercialized or sold in Europe independently if they are being manufactured in other continents and 60.1% take into account the certification schemes operating in producer European countries. This is a reflection of the large number of certification schemes that could potentially be selected when addressing an analysis framed within a European context and also fulfil the first criteria described in **section 2.1.1**.

Regarding the sector selection, the database considers 19 possible filters. Only five were used for BioReCer: agriculture, aquaculture, fisheries, forestry and floriculture and horticulture. All these sectors were considered to give response to the needs of criteria, to be collected from the documentation selected, from the sectors related to the BioReCer case studies. Although the complete description is provided in **D6.1** (*Mid-report about case studies*), a summary is provided below to give a reasoning for the selection of the documents based on the systematic literature review on the database Standards Map.

- **Case study 1:** This case study has been located in Galicia (Spain) and led by CETAQUA (Centro Tecnológico del Agua) and ANFACO (Asociación Nacional de Fabricantes de Conservas de Pescados y Mariscos). Two types of feedstocks were valorised. On the first hand, industrial fish and seaweed wastes were fed for the manufacturing of fish oil, collagen and polysaccharides. Secondly, sewage sludge from wastewater treatment plants was subjected to a fermentation process to produce volatile fatty acids (acetic, propionic, butyric, valeric and others).

- **Case study 2:** This case study has been developed around secondary raw materials from urban (i.e., organic fraction of municipal solid waste or sewage sludge) and industrial activities. The goal of the valorization processes located in Lombardy (Italy) was the production of polyhydroxybutyrate (a biodegradable polymer). The definition of the case study and data collection were carried out in this case by UNIVPM (Universitá Politecnica delle Marche), CAP HOLDING SPA and SPRING.
- **Case study 3:** The agricultural wastes (straw and stems, pruning and food waste from the processing industry) from the Region of Central Macedonia (Greece) were gathered to manufacture bio-based soil enhancers and particle boards. In this case, the case study was led by CERTH (Centre for Research and Technology Hellas).
- **Case study 4:** A thermochemical pre-treatment, fermentation, hydrothermal carbonisation and hydrothermal liquefaction were the technologies of this case study located in Västernorrland (Sweden) for the recovery of residues and or by-products from the forestry industry. The partner in charge of this case study was RISE (Research Institutes of Sweden).

It should be noted that in Standards Map a category for the wastewater or sewage sector is missing in the database, which is a limitation to ensure the representativeness of the requirements selected for the BioReCer using only certification schemes. Because of this, other potential certification schemes for the water sector were collected outside the Standards Map tool. NFS, The Water Quality Association, IAMPO R&T, European Drinking water, European Water Stewardship, Smart Approved Watermark and WAVE (Water Stewardship Verified). Although all of them have web pages available for public consultation, the documents showing the criteria of the certification systems are not accessible. Moreover, they approach the urban water cycle in an integrative manner, without promoting the specificities of each stage of the value chain. Therefore, the wastewater or water approach is not represented by certification schemes. In this case, the information has been completed using the European directives in force. The share of available certification schemes for the other sectors is shown in **Figure 1A**. The certification schemes that are verified by third parties represent almost 75% of the database. Among them, almost 50% are from the agricultural sector. The lowest representativeness is given to aquaculture with 9.4% (shown in **Figure 1B**). When limiting the verified certification schemes for Europe, the percentage of available verified schemes increases between 3.3%-11.6% (agriculture and horticulture) depending on the sector. The first three screening criteria are covered, and the fourth is market recognition. The results considering CGF SSCI, ISEAL, FEFAC and GSSI are shown in **Figure 1D**.

Based on the first 4 filtering criteria of **section 2.1.1** a total of 32 certification schemes were identified. Among them, 18 were removed because they did not meet the latest selection criteria referring to the exclusion of fuels and food. Four other certification schemes were included in BioReCer because, although they are not yet recognized by the

CGF SSCI, ISEAL, FEFAC or GSSI, they have a strong market presence and have been recognized by other bodies (e.g. the Dutch Accreditation Council). Moreover, they are relevant in the benchmarking between certification systems and the gap analysis performed in WP4. More information regarding this is on **D4.3**. All the certification schemes considered are listed in **Tables 2** and **3**.

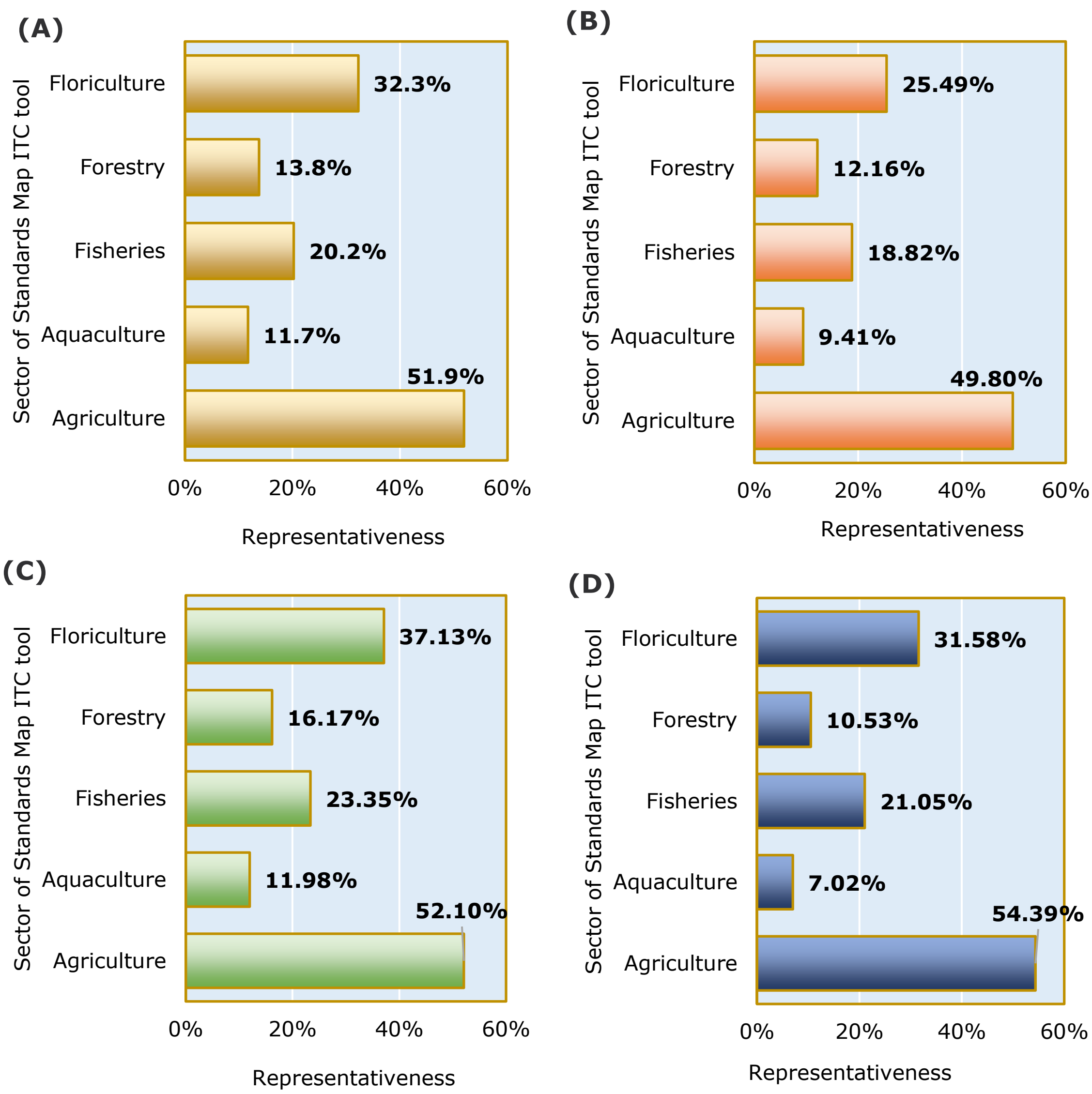


Figure 1: Representativeness of available certification schemes in Standards Map ITC tool for (A) based on the BioReCer selected sector, (B) verified by third bodies, (C) verified by third bodies and applicable for Europe and (D) verified by third bodies, applicable for Europe and recognised by CGF SSCI, ISEAL, FEFAC or GSSI.

2.1.3 Characteristics of Selected Certification Schemes

The characteristics of the selected certification schemes can be found in **Tables 2** and **3**. As shown, the majority of certification schemes apply to the agricultural and/or forestry sector (12 out of the 18 selected). The differences in the structure, requirements and methodologies used for the validation of the certification schemes are very similar between both sectors and in many cases, they cannot be classified independently. The fisheries/aquaculture sector follows with 5 certification schemes (one of them is shared with the agricultural sector and was previously mentioned in the other sector). The last certification scheme applies to the water sector, whose requirements have been included and extrapolated to the wastewater and sewage sludge sectors.

Based on the stages considered on the value chain, ISSC, FSC, Better Biomass and SURE were the four certification schemes including all the value chain stages (production, manufacturing or processing, consumption and distribution) while only one (SBP) considered the production stage. Most of the certification schemes consider three stages, with the consumption stage being included only in the certification of ISSC, FSC, Better Biomass, RSB and SURE.

In terms of market recognition, more than half of them comply with the ISEAL code and 3 are approved by FEFAC.

2.2 Completing certification schemes with legislation

A total of 23 Directives and European Regulations (7 of them) were reviewed to complete the framework of pillars, principles, criteria and requirements of the BioReCer project that would support other WP2 tasks and other project WPs. There was a two-fold reason for the inclusion of such directives. On one hand, the goal is to try to accomplish a representative framework also for the wastewater and fisheries sectors. This is especially important for the wastewater sector, as the Alliance for Water Stewardship certification system focuses more on water catchment-related phases than on treatment. Second, address the specific needs of the case studies as well as generic sustainability issues. You can find each of the European legislations revised on **Tables 4, 5, 6, 7** and **8**.

Table 2: Outcomes of the systematic review done in Standards Map database.

Certification scheme	Logo	Consumer label	Purpose	Typology	Recognition	Value chain focus	Sector	Document availability
Aquaculture Stewardship Council (ASC)	asc	Businesses and consumers	Verification/ certification	Private standard	ISEAL Community Member and ISEAL Code Compliant Member	Production, manufacturing and distribution. The consumption stage is not included	Fisheries	Yes
GLOBAL G.A.P Aquaculture	GLOBALG.A.P.	Businesses and consumers	Verification/ certification, Accreditation and Benchmarking	Private standard	GFSI and GSSI	Production and manufacturing. The distribution and consumption stages are not included	Fisheries	Yes
Cargill Triple S Soya Products	Cargill	Businesses	Not applicable	Private standard	FEFAC benchmarked	Production and manufacturing. Distribution and consumption are not included	Agriculture, manufactured products and services	Yes
ISSC EU	ISCC	Businesses and consumers	Verification/ certification and accreditation	Private standard	FEFAC benchmarked, ISEAL Community Member and RED directive compliant	Production, manufacturing, distribution and consumption	Agriculture, Energy, Floriculture and Horticulture and Manufactured products	Yes
ISCC PLUS	ISCC	Businesses and consumers	Verification/ certification and accreditation	Private standard	FEFAC benchmarked and ISEAL Community Member	Production, manufacturing and consumption. Distribution is not included	Agriculture, Energy, Floriculture and Horticulture and Manufactured products	Yes
Global Seafood Alliance (GSA)	Global Seafood ALLIANCE	Not applicable	Verification/ certification	Internationa l Standard	SSCI recognized	Production and manufacturing. The distribution and consumption stages are not included	Aquaculture, Fisheries, Manufactured Products	Yes
Amfori Business Social Compliance Initiative (BSCI)	amfori BSCI	Businesses and consumers	Best practices and guidelines	Private standard	SSCI recognition: in process	Production and manufacturing. The distribution and consumption stages are not included	Agriculture, Aquaculture, Clothing, Culture, Education, Energy, Finance, Fisheries, Floriculture & Horticulture, Forestry, Livestock, Manufactured products, Mining, Processed food, Retail, Services, Textiles and Tourism	Yes

Table 2: Outcomes of the systematic review done in Standards Map database (continuation).

Certification scheme	Logo	Consumer label	Purpose	Typology	Recognition	Value chain focus	Sector	Document availability
Alliance for Water Stewardship (AWS)		Businesses and consumers	Best practices and guidelines	Private standard	ISEAL Community Member	Production, manufacturing and distribution. The consumption stage is not included	Agriculture, Aquaculture, Clothing, Culture, Education, Energy, Finance, Fisheries, Floriculture & Horticulture, Forestry, Livestock, Manufactured products, Mining, Processed food, Retail, Services, Textiles and Tourism	Yes
Better cotton		Businesses	Verification /Certification, Benchmarking, best practices and guidelines	Private standard	ISEAL Community Member and ISEA Code Compliant Member	Production and manufacturing. The distribution and consumption stages are not included	Agriculture	Yes
Forest Stewardship Council (FSC)		Businesses and consumers	Verification /Certification and accreditation	Private standard	ISEAL Community Member and ISEA Code Compliant Member	Production, manufacturing, distribution and consumption	Agriculture, forestry and manufactured products	Yes
MarinTrust Standard		Businesses	Verification /Certification	Private standard	ISEAL Community Member and ISEAL Code Compliant Member	Production, manufacturing, distribution. The consumption stage is not included	Agriculture, Fisheries and manufactured products	Yes
Marine Stewardship Council (MSC)		Not applicable	Verification /Certification	Private standard	ISEAL Community Member and ISEA Code Compliant Member	Production, manufacturing, distribution. The consumption stage is not included	Fisheries	Yes
Sustainable Biomass Program (SBP)		Businesses	Verification /Certification	Internationa l Standard	ISEAL Community Member and RED directive compliant	Only production stage is included	Floriculture & Horticulture and forestry	Yes
Union for Ethical BioTrade (UEBT)		Businesses and consumers	Verification /Certification and best practices and guidelines	Private standard	ISEAL Community Member and ISEA Code Compliant Member	Production and manufacturing. The distribution and consumption stages are not included	Agriculture, Floriculture & Horticulture, forestry and manufactured products	Yes

Table 3: Characteristics of certification schemes not selected according to Standards Maps ICT tool filtering.

Certification scheme	Logo	Consumer label	Purpose	Typology	Recognition	Value chain focus	Sector	Products	Document availability
Better Biomass		Not applicable	Benchmarking	Private standard	Complies with the Dutch Accreditation Council (RvA). Certification on the basis of NTA 8080-1 and NTA 8080-2. RED directive compliant.	Production, manufacturing, distribution and consumption	Energy and floriculture & Horticulture	Biofuels and plants	Yes
Programme for the Endorsement of Forest Certification (PEFC)		Businesses and consumers	Verification /Certification and benchmarking	Private standard	Compliant with ISO/IEC 17021-1 conformity assessment-requirements for bodies providing audits and certification of management systems-Part 1: requirements	Production, manufacturing, distribution. The consumption stage is not included	Forestry and manufactured products	Health, Households, Other products	Yes
Roundtable on Sustainable Biomaterials (RSB)		Businesses and consumers	Not applicable	International standard	ISEAL Community Member, ISEAL code complian and RED directive compliant.	Production, manufacturing and consumption. The distribution stage is not included.	Agricultural, forestry, marine and aquatic	Any bio-based feedstock or biomass-derived material, plastics, textiles, pharmaceuticals, packaging, tableware, cosmetics, food, feed, pulp, paper and others	Yes
Sustainable Resources voluntary scheme (SURE)		Businesses	Verification /Certification and benchmarking	-	Accredited by the German Accreditation Body (DAkkS), complies with the ISO 17065 standard for certification bodies and is RED Directive compliant	Production, manufacturing, distribution and consumption	Agricultural and forestry	Agricultural crops and residues, forest biomass, and waste biomass	Yes

Table 4: Generic-industrial European legislation used within for the criteria framework of BioReCer.

Generic-industrial European legislation
Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment
Directive 2012/18/EU of the European Parliament and of the Council of 4 July 2012 on the control of major-accident hazards involving dangerous substances, amending and subsequently repealing Council Directive 96/82/EC
Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC
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
Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe
Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives
Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste
Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics

Table 5: European legislation applicable within the fisheries sector and used within the criteria framework of BioReCer.

Fisheries sector European legislation
Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy
Council Regulation (EC) No 1967/2006 of 21 December 2006 concerning management measures for the sustainable exploitation of fishery resources in the Mediterranean Sea, amending Regulation (EEC) No 2847/93 and repealing Regulation (EC) No 1626/94
Council Regulation (EC) No 1005/2008 of 29 September 2008 establishing a community system to prevent, deter and eliminate illegal, unreported and unregulated fishing, amending Regulations (EEC) No 2847/93, (EC) No 1936/2001 and (EC) No 601/2004 and repealing Regulations (EC) No 1093/94 and (EC) No 1447/1999
Council Regulation (EC) No 1224/2009 of 20 November 2009 establishing a Community control system for ensuring compliance with the rules of the common fisheries policy, amending Regulations (EC) No 847/96, (EC) No 2371/2002, (EC) No 811/2004, (EC) No 768/2005, (EC) No 2115/2005, (EC) No 2166/2005, (EC) No 388/2006, (EC) No 509/2007, (EC) No 676/2007, (EC) No 1098/2007, (EC) No 1300/2008, (EC) No 1342/2008 and repealing Regulations (EEC) No 2847/93, (EC) No 1627/94 and (EC) No 1966/2006

Table 6: European legislation applicable within the wastewater sector and used within the criteria framework of BioReCer.

Wastewater/water sector European Legislation
Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment
Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council
Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture
Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources
Council Directive 91/676/EEC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources
Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
Directive 2008/105/EC of the European Parliament and of the Council of 16 December 2008 on environmental quality standards in the field of water policy, amending and subsequently repealing Council Directives 82/176/EEC, 83/513/EEC, 84/156/EEC, 84/491/EEC, 86/280/EEC and amending Directive 2000/60/EC of the European Parliament and of the Council
Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse

Table 7: European legislation for sustainability issues and used within the criteria framework of BioReCer.

Sustainability European legislation
Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088
Commission Delegated Regulation (EU) 2023/2486 of 27 June 2023 supplementing Regulation (EU) 2020/852 of the European Parliament and of the Council by establishing the technical screening criteria for determining the conditions under which an economic activity qualifies as contributing substantially to the sustainable use and protection of water and marine resources, to the transition to a circular economy, to pollution prevention and control, or to the protection and restoration of biodiversity and ecosystems and for determining whether that economic activity causes no significant harm to any of the other environmental objectives and amending Commission Delegated Regulation (EU) 2021/2178 as regards specific public disclosures for those economic activities

Table 8: Other European legislation used within the criteria framework of BioReCer.

Other European legislation
Directive 2004/109/EC of the European Parliament and of the Council of 15 December 2004 on the harmonisation of transparency requirements in relation to information about issuers whose securities are admitted to trading on a regulated market and amending Directive 2001/34/EC

2.3 ISO standards and initiatives

The choice of documents is the result of an iterative process of gap detection (as a result of the collaboration between the University of Santiago de Compostela and Meo Carbon Solutions GmbH) during the progressive identification of requirements inside certification schemes and directives. The ISO standards were used to strengthen those aspects being less often or not considered inside the previously mentioned documents. For example, it was noticed that the BioreCer framework of principles, criteria and requirements for circularity has been more represented by ISO standards and initiatives than by certification schemes and directives (more information in **section 3.3.2**). This is because, although the concept of circular economy originated in 1970, it was not until 2013 when research interest started to grow exponentially (Arruda et al., 2021). Almost 89% of the articles found between 2005 and 2020 were published between 2017 and 2020 (three years) (Meseguer-Sánchez et al., 2021). The following is the list of standards used in the BioReCer framework, classified by topics.

Table 9: ISO standards related to environmental areas of concern incorporated in the BioReCer criteria framework.

Standard code	Standard name
ISO 14001:2015	Environmental management systems — Requirements with guidance for use
ISO 15259:2023	Air quality — Measurement of stationary source emissions — Requirements for measurement sections and sites and for the measurement objective, plan and report
ISO 14064-1:2012	Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removal
ISO 9001:2015	Quality management systems — Requirements
ISO 50001:2018	Energy management systems — Requirements with guidance for use
AGRO 2-1 and 2-2:2019	Management of Rural Environment - Integrated Management in Agricultural Production.

Table 10: ISO standards related to environmental methodologies incorporated in the BioReCer criteria framework.

Standard code	Standard name
ISO 14044:2006/A2:2021	Environmental management - Life cycle assessment Requirements and guidelines - Amendment 2
ISO 14046:2014	Environmental management — Water footprint — Principles, requirements and guidelines
ISO 14067:2019	Greenhouse gases - Carbon footprint of products - Requirements and guidelines for quantification
ISO 22948:2020	Carbon footprint for seafood — Product category rules (CFP–PCR) for finfish

Table 11: ISO standards related to social and economic areas of concern incorporated in the BioReCer criteria framework.

Standard code	Standard name
ISO 45001:2023	Occupational health and safety management systems - Requirements with guidance for use
ISO 15663:2021	Petroleum, petrochemical and natural gas industries — Life cycle costing
ISO 30414:2018	Human resource management — Guidelines for internal and external human capital reporting
ISO 14045:2012	Environmental management — Eco-efficiency assessment of product systems — Principles, requirements and guidelines

Table 12: ISO standards related to sustainability and circularity aspects incorporated in the BioReCer criteria framework.

Standard code	Standard name
UNE-EN 16751:2016	Bio-based products. Sustainability criteria
ISO 34101-2:2019	Sustainable and traceable cocoa. Part 2: Requirements for performance (related to economic, social and environmental aspects)
ISO 20400:2017	Sustainable procurement — Guidance
BS 8001:2017	Framework for implementing the principles of the circular economy in organizations – Guide
ISO standards such as ISO/DIS 59004, ISO/DIS 59010, ISO/DIS 59020, ISO/DIS 59021, ISO/DIS 59032 and ISO/DIS 59040 were not revised because they were under development during the execution of task 2.2 of the project.	

With the documents mentioned above, the requirements of the sustainability pillars were covered. However, further requirements of the circular economy initiatives have been collected. It should be noted that these documents, like those of the standards, were not sectoral. Therefore, the collection of information in this case has been carried out following a top-down (generic) to bottom-up (specific) approach.

Five documents are building the non-sectorial framework of principles and criteria: The Montreal Process report, the European Green Deal, the Catalogue of Best Practices in Circular Economy, the Categorisation system for the circular economy and the EEA (European Environment Agency) Report 2/2016 (European Commission, 2020; European Environment Agency, 2016; Ministerio para la Transición Ecológica y el Reto Demográfico, 2021; The European Green Deal, 2019; The Montréal Process Working Group, 2015). These can be considered as the main documents laying the foundations for other governmental reports in the topics of circular economy. **Table 13** shows a list of the reports found.

Table 13: Governmental reports on circular economy.

Report name	Location	Date
España Circular 2030	Spain	NA
Promoting the Green and Circular Economy in Catalonia	Catalonia (Spain)	NA
Extremadura 2030. Green and Circular Economy Strategy	Extremadura (Spain)	2018
Circular Bilbao and Bizkaia	Bilbao (Spain)	2018
Agenda for the Development of the Circular Economy in Navarra 2019-2030	Navarre (Spain)	2019
Galician Strategy of Circular Economy 2019-2030	Galicia (Spain)	2019
Basque Country Circular Economy Strategy 2030	Basque Country (Spain)	2019
The Green and Circular Economy of Barcelona City Council	Barcelona (Spain)	2019
Spanish Strategy for Circular Economy: España Circular 2030 (2020)	Spain	2020
1st Roadmap Paris Circular Economy Plan (2017)	Paris (France)	2017
Paris Circular Economy Plan: 2017-2020	Paris (France)	2017
1st Roadmap Paris Circular Economy Plan	Paris (France)	2017
10 Key Indicators for Monitoring the Circular Economy	France	2017
Circular Economy Roadmap	France	2018
2nd Roadmap Paris Circular Economy Plan	Paris (France)	2018
Key indicators for monitoring the circular economy	France	2021
Measuring Scotland’s progress towards a circular economy to help combat the climate emergency. Results from a preliminary scoping study reviewing key indicators.	Scotland (United Kingdom)	NA
Making Things Last A Circular Economy Strategy for Scotland	Scotland (United Kingdom)	2016
London´s circular economy route map	London (United Kingdom)	2017
Measuring the Circular Economy Developing and indicator set for Opportunity Peterborough	Peterborough (United Kingdom)	2018
Monitoring framework for the circular economy	European Union	2019

Table 13: Governmental reports on circular economy (continuation).

Report name	Location	Date
Circular Economy Framework Monitoring Report	Greater Porto Area (Portugal)	NA
Circular Economy Route Map for Glasgow 2020-2030	Glasgow (United Kingdom)	2020
Circular Rotterdam: Opportunities for new jobs in a zero waste economy	Rotterdam (The Netherlands)	NA
Circular Amsterdam - A Vision and Action Agenda for the City and Metropolitan Area	Amsterdam (The Netherlands)	2016
Circular economy: what we want to know and can measure	Netherlands	2018
Circular Economy in Europe (2016)	Europe	2016
Categorisation system for the circular economy (2020)	European Union	2020
The EIB Circular Economy Guide (2020)	European Investment Bank	2020
Regional Programme for the Circular Economy 2016-2020 (PREC)	Brussels-capital Region (Belgium)	2016
Indicators for circular economy (CE) transition in cities (2019)	Brussels (Belgium)	2019
Leading the transition [Action plan for the circular economy in Portugal: 2017-2020]	Portugal	2017
Towards a Model of Circular Economy for Italy- Overview and Strategic Framework	Italy	2017
German Resource Efficiency Programme II	Germany	2016
Resource Wisdom Roadmap	Turku (Finland)	NA
Roadmap of the Circular Economy of North Karelia	North Karelia (Finland)	2018
Roadmap towards the circular economy in Slovenia	Slovenia	2018
Roadmap for circular economy in Serbia	Serbia	NA
Measuring circularity: a critical analysis of some relevant indicators (2020)	Fondazione Eni Enrico Mattei (FEEM)	2020
Circularity Indicators: An Approach to measuring Circularity (2019)	Ellen MacArthur Foundation	2019
Circular Indicators for Governments: Accelerating action in the circular economy	Platform for Accelerating the Circular Economy (PACE)	2021
Circular Transition Indicators V3.0: Metrics for business, by business	World Business Council for Sustainable Development	2022
4th Fundamental plan for establishing a sound material-cycle society	Japan	NA
Sustainable Materials Management: The Road Ahead	United States	2009
Inclusive Recycling Programme	Peñalolén (Chile)	2013
Introduction of the Framework Act on Resource Circulation toward Establishing a Resource- Circulating Society in Korea	Korea	2016
Circular Economy Procurement Implementation Plan and Framework	Toronto (Canada)	2018
National Strategy for the Circular Economy (2019)	Colombia	2019
National Resource Efficiency Policy	India	2019
National Waste Management Strategy	Republic of South Africa	2020
Measuring the circular economy: An Australian perspective	Australia	2022

2.4 Documents specifically applicable to the BioReCer case studies

Although each BioReCer case study is based on a different geographical location (CS1 in Spain, CS2 in Italy, CS3 in Greece and CS4 in Sweden), the documentation was classified according to the type of facility and sector. For example, CS1 has facilities in the fisheries and wastewater or waste treatment sectors. This section aims to give an overview of the documents required for the facilities considered as case studies for BioReCer.

01. **The fisheries waste and algae processing facilities:** ASC, GSA, GLOBAL G.A.P, MSC and MarinTrust are examples of certification schemes that can be applied to the fisheries sector. However, the first three were more focused on aquaculture activities rather than marine fisheries or waste processing. The selection of documents was supported by the company ANFACO in relation to the case study CS1 (which they have led).

02. **The wastewater and sewage sludge facilities:** AWS, ISO 14001:2015, ISO 14064:2012, ISO 50001:2018, ISO 9001:2018, ISO 14045:2012, ISO 20400:2017 were used for wastewater facilities. Although publicly available documentation on certification systems is limited for this sector, voluntary accreditation to ISO standards can cover aspects of environmental management, quality, energy and sustainable procurement. Measurement of eco-efficiency and greenhouse emissions has also been considered. There is a lack of a certification system with an end-of-life perspective for this sector and currently facilities need to apply more than one standard to obtain certification. Within this context, the BioReCer project has collected all the requirements from these voluntary standards to create a framework that could also be representative of this sector's particularities . The selection of the documents for this sector has been supported by CETAQUA, UNIVPM and CAP.

03. **Particle board industry and manufacturing of soil amendments:** Although CS3 of BioReCer also covers agricultural small-scale activities, the certifications schemes selected with the systematic literature review are not able to cover small-scale farmers. This is an aspect that differentiates CS3 from the others. As far as the industry approach, the following documents were considered: GLOBAL G.A.P., FSC, ISO 14001:2015, ISO 9001:2018 and ISO 45001:2018. Other certifications were studied in the case study, such as the International Food Standard (IFS), BRCS Food Safety, Sedex Advance platform, ISO 22000:2005, BRC, among others. Their requirements were not adopted by the BioReCer framework because the documents did not meet the selection criteria described in **section 2.1.1**. For this sector, the CERTH has collaborated in the provision of additional documents that could serve for CS3 in the subsequent identification of requirements to be integrated inside the framework.

04. **Hydrothermal liquefaction of wood chips:** SBP, FSC, PEFC, RSB, ISCC, SURE, Better Biomass and ISO 14001: 2015 were documents applicable to the activities of CS4. This is the most robust case study in terms of documentation availability and thus requirements gathering. RISE (Research Institutes of Sweden) helped to identify relevant documents.

3 Definition of the BioReCer framework (criteria)

Each of the documents collected in **section 2** of this **deliverable 2.2** (*Modified Assessment Methodologies*) has information regarding the actions to be taken by the companies to be sustainable and circular, the so-called requirements. These actions must be performed to achieve predefined objectives, called criteria, which subsequently seek to follow a main purpose (principle). This section describes the construction of the BioreCer framework of requirements, criteria and principles that subsequently feed **task 2.5** (**D2.5.**, named as *Guidelines for integration to bio-based certification schemes*) and finally be used by WP3, WP4 and WP5.

3.1 Definitions applicable in BioReCer

Before determining the content of the framework, a first step is to clarify the relevant terms to be used. This is important for topics or aspects that are currently used in different contexts and that may be subject to a certain degree of subjectivity as to their meaning and use. This could be, as example, the use of "Principle", "Criterion" and "Indicator". Colfer et al. (1995), BOPP (2012), Ritchie et al. (2000) and UNE-EN 16751:2016 are examples of references that address different explanations and interpretations for each. This divergence can also be found between certification systems, whose structural differences are wider between sectors. For example, the AWS certification scheme consisted of steps, criteria and qualitative indicators. There, the actions to be followed by the certification scheme are defined as indicators instead of requirements or criteria. ISCC EU, has six principles and the terms requirements and criteria are used interchangeably. FSC has ten principles, and the interpretation of criteria and requirements is similar to those of ISSC. ASC on the other hand, consists of principles, criteria, indicators and requirements. The requirements, on the other hand, are the thresholds that the indicators must not exceed. Indicators are qualitative and serve to measure the degree of compliance with the criteria. They define the existence of documentation or other evidence rather than pointing to actions to be taken by the company.

Within this context, the structure of the framework of sustainability and circularity principles and criteria for BioReCer has been predefined based on the definitions of the previously discussed concepts:

- **Pillar:** Aspect or area in which the principles are supported (i.e., environmental, social or economic).
- **Principle:** Fundamental truth or law that provides a rationale for action (i.e., protection of ecosystems or working conditions).

- **Criterion:** Objective that must be met to achieve the aspirational goal or principle that governs decisions and behavior.
- **Requirement:** Necessary condition that must be met in order to apply for accreditation, comply with legislation or be judged by a third party.
- **Indicator:** Quantitative, qualitative or binary variable that can be measured or described for the evaluation of a defined aspect (in agreement with the definition of UNE-EN 16751:2016).
- **Threshold:** Quantitative, qualitative or binary variable that indicates the level of compliance with the requirement or indicator.

In addition to the definitions established to structure the framework, others have been considered, as they are necessary for the understanding of the requirements. These are also definitions that will be used in the following deliverables of the consortium.

- **Product:** Any substance or object that is manufactured or refined for sale.
- **Waste:** Any substance or object which the holder discards or intends or is required to discard.
- **Residue:** Any substance that is not the end-product that a production process directly seeks to produce; it is not a primary aim of the production process, and the process has not been deliberately modified to produce it.
- **Co-product:** Any of two or more products coming from the same unit process or product system.
- **By-product:** Secondary product derived from a production process, manufacturing process or chemical reaction; it is not the primary product or service being produced.
- **Unsold finished good:** Product that have gone through the complete production process and are ready for sale to customers.
- **Bioproduct:** A (typical commercial) product derived from biological materials.
- **Secondary raw material:** Recycled material substances that meet end-of-waste criteria as defined in the Directive 2008/98/E on waste.

As indicated on **section 2.3**, the increase of interest in the topic of circular economy started in 2013. This is the reason why there is still no agreement on the definition of some circular economy concepts. The terms defined below when presented as indicated in the research of Kirchherr et al. (2023), who analysed several definitions and concepts from 114 publications in the topic of circular economy, the standard BS8001:2017, the ISSC certification scheme and the initiative "Categorisation system for circular economy" (European Commission, 2020).

- **Refuse:** Make a product redundant by abandoning its function or offering the same function with a radically different product.
- **Rethink:** Make the use of the product more intensive (e.g., by sharing the product).
- **Reduce:** Increase efficiency in product manufacture or use by consuming fewer natural resources and materials.
- **Reuse:** Reuse by another consumer of discarded product which is still in good condition and fulfils its original function.
- **Repair:** Repair and maintenance of defective product so it can be used for its original function.
- **Refurbish:** Restore an old product and bring it up to date.
- **Remanufacture:** Use parts of a discarded product in a new product with the same function.
- **Repurpose:** Use a discarded product or its parts in a new product with a different function.
- **Recycle:** Means of any operation by which a discarded or wasted material is reprocessed into products with the same of other purpose.
- **Recover:** Means of any operation by which a discarded or wasted product is having a useful purpose and replaces other materials which could be otherwise been used for the same particular function.
- **Reclaim:** Collection of products, components or materials to avoid waste and with the purpose of reuse or recycling.

3.2 Selection of requirements

This section provides the methodological procedure for the selection of the requirements constituting the framework inside BioReCer, the description of the framework, and the analysis of the selected requirements, principles and criteria inside the documents.

3.2.1 Procedure for the selection of requirements

There are two viable ways of studying the principles, criteria and requirements of certification systems. The first involves the separate collection of each aspect or key area under protection inside each of the certification schemes and their subsequent analysis and integration. This can be done for certification schemes that consider the same structure in terms of principles, criteria, requirements and indicators, so there is the possibility of listing them. This is suitable, for example, for the comparison of the FSC and ISSC (task done within WP4 and analysis provided on **D4.3)**. However, the BioReCer framework, although applicable to biomass and bio-based products, is multidisciplinary. The use of certification systems from different sectors and the diversity of certification procedures make it difficult to systematically select requirements and criteria when these have been defined differently from one sector to another. This is especially important when trying to study a large list of certification schemes. It also complicates the integration of requirements from other documents such as standards or directives. Therefore, the work carried out within BioReCer inside **task 2.2** has initially been approached considering the collection of requirements or key areas of protection starting from one document and ensuring that the subsequent documents under analysis did not have additional requirements that could be potentially incorporated into the framework. Since the data gathered was sectorial and specific for biomasses, a bottom-up approach was used.

As previously mentioned, **(section 3.1)**, the first step was to define which was a requirement for the consortium. With that in mind, requirements were collected from all the documents cross-checking that all possible key aspects of concern were addressed. Examples could be the determination of carbon footprint emissions to the environment or to ensure gender equality at work. Once the actions that companies or applicants could take are collected, the next step is classifying those actions to guarantee that they pursue the same goals. In these regards, criteria and principles were proposed. The selection of requirements was continuously under assessment with the incorporation of documents as well as their reduction and filtering considering the results from their bibliometric analysis, their validation using the BioReCer case studies and the creation of an expertise panel inside WP2. The automatic decision based on the use of the documents consisted of a tool on which all the requirements were neglected if they were not considered at least in 10% of the certification schemes under study. For a percentage higher than 25%, the requirements were assumed to be relevant enough to be adopted by the framework. The second layer was the use of field data from the case studies. Therefore, questionnaires were created to be completed by each case study leader and stakeholders.

The questionnaires consisted of qualitative questions related to the preliminary list of requirements. The questionnaires were answered with "Y" if data was available to address the requirement, "N" when data cannot be provided, "NA" when data is not available and "NM" for data that is not currently measured but that can be measured in the future. Based on the answers from the case studies, criteria were proposed to select or reject the requirement. When the question was answered by all case studies as "Y" or "NM", the requirement has the potential to be tackled by all bio-based industries when they decide to be certified. On the other hand, answers like "NA" or "N" were assumed to be difficult to measure. Further information is provided in **section 3.4.** On the other hand, **Figure 2** is a summary of the stages indicated.

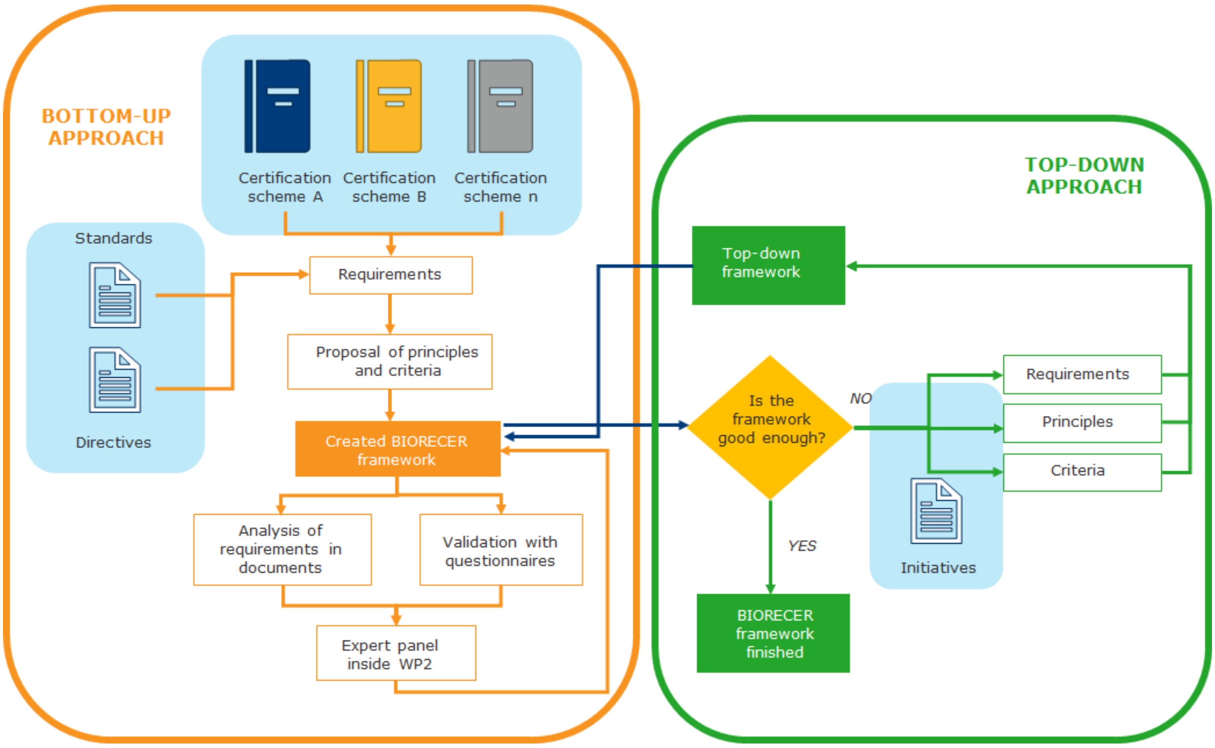


Figure 2: Summary of each of the stages followed to finalize the selection of the requirements.

Table 14: Principles of circular economy found on initiatives (European Commission, 2020; European Environment Agency, 2016; Ministerio para la Transición Ecológica y el Reto Demográfico, 2021).

Catalogue of Best practices in Circular economy	Categorization system for the circular economy	Circular economy in Europe. EEA Report 2/2026	BS 8001:2017
Systemic and holistic thinking Responsibility To re-thinking/re-generate To innovate and virtualise To optimise To "closing the loop" To share and collaborate Communication and transparency	Circular design and production Circular use Circular value recovery Circular support	Less input and use of natural resources Increase share of renewable and recyclable resources and energy Reduced emissions Fewer material losses/residuals Keeping the value products and materials in the economy Circular economy incentives and finance Business models Governance, skills and knowledge	Systems thinking Innovation Stewardship Collaborations Value optimization Transparency

A drawback was found when creating the circularity framework with a bottom-up approach: the requirements did not have enough information to propose a solid list of principles and criteria. Therefore, the top-down or non-sectorial/non-specific approach but taking into account initiatives to collect principles and criteria that could potentially match the requirements collected from the bottom-up. In addition to the Ellen McArthur Foundation principles (remove waste and pollution, circulate products and materials, and regenerate nature), **Table 14** shows the original principles considered for some of the initiatives or standards focused on circular economy considered for analysis in BioReCer.

3.2.2 Structure and interpretation of the framework

Based on the explanations from **section 3.2.1** and definitions provided inside **section 3.1**, the BioReCer framework has been structured into pillars, principles, criteria, requirements and indicators as shown in **Figure 3**. The number provided in the figure indicates the diverse items involved for each of the fields mentioned. The theoretical BioReCer framework has been also subdivided into two, as shown in the previously mentioned figure, depending on if the goal of the requirements was to satisfy sustainability or circularity aspects. It should be noted that **Figure 3B** does not include the indicators. This is because circularity indicators have been developed within **task 2.4** (*Circularity Indicators for bio-based products*) and, thus, provided within **D2.3** (*Circularity indicators*).

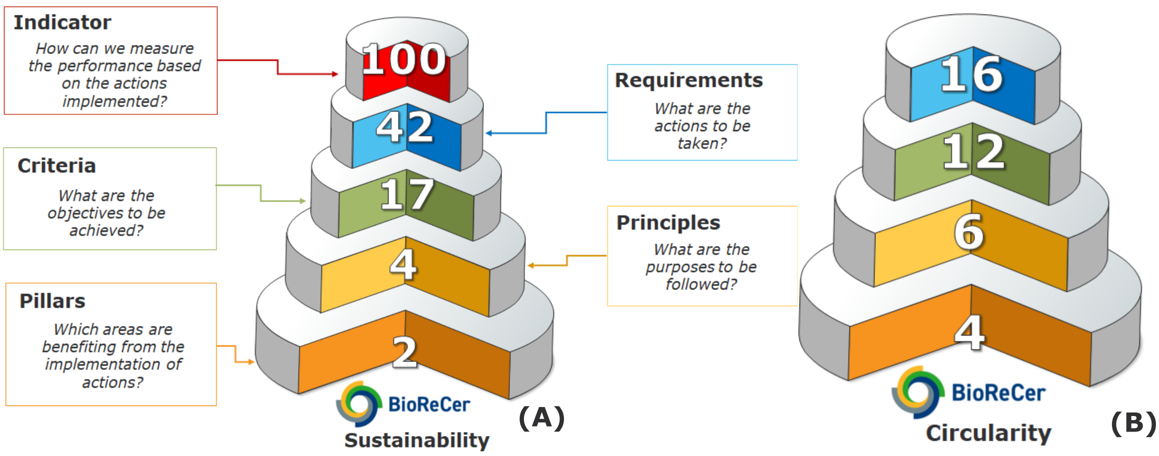
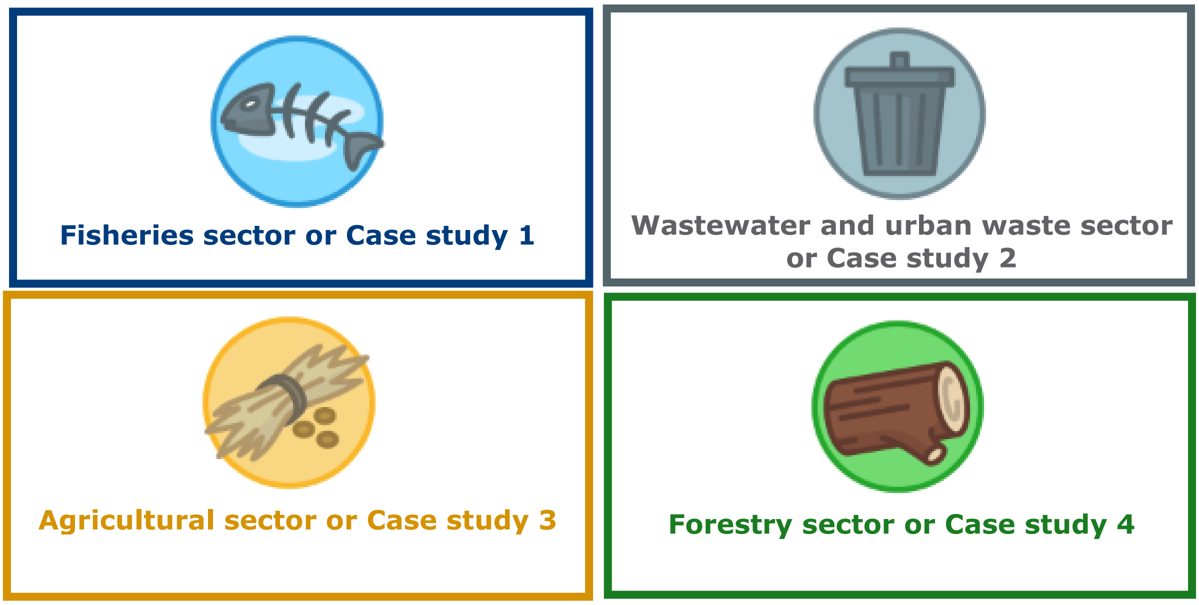


Figure 3: Structure of the (A) sustainability and (B) circularity framework of the BioReCer project.

Although the framework is designed to be applicable to all types of biomasses, some of the requirements can be used specifically for some of the sectors under study. The following icons have been used to represent this framework:



It should also be considered that the framework presented in the sections below is not the final framework for BioReCer. The final version is provided on **deliverables 2.5**. Also, an explanation for each of the selected requirements have been included in **deliverable 4.3**. This is because the framework provided below is the result of a theoretical analysis of documentation and lacks the experimental validation/testing from the case studies and the work done (**deliverable 2.3**) regarding the circularity indicators selected.

3.2.3 Presentation of the BioReCer sustainability framework

THE ENVIRONMENTAL PILLAR

Principle 1. Protection of ecosystems

Definition: Efforts should be made to ensure the maintenance of the ecosystems in terms of biological diversity of species, conservation of value, and the restriction on the use of foreign species. On the other hand, this principle also advocates for the limitation of emissions leading to environmental changes and affecting the quality of soil, water and air. Measurements, characterisation of inputs and outputs, and identification/proposal of strategies are some of the actions taken to ensure the ecological integrity of the environment.

Criteria 1.1 The company defines functions to conserve and manage the environment	
1.1.1. The company has data available about the *type of sources of water* used for the production process	
1.1.2. The company has proposed *strategies to protect water, soil and air* quality and prevent negative impacts	
1.1.3. The company identifies the water sources affected by *runoffs and discharges*	
1.1.4. The company shall provide the most updated *Environmental Impact Assessment (EIA)* of the area before starting its operations	
1.1.5. The company shall indicate whether it adopts ecosystem regeneration and *rehabilitation measures*	
1.1.6. The company uses and maintains *appropriate machinery*, processing, disposal containers and facilities for handling products, materials and wastes, excluding legal and safety matters.	

Criteria 1.2. The company develop strategies for mitigation and adapting to climate change	
1.2.1. The company measures its *carbon emissions* and has established a reduction plan	

Criteria 1.3. The company ensures the preservation of ecosystem diversity	
1.3.1. The company shall have evaluations about the *state of the biodiversity* within the area and a plan to maintain and improve biodiversity	
1.3.2. The company shall identify whether its activity is carried out in a *protected area*	

Criteria 1.4. The company has mechanisms to control polluting emissions	
1.4.1. The company has some kind of *treatment technology* to prevent emissions to the environment	
1.4.2. The company identifies and *characterizes emissions* to air, soil, and water to comply with legal thresholds	
1.4.3. The company *measures the noise and odour* to ensure that they are under the legal threshold	

Criteria 1.5. The company manages waste under an environmentally sound approach	
1.5.1. The company has appropriate *labelling for hazardous waste* considering aspects of classification and management	
1.5.2. The company applies the *waste hierarchy* to reduce and valorise its waste	

Criteria 1.6. The company identifies genetically modified species when utilised
1.6.1. The company characterizes the introduced genetically modified species

Criteria 1.7. The company restricts the use of invasive species and pathogens
1.7.1. The company quantifies and limits the use of non-indigenous/invasive species and pathogens introduced into the ecosystem

Principle 2. Safe and sustainable use of resources

Definition: This principle aims to avoid the depletion of natural resources while maintaining their sustainable use. In this sense, the company must have control and monitoring of any of the resources used.

Criteria 2.1. The company ensures the continuous provision of resources by preserving the resilience of ecosystems
2.1.1. The company considers the *resilience of the ecosystem* to ensure sustainability
2.1.2. The company establishes and monitors *key performance indicators* to ensure the responsible use of resources and avoid the degradation of ecosystems

Criteria 2.2. The company promotes the management of natural resources sustainably
2.2.1. The company has an *energy efficiency* plan in place
2.2.2. The company has a plan to *manage resources* and water efficiently

Criteria 2.3. The company promotes the safe commercialization of resources
2.3.1. The company identifies and quantifies the use of *chemicals and hazardous substances*
2.3.2. The company identifies whether action has been addressed to ensure *food security* in biomass production systems

THE SOCIO-ECONOMIC PILLAR

In contrast with the environmental pillar of sustainability, the social and economic pillar were grouped into one. This is because the majority of the selected requirements are applicable to both pillars. Requirement 3.2.1 is a good example of the interconnection between them. In this case, the company needs to make an economic effort to train its workers which could have repercussions in terms of productivity. On the other hand, the training of workers is a social measure since it improves the confidence of the worker, prevents occupational injuries and releases stress at work. Another example could be requirement 3.1.3 regarding the use of bio-based materials. The use of this kind of materials is not always profitable for companies since many current biological processes are not as developed as those using fossil-fuel materials. Therefore, their use may become a challenge for companies since they need to achieve the same level of competition inside the market. On the other hand, requirement 3.1.3 promotes the use of non-fossil fuel materials, which helps reduce the pressure over the consumer prices. Regarding to social corporate responsibility, many of the measures taken by organizations need money investment to become true which also has an impact on their economic balance sheets.

Principle 3. Business models and value creation

Definition: This principle looks for the definition of business strategies leading to value creation, innovative thinking, transparency and traceability while enabling the sustainable management of resources. It explains how the company can offer products along the value chain that meet the customer's socio-environmental expectations.

Criteria 3.1. The company ensures the quality and traceability of its products and other outputs	
3.1.1. The company has established measures to *track the disposal* of by-products and waste	
3.1.2. The company has established measures to improve *product traceability*	
3.1.3. The company promotes the *use of materials with bio-based origin* as well as non-virgin materials on its final products	

Criteria 3.2. The company makes good use of its assets	
3.2.1. The company has investments and expenditures related to research, development and *training of employees*	
3.2.2. The company has good management of the *unsold finished goods*, prevention of generation of waste	
3.2.3. The company has in place measures to ensure the optimization of cost (operational, infrastructure, waste treatment)	
3.2.4. The company must ensure that subcontractors also comply with the requirements of the certification schemes	

Criteria 3.3. The company respects private property	
3.3.1. When applicable, the company has fully documented property rights	

Criteria 3.4. The company promotes transparency	
3.4.1. The company is a legally defined entity with a clear and documented legal record	

Criteria 3.5. The company promotes corporate social responsibility	
3.5.1. The company takes into consideration green procurement criteria in the selection of its suppliers	
3.5.2. The company complies with certification schemes and standards verified by a third-party	

Principle 4. Working conditions and society

Definition: The objective of this principle is to ensure that the company provide a healthy and safe working environment while contributing to the economic growth of the communities.

Criteria 4.1. The company complies with the labour conditions established by the regulatory framework	
4.1.1. The company allows work and personal life combinations by limiting standard working hours as per national regulations, ILO standards, WHO guidelines, etc.	
4.1.2. The company has a Health and Safety plan in place	
4.1.3. The company provides accident insurance coverage and adequate compensation for all workers	
4.1.4. The company has effective complaints and grievance mechanisms and takes measures to resolve the reported complaints and grievances	
4.1.5. The company ensures gender equality	
4.1.6. The company keep records of work-related accidents or incidents	
4.1.7. The company promotes the participation of its employees on certified training activities and competencies	

Criteria 4.2. The company contributes to job creation and helps to meet community needs	
4.2.1. The company contributes to enhancing the employment level in the sector	
4.2.2. The company ensures the payment of wages that meet or exceed industry minimum standards	

3.2.4 Presentation of the BioReCer circularity framework

Instead of presenting 2 pillars as shown for the sustainability criteria, circularity displays 4 pillars. Apart from the typical environmental, social and economic pillars a mixed environmental-economic pillar was included. The reasoning behind this separation was the high connection between activities with a closing-the-loop vision, which entails, among others, the decrease of consumption of materials with an associated extraction environmental impact and economic value. The economic pillar was not integrated with the social because, in contrast with what was shown for sustainability, the criteria proposed has no requirements that directly affect the population but rather only the organisation itself or other collaborating companies.

THE ENVIRONMENTAL PILLAR

Principle 5. Elimination of waste and pollution

Definition: Elimination of waste, losses, residuals and reduction of pollution

Criteria 5.1. The company considers end-of-life treatment as a possible strategy for valorisation	
5.1.1. The company quantifies the waste and selects the most appropriate treatment	

Criteria 5.2. The company monitors the reduction of environmental impacts after the application of circular economy strategies	
5.2.1. The company has identified the environmental benefits resulting from the implementation of circular economy strategies (reduction, recycling, recovering…)	

THE ECONOMIC PILLAR

Principle 6. Systems thinking and business models

Definition: Organizations take a holistic approach to understanding how individual decisions and activities interact within the larger systems of which they are a part (industrial symbiosis). Organizations continually innovate to create value by enabling the sustainable management of resources through the design of processes, products/services and business models.

Criteria 6.1. The company promotes strategies of industrial symbiosis	
6.1.1. The company has collaborations with other companies aiming at the good use of resources	

Criteria 6.2. The company has an appropriate circular business stewardship to create value	
6.2.1. The company can demonstrate that the implementation of plans, initiatives and practices in a circular economy has resulted in economic benefits	

Criteria 6.3. The company promotes innovation and procurement to create value	
6.3.1. The company allocates resources to research and develop circular economy strategies within its value chain	
6.3.2. The company has contracts with suppliers selling products/materials certified as circular	

Criteria 6.4. The company promotes its transparency in terms of circularity	
6.4.1. The company is willing to share information publicly about its activities related to the circular economy	

THE SOCIAL PILLAR

Principle 7. Social procurement

Definition: Circularities enhance the awareness and welfare on social communities.

Criteria 7.1. The company has communication and education programmes	
7.1.1. The company has participated in awareness campaigns to promote the benefits of the circular economy	
7.1.2. The company has programmed training activities for workers to tackle the specificities of circular technologies and/or strategies	

Criteria 7.2. The company has created employment and skills opportunities	
7.2.1. The company has created new job positions in line with the needs of the circular economy strategies implemented	

THE ENVIRONMENTAL AND ECONOMIC PILLAR

Principle 8. Availability of resources by keeping them at their highest value and utility at all times

Definition: Reduction of dependence on virgin resources aiming to decrease the demand of inputs to the process from the nature.

Criteria 8.1. The company promotes the substitution of virgin materials by secondary raw materials	
8.1.1. The company achieves goals of reduction or substitution of resources	

Principle 9. Protect and contribute to the resilience and regeneration of natural capital

Definition: Promote the resilience of materials through their recycling and reuse in the production process or value chain, in terms of both environmental and economic perspectives.

Criteria 9.1. The company promotes the recovery of resources	
9.1.1. The company has plans, initiatives or practices for the recovery of waste and the use of non-virgin materials on its final products	
9.1.2. The company considers water reclamation onsite or outside the facilities of the company	

Principle 10. Value creation

Definition: Efforts should be made to increase the functionality and performance (productivity, efficiency, intensity) of the activity, concerning enhancing environmental, social and economic value, as well as promoting the use of renewable resources.

Criteria 10.1. The company designs and manufactures products and assets taking into account circular economy strategies	
10.1.1. The company can demonstrate that its products have the same characteristics and quality as its conventional counterpart	

Criteria 10.2. The company strategically promotes the creation of added value	
10.2.1. The company has plans, initiatives or practices to ensure the increase of resource productivity	
10.2.2. The company has defined strategies to promote a system thinking of processes and the analysis of material loops	

3.3 Analysis and document availability

The BioReCer framework of **sections 3.2.3** and **3.2.4** is correlated within this section with the documents from where the information was collected (**sections 2.1, 2.2, 2.3 and 2.4**) to unveil the relevancy of the proposed requirements, criteria and principles among them. Here, the results of the representativeness of each of the framework levels have been discussed.

3.3.1 Study of the sustainability framework

Regarding the environmental pillar of sustainability, ISCC EU, ISSC PLUS, GLOBAL GAP and FSC are the certification schemes considering the largest number of requirements of the theoretical BioReCer framework. As shown in **Figure 4A**, they can certify 19, 19, 15 and 11 of the 22 requirements proposed within the project. This implies that a company already certified by ISCC, for example, would only need to put in additional effort to satisfy 3 more requirements to have full compliance with the theoretical BioReCer scheme. It should take into account that not all requirements inside BioReCer are compulsory, but that is a topic that will be addressed on **section 6.2.** of this **D2.2**. Inside this pillar, there are 2 requirements being considered by 83.3% of the 18-certification studies. The first one is requirement 1.1.2 referring to the strategies to protect water, soil and air quality and prevent negative impacts. The other one the requirements is 1.3.1, related to the maintenance and improvement of biodiversity. Less attention has been paid to requirements 1.1.5 and 1.4.1, which refer to measures taken to regenerate the ecosystem and technologies used to avoid emissions to the environment.

Although requirements were included for all BioReCer sectors (fisheries, agriculture, forestry and wastewater), certification systems tend to certify agricultural and forestry activities, while other sectors are less represented, accordingly, the higher representation of certain indicators can be attributed to this fact. On average, environmental sustainability requirements are counted 5.2 times for the forestry-agriculture sector, 1.4 for the fisheries sector and 0.2 for the wastewater sector.

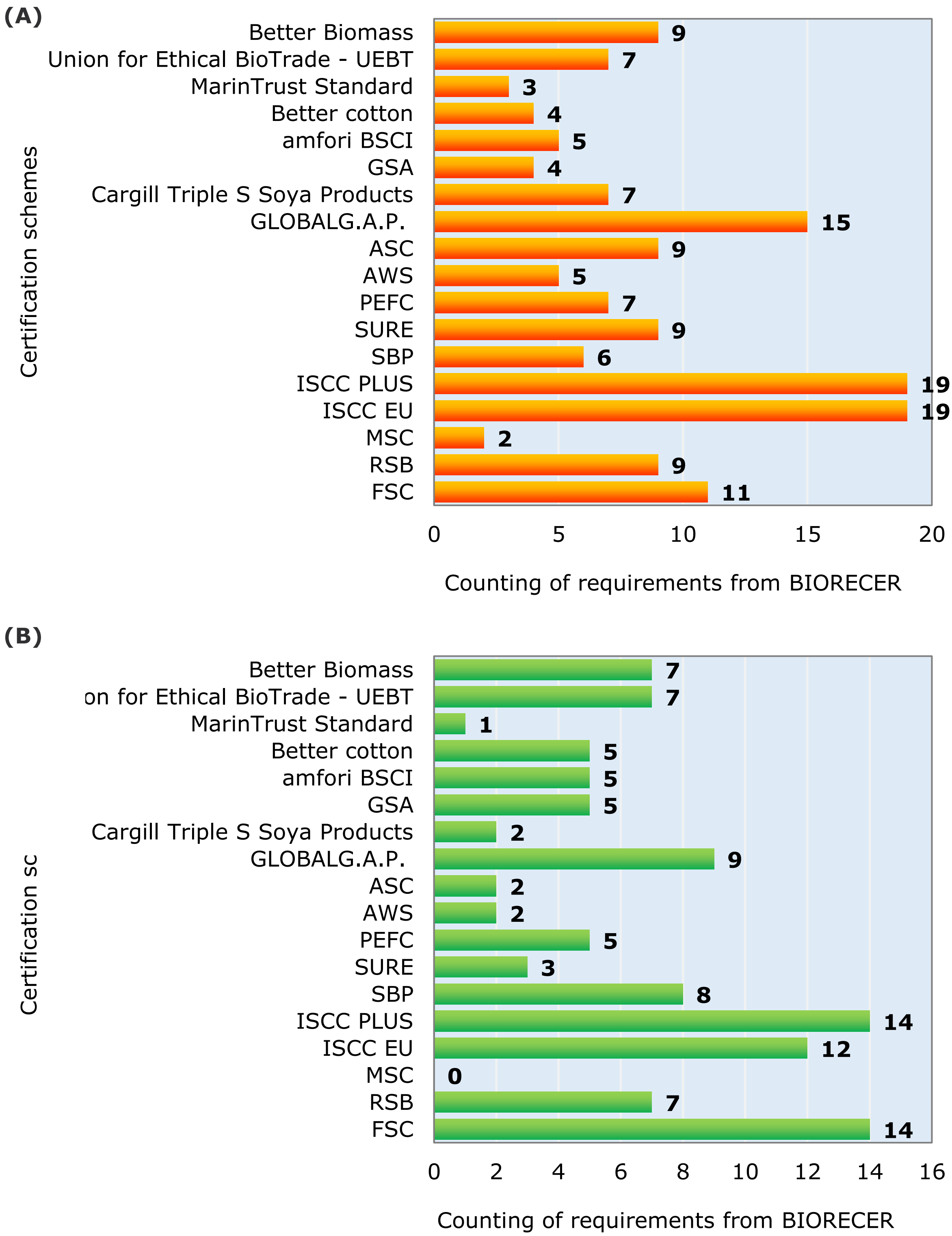


Figure 4: Representativeness of available BioReCer requirements between certification schemes for (A) the environmental pillar of sustainability and (B) the socio-economic pillar of sustainability.

The top 4 certification schemes for the socio-economic pillar of sustainability are again FSC, ISCC PLUS, ISCC EU and GLOBAL G.A.P but in this case, the best certification schemes are FSC and ISSC PLUS (shown in **Figure 4B**). Both consider 14 of the 20 requirements of BioReCer. The most repeated requirement among certification schemes is 4.1.7 with a percentage of 72.2%. This requirement is referring to the participation of the employees of a company on certified training activities and competencies. There are three requirements not being considered inside certification schemes: 3.1.3, 3.2.4 and 3.5.1. The first is related to the use of bio-based materials in products and the other two are aimed at ensuring the use of green procurement criteria and requirements by subcontractors and suppliers. As for the distribution by sector, the results are similar to those obtained for the environmental pillar. About 4.5 times the requirements were considered for the forestry and livestock sector, compared to 0.9 and 0.1 times for the fisheries and wastewater sectors. The distribution of the use of the requirements of each certification system for the environmental and socioeconomic sustainability pillars are shown in **Tables 15** and **16**. Finally, **Figure 5A** also shows the distribution of the relevancy among certification schemes of the criteria and the principles. The most important sustainability criteria is 1.3, which ensures the preservation of ecosystem diversity (63.9%). In line with this, the principle with higher relevancy is the protection of the ecosystems (42.1%). The principle with the smaller representativeness is business models and value creation (18.8%).

Apart from certification schemes, the mapping of the requirements used on documents was also done for the directives and standards studied within BioReCer. **Tables 17, 18, 19 and 20** show the correlation between the requirement and the documents revised. Besides this, **Figures 5B** and **5C** illustrate the contribution of the documents to each of the criteria and principles. When considering the directives, the most important sustainability criteria also belong to the environmental pillar, but in this case to the other principle: the safe and sustainable use of resources. The most worrying criterion among the selected directives concerns the objective of promoting the sustainable management of natural resources (criterion 2.2). Since directives related to working conditions were not included in the framework, the results shown in **Figure 5B** are 0%. Also, unlike the certification systems and in line with the directives, criterion 2.2 is the most incorporated point in the standards. The second most important criterion relates to the development of climate change mitigation and adaptation strategies (C1.2 in **Figure 5C**). In contrast to what was expected to certification schemes and directives, the second most important principle is "working conditions and society", followed by "business models and value creation". Criteria 3.4 and 3.5 (related to private property and social responsibility) became relevant for standards even more than for certification schemes. This seem to indicate that certification schemes are stronger in terms of environmental protection, but standards give also relevance to economic business and the use of resources.

The analysis of initiatives is also shown in **Table 21** for sustainability. However, the initiatives were selected thinking about completing the circularity framework and thus the results achieved from then cannot be conclusive for sustainability. The initiatives have been analysed in more detail in **section 3.3.2** for the circularity framework.

The aggregation of all the results achieved, giving equal weighting per document type, is shown in **Figure 6**. The first three criteria are environmental. Environmental research and assessments have then focused on developing strategies for climate change mitigation, preservation of ecosystem diversity, and sustainable resource management. The two environmental principles have the same proportion of use within the documents (an average of 18.9% for the protection of ecosystems and 18.1% for the safe and sustainable use of resources. Except in the case of directives, the results obtained seem to indicate that voluntary certification or alignment with initiatives is stronger for the environmental pillar than for the socioeconomic pillar.

Table 15: Analysis of certification schemes per requirements of the BioReCer framework for the environmental sustainability pillar.

Requirement number	FSC	RSB	MSC	ISCC EU	ISCC PLUS	SBP	SURE	PEFC	AWS	ASC	GLOBAL G.A.P.	Cargill	GSA	amfori BSCI	Better cotton	MarinTrust Standard	UEBT	Better Biomass
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Table 16: Analysis of certification schemes per requirements of the BioReCer framework for the socio-economic sustainability pillar.

Requirement number	FSC	RSB	MSC	ISCC EU	ISCC PLUS	SBP	SURE	PEFC	AWS	ASC	GLOBAL G.A.P.	Cargill	GSA	amfori BSCI	Better cotton	MarinTrust Standard	UEBT	Better Biomass
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4.2.2																		

Table 17: Analysis of directives per requirements of the BioReCer framework for the environmental sustainability pillar.

Requirement number	2011/92/EU	2012/18/EU	91/271/EEC	2008/105/EC	2003/87/EC	2004/109/EC	2018/2001/EU	86/278/EEC	91/676/EEC	2006/118/CE	2000/60/EC	2008/105/EC	2008/50/CE	2008/98/EC	2008/56/EC	1999/31/EC	2023/2486/EU	2150/2002/EC	1967/2006/EC	1005/2008/EC	1224/2009/EC	2020/741/EU	2020/852/EU
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2.2.2																							
2.3.1																							

Table 18: Analysis of directives per requirements of the BioReCer framework for the socio-economic sustainability pillar.

Requirement number	2011/92/EU	2012/18/EU	91/271/EEC	2008/105/EC	2003/87/EC	2004/109/EC	2018/2001/EU	86/278/EEC	91/676/EEC	2006/118/CE	2000/60/EC	2008/105/EC	2008/50/CE	2008/98/EC	2008/56/EC	1999/31/EC	2023/248/EU	2150/2002/EC	1967/2006/EC	1005/2008/EC	1224/2009/EC	2020/741/EU	2020/852/EU
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4.2.1																							
4.2.2																							

Table 19: Analysis of standards per requirements of the BioReCer framework for the environmental sustainability pillar.

Requirement number	ISO 14001 :2015	BS 8001: 2017	AGRO 2-1 and 2-2:2019	ISO 9001: 2015	ISO 50001 :2018	ISO 45001 :2023	UNE-EN 16751 :2016	EN ISO 14044:2006/A2:2021	UNE-EN ISO 14046:2016	UNE-EN 15259:2008	UNE-EN ISO 15663:2021	ISO 30414:2018	ISO 34101 - 2:2019	ISO 22948:2020	ISO 20400:2017	ISO 14064-1:2012	ISO 14045:2012	ISO 14067: 2019
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1.7.1																		
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2.1.2																		
2.2.1																		
2.3.1																		
2.3.2																		

Table 20: Analysis of standards per requirements of the BioReCer framework for the socio-economic sustainability pillar.

Requirement number	ISO 14001 :2015	BS 8001: 2017	AGRO 2-1 and 2-2:2019	ISO 9001: 2015	ISO 50001 :2018	ISO 45001 :2023	UNE-EN 16751:2 016	EN ISO 14044:2006 /A2:2021	UNE-EN ISO 14046:2 016	UNE-EN 15259: 2008	UNE-EN ISO 15663:2 021	ISO 30414 :2018	ISO 34101 - 2:2019	ISO 22948: 2020	ISO 20400:2 017	ISO 14064-1:2012	ISO 14045 :2012	ISO 14067: 2019
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3.1.2																		
3.1.3																		
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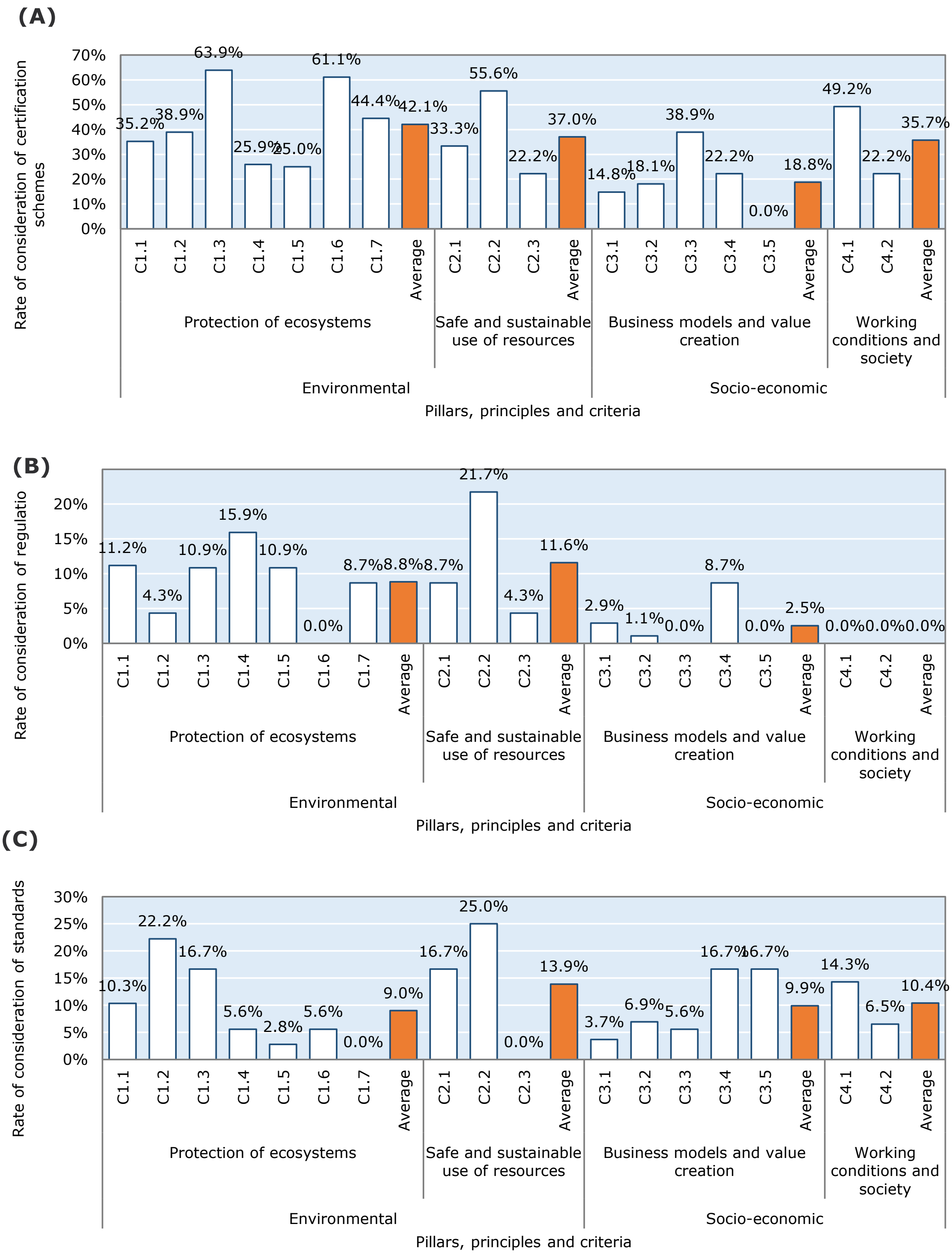

Figure 5: Representativeness of available BioReCer requirements between (A) certification schemes, (B) Directives and regulations and (C) standards considering the pillar, principles and criteria of sustainability. The orange bars indicate the average results for the principles.

Table 21: Analysis of initiatives per requirements of the BioReCer framework for the environmental and socio-economic sustainability pillar.

Requirement number	Montreal Process	European Green Deal	Catalogue of Best practices in Circular economy I,II and III	Categorization system for the circular economy	Circular economy in Europe. EEA Report 2/2026 ISSN 1977-8449
1.1.1					
1.1.2					
1.1.3					
1.1.4					
1.1.5					
1.1.6					
1.2.1					
1.3.1					
1.3.2					
1.4.1					
1.4.2					
1.4.3					
1.5.1					
1.5.2					
1.6.1					
1.7.1					
2.1.1					
2.1.2					
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2.3.1					
2.3.2					
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3.1.2					
3.1.3					
3.2.1					
3.2.2					
3.2.3					
3.3.1					
3.4.1					
3.5.2					
4.1.1					
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4.1.4					
4.1.5					
4.1.6					
4.1.7					
4.2.1					
4.2.2					

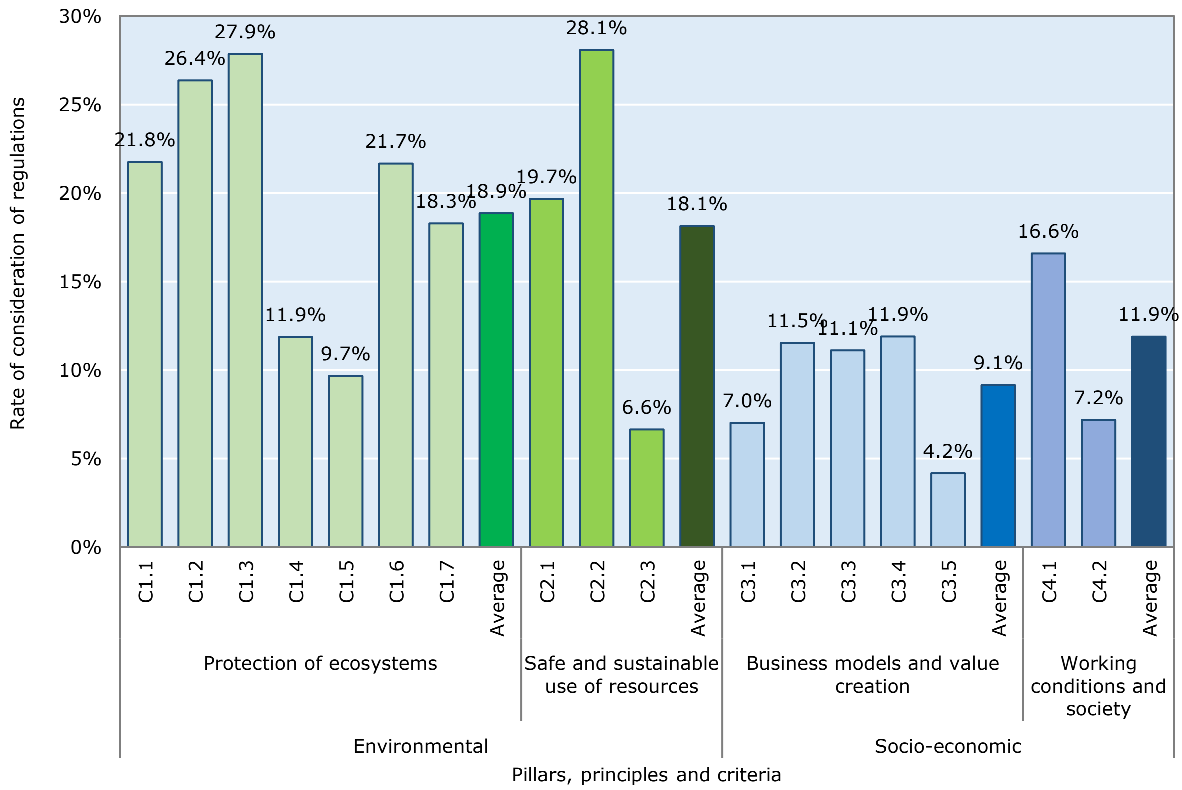

Figure 6: Degree of coverage of the criteria and principles per pillar by the documents considered inside BioReCer. Green bars were use for the environmental pillar while the blue bars were employed for socio-economic criteria. Darkers colours are representing the principles averages.

It should be noted that the requirements and criteria proposed within BioReCer do not include aspects related to the use or consumption of food, such as food safety (except when the bioindustry generates a displacement in the use of resources and jeopardizes the food supply to the population), nutrition and human health.

3.3.2 Study of the circularity framework

Of the 16 requirements covered by BioReCer, only a maximum of 4 (within ISCC) were addressed by the certification schemes. A total of 7 were covered by any of them, which means that there is room for improvement of all certification schemes currently on the market related to the bio-based industry. In fact, 6 of the 18 certification schemes studied have no requirements related to circularity. **Table 22** shows the mapping of the requirements inside the certification schemes. The 9 requirements that have not been taken into account are listed below:

- The company can demonstrate that the implementation of plans, initiatives and practices on a circular economy has resulted in economic benefits.

- ☐ The company allocates resources to research and develop circular economy strategies within its value chain.
- ☐ The company has contracts with suppliers selling products/materials certified as circular
- ☐ The company is willing to share information publicly about its activities related to the circular economy.
- ☐ The company has participated in awareness campaigns to promote the benefits of the circular economy.
- ☐ The company has programmed training activities for workers in order to tackle with the specificity of circular technologies and/or strategies.
- ☐ The company has created new jobs positions in line with the needs of the circular economy strategies implemented.
- ☐ The company can demonstrate that its products have the same characteristics and quality as its conventional counterpart.
- ☐ The company has defined strategies to promote a system thinking of processes and the analysis of material loops.

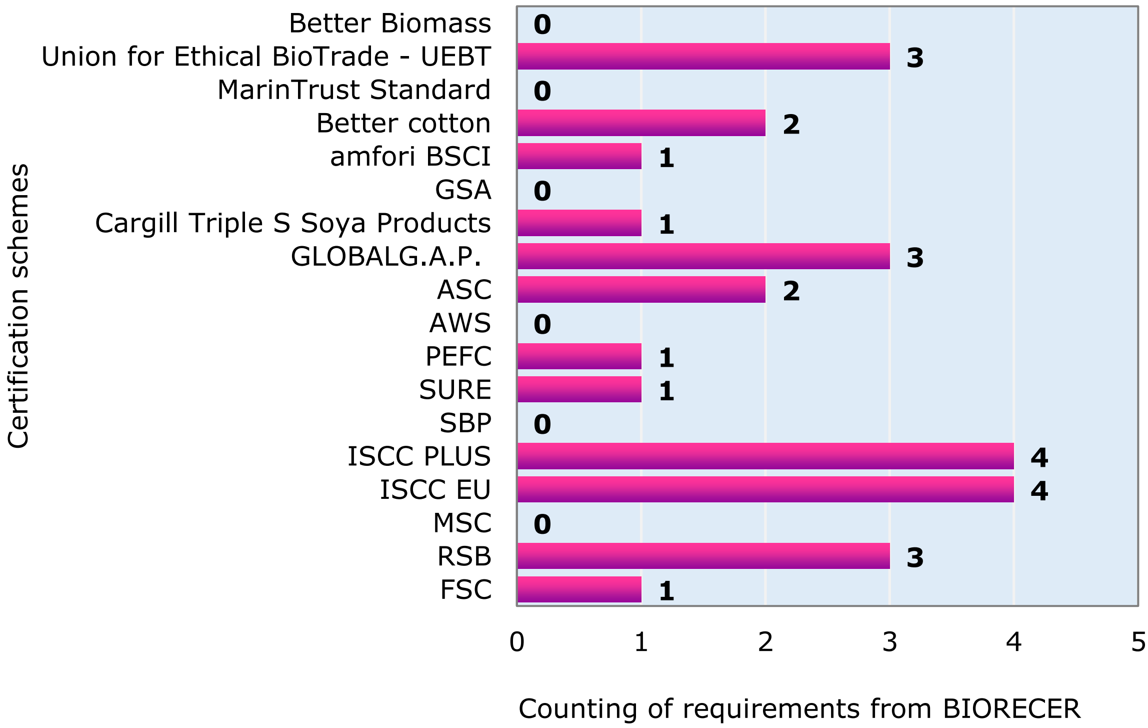

Figure 7: Representativeness of available BioReCer requirements between certification schemes for circularity.

The mostly addressed (38.9% implementation) circularity criteria (shown in **Figure 7**) is 5.1, which advocates for the valorisation of waste as a strategy for end-of-life treatment. The criteria 10.2, for the promotion of the creation of added value, follows with a 25%

representativeness. Related to the principles, only 3 principles can be fully complied by certification schemes: (1) elimination of waste and pollution, (2) availability of resources by keeping them at their highest value and utility at all times and (3) protect and contribution to the resilience and regeneration of natural capital. Systems thinking and business models and social procurement were principles hardly covered by certification schemes. These two principles were not covered by directives, which mainly focused again on the criteria 5.1 (17.4% of the directives) of the elimination of waste and pollution principle. Implementation ratios inside directives were found between 4.4%-8.7% for the principles 8, 9 and 10. Similar results were obtained for standards, which can give requirements for principles 5 and 10. Criterion 6.4, related to the exchange of information by companies on circularity aspects, has been taken into account by the standards and not by the other two documents mentioned above.

The study of the directives (top-down approach) gives a different picture of the relevance of the key aspects of the circularity framework. These initiatives are indicative of what is expected and will be implemented in the future at the European legislative level. While waste treatment and recovery remain a hot topic, it is also important for the company to achieve resource reduction and substitution targets and the demonstration that products manufactured (from recycling or refurbishment, for example) can offer similar characteristics to brand new products. Regarding principle 6 (for the economic pillar), it should be noted that companies establish collaborations with other companies to create a network that optimizes the use of resources. Just as important as the optimization of processes or facilities is the creation of synergies between nearby factories.

A generic overview through the results achieved for the requirements, criteria and principles of all documents (**Figure 9**) still gives the higher weight to the valorisation of waste (criteria 5.1) followed by the criteria of principle 10 (value creation): (1) for the manufacturing of products and assets taking into account circular economy strategies and (2) for the creation of added value (i.e., increase resource productivity and analysis of material loops).

Table 22: Analysis of certification schemes per requirements of the BioReCer framework for circularity.

Requirement number	FSC	RSB	MSC	ISCC EU	ISCC PLUS	SBP	SURE	PEFC	AWS	ASC	GLOBAL G.A.P.	Cargill	GSA	amfori BSCI	Better cotton	MarinTrust Standard	UEBT	Better Biomass
5.1.1																		
5.2.1																		
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6.3.1																		
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10.2.1																		
10.2.2																		

Table 23: Analysis of initiatives per requirements of the BioReCer framework for circularity.

Requirement number	Montreal Process	European Green Deal	Catalogue of Best practices in Circular economy	Categorisation system for the circular economy	Circular economy in Europe. EEA Report 2/2026
5.1.1					
5.2.1					
6.1.1					
6.2.1					
6.3.1					
6.3.2					
6.4.1					
7.1.1					
7.1.2					
7.2.1					
8.1.1					
9.1.1					
9.1.2					
10.1.1					
10.2.1					
10.2.2					

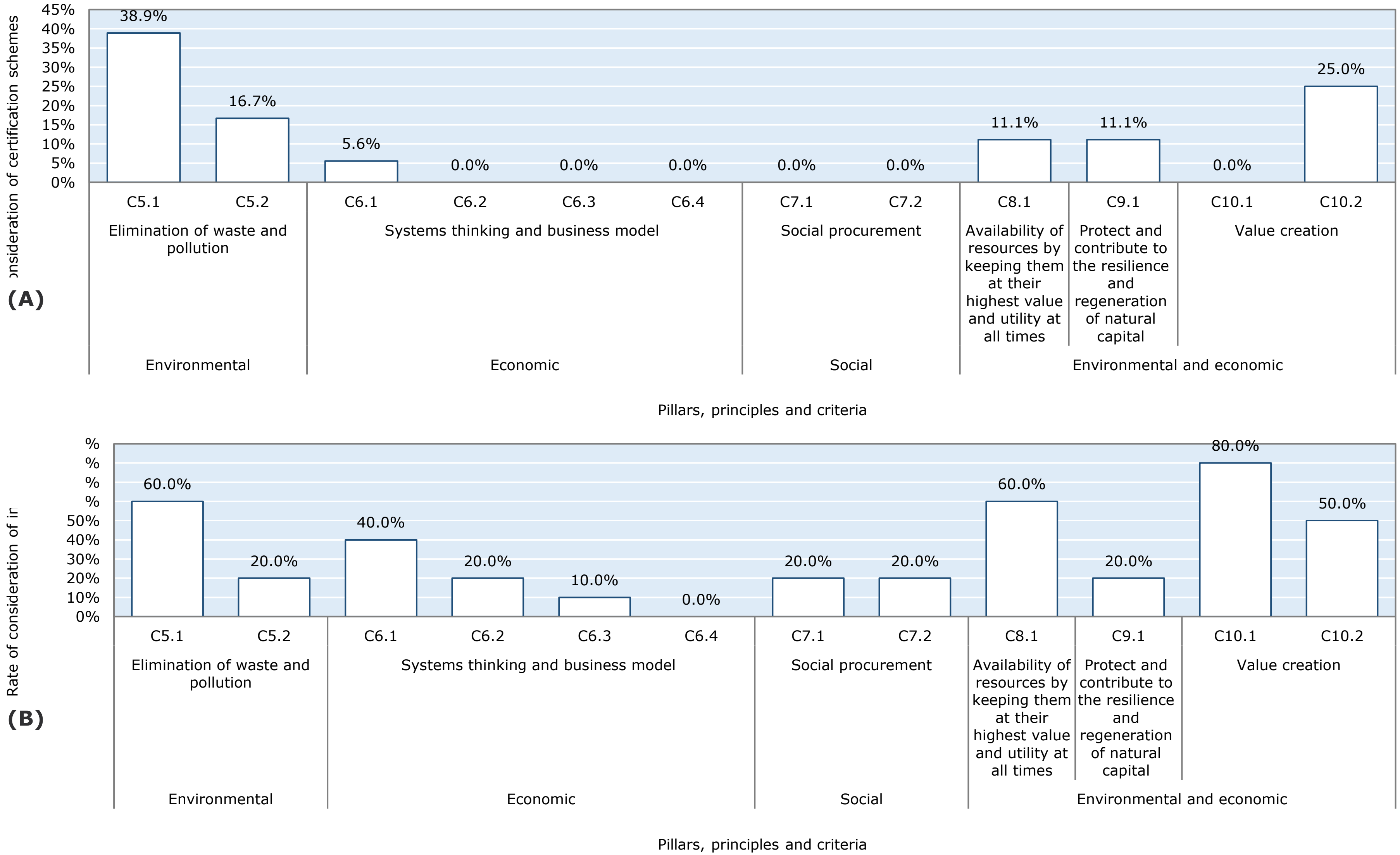

Figure 8: Representativeness of available BioReCer requirements between (A) certification schemes, (B) initiatives for circularity.

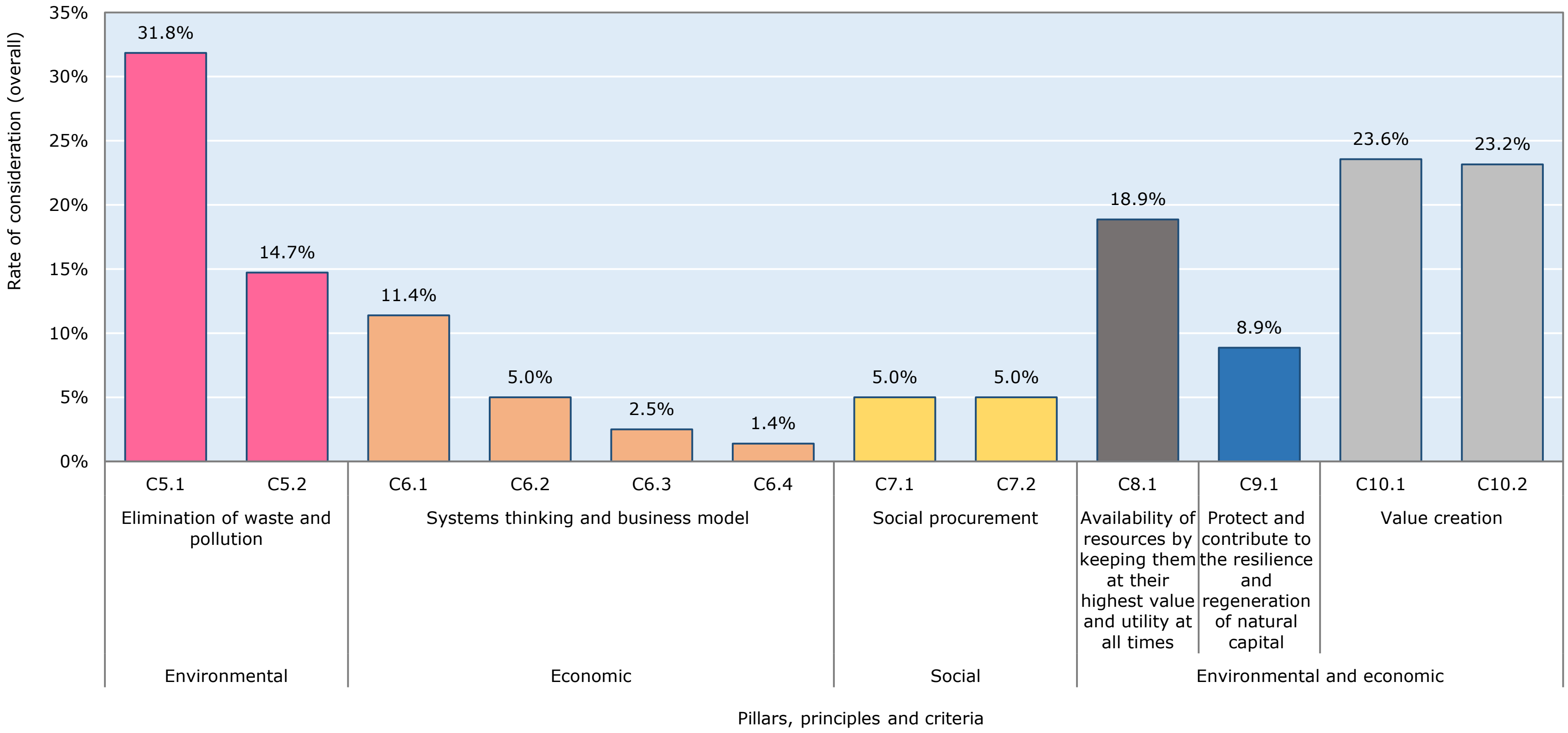

Figure 9: Degree of coverage of the criteria and principles per pillar by the documents considered for circularity inside BioReCer.

3.4 Suitability of the requirements

As mentioned in **section 3.2.1,** three layers were used for the selection of the most suitable requirements: (1) bibliometric analysis based on certification schemes, (2) answers from the questionnaires of the case studies and (3) creation of a panel expert between partners collaborating in WP2. The results of the automatic decision from the bibliometric analysis are shown in **Tables 24** and **25** for both the sustainability and circularity requirements. The coverage level of requirements refers to the times that the requirements were embodied inside certification schemes. The possible questions for the questionnaires to be used in the case studies are shown in **Annex A** in Excel format. Each question has been correlated to each respective requirement, criteria and principle. The answers to the questions for all case studies as "Y", "N", "NM" or "NA" were used as input to help determine the final form of the framework.

Table 24: Final results based on the suitability of the requirements based on certification schemes for sustainability aspects

Requirement number	Coverage level of requirements	Decision from documents
1.1.1	38.89%	Yes
1.1.2	77.78%	Yes
1.1.3	16.67%	Under assessment
1.1.4	16.67%	Under assessment
1.1.5	11.11%	Under assessment
1.1.6	16.67%	Under assessment
1.2.1	33.33%	Yes
1.3.1	77.78%	Yes
1.3.2	38.89%	Yes
1.4.1	11.11%	Under assessment
1.4.2	50.00%	Yes
1.4.3	16.67%	Under assessment
1.5.1	22.22%	Under assessment
1.5.2	22.22%	Under assessment
1.6.1	55.56%	Yes
1.7.1	38.89%	Yes
2.1.1	22.22%	Under assessment
2.1.2	38.89%	Yes
2.2.1	27.78%	Yes
2.2.2	77.78%	Yes
2.3.1	16.67%	Under assessment
2.3.2	16.67%	Under assessment
3.1.1	22.22%	Under assessment

Table 24. Final results based on the suitability of the requirements based on certification schemes for sustainability aspects (continuation)

Requirement number	Coverage level of requirements	Decision from documents
3.1.3	0.00%	No
3.2.1	5.56%	No
3.2.2	16.67%	Under assessment
3.2.3	38.89%	Yes
3.2.4	0.00%	No
3.3.1	33.33%	Yes
3.4.1	16.67%	Under assessment
3.5.1	0.00%	No
3.5.2	33.33%	Yes
4.1.1	66.67%	Yes
4.1.2	61.11%	Yes
4.1.3	22.22%	Under assessment
4.1.4	55.56%	Yes
4.1.5	38.89%	Yes
4.1.6	16.67%	Under assessment
4.1.7	72.22%	Yes
4.2.1	16.67%	Under assessment
4.2.2	22.22%	Under assessment

Table 25: Final results based on the suitability of the requirements based on certification schemes for circularity aspects.

Requirement number	Coverage level of requirements	Decision from documents
5.1.1	33.33%	Yes
5.2.1	11.11%	Under assessment
6.1.1	5.56%	No
6.2.1	0.00%	No
6.3.1	0.00%	No
6.3.2	0.00%	No
6.4.1	0.00%	No
7.1.1	0.00%	No
7.1.2	0.00%	No
7.2.1	0.00%	No
8.1.1	5.56%	No
9.1.1	5.56%	No
9.1.2	16.67%	Under assessment
10.1.1	0.00%	No
10.2.1	50.00%	Yes
10.2.2	0.00%	No

4 Revision of existing methodologies

Determining compliance with the sustainability criteria applicable to certification schemes cannot be addressed by considering only one key point of analysis. One possible control mechanism to ensure that the various actors involved in any value chain (i.e. producers, importers and distributors) operate in accordance with the sustainability obligations defined by the pre-established criteria and requirements is the creation of a verification guide. Confirmation that the information provided in the verification guide is under control must be made through explicit confirmation by an auditor (Pavlovskaia, 2014). This aspect has been done within WP4 and, thus, it was not described within this **D2.2**. Besides reporting a list of obligations, a second approach to establishing sustainability is the measurement of key figures with the use of existing environmental, social and economic methodologies. Although they can be used to determine the performance of different stages, their use often requires wide expertise, they are not comparable between each other, and they may be subjective. They can be further divided into qualitative or conceptual, semi-quantitative, and quantitative; into standardised and non-standardised (Quernheim et al., 2023). When attempting to apply methodologies, methods or procedures already predefined in certification schemes, there is a limitation: the multidisciplinary analysis required for certification schemes (in line with a multi-criteria framework) may not be fully represented by a single methodology. Moreover, the results obtained may vary substantially when using different methodologies for the same criteria. Therefore, it is important to create a system capable of representing the diversity of sustainability and circularity goals and objectives of the BioreCer framework.

One way to do this is by creating a set of indicators (quantitative or qualitative) that can be used to test and evaluate compliance with sustainability requirements once they have been assigned to them. Although the indicators can be interpreted separately to determine whether the requirement has been met, the task is not trivial, as they can differ in both magnitude and direction of change and the results obtained from the analysis of one indicator are not sufficient to understand the sustainable and/or circular performance of a company (Food and Agricultural Organisation of the United Nations, 2019). To solve this, they can be aggregated mathematically to obtain scores that reflect the integrated characteristics of a group of requirements as part of a criterion or principle. However, the construction of an index may make it difficult to know the values achieved by each indicator and therefore not know if the indicator is good enough to accurately reflect the functions of the certification system requirements. For this reasoning, the set of indicators collected for BioReCer should be tested with the case studies. The objective is to know whether sufficient data exist for their estimation, whether they are sufficiently sensitive to changes over time and to different processes, the level of knowledge required for their calculation and whether they are understandable to users. Therefore, **section 4** provides an overview of the following: (1) an analysis of existing methodologies to verify aspects that could be included within the BioReCer scoring system, (2) a review of how current certification schemes determine compliance with their criteria, (3) creation of quantitative and qualitative datasets assigned to each BioReCer requirement, (4) proposed procedure for the selection of eligible indicators and (5) proposal of scoring system for BioReCer (as background).

4.1 Study of environmental and economic impact assessment methodologies

A total of 23 standards/directives were compiled to identify impact assessment methodologies. Many of these (11) were ISO 14000 family standards. The search resulted in 12 standardized methodologies (see **Table 26**). However, others from the scientific and grey literature were detected (11). For those methodologies that are already standardised advantages and disadvantages are provided in **Table 27**.

Table 26: Methodologies classified according to standardization.

From standards		Not from standards
Methodology name	**Standard code**	**Methodology name**
Life Cycle Assessment (LCA)	ISO 14040:2006 and ISO 14044:2006	Cost-benefit Analysis (CBA)
Carbon footprint	ISO 14064-1:2018, ISO 14064-2:2006, ISO 14064-3:2019, ISO 14067:2018, ISO/TR 14069:2013 and PAS 2050	Impact Pathway Approach (IPA)
Water footprint	ISO 14046:2014	Material intensity analysis
Plan Do Check Act (PDCA) / Environmental Management systems	ISO 14001:2015	Direct material consumption
Eco-efficiency	ISO 14045:2012	Green Index
Circularity Assessment	ISO/DIS 59004, ISO/DIS 59010, ISO/DIS 59020, ISO/DIS 59021, ISO/DIS 59032 and ISO/DIS 59040	Ecological footprint
Environmental Risk Assessment	Directive 2001/18/EC	Planetary boundaries
Life Cycle Cost (LCC)	ISO 15686-5:2017	Multiple Attribute Analysis (MAA)
Eco-design	ISO 14006:2020	Building research establishment environmental assessment method (BREEAM)
Environmental Impact Assessment (EIA)	Directive 2011/92/EU (as amended by 2014/52/EU)	Technique for order of preference by similarity to ideal solution (TOPSIS)
Strategic Environmental Assessment	Directive 2001/42/EC	Techno-economic analysis (TEA)
System of Economic and Environmental Accounts (SEEA)	Regulation (EU) No 691/2011	-

Table 27 : Advantages and disadvantages of the methodologies standardised.

Methodology	Advantages	Disadvantages
Life Cycle Assessment (LCA)	☐ Identification of possible environmental areas of intervention in both the design and the development of a product. ☐ Helpful in the establishment of priorities in the strategic planning of the product. ☐ Multicriteria analysis with possibilities in choosing environmental performance indicators, including measurement techniques. ☐ Helpful in the design and implementation of ecological marketing strategies.	☐ Evaluation of potential but not real impacts ☐ Use of different databases, methods and software which induces a significant degree of variability in the results ☐ Subjectivity in the selection of system boundaries ☐ Inventory data might be difficult to obtain ☐ Costly and time consuming ☐ Requires expertise to perform a judgement on environmental priorities
Carbon footprint	☐ Ease communication and interpretation of results since all emissions are expressed in carbon dioxide equivalents	☐ Unidimensional analysis, since it only considers one environmental aspect
Water footprint	☐ High applicability under different contexts ☐ It can be linked to another methodology	☐ It does not take into account the water scarcity of the region. There is a catchment perspective. ☐ It does not address the issues of flooding or the lack of access to proper clean water. ☐ It does not take into account the pollution of seawater ☐ It provides a unidimensional analysis
Plan Do Check Act (PDCA)	☐ Flexible and easy to understand ☐ Iterative process, which is beneficial in evolving environments	☐ Uncertainty may arise from the simplification of complex solutions ☐ Time-consuming (dependent on the system) ☐ The iterative process can lead to a lack of a clear endpoint. ☐ It demands effective data collection and analysis skills
Eco-efficiency	☐ It is a tool that can be used by non-LCA experts ☐ It shows different alternatives for the assessment ☐ Development a decision-making process	☐ Different weighting and aggregation data ☐ It is needed the use of added value instead of costs ☐ Lack of social aspects during the measurements

Table 27. Advantages and disadvantages of the methodologies standardised (continuation).

Methodology	Advantages	Disadvantages
Environmental Risk Assessment	☐ Identification of hotspot hazards ☐ Quantifying the potential risk of exposure to the toxic compounds through a toxicological evaluation. ☐ Development of a plan to mitigate risk	☐ Expertise requirement for the proper interpretation of results ☐ Time and resources consuming.
Life Cycle Cost (LCC)	☐ Increases the reliability of a project or product manufacturing, as well as reduces the risks of implementation.	☐ It does not foresee productivity drops ☐ It does not take into account the technology readiness level. ☐ Only processes or products with comparable characteristics should be benchmarked.
Eco-design	☐ It allows for environmental product benchmarking ☐ It increases the access of the products to new markets ☐ Flow material and parts of use control	☐ Assumptions must be made since not all environmental criteria can be integrated in the design ☐ The eco-design of products becomes vague after the phase of purchase since the tool cannot predict the consumer's behaviour.
Environmental Impact Assessment (EIA)	☐ It provides a comprehensive list of possible impacts on the environment ☐ Ease integration of environmental aspects into decision-making ☐ Transparent process which encourages stakeholder and public engagement.	☐ The methodology has a high degree of subjectivity ☐ The identified environmental factors are qualitative in nature ☐ A modelling for handling uncertainty is needed ☐ Cumulative and indirect impacts resulting from the combined effects may not be fully addressed. ☐ The prediction of long-term impact is challenging.
Strategic Environmental Assessment (SEA)	☐ Analysis complementary to the Environmental Impact Assessment ☐ Increases the transparency of the decisions taken ☐ It strengthens policy, plan and programme-making processes.	☐ Social and economic aspects are not taken into consideration ☐ Time and resources consuming ☐ New methodology whose procedures are still in an early development phase.
Systemic of Economic and Environmental Accounts (SEEA)	☐ It created interrelationships between the environment and economy and the natural resources stocks	☐ Requires primary precise data to be reliable ☐ Since it is a statistical tool, it is subjected to uncertainty.

Among the methodologies cited in **Table 26**, Life Cycle Assessment, Life Cycle Costing, Carbon Footprint and Water Footprint can be used within the proposed BioReCer framework, as they have indicators that could be chosen and correlated with the requirements and criteria. While these methodologies could feed into the BioReCer indicator-criteria methodological structure, the Environmental Impact Assessment could use some of the proposed criteria as environmental factors for the methodology (especially related to the circularity pillar). Biodiversity, land and soil use, water, air, climate and material assets are some of the environmental factors that should be covered by both the EIA and BioReCer.

4.2 Requirement and criteria assessment inside certification schemes

One of the key activities when applying for a certification scheme is the evaluation, as it would determine the degree of conformity of the company or applicant with the requirements or criteria advocated by the certification scheme. After determining the degree of conformity and passing the assessment, the applicant can be certified. The procedure to be followed during the evaluation is unique for a given certification scheme but may differ from one to another. In the context of the BioReCer project, three evaluation models were recognized: qualitative, semi-quantitative and semi-qualitative. The selection of the evaluation model for BioReCer is important considering that quantitative environmental, economic and social indicators must be included within the requirements and criteria framework. This affects the evaluation structure of the BioReCer certification model.

Qualitative: It is the most used among certification schemes. It has been used, for example, inside FSC, ISCC RSB, Better Biomass and SURE. Certification systems use checklists with qualitative questions or indicators in the audit to identify the degree of conformity (minor and major non-conformities or conformity). In some cases, a pre-assessment of the requirements is carried out with data provided by the company. If the pre-assessment is passed, the data collected is used in the subsequent main assessment.

Semi-qualitative: The certification scheme uses qualitative indicators, but numeric scores are given from the audit to show the performance of the applicant. The operation can be classified into levels with core minimum requirements that must be met to be certified and others advanced. This is the evaluation structure followed by MSC and AWS.

Semi-quantitative: The indicators (and also requirements) have an assigned score depending on their qualitative or quantitative nature and if they follow or do not policies. This is the case followed by the finished European project STARPROBIO.

More information about how the evaluation has been done for the BioReCer has been provided within **deliverable 4.3.**, which belongs to WP4, and **deliverable 2.5**.

5 Creation of a database of sustainability indicators

Indicators are quantitative, qualitative or binary measures that can be used to measure an aspect. They can be expressed in different units and in relative or absolute terms. They can also provide a simplified picture of system performance, a change over time or a comparison with another system or benchmark. Like other methodologies, such as the Life Cycle Impact Assessment, their results are defined in terms of benchmark targets, thus providing information on the distance to reach a predefined target. Indicators can be classified as descriptive or outcome indicators, depending on whether they describe a situation or show progress towards a set target. When it comes to inserting indicators into certification systems, it is best to use outcome indicators, as they can be associated with objectives and thus be used to verify compliance with a requirement. There are other categorizations for indicators depending on the precision with which they reflect the object of analysis: direct and indirect or proxy. The second type of indicator refers to abstract issues that cannot be measured directly. Indicators can also be classified according to their affinity with a certain sector, because they can be used at different stages of the value chain, and their application at different levels (micro or product and macro or territorial scale), their contribution to the pillars of sustainability and because they refer to key areas of interest (e.g. climate change, biodiversity, water consumption, among others).

Considering this variety of classifications for the indicators, the BioReCer project has stablished its own categorization based on the needs of the sectors selected to represent the bio-based industry. Firstly, separate datasets were created for quantitative (also outcomes indicators) and qualitative indicators (also descriptive). A quantitative indicator can be any mathematical equation that is able to measure an aspect numerically. The quantitative indicators were selected from a dataset created from bibliographic literature and subsequently classified according to sector, key areas of concern and sustainability pillar. After this, some of the found indicators were associated with the BioReCer framework of principles, criteria and requirements. The qualitative indicator has been designed as a question and thus, to give results as “yes” or “no”. They were, in contrast with the quantitative indicators, searched to adapt to the BioReCer verification guidance and with the requirements.

5.1 Use of quantitative indicators

5.1.1 Bibliographic database per sector and key area

A database of quantitative sustainability indicators has been created for each of the sectors related to the case studies of BioReCer. The indicators were collected from both reports and scientific articles. All the indicators collected for the database are shown in **Annex B**. A total of 353 indicators were collected for BioReCer, 13.3% for forestry, 49.3% for agriculture, 19.5% for wastewater and 4.3% for fisheries. The remaining indicators can be classified as generic because they can be applied to any sector. All the indicators were also classified by key areas and within each of the pillars of sustainability. **Figure 10** shows the representativeness per pillar and sector.

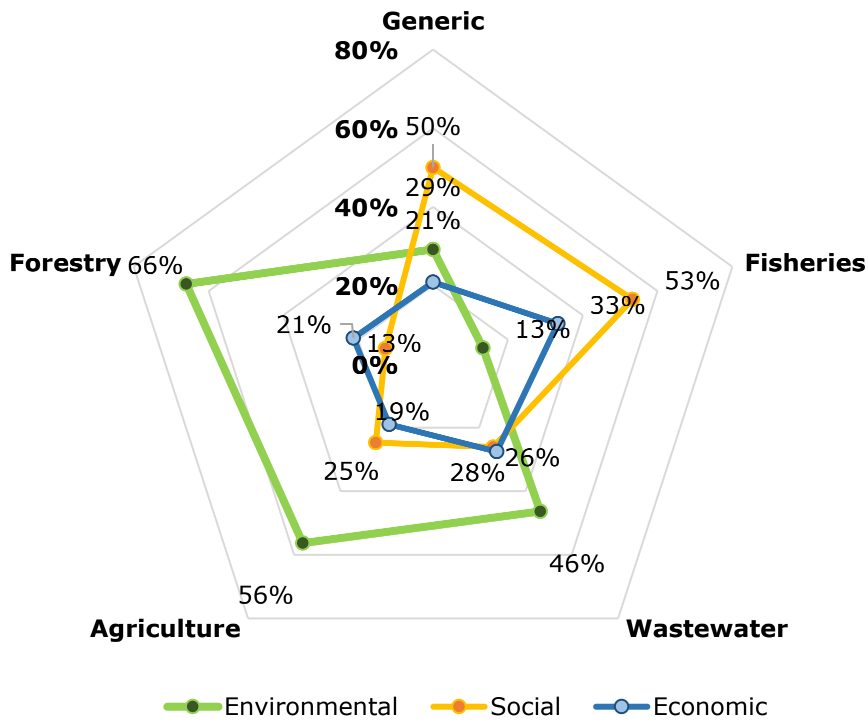

Figure 10: Distribution per sector and pillar of the sustainability indicators to be found on the Annex B or BioreCer indicator dataset.

5.1.2 Assignment of quantitative indicators to requirements

The total of indicators chosen was 100 for the sustainability requirements (also shown in **Figure 3**), this implies that there could be more than one indicator for some of the requirements. For example, the maximum number of possible indicators found for a requirement is 9 and applies to 3.2.3. ("*The company has in place measures to ensure the optimization of cost (operational, infrastructure, waste treatment)*"). This is because many of them were out of the areas of concerned exposed by each of the requirements of the BioReCer framework. This is the case of indicators related to food quality, demography, technical complexity of facilities and quality of life of the population, among others. On the other hand, similar indicators were found among sectors and therefore only one reference source was used while choosing one indicator inside each topic.

Besides, not all the requirements from **section 3.2.3** could be associated with the quantitative indicators from the dataset described in **section 5.1.1**. As shown in **Table 28**, there are a total of 11 out of 42 sustainability requirements without quantitative indicators. It should be noted that the 100 indicators of **Table 28** differ from the 353 of **Annex B**.

Table 28: Indicators associated with the requirements of the BioReCer framework.

<table>
<tr><th rowspan="2">Criteria</th><th rowspan="2">Requirement</th><th colspan="4">Quantitative Indicators</th><th rowspan="2">Reference</th></tr>
<tr><th>Fisheries</th><th>Wastewater</th><th>Agriculture</th><th>Forestry</th></tr>
<tr><td rowspan="10">**1.1** The company defined functions to protect and manage the environment</td><td rowspan="5">**1.1.1.** The company has data available about the type of sources of water used for the production process</td><td colspan="4">**Blue water footprint (m^3/d)** = Volume of water abstracted from the ground or surface water (m^3/d) - Volume of water returned to the system (m^3/d)</td><td>Hoekstra (2015)</td></tr>
<tr><td>-</td><td>-</td><td>**Irrigation supply (-)** = Total annual volume of irrigation supply / Total annual volume of (crop) water demand</td><td>-</td><td>Parra et al. (2020)</td></tr>
<tr><td colspan="4">**Freshwater reduction (-)** = 0.2 Available water (m^3/d) / Water demand (m^3/d)</td><td>Sacramento-Rivero, (2012)</td></tr>
<tr><td>-</td><td>-</td><td colspan="2">**Water scarcity (m^3/d)** = External natural inflows (m^3/d) + precipitation (m^3/d) – evapotranspiration (m^3/d) - natural storage (m^3/d)</td><td>Casadei et al. (2020)</td></tr>
<tr><td colspan="4">**Relative change in demand and availability (%)** = Water demand (m^3/year) / Water availability (m^3/year) · 100</td><td>Silva et al. (2020)</td></tr>
<tr><td rowspan="5">**1.1.2.** The company has proposed *strategies to protect water, soil and air* quality and prevent negative impacts</td><td colspan="4">**Climate change (kg CO_2eq)** = Use of characterization factors from selected methods used in the LCA methodology</td><td>ISO 14040:2006 and ISO 14044:2006</td></tr>
<tr><td colspan="4">**Ozone depletion (kg CFC-11eq)** = Use of characterization factors from selected methods used in the LCA methodology</td><td>ISO 14040:2006 and ISO 14044:2006</td></tr>
<tr><td colspan="4">**Particulate matter formation (kg PM10 eq)** = Use of characterization factors from selected methods used in the LCA methodology</td><td>ISO 14040:2006 and ISO 14044:2006</td></tr>
<tr><td>-</td><td>**Effluent quality index (kg/d)** = [1 / (Total evaluation time · 1000)]· Integral From t=245 to t=609 days [2·Total Suspended Solids in the Effluent (mg/L) + Chemical Oxygen demand (mg/L) + 30·Kjeldahl nitrogen concentration in the effluent (mg/L) + 10 · Nitrate concentration in the effluent (mg/L) + 2·Biochemical Oxygen demand (mg/L)]· Effluent Flow Rate (m^3/d)· dt</td><td>-</td><td>-</td><td>Barbu et al. (2017) and Nopens et al. (2010)</td></tr>
<tr><td>-</td><td>**Industrial wastewater treatment (%)** = Total wastewater treated (m^3/year) / Total wastewater generated (m^3/year)</td><td>-</td><td>-</td><td>UNSD (2023)</td></tr>
</table>

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

Criteria	Requirement	Quantitative Indicators				Reference
		Fisheries	Wastewater	Agriculture	Forestry	
1.1 The company defined functions to protect and manage the environment	**1.1.3.** The company identifies the water sources affected by *runoffs and discharges*	-	**Intermittent overflow discharge frequency (Number/ overflow device)** = Number of overflow events / Number of devices susceptible to overflow	-	-	Matos et al. (2003)
		-	**Intermittent overflow discharge volume (m^3/overflow device)** = Volume of overflow discharge (m^3/d) / Number of devices susceptible to overflow	-	-	Matos et al. (2003)
		-	**Intermittent overflow discharge volume per capacity (%)** = Overflow flowrate (m^3/d) / Actual treatment capacity (m^3/d)	-	-	Kang et al. (2020)
		-	**Intermittent overflow discharge related to rainfall (%)** = Volume of overflow discharge (m^3/d) / Volume of rainfall (m^3/d)	-	-	Matos et al. (2003)
		-	**Spills and/or leakages of chemicals, by-products and wastewater (kg/10^6 m^3)** = Gas chemicals accidentally released (kg/d) / Treated wastewater (m^3/d) · 10^6	-	-	Quadros et al. (2010)
	1.1.4. The company shall provide the most updated *Environmental Impact Assessment (EIA)* of the area before starting its operations	-	-	-	-	-
	1.1.5. The company shall indicate whether it adopts ecosystem regeneration and *rehabilitation measures*	-	-	**Soil management (-)** = Area on which soil conservation practices are adopted including the use of winter cover crops, and appropriate tillage practices (ha) / Total area covered (ha)	-	OECD (1999)
		-	-	-	**Annual afforestation intensity index** = Annual afforestation area (ha) / Total Forest area covered (ha)	Lu et al. (2020)
	1.1.6. The company uses and maintains *appropriate machinery*, processing, disposal containers and facilities for handling products, materials and wastes, excluding legal and safety matters.	**Equipment maintenance (-)** = Number of periodic analyses and equipment maintenance / Number of analyses and equipment maintenance required by the framework of the management plan				Popovic & Kraslawski (2017)
		Overall equipment effectiveness (-) = Average usage time of the equipment (h) / Lifetime of the equipment (h)				Fasciolo et al. (2024)
		Overall equipment effectiveness (-) = Mean time to repair or mean time to failure of the equipment (h) / Lifetime of the equipment (h)				Fasciolo et al. (2024)

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

<table>
<tr><th rowspan="2">Criteria</th><th rowspan="2">Requirement</th><th colspan="4">Quantitative Indicators</th><th rowspan="2">Reference</th></tr>
<tr><th>Fisheries</th><th>Wastewater</th><th>Agriculture</th><th>Forestry</th></tr>
<tr><td rowspan="4">1.2. The company develop strategies for mitigation and adapting to climate change</td><td rowspan="4">1.2.1. The company measures its carbon emissions and has established a reduction plan</td><td colspan="4">Carbon footprint (kg CO_2eq) = ∑ (carbon dioxide equivalent emissions generated through all) the life cycle stages</td><td>ISO 14067:2018</td></tr>
<tr><td colspan="4">Emissions from fuel and electricity (kg CO_2eq/kg) = Equivalent carbon footprint for the consumption of fuels and electricity (kg CO_2eq) / amount of product generated (kg)</td><td>Ryan et al. (2016)</td></tr>
<tr><td>-</td><td>-</td><td>Emissions from fertilisers to air (kg/year) = Quantity of NH_3 emitted (kg/year) + Quantity of N_2O emitted (kg/year) + Quantity of NO_x emitted (kg/year) + Quantity of other compounds emitted (kg/year)</td><td>-</td><td>Yli-Viikari (1999)</td></tr>
<tr><td>-</td><td>-</td><td>Soil Organic Matter Indicator (kg CO_2eq) = Carbon dioxide that has been removed from the atmosphere by plants and stored, or sequestered, as soil organic carbon in agricultural soils (kg CO_2eq)</td><td>-</td><td>Government of Canada (2021)</td></tr>
<tr><td rowspan="8">1.3. The company ensures the preservation of ecosystem diversity</td><td rowspan="5">1.3.1. The company shall have evaluations about the state of the biodiversity within the area and a plan to maintain and improve biodiversity</td><td colspan="4">Biodiversity structures (-) = (Existence of nests + existence of beehives + existence of spider webs) / 3
1. Existence of nests (Values: 0 rarely, 1 occasionally, 2 sometimes, 4 usually)
2. Existence of beehives (Values: 0 rarely, 1 occasionally, 2 sometimes, 4 usually)
3. Existence of spider webs (Values: 0 rarely, 1 occasionally, 2 sometimes, 4 usually)</td><td>INSPIA (2023)</td></tr>
<tr><td>-</td><td>-</td><td>Crop or animal diversity (-) = Number of insects (Pitfall traps and yellow bowl traps) and/ or animals (Appropriate sampling method depending on the species)</td><td>-</td><td>Chopin et al. (2021)</td></tr>
<tr><td>-</td><td>-</td><td>Overall biodiversity condition: crop richness (number/year) = Number of crops produced by farmers in a year</td><td>-</td><td>Talukder et al. (2020)</td></tr>
<tr><td>-</td><td>-</td><td>Overall biodiversity condition: crop rotation (number/year) = Number of crop rotations reported by farmers in a year</td><td>-</td><td>Talukder et al. (2020)</td></tr>
<tr><td>-</td><td>-</td><td>Inclusion of patches for biodiversity (ha) = Plot area used to conserve biodiversity (ha)</td><td>-</td><td>Chopin et al. (2021)</td></tr>
<tr><td rowspan="3">1.3.2. The company shall identify whether its operation is happening in a protected area</td><td colspan="4">Habitat representativeness/extension (-) = Area of the habitat in the potential protected area (ha) / Total area of the habitat at the administrative level (ha)</td><td>Rita et al. (2017)</td></tr>
<tr><td>-</td><td>-</td><td colspan="2">High value farmland and forestry (-) = Utilised Agriculture Area of high nature value farmland (ha) / Total area covered (ha)</td><td>OECD (2013)</td></tr>
<tr><td colspan="4">Water quality (-) = Surface designated as nitrate vulnerable zone (ha) / Total area covered (ha)</td><td>OECD (2013)</td></tr>
</table>

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

Criteria	Requirement	Quantitative Indicators				Reference
		Fisheries	Wastewater	Agriculture	Forestry	
1.4. The company has mechanisms to control polluting emissions	**1.4.1.** The company has some kind of treatment technology to prevent emissions to the environment	-	-	-	-	-
	1.4.2. The company identifies and characterizes emissions to air, soil, and water to comply with legal thresholds	**Air quality (ppm)** = Suspended particulate matter concentration in the air (ppm)				Wohlenberg et al. 2022)
		Nitrate groundwater (mg NO_3^-/L) = Groundwater nitrate concentration (mg NO_3^-/L)				Lebacq et al. (2013)
	1.4.3. The company measures the noise and odour to ensure that they are under the legal threshold	**Noise level (dBA)** = $10 \cdot \log (14/24 \cdot (10^{\text{Noise level during the daytime}} (dBA)) + 2/24 \cdot (10^{\text{Noise level during the evening -time}} (dBA)) + 8/24 \cdot (10^{\text{Noise level during the night-time}} (dBA)))$				Collivignarelli et al. (2022)
		-	**Odour level** = ∑ (maximum or influent COD concentration in the treatment unit i · odour emission flowrate per type of treatment unit (i.e., physical, chemical, biological or thermal))	-	-	van Schaik et al. (2021)
		Odor indicator (-) = Number of monthly complaints from the impact of odour emissions				Wohlenberg et al. (2022)
1.5. The company manages waste under and environmentally sound approach	**1.5.1.** The company has appropriate labelling for hazardous waste considering aspects of classification and management	**Upper-tier establishment classification (-)** = ∑ (quantity of dangerous substance (ton) · falling within Part 1 or Part 2 of Annex I of Seveso III directive / Qualifying quantity for the dangerous substance or category (ton) · from column 3 Part 1 or from column 3 of Part 2 of Annex I of Seveso III directive)				Directive 2012/18/EU
		Lower-tier establishment classification (-) = ∑ (quantity of dangerous substance (ton) · falling within Part 1 or Part 2 of Annex I of Seveso III directive / Qualifying quantity for the dangerous substance or category (ton) · from column 2 Part 1 or from column 2 of Part 2 of Annex I of Seveso III directive)				Directive 2012/18/EU
	1.5.2. The company applies the waste hierarchy to reduce and valorised its waste	**Composition of collected waste (%)** = Mass amount of each waste stream (kg/year) / total mass of collected waste (kg/year)				Bastos et al. (2019)
		Waste management (%) = Total waste that is dealt with in a controlled facility (kg/year) / total solid waste destined for treatment or disposal (kg/year)				Bastos et al. (2019)
		Pollution intensity (-) = Mass or volume of waste generated (kg/d) / Mass or volume of product generated (kg/d)				UNIDO and UNEP (2010)
		Mass fraction of hazardous solid waste (%) = Mass of hazardous solid waste (ton/year) / Total mass of solid waste (ton/year)				Krajnc & Glavič, (2004)
1.6. The company identifies genetically modified species when utilised	**1.6.1.** The company characterizes the introduced genetically modified species	-	-	-	-	-

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

Criteria	Requirement	Quantitative Indicators: Fisheries	Wastewater	Agriculture	Forestry	Reference
1.7. The company restricts the use of invasive species and pathogens	**1.7.1.** The company quantifies and limits the use of non-indigenous/invasive species and pathogens introduced into the ecosystem		**Risk of infection potential** = log10 ([concentration of the pathogen in the influent] / [regulatory (health-based) standard per recovered resource]) / log10 [reduction achieved by a treatment train per resource])			van Schaik et al. (2021)
		Microbiological tests compliance (%) = Number of tests showing compliance of microbiological parameters / Number of microbiological tests performed ·100				Staben et al. (2010)
2.1. The company ensures the continuous provision of resources by preserving the resilience of ecosystems	**2.1.1.** The company considers the resilience of the ecosystem to ensure sustainability	-	-	**Discontinuity in the agricultural landscape (ha/number)** = Mean area for agricultural activities (ha) / Total number of plots	-	Gómez-Limón & Sanchez-Fernandez (2010)
		-	-	**Buffers and security areas (-) = Σ** (Buffer and security areas (ha)) / Total area of the farm (ha)	-	INSPIA (2023)
		-	-	**Soil erosion (t/ha·year) =** Quantity of topsoil loss per year (t/year) / Total area covered (ha)	-	Pretty et al. (2008)
	2.1.2. The company establishes and monitors key performance indicators to ensure the responsible use of resources and avoid the degradation of ecosystems	-	-	**Farm or agricultural yield =** ∑ (Area assigned to the plot (ha) · Crop yield of each plot (t/ha) ·100 / Potential crop yield) / Total area considered (ha)	-	INSPIA (2023)
		-	-	**Water use efficiency of the field =** Total production or yield harvested (kg/year) / volume of water used by the field (m^3/year)	-	Hoover et al. (2023)
		-	-	**Growing stock (m^3/ha) =** Biomass collected (m^3/year) / Total area covered (ha/year)		Pieratti et al. (2019)
		-	-	**Harvest productivity (m^3/ha) =** Volume harvested of wood or crop (m^3/year)/ Total area covered (ha/year)		Pieratti et al. (2019)
2.2. The company promotes the management of natural resources sustainably	**2.2.1.** The company has an energy efficiency plan in place	**Share of renewable energy (%)** = Renewable energy consumption (kWh/d) / (Energy consumption (kWh/d) + Energy grid losses (kWh/d) + Self-consumption (kWh/d))				Eurostat (2023)
		Share of non-renewable energy (%) = Fossil fuel energy consumption (kWh/d) / (Renewable energy consumption (kWh/d) + Fossil fuel energy consumption (kWh/d))				Sacramento-Rivero (2012)
		Use of external energy (kWh/kg or m^3) = (Energy bought (kWh/d) - Energy sold (kWh/d)) / Raw material input (m^3/d or kg/d)				Cassidy et al. (2020)
				Overall energy efficiency (kWh/year) = Total energy output of crops produced in a year (kWh/year) / Total energy input for all crops produced in a year (kWh/year)		Talukder et al. (2020)

Table 19: Indicators associated with the requirements of the BioReCer framework (continuation).

Criteria	Requirement	Quantitative Indicators				Reference
		Fisheries	Wastewater	Agriculture	Forestry	
2.2. The company promotes the management of natural resources sustainably	**2.2.2.** The company has a plan to manage resources and water efficiently	**Consumption of chemicals (%)** = Acid and bases consumed (kg/d) / raw material input (kg/d)				Quadros et al. (2010)
		-	-	**Nitrogen balance (kg/ha)** = ((Nitrogen from fertilisers (kg/d) + net input of livestock manure (kg/d) + seeds and planting materials (kg/d) + biological nitrogen fixation (kg/d) + atmospheric deposition (kg/d)) - (Total harvested crops (kg/d) + total forage (kg/d))) / Total area of agricultural land (ha)	-	OECD (2001)
		-	-	**Phosphorus balance (kg/ha) =** (Quantity of phosphorus input (kg/year) – Quantity of phosphorus outputs (kg/year)) / Total area covered (ha/year)	-	Gómez-Limón and Sanchez-Fernández (2010)
		-	-	**Water productivity (€/m³)** = Net benefits from agricultural systems (€/year) / Amount of water used to produce the benefits (m³/year)	-	Hoover et al. (2023)
		-	-	**P productivity (kg/ha) =** (Crop phosphorus productivity i (kg/ha) · Area for the crop I (ha)) / Total area considered (ha)	-	Inspia (2024)
2.3. The company promotes the safe commercialization of resources	**2.3.1.** The company identifies and quantifies the use of chemicals and hazardous substances	**Volatile organic carbons (-)** = Quantity of hazardous volatile organic carbons (kg) / Mass of recycle produced (kg)				Briassoulis et al. (2021)
		-	-	**Chemical response to pest stress (-) =** Farmers reporting not using chemical pesticide for agriculture (number) / Total number of working farmers questioned (number)	-	Talukder et al. (2020)
	2.3.2. The company identifies whether action has been addressed to ensure food security in biomass production systems	-	-	**Dietary diversity (-)** = Nutrient produced (kcal) /nutrient needs (kcal)	-	Sannou et al. (2023)

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

<table>
<tr><th rowspan="2">Criteria</th><th rowspan="2">Requirement</th><th colspan="4">Quantitative Indicators</th><th rowspan="2">Reference</th></tr>
<tr><th>Fisheries</th><th>Wastewater</th><th>Agriculture</th><th>Forestry</th></tr>
<tr><td rowspan="4">3.1. The company ensures the quality and traceability of its products and other outputs</td><td>3.1.1. The company has established measures to track the disposal of by-products and waste</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="2">3.1.2. The company has established measures to improve product traceability</td><td colspan="4">Logistic feasibility, transport efficiency (kg/truck) = Quantity of products to be transported (kg/year) / Number of trucks used (Truck/year)</td><td>Fasciolo et al. (2024)</td></tr>
<tr><td colspan="4">Products trade and commercialization (-) = Quantity of product exports (t/year)/ Quantity of product generation (t/year)</td><td>Diaz-Balteiro et al. (2022)</td></tr>
<tr><td>3.1.3. The company promotes the use of materials with bio-based origin as well as non-virgin materials on its final products</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="7">3.2. The company makes good use of its assets</td><td rowspan="2">3.2.1. The company has investments and expenditures related to research, development and training of employees</td><td colspan="4">Expenses for education and training (€/employee) = Expenditure for the training of the workers (€/year)/ Number of the workers of the organization (number/year)</td><td>Staben et al. (2010)</td></tr>
<tr><td>-</td><td>Investment in research and technology (-) = Investment in research and technology (€/year) / Income associated with water resource uses (€/year)</td><td>-</td><td>-</td><td>da Silva et al. (2020)</td></tr>
<tr><td>3.2.2. The company has good management of the unsold finished goods, prevention of generation of waste</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td rowspan="4">3.2.3. The company has in place measures to ensure the optimization of cost (operational, infrastructure, waste treatment)</td><td colspan="4">Profits from feedstocks (-) = Cost of the feedstock (€/year) / economic value of all the products (€/year)</td><td>Sacramento-Rivero (2011)</td></tr>
<tr><td colspan="4">Unitary product prices (-) = Product price (€/kg) / Unitary cost of synthesis of the product (€/kg)</td><td>Van Schoubroeck et al. (2018)</td></tr>
<tr><td colspan="4">Sales outcomes (€/ton) = Gross profit (€/year) / Net sales volume (ton/year)</td><td>Sacramento-Rivero (2011)</td></tr>
<tr><td colspan="4">Expenses for environmental protection measures (€/year) = Costs for environmental management during operation throughout the life span of the product or process (€/year)</td><td>Staben et al. (2010)</td></tr>
</table>

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

Criteria	Requirement	Quantitative Indicators				Reference
		Fisheries	Wastewater	Agriculture	Forestry	
3.2. The company makes good use of its assets	**3.2.3.** The company has in place measures to ensure the optimization of cost (operational, infrastructure, waste treatment)	-	-	-	**Environmental taxes (-) =** Environmental taxes wood products industry (€/year) / Total manufacturing environmental taxes (€/year)	Diaz-Balteiro et al. (2022)
		Total cost coverage ratio (-) = Net operating revenues (€/year) / Principal and interest payments on all long-term debt (€/year)				Staben et al. (2010)
		Ratio of maintenance of assets (%) = The total maintenance cost (€/year)/ The total asset value (€/year) ·100				Staben et al. (2010)
		Investment in capacity (-) = (Cost of maintenance (€/year) + Cost of depreciation in equipment (€/year)) / Investment of the company (€/year)				da Silva et al. (2020)
				Land tenure (€/person) = Capital value of own assets (€/year) / Total number of working farmer (person/year)		Sannou et al. (2023)
		Gross (net) output from external non-renewable input (€/year) = Energy (money) produced by the system (€/year) / unit of non-renewable energy (money) introduced into the system (€/year)				Tellarini & Caporali (2000)
	3.2.4. The company must ensure that subcontractors also comply with the requirements of the certification schemes	-	-	-	-	-
3.3. The company respects private property	**3.3.1.** When applicable, the company has fully documented property rights	-	-	-	-	-
3.4. The company promotes transparency	**3.4.1.** The company is a legally defined entity with a clear and documented legal record	-	-	-	-	-
3.5. The company promotes corporate social responsibility	**3.5.1.** The company takes into consideration green procurement criteria in the selection of its suppliers	-	-	-	-	-
	3.5.2. The company complies with certification schemes and standards verified by a third-party	**Audits performance (no./year)** = Total number of audits / Timeframe (year)				Popovic et al. (2017)
		External audit findings = Number, type and source of external audit findings and actions arising from these				UNI ISO 30414:2019

Table 28: Indicators associated with the requirements of the BioReCer framework (continuation).

<table>
<tr><th rowspan="2">Criteria</th><th rowspan="2">Requirement</th><th colspan="4">Quantitative Indicators</th><th rowspan="2">Reference</th></tr>
<tr><th>Fisheries</th><th>Wastewater</th><th>Agriculture</th><th>Forestry</th></tr>
<tr><td rowspan="18">4.1. The company complies with the labour conditions established by the regulatory framework</td><td rowspan="4">4.1.1. The company allows work and personal life combinations by limiting standard working hours as per national regulations, ILO standards, WHO guidelines, etc.</td><td colspan="4">Working hours (h/d) = $\sum$ (time consumed on each of the operations · operations performed in the company (h/d)) / Total number of workers</td><td>INSPIA (2023)</td></tr>
<tr><td colspan="4">Workforce availability = Full-time equivalents</td><td>UNI ISO 30414:2019</td></tr>
<tr><td colspan="4">Working hours (h/m^3) = Working hours per organization (h/year) / Production capacity (m^3/year)</td><td>Jarosch et al. (2020)</td></tr>
<tr><td colspan="4">Workload (d/year) = Days off from work per person (d/year)</td><td>Sannou et al. (2023)</td></tr>
<tr><td>4.1.2. The company has a Health and Safety plan in place</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>4.1.3. The company provides accident insurance coverage and adequate compensation for all workers</td><td>-</td><td>-</td><td>Insured area (-) = Farm area covered by an agricultural insurance policy (ha) / Total area considered (ha)</td><td>-</td><td>Chopin et al. (2021)</td></tr>
<tr><td rowspan="2">4.1.4. The company has effective complaints and grievance mechanisms and takes measures to resolve the reported complaints and grievances</td><td colspan="4">Grievance filed (-) = Number and type of grievance file</td><td>UNI ISO 30414:2019</td></tr>
<tr><td colspan="4">Service complaints (Number/customer/year) = Number of service complaints / Assessment period (year) / Population involved</td><td>Staben et al. (2010)</td></tr>
<tr><td rowspan="3">4.1.5. The company ensures gender equality</td><td colspan="4">Female employees in management positions (%) = Number of female employees in management positions (1st or 2nd level) / Total number of employees ·100</td><td>Jarosh et al. (2020)</td></tr>
<tr><td colspan="4">Ratio of female employees (%) = Number of female employees / Total number of employees ·100</td><td>Jarosh et al. (2020)</td></tr>
<tr><td colspan="4">Gender equity (€/year) = Average male wages (€/year) - Average female wages (€/year)</td><td>Sannou et al. (2023)</td></tr>
<tr><td rowspan="4">4.1.6. The company keep records of work-related accidents or incidents</td><td colspan="4">Occupational accidents (-) = Amount of accidents / Number of employees</td><td>Jarosh et al. (2020)</td></tr>
<tr><td colspan="4">Lost time for injuries (-) = Amount of working time lost due to accidents at work in a given time period (h/year) / Total amount of expected working time in a given time period (h/year)</td><td>UNI ISO 30414:2019</td></tr>
<tr><td colspan="4">People killed (-) = Number of people killed during work</td><td>UNI ISO 30414:2019</td></tr>
<tr><td colspan="4">Emergency response (min/no.) = Response time to emergency (min) / Number of emergency events</td><td>Quadros et al. (2010)</td></tr>
<tr><td rowspan="3">4.1.7. The company promotes the participation of its employees on certified training activities and competencies</td><td colspan="4">Ratio of employees participated in training (%) = Number of employees participating in training activities / Total number of employees ·100</td><td>Jarosh et al. (2020)</td></tr>
<tr><td colspan="4">Trained employees (%) = Percentage of employees who have completed training on compliance and ethics</td><td>UNI ISO 30414:2019</td></tr>
<tr><td colspan="4">Training time (h/employee/year) = Yearly hours of training (h/year) / Total number of employees</td><td>Nam et al. (2019)</td></tr>
<tr><td rowspan="3">4.2. The company contributes to job creation and</td><td>4.2.1. The company contributes to enhancing the employment ratio in the sector</td><td>-</td><td>-</td><td>Contribution to job creation (h/ha) = Labour required (h/year) / unit of agricultural land (ha/year)</td><td>-</td><td>Sannou et al. (2023)</td></tr>
<tr><td rowspan="2">4.2.2. The company ensures the payment of wages that meet or exceed industry minimum standards</td><td colspan="4">Average annual salary (€/year) = Average salary paid to staff (€/year)</td><td>OECD (2022)</td></tr>
<tr><td colspan="4">Average salary (-) = Average salary (€/year) / Remuneration (€/year)</td><td>UNI ISO 30414:2019</td></tr>
</table>

5.2 Use of qualitative indicators

Because quantitative indicators were not found for all requirements, this section provides qualitative indicators for each requirement based on literature and recommended to be included in the BioReCer verification guidance. Also, feedback has been received for the creation of this list from WP4. All the qualitative indicators are YES/NO answers.

Table 29: Qualitative indicators associated with sustainability BioReCer requirements.

Requirement	Qualitative indicators
1.1.1	Does the company have reports or inventory records for the water consumed? Has the source type and the quantity been specified?
1.1.2	Does the company have soil impacted survey results?
1.1.3	Does the company have reports on the amount of wastewater, runoffs and other discharges produced?
1.1.4	Does the company fall under the scope of Article 4(1) and Annex I of the EIA Directive? If so, does the construction project have been performed before the implementation of the directive? Does the company have documentation about the EIA?
1.1.5	Does the have company's Environmental impact monitoring been recorded?
1.1.6	Does the company have equipment documentation and records on maintenance? Does the company have registered the storage tanks/containers, including size? Does the company have permits or licences from the authorities about the construction and use of containers? Does the company have information about the dates when containers have been emptied how often containers are emptied?
1.2.1	Does the company have done a Life Cycle Assessment or carbon footprint study? Does the company have documented savings and reduction strategies for emissions that could potentially affect the climate change?
1.3.1	Does the company have mapped on natural vegetation? Does the company have wildlife evaluation been recorded? Does the company have mapped protected areas, existing ecological corridors, and buffer zones and shown points of action? Does the company have up-to-date maps of the management site? Does the company have protocols, tools or any other kind of documentation identifying where high conservation values occur? Does the company have used databases, satellite images etc. to verify compliance? Does the company have control measures to avoid illegal or inappropriate hunting, fishing, trapping or collecting activities?
1.3.2	Does the company records on the total area of the farm/ plantation classified as pasture, cropland and other areas (such as compensation area, set-aside-land, forest etc.), including all rented and leased areas for the respective certification period?
1.4.1	Does the company have records and equipment documentation for Best Available Techniques?
1.4.2	Is the company able to provide documentation about the sampling and laboratory analysis performed to characterize the quantity and composition of emissions to the environment? Does the company have a written management system? Does the company have records of the environmental incidents happened?
1.4.3	Does the company have reports or documents with the results of dynamic olfactometric studies and modelling?
1.5.1	Does the company have a plant operation permit, including a layout plan and capacities of storage facilities? Does the company have performed noise emission studies by equipment that will be used outdoors?

Table 29: Qualitative indicators associated with sustainability BioReCer requirements (continuation).

Requirement	Qualitative indicators
1.5.2	Does the company have a permit or license for the collection of waste issued by the competent authority? Does the company have reported on the amounts and management of solid waste and wastewater?
1.6.1	Does the company have existing certificates, and label tags on seed packaging?
1.7.1	Is the company able to provide the permits or authorisations for the use of invasive species? Does the company have a management plan for the monitoring and control of invasive species?
2.1.1	Does the company have recorded any internal processing of sustainable products, including the respective yields/conversion factors? Does the company have harvesting and production records?
2.1.2	Does the company have GHG calculations, as well as the input data used for the calculation?
2.2.1	Does the company have documentation for the energy plan in place?
2.2.2	Does the company have chemical use records?
2.3.1	Does the company have authorisations for substances that may raise risks and to ensure that they are properly controlled? Does the company have a registration dossier with the hazard information and the risk assessment of the substances? Does the company have the ECHA dossier proposing restrictions in the production of substances? Does the company have available the EU declaration of conformity document?
2.3.2	Does the company have documents with periodic market studies to ensure that food prices are not being rise because of the use of feedstock for the manufacturing of bio-based processes?
3.1.1	Does the company have recorded on applicable national and regional legislation for the storage and disposal of wastes? Does the company have records identifying the different types of wastes and risk identification?
3.1.2	If the mass balance is applicable, has the company mass balances for the production/treatment/valorisation process? Does the company have a harvesting permit? Does the company have a forest management plan? Does the company have a silo of tank storage plan? Does the company have records of weighbridge tickets and bill of lading? Does the company have sustainability declaration/Proof of Sustainability or other documents for incoming and outgoing sustainable material? Does the company have documented on the periodical reporting on opening and closing stock for incoming and outgoing sustainable and non-sustainable material? Does the company have a production report (periodically, annually) including processing and allocation factor (if not provided within GHG calculation) and description of waste/residues, losses and co-products (if relevant and applicable e.g. for processing units)? Does the company have a written commitment to the management? Does the company have documentation requirements including records and documents on traceability and quantity bookkeeping, which must be complete, up-to-date and accessible at the certified supply chain element?
3.1.3	Does the company have technical product documentation? Does the company have reports on eco-design? If so, has bio-based material been included as part of the product?
3.2.1	Does the company have plans and activities to support the long-term economic viability of the site?
3.2.2	Does the company have documents on quantity bookkeeping for unsold finished products? Has the company a management plan in place for the recycling, valorisation or disposal of unsold finished goods?
3.2.3	Does the company have purchase and sales documentation?

Table 29: Qualitative indicators associated with sustainability BioReCer requirements (continuation)

Requirement	Qualitative indicators
3.2.4	Does the company have a list and corresponding contracts with relevant subcontractors, and service providers (e.g. warehouses, dependent collectors, etc.)? Does the company have a report and action plan of the last/previous external audit (n.a. during the first certification)? Does the company have a list and corresponding contracts with all suppliers and recipients of sustainable material? Does the company have saved subcontractor documentation supporting its certification by recognised standards?
3.3.1	Does the company have documentation shown tenure or land rights?
3.4.1	Does the company have documented all the European and national legislation applicable to its activity?
3.5.1	Does the company have any of the following procurement documents: request for information, request for proposal, request for quotation, invitation for bid, sales proposal, purchase and sales agreement and purchase order?
3.5.2	Does the company records of internal audits, non-conformities with this standard, related corrective actions and/or identified discrepancies within the documentation? Does the company records of other certification standards with comparable scopes used, non-conformities with these standards and related corrective actions, and, if applicable, information on withdrawn or suspended certificates?
4.1.1	Does the company have a time recording system for workers?
4.1.2	Does the company have a risk assessment documentation?
4.1.3	Does the company have proof for contracts? Does the company have relevant proof of payments?
4.1.4	Does the company have available a complaint form and/or procedure for workers and surrounding communities?
4.1.5	Does the company have publicly available equal opportunities policies including identification of relevant/ affected groups in the local environment?
4.1.6	Does the company have a management system in place?
4.1.7	Does the company have training material and course planning documents? Does the company have distribution lists, emails, participant lists and certificates?
4.2.1	Does the company have reports or market studies demonstrating that its activity actually improves the employment ratio in the area?
4.2.2	Does the company have payslips or other evidence to demonstrate that living wages meet at least legal or industry minimum standards?

6 Weighting and scoring of the indicators

6.1 Procedure and fundamental for the scoring of the indicators

As proposed by Dobbie & Dail (2013), five steps can be followed to build a composite indicator score applicable for a certification scheme framed within a bio-based sector and residual feedstocks.

- **Step 1:** Defining a theoretical framework to support the index composition
- **Step 2:** Deciding on sustainability concepts (weak and strong sustainability)
- **Step 3:** Selecting, cleaning and manipulating the raw indicator data
- **Step 4:** Standardizing the data (normalization)
- **Step 5:** Weighting and aggregation of the indicators

The first step has already been addressed in **section 3** since the sustainability and circularity framework of requirements, criteria, principles and pillars developed for the BioReCer certification scheme will be used. Although the goal of this project is to provide a tool for companies and policymakers (reductionist approach), uncondensed data for the framework and suggestions of different indicators (**Table 28**) were provided for scientists (holistic approach) (Paracchini et al., 2008). The reasoning behind this is that uncondensed data can be statistically studied and also introduced for the development and improvement of other methodologies. The subsequent steps of the scoring procedure have been explained in **sections 6.2** to **6.5**. It should be considered that the use of scoring for indicators and the use of indicators themselves is a possible route for the conformity assessment of certification schemes. The final decision of the evaluation procedure for the BioReCer has been provided on **deliverable 2.5** (*Guidelines for integration to bio-based certification schemes*) since the indicators would be tested considering their application in the case studies (WP6) and for their use in the ICT tool developed within the project.

6.2 Giving a ranking to the sustainability criteria

When it comes to giving relevancy to the requirements and criteria of the BioReCer two aspects should be differentiated: (1) determination of the level of conformity to be implemented within the certification schemes for each of them (lower, higher or other degree of conformity) and (2) definition of the type of sustainability (strong or weak) as it will define the weighting and aggregation methods to be used. Both aspects have in common that they identify whether the requirements and criteria have the same importance or not, but they might not necessarily be correlated. To establish a connection between weighting and aggregation methods and the degree of compliance within the certification systems, two levels of compliance have been considered within BioReCer: basic and advanced. Compliance with the basic requirements is always required for the first certification period. These requirements must be addressed as a priority. This is because the basic level has been associated with mandatory legislative requirements. This also implies what is called weak sustainability, as companies do not go beyond what is expected by legislation. The association of the BioReCer requirements with the legislation is provided in **deliverable 2.5**. The advanced level is associated with strong sustainability since it considers issues that make the company different in terms of sustainability. Thus, flexible requirements are considered, and compliance leads to a remarkable rise in the score achieved by the company. The advanced level may have indicators that could be estimated at the moment of the certification but also others that should be implemented in the future. When assessing sustainability under a weak sustainability (basic level) paradigm, substitution or compensatory weighting and aggregation methods can be used.

For strong sustainability, on the other hand, substitutability cannot be allowed, and thus non-compensability must be taken into account. Also, proper non-equal weights should be used, and threshold values should be defined. Within this context, the advanced requirements are not equally important, and they could be analysed in the following ways: (1) veto thresholds, (2) a hierarchical structure and (3) weighting. In the first case, a minimum performance benchmark is established (based on expected optimal performance, best industry performance, legal thresholds or comparison with best available techniques). In the second option, the requirements are ranked according to their importance and in the third, as in the case of weak sustainability, a numerical value is given according to their importance.

6.3 Procedure proposal for the selection of eligible indicators

All the sustainability requirements from **section 3.2.3** were associated with possible indicators (as indicated in **section 5**) that could be used inside the theoretical framework proposed for BioReCer. This deliverable does not provide the final selection list of indicators since the indicators correlated with the requirements of the theoretical framework should be tested first through the case studies. The **deliverable 6.2.** from WP6 will show the results of feasibility for the selection of such indicators while **deliverable 2.5**, associated with **task 2.5**, has the integrated framework with the final selection of indicators based on their viability of being calculated and used by the companies. Also, the results of the pilot test assessment are mentioned in deliverable **D4.3**.

This section of this deliverable proposes a procedure to estimate the viability of the indicators. In this way, the subjectivity of the traditional subjective process of indicator selection can be reduced. The steps to be followed are listed below in order of importance:

1. Determine the input-output parameters from which the case studies or processes have data and create a list. For example: mass of feedstock feed, renewable electricity consumed, mass of reagents (per type) consumed in the process. This

can be done through the use of the input-output analysis done and published on **deliverable 6.2.** from WP6.

2. Take the proposed list of indicators from the framework and specify also in a list the parameters that are needed for their estimation.
3. Perform multivariate exploratory analysis in order to impute missing values from the indicators of the framework and the type of data that is needed.
4. Verify whether the qualitative questionnaires generated to construct the BIORECER framework of principles, criteria and requirements are solving these gaps. If more information is required, confirm that the question has been answered as "Y". If so, put in contact with the companies to take evidence to complete the data of the parameter and finally estimate the indicator.
5. Classify the indicators in (1) easily estimated, (2) more information is required and (3) hardly estimated, (4) to be estimated in the future and (5) not feasible. Indicators can be considered easily estimable only when input-output process analysis is used. The second category corresponds to indicators that need information from qualitative questionnaires to be estimated, but the company can provide the data. Indicators that are difficult to estimate are those for which the company needs to provide data and needs to make additional measurements to do so. The fourth category corresponds to indicators that cannot be estimated at the moment but that the company could estimate in the future (e.g. due to the purchase of new laboratory equipment for measurements). The last category is assigned to indicators that cannot be estimated by any of the above means.
6. Remove the not feasible indicators from the framework. Type 1 and 2 indicators will be the core of advisable indicators of the BioReCer while types 3 and 4 will be supplementary indicators.

6.4 Normalization of the indicators

Since the indicators selected in the previous section are measured in different units, the results are normalized to common dimensionless units. This can be done through different normalization methods such as standardisation or weighting, ranking or hierarchical structure, re-scaling and benchmarking. For both the basic and advanced levels of requirements, only one indicator is selected, and the normalization can be done through re-scaling. Therefore, a score of 1 could be assigned to each compliant requirement, 0.5 for minor non-compliance and 0 for non-compliance.

6.5 Weighting and aggregation of the indicators

Once the indicators have been normalized, they can be combined and aggregated. A relative importance or weighting can be assigned to each of them. There are different weighting procedures depending on the contribution to the index. Equal weighting can be used when it is assumed that all indicators have the same relevance. When statistical characteristics of the data are used, weighting based on statistics can be used. Finally, the expert public opinion procedure is based on stakeholder judgment. In BioReCer, as all requirements are equally important, the chosen indicators were also weighted equally.

Based on the degree of compensation there are compensatory and non-compensatory methods for aggregation of the weighted indicators. The first group it is includes additive aggregation methods (e.g., arithmetic), and multiplicative aggregation methods (e.g., geometric) (Matos et al., 2003). The importance of the indicator associated is not indicated and there is a possibility of trade-offs or offsetting one indicator with another. In the case of additive methods, the results of the normalized indicators are summed up to result in the criteria sustainability index. The geometric aggregation methods utilize multiplicative instead of additive functions. Because the compensation between strong sustainability criteria is unacceptable, a non-compensatory method should be used (i.e., multi-criteria decision making).

7 Conclusions

Sustainability certification has been playing an important role in ensuring that companies are engaged in achieving a society that is able to meet the needs of the future. However, the certification framework, by which auditors can assess compliance with the set of standards or requirements of the certification scheme, needs to be updated to assimilate the new precepts of sustainability and circularity of bio-based products. On the other hand, it is necessary to look for methodologies capable of quantitatively measuring the requirements. Apart from this, the certification procedures already developed are strong for the early stages of the life cycle (i.e. production and distribution), while the criteria are not capable of adapting to end-of-life processes.

Based on this, the BioReCer project has been involved in the identification of principles, criteria and requirements that could be used in waste material valorisation processes of different bio-based sectors (fisheries, agriculture, forestry and waste/wastewater). A theoretical framework based on documents (certification systems, directives, standards and initiatives) was provided. The results obtained show that circularity requirements are barely covered by certification systems, legislation and standards, while interest in the topic continues to grow through initiatives. Pollution and waste management, as well as value creation, are the aspects of greatest concern in terms of circularity, while systems thinking (i.e. industrial symbiosis) is yet to be developed.

All these requirements must be assessed when companies are to be certified. The major trend within certification schemes is the use of qualitative indicators, which decreases the possibilities of computerization of the certification process and leaves the results to subjectivity. One solution is to evaluate the use of quantitative indicators to verify if they reach a predefined target. Therefore, BioReCer provides a dataset of quantitative sustainability indicators that could be used for the above-mentioned sectors. Some of these plausible indicators (a total of 100) could be correlated with the above-mentioned theoretical certification framework. Due to the abstract nature of some requirements, not all of them could be covered by quantitative indicators. Thus, additional qualitative indicators were proposed.

8 List of Abbreviations

AACS	Australian Agricultural Certification Scheme
ANFACO	Asociación Nacional de Fabricantes de Conservas de Pescados y Mariscos
ASC	Aquaculture Stewardship Council
AWS	Alliance for Water Stewardship
BioReCer	Biological Resources Certification Schemes
2BSvs	Biomass Biofuels voluntary scheme
BREEAM	Building research establishment environmental assessment method
BSCI	Business Social Compliance Initiative
CBA	Cost – Benefit Analysis
CERTH	Centre for Research and Technology Hellas
CETAQUA	Centro Tecnológico del Agua
EEA	European Environment Agency
EIA	Environmental Impact Assessment
EU	European Union
FEFAC	European Compound Feed Manufacturers' Federation
FEMAS	Feed Materials Assurance Scheme
FSC	Forest Stewardship Council
GFSI	Global Food Safety Initiative
GSA	Global Seafood Alliance
GSSI	Global Sustainable Seafood Initiative
IPA	Impact Pathway Approach
ISCC	International Sustainability and Carbon Certification
ISEAL	International Social and Environmental Accreditation and Labelling Alliance
ISO	International Organization for Standardisation
ITC	International Trade Centre
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MAA	Multitude Attribute Analysis

MFA	Material Flow Analysis
MSC	Marine Stewardship Council
PCR	Product Category Rules
SEEA	System of Economic and Environmental Accounts
PDCA	Plan Do Check Act (PDCA)
PEFC	Programme for the Endorsement of Forest Certification
RED	Renewable Energy Directive
RISE	Research Institutes of Sweden
RSB	Roundtable on Sustainable Biomaterials
RSPO	Roundtable on Sustainable Palm Oil
RTRS	Round Table on Responsible Soy
SBP	Sustainable Biomass Program
SQC	Scottish Quality Farm Assured Combinable Crops
SURE	Sustainable Resources voluntary scheme
TEA	Techno-economic Analysis
UEBT	Union for Ethical BioTrade
UFAS	Universal Feed Assurance Scheme
UNIVPM	Universitá Politecnica delle Marche

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