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On the societal impact of publicly funded Circular Bioeconomy research in Europe

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Abstract

Europe has taken a world leadership position in setting policy priorities for Circular Bioeconomy (CBE) as a key determinant of economic, social, and environmental sustainability. Consequently, European R&D investment in this area keeps growing along with the societal pressure to demonstrate the return of investment of publicly funded projects. Thus, this work presents a pioneering exploratory analysis of the extent to which projects funded at the European level incorporate the policy priorities for which they are being designed in the context of CBE, and how can the impact they are having on society be assessed. Thence, project impact evaluation is carried out in the short- and medium-term, and categorized under Industrial Competitiveness, Sustainable Development, and Community and Public Policies. For this purpose, secondary information was gathered from the European projects database Cordis, as well as primary information through a questionnaire survey of project coordinators. The empirical data collected suggest that European Framework Programmes have been fulfilling their purpose, as they are increasingly societal challenges-driven and market-oriented. This is evidenced by market-related topics addressed in the projects analysed and by the active participation of companies that outnumber academic institutions. As far as impact is concerned, scientific publications continue to be the main result of this type of project in the short-term, whereas in the medium-term social and economic benefits were also identified. Notably, the creation of scientific jobs in the industry, of industrial joint ventures, and the generation of documents to support the improvement of public and EU policies on biobased products.

Keywords: Circular Bioeconomy; EU-funded projects; public policies; project benefits; research and innovation impact

1. Introduction

The Circular Bioeconomy (CBE) paradigm has emerged as a promising tool to modernize the economy in terms of resource use. To this end, it relies on the bioeconomy (BE), which according to the European Commission (EC) covers the production of renewable biological resources and the conversion of these resources and waste streams into value-added products (European Commission 2018a), to which the principles of circularity of flows are added. The transition from a linear economy, dependent on fossil resources, to a circular one, which reduces this dependence and preserves natural capital, can mitigate current economic, environmental, and social problems (Mohan et al. 2019).

The European Union (EU) has shown its particular interest in this economic concept, namely as a tool to fulfil its ambition of becoming the first climate-neutral continent, relying on a clean and circular economy (CE) as 'green thread' for all future activities in Europe (European Commission 2019). Such policy priorities have successfully fostered research and innovation (R&I) funding in the EU, whose budget dedicated to the BE has substantially increased in recent Framework Programmes (FPs) (Directorate-General for Research and Innovation 2014). Furthermore, private sector and public–private partnerships have been sponsored by the EU as a policy tool that fosters the translation of scientific advances into marketable products (Council Regulation (EU) 2021/2085, 2021). While the funding of academic–industry partnerships is known to affect the innovative character of firms, this is essentially illustrated by the increase in the number of scientific publications and patents (Chai and Shih 2016). The same trend is followed in relation to CBE, in that there has been a significant volume of both publications and related patents, but without this translating into successful commercial applications to the same extent (Brandão, Gonçalves and Santos 2021).

Given the high European investment in scientific research-based entrepreneurship, it is increasingly important to measure the societal, rather than just the scientific impact of CBE, and the consequent return on investment of EU-funded projects in this field. Such importance was also highlighted by the EC when reviewing the 2012 Bioeconomy Strategy and its Action Plan, by referring to the need for better monitoring and evaluation frameworks to assess progress (European Commission 2017a). In the same vein, in 2018, the EC developed a monitoring framework, based on a set of key indicators, to assess how the CE is progressing in the EU, including the impacts on competitiveness, innovation, and employment (European Commission 2018b). Moreover, several major frameworks have been developed for assessing trends and progress of policy goals in the area of sustainability and development. Examples are the 102 EU Sustainable Development Goals (SDGs) indicators (European Commission 2021a), the 231 UN SDGs indicators (United Nations Statistics Division 2017), or the 1400 World Bank World Development Indicators (The World Bank 2022). When it comes to CBE, an increasing number of indicators (economic, social, or environmental) mainly focused on quantifying socio-economic aspects (D'Adamo, Falcone and Morone 2020; D'Adamo et al. 2020a,b) have also been developed as a key measurement tool to analyse and measure the performance of sustainable transitions in the EU. These indicators, and depending on those being considered, have then been used to assess the performance of CBE per se (D'Adamo, Falcone and Morone 2020) or in specific sectors (D'Adamo et al. 2020a), both at the EU (Kardung and Drabik 2021) and national levels, including regional analysis (D'Adamo et al. 2020b). More recently, there has also been an academic effort to develop decision support tools that, together with indicators, are intended to facilitate decision-making by policy-makers towards CBE (Kokkinos, Karayannis and Moustakas 2020). Despite all the literature advances mentioned above, especially in the quantitative measurement of various CBE developmental characteristics, the societal impact of EU-funded CBE projects remains a critical topic that has not received enough attention. With EU spending a significant amount of public money on R&D projects addressing CBE, their impact must be critically evaluated. Moreover, such an evaluation exercise makes it possible to understand to what extent European funds are being efficiently used and whether public policies are being complied with.

This article contributes to address this gap. In our work, we take a sample of EU-funded projects from the CORDIS database (https://cordis.europa.eu) within the scope of the CBE and develop a framework to assess the impacts they are having on society. The method involved qualitative analysis based on case studies enriched by a brief questionnaire filled by project coordinators. The main focus was to assess, in the short- and medium-term, whether EU-funded research is reaching the market in the form of marketable products and/or services, as provided for in the FP that funded them. Prior to this, a characterization of our sample was also carried out in order to understand the dynamics and evolution of European FPs within the CBE scope.

Our article contributes to the current literature in that our case study evaluation complements previous societal impact quantitative assessments of mobilizing sustainable investment in Europe, by providing an additional qualitative perspective. Furthermore, to the best of our knowledge, this is the first study to characterize and monitor EU-funded projects under the CBE scope, in the short- and medium-term, with the primarily aim of tracking the proximity of their results to the market. Ultimately, it may provide insights into the effectiveness of current policy actions to drive the transition to an innovative and sustainable economy.

2. Background

2.1 The CBE paradigm

The biosphere is in an extremely fragile situation. With population growth also comes the need to increase the supply scale of goods and services (United Nations 2019), which from an environmental point of view has placed humanity in a situation of accumulated debt (Global Footprint Network 2022). This phenomenon, which has been described as 'living on credit', has been maintained since the early 1970s, the last time society consumed within the limits of the regenerative capacity of ecosystems. Since then, the event known as Earth Overshoot Day, which marks the day from which in a given year we start consuming the natural resources of the following years, appears earlier and earlier in the calendar (Earth Overshoot Day 2021). Considering the traditional linear 'produce-use-dispose' economic methods, its unsustainability is not only in the excessive extraction of natural resources upstream, but also in the excessive production of waste and residues downstream, both consequences being closely linked to global issues such as climate change (United Nations Environment Programme 2021). The concept proposed to fight these excesses using sustainable bio-based solutions is the CBE. In particular, CBE innovates our production and consumption system by developing a second generation of technologies that use biowaste as a resource for various industrial sectors (Brandão, Gonçalves and Santos 2021). This can be illustrated by waste biorefineries, considered the pillars of CBE, which allow the conversion of what is the current biomass management challenge into high value-added solutions (Mohan et al. 2019; Stegmann et al. 2020). Such potential has been actively documented in a growing number of scientific publications (Brandão, Gonçalves and Santos 2021; Yaremova et al. 2021). The same applies to the definition of the paradigm itself, as an increasing number of publications have sought to clarify the underlying combination of its basic concepts of BE and CE (Carus and Dammer 2018; Mohan et al. 2019; Stegmann et al. 2020; D'Amato and Korhonen 2021). In face of the above, the CBE can be defined as an entrepreneurial economic paradigm that integrates the synergies of the BE and the CE to provide alternative business models for developing sustainable products and processes by ensuring the preservation of natural capital. From the BE, it inherits the principle of replacing fossil carbon by renewable carbon from biomass (agricultural, forestry, and marine), with special focus on by-products and waste. From the CE, it inherits the principle of using such biomass (i.e. waste and by-products) in closed cycles, maintaining its value in the economy for as long as possible. From both, CBE inherits the relevant perspective of the industrial symbiosis of production processes, where an industry by-product is another industry input (D'Adamo et al. 2020a).

There is a wide range of CBE drivers in European regions, both in urban (Taffuri et al. 2021) and rural areas (Brandão and Santos 2022), which puts the EU at the world forefront in the sustainable use of natural resources (European Commission 2018a). Such drivers can be found internally, in the regional resources and assets that could form part of the regional CBE (locally available feedstocks from agriculture, agro-food sector, forestry, maritime and fishing activities, waste watercourses, municipal biowaste, etc.); or externally, for example through policies aimed at increasing competitiveness and promoting economic development or reducing a territory's dependence on imported raw materials and fuels (Naudet and Marrazzo 2021).

Realizing the enormous potential of the CBE to overcome current challenges and develop the society of the future requires the ability to transform the opportunities provided by this type of innovation into new products and services available on the market. To this end, the CBE is faced with the need to integrate key areas, such as education, research and development (R&D), innovation, digitalization, biorefineries, infrastructure development, and funding/financing, as building blocks of a transition to a more sustainable and circular world (Mohan et al. 2019; D'Amato and Korhonen 2021; Yaremova et al. 2021).

2.2 European priorities and reference policy documents relevant to the CBE

In Europe, science and technology public policies at the transnational level are developed and implemented by the EC. Thus, the major impulse to CBE is provided by proposing policies and laws that will be adopted by the European Parliament (representing EU's citizens) and the Council of the EU (representing governments of the individual Member States).

The updated 2018 BE Strategy (originally adopted in 2012) is the main driving document for the European BE deployment, stating that 'to be successful, [BE] needs to have sustainability and circularity at its heart' (European Commission 2018a). Likewise, the Green Deal, launched in 2019 as Europe's new growth strategy, highlights the circular use of biomass, or even CBE, as a way to eliminate pollution and achieve a green industry (European Commission 2019). Other European policy priorities such as the Circular Economy Action Plan (European Commission 2015), Accelerating Clean Energy Innovation (European Commission 2016), or the renewed Industrial Policy Strategy (European Commission 2017b), also highlight the importance of a sustainable and CBE to achieve their goals. In fact, although there is no specific EU legislation on CBE, the EC strives to ensure a coherent approach through different programmes and instruments that complement the existing policies and are relevant to the field, such as some sectorial and horizontal EU policy initiatives (not mentioned above) listed in the Table 1. Furthermore, all these European priorities mentioned so far as relevant to CBE are aligned with global policy documents adopted in 2015, such as The Paris Climate Agreement and the 2030 Agenda on Sustainable Development and its 17 SDGs, helping to solidify international cooperation to mitigate climate change and achieve a sustainable future for humanity.

Together, all these policy initiatives drive the efficient use of resources mobilized in the economy, generating gains in material and environmental productivity and creating jobs. In addition, this will enable an agenda to achieve a cleaner and more competitive Europe in collaboration with businesses, consumers, and civil society.

2.3 European research, innovation, and funding programmes supporting public policies on CBE

For over 40 years, the EU has been investing resources to put Europe at the forefront of key technologies through the creation of a wide range of instruments and funding mechanisms that can directly or indirectly support the deployment of CBE activities as documented below.

The FPs have become the main instrument for implementing the EU's common R&I policy. The first FP was launched in 1984 and Europe counts a total of nine so far, with the new and most recent one launched in February 2021 for a total of 7 years. In each funding period, FPs have evolved in terms of ambition, both in scale and scope (Figure 1).

In the 1980s, there was only a small programme to support basic research. In the 1990s, the budget was gradually increased, and in 2007 it exceeded 55 billion euros with FP7, which was more focused on technological research. However, Horizon 2020 (H2020) was the major milestone in the history of FP's with its EUR 80 billion budget available over 7 years (2014–20). It included R&I funding not only for multinational collaborative projects but also for individual researchers, with a special funding instrument for SMEs. Calls for proposals related to the BE were published under Societal Challenge 2—'Food security, sustainable agriculture and forestry, marine, maritime and inland water research, and the bioeconomy' (Naudet and Marrazzo 2021). From 2021 to 2027, Horizon Europe (HE), the ninth FP, is the most ambitious programme ever, with a budget nearly of EUR 100 billion. Regarding CBE, the pillar 'Global Challenges and European Industrial Competitiveness' (one of the three pillars around which it was built) includes a cluster on BE, Food, Natural Resources, Agriculture, and Environment (Naudet and Marrazzo 2021).

In addition to the research FPs, Europe has established funding mechanisms that are specifically related to the concept of CBE. Aimed at investing EUR 300 million in growth-stage companies with high potential for innovation, favourable returns, and sustainable impact, the European Circular Bioeconomy Fund (ECBF) (ECBF) is the first venture capital fund exclusively dedicated to the CBE resulting from the cooperation between European Investment Bank, the EC, and the ECBF Management GmbH. Another example is the European Biobased Circular Joint Undertaking (CBE JU 2021), a EUR 2 billion partnership between the EU and the Bio-based Industries Consortium, which was set up to fund projects promoting competitive circular bio-based industries in Europe. It is operating under the rules of HE and is building on the success of its predecessor, the Bio-based Industries Joint Undertaking (BBI JU). Furthermore, the BlueInvest, enabled by the European Maritime, Fisheries, and Aquaculture Fund, will mobilize an additional EUR 500 million of EU funds for early-stage business, SMEs, and scale-ups investing in the blue economy. The main aim of this initiative is to foster innovation and investment in technologies for the sustainable use of ocean resources, notably new ways to bring bio-based products and services to the market (Directorate-General for Maritime Affairs and Fisheries 2022).

Not so closely related to CBE, there are still the European Structural and Investment Funds (ESIF), whose objectives include the investment in a sustainable European economy (ESIF); the LIFE European Programme for co-funding projects that demonstrate or pilot solutions that tackle environmental (including CE, nature, and biodiversity) or climate issues (LIFE Programme); and the Recovery Plan for Europe, a new temporary instrument providing financial support to all member states to recover from the adverse effects of the COVID-19 pandemic, with the particularity that 30% of the total expenditure targets climate-related projects (Recovery Plan for Europe).

Characterizing and documenting how projects funded at the European level are being carried out and which value (social, environmental, and economic) they are generated is important as it provides insights into the feasibility of the strategies defined in the FPs and the funding instruments, which downstream determine the direction, structure, and requirements of the R&I activities themselves, including those supporting CBE.

2.4 Assessment of the impact of research projects on society

Investment by governments in scientific research has always been a priority for decades, namely when military or

Table 1. Some sectorial and horizontal EU policy initiatives relevant to CBE

Policy initiative	Brief description	Reference
Waste Framework Directive	Revised in 2018, it includes targets for the separation and collection of various waste fractions, in particular the mandatory separate collection of biowaste by the end of 2023.	(Directive 2008/98/EC 2008)
EU Forest Strategy	Adopted in 2013, it promoted, in particular, the sustainable and efficient mobilization and use of forest biomass resources, the development of the bioeconomy, access to national and international markets, and the strengthening of R&I.	(European Commission 2013)
Blue Growth—the EU's integrated Maritime Strategy	This is the long-term strategy to support sustainable growth in the marine and maritime sectors.	(European Commission 2014)
Renewable Energy Directive	Revised in 2018, it includes strengthened sustainability criteria, in particular for energy from biomass. It also promotes the shift towards advanced biofuels based on waste and non-reusable and non-recyclable waste.	(Directive (EU) 2018/2001 2018)
Future of the Common Agricultural Policy	Presented in 2018, these are legislative proposals on the common agricultural policy for the period 2021–7. The proposals are built around nine key objectives, including 'action against climate change' and 'jobs and growth in rural areas', to which the bioeconomy has been specifically identified as a key positive contribution.	(European Commission 2021b)
Farm to fork Strategy	This strategy is at the heart of the EU Green Deal with the aim of making food systems fair, healthy and environmentally friendly. It refers in particular to the bioeconomy as a way to provide new business opportunities, for example linked to the use of food waste.	(European Commission 2020a)
FOOD2030 Initiative	It is the EU R&I policy framework to boost sustainable, healthy and inclusive food systems and thus achieve co-benefits for the four priorities of nutrition, climate, circularity, innovation and communities.	(Directorate-General for Research and Innovation 2020)
EU Biodiversity strategy for 2030	Adopted in 2020, it calls for reversing biodiversity loss and restoring nature. In particular, the strategy specifically refers to sustainable bioenergy, with the aim of reducing the use of whole trees and food and feed crops for energy production.	(European Commission 2020b)

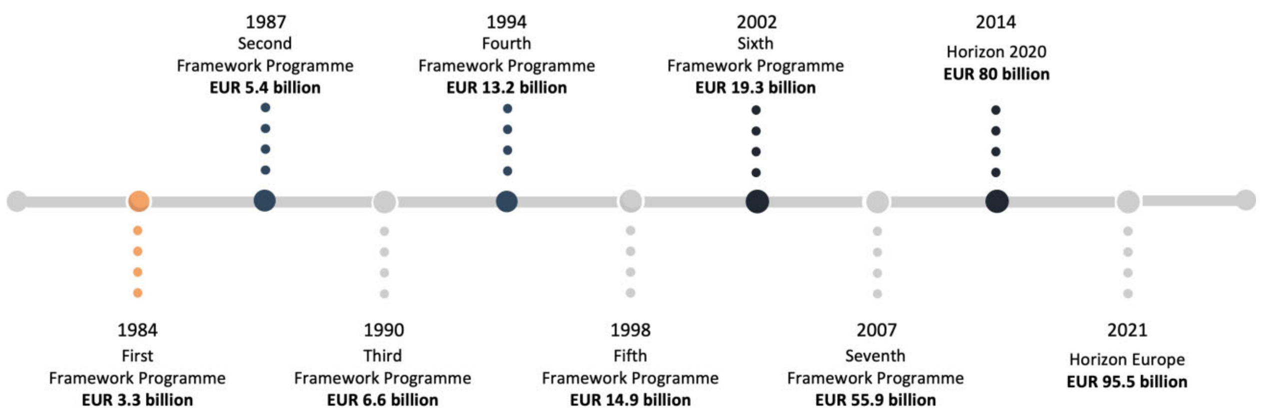

Figure 1. Framework Programmes developed by the European Union over time and the respective investment allocated to each one (adapted from Directorate-General for Research and Innovation 2014).

commercial potential is apparent. This practice has been greatly expanded since the end of the Second World War, which has greatly contributed to the growth of scientific research. However, such expansion has exceeded the public resources available to fund it, which has increasingly challenged funding agencies and politicians to find solutions for the effective distribution of limited resources among researchers and research projects (Bornmann 2012). Thus, since the early 1980s, evaluation exercises have become a legal requirement of the European Research and Technological Development programmes (Williams and Rank 1998).

The traditional model for assessing the quality of research relies basically on the production of scientific publications, but over time, this approach has been deemed insufficient by the research community and by the policy-makers themselves. It is now increasingly recognized that in order to justify their

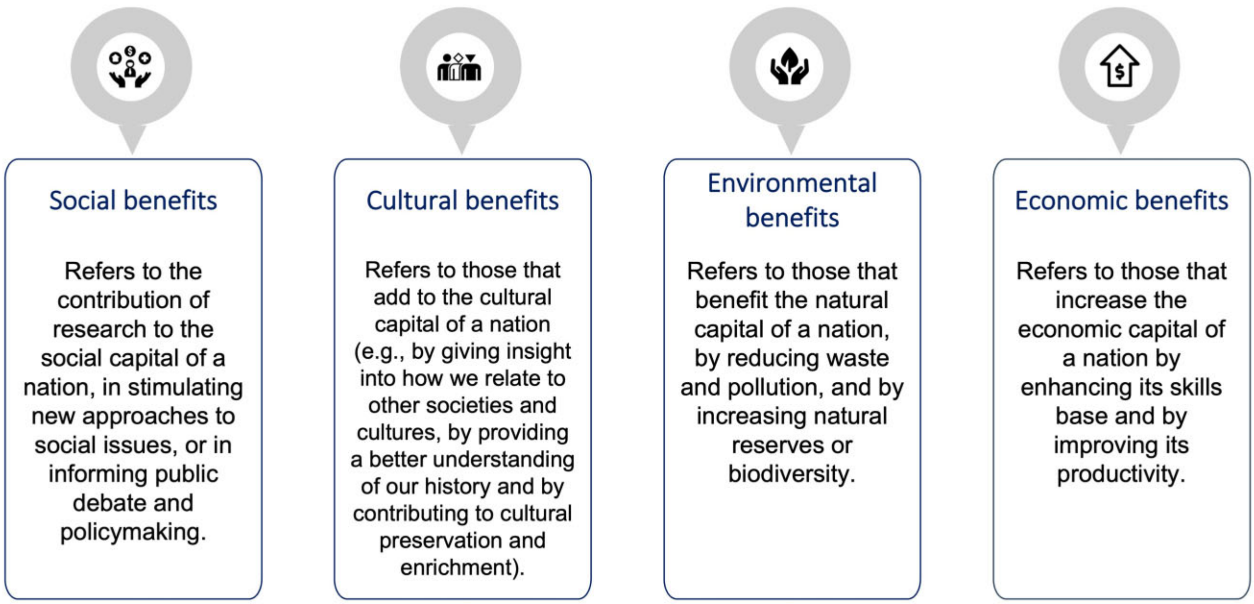

Figure 2. Defining societal impact of research in its different dimensions (adapted from Bornmann 2012).

existence, publicly funded research projects must be able to generate benefits for the society at large. But, in fact, the first challenge is to define what is meant by 'benefits'. The literature is rich in benefit concepts (Ward and Daniel 2005; Twproject 2022). However, they all try to answer the following questions: (1) How does a R&I project affect an individual or a whole society? and (2) Does it have a different impact on the public (e.g. current user or end-user), academia (e.g. scientists, engineers, leaders), or industry (e.g. managers, workers)? According to our understanding, benefits can be defined as the assessable change originating from a R&I result and perceived as an advantage by stakeholders. Depending on whether such change can be measured accurately or not (although its effects can be seen), the benefits can be tangible (e.g. increase in the use of biodegradable plastics) or intangible (e.g. increasing environmental awareness), respectively. Existing benefit models include e.g. environmental, technological, economic, social, strategic, political, and cultural impacts (Becker 2001; Joly et al. 2015). In the context of this study, we adopted as a basis a simplified model based on Lutz Bornmann's proposal to define the societal impact of research (Figure 2).

When applied to R&I activities, the term 'impact' refers to (observable) benefits beyond academia, namely individuals, organizations, communities, industries, or economies (Pan and Pee 2020). In fact, the terms 'benefit' and 'impact' cannot be dissociated. For this reason, we will use them herein interchangeably.

Unlike the measurement of scientific impact, that is mainly focused on the volume and quality of scientific publications, societal impact is a complex phenomenon that is difficult to quantify. Moreover, data necessary for the evaluation of the societal benefits of science is often not available in sufficient volume or suitable form (European Commission 2010).

Many of these benefits, especially in what concerns basic research, are quite difficult to assess. First, because there is no direct link between the scientific quality of a research project output (e.g. number of citations of a paper) and the resulting societal benefit. Second, because the time-scale over which the potential impact can be evident can be very wide and depends on the subject matter area (e.g. chemical engineering vs. mathematics). As Bornmann (2012) points out: 'It might take years, or even decades, until a particular body of knowledge yields new products or services that affect society'. Bornmann illustrates this statement with an interesting comparison: a high-quality original research work into apoptosis with no measurable impact on health vs. research into the cost effectiveness of different incontinence pads, which has had an immediate and important societal impact despite its low scientific 'value' (Bornmann 2012).

There is no single framework that can be applied to tackle holistically the challenging issue of measuring societal change. By surveying the literature on research assessment in a broader sense, many different methodological approaches can be found. As part of the Research Excellence Framework in the UK, higher education institutions are required to showcase the impact of research beyond academia via impact case studies (Higher Education Funding Council for England 2009). The Excellence in Research for Australia uses bibliometrics, and other quantitative indicators to map R&D output (Australian Research Council 2022). In the USA, the STAR METRICS consortium (a partnership between US federal science agencies and research institutions) used data mining to account for federal R&D spending (National Institutes of Health 2010). In Europe, the SIAMPI consortium developed a flexible approach, based on 'productive interactions', to help institutions learn and improve their performance against their own goals, using mixed qualitative/quantitative tools. It includes interviews and focus groups, quantitative data collection, and annual reports to assess direct (personal), indirect (media), and financial (or in-kind support) productive interactions, respectively (SIAMPI 2012).

In order to define an evaluation framework of EU-funded projects on CBE, we used as a starting point the assessment framework proposed by Tuominen et al. (2011) for EC FP projects on 'transports', which allowed us to clarify and define key evaluation concepts such as output, outcome, impact, time-scales, and types of evaluation (Figure 3).

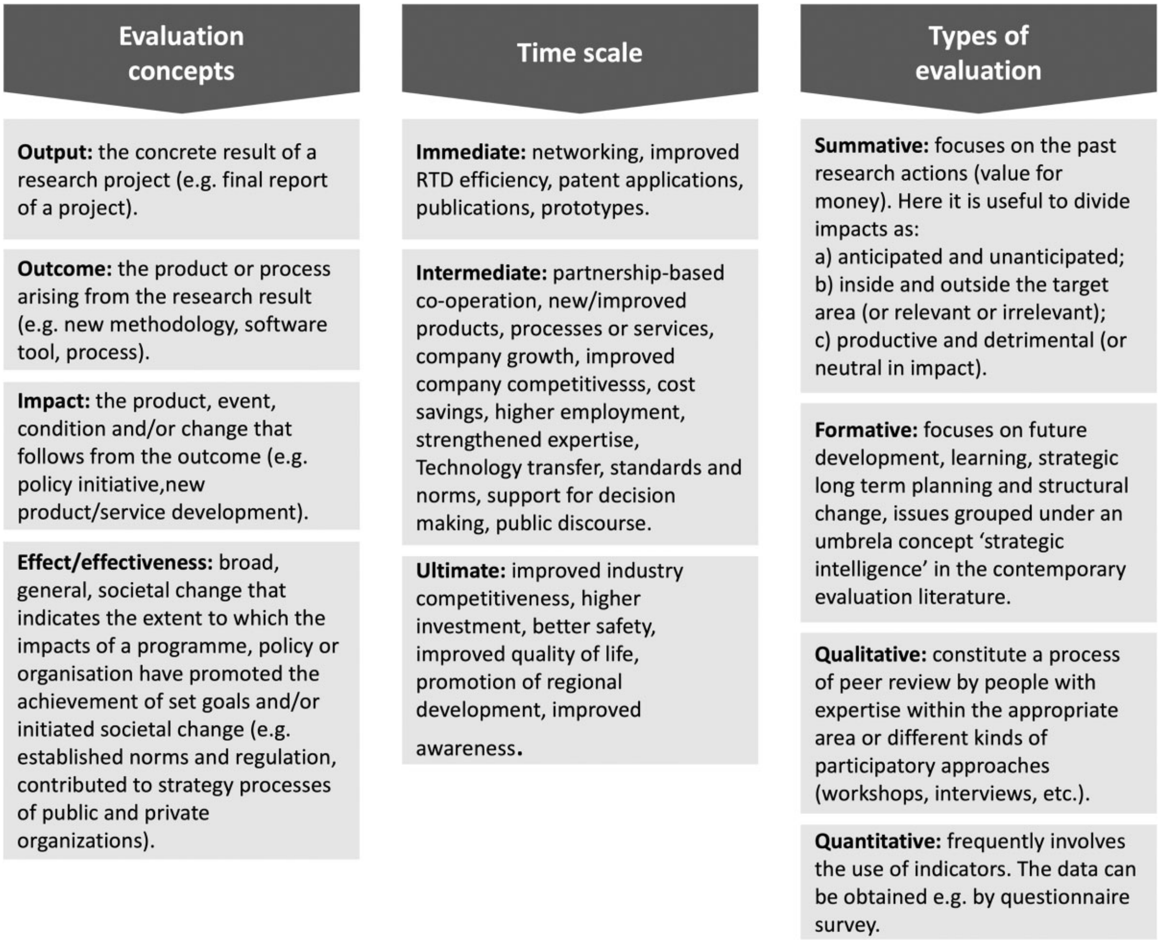

Figure 3. Main criteria to be considered when assessing the societal impact of research projects (adapted from Tuominen et al. 2011).

Based on these principles, a practice-oriented framework for societal impact evaluation of CBE R&I projects is proposed in Figure 4 and its rationale explained next.

Essentially, in the short-term, outputs and outcomes are evaluated, although, as mentioned before, immediate impact and effectiveness can also be verified in some cases. This translates into a summative analysis, which may be either quantitative or qualitative, based on information from secondary sources such as published documents. With regard to the medium and/or long terms, the dimensions considered are essentially impacts and effects/effectiveness. In this case, the type of evaluation is formative, using mainly primary sources of information, such as case studies, interviews, questionnaires, etc., and again it can be either qualitative or quantitative.

The implementation of the developed framework is detailed in the next section.

3. Methodology

The methodology used in this study consisted of two main phases (Figure 5). Phase I included the following two steps. First, the EU-funded projects in the field of CBE were identified from the CORDIS website, using 'circular bioeconomy' as a keyword in the 'Projects and Results' section, between 29 April and 3 May 2021. Second, the projects gathered underwent a detailed characterization analysis based on a set of information acquired through each project's page on the CORDIS website. CORDIS was the EC's first permanent website in 1994. Its content dates back to the 1990s and it provided web services for FP4, FP5, FP6, FP7, and other EC R&I activities.

Phase II consisted in putting into practice the framework developed for the societal impact assessment of European projects in the field of CBE. The framework takes a two-dimensional approach to project impact evaluation. First, it evaluates the projects' achievements in the short-term (up to 1 year after project closure), namely outputs and outcomes, based on what is published, namely, for example in the form of scientific publications, project deliverables, datasets, software, etc. The evaluation was therefore summative and quantitative. Second, it evaluates the projects' impacts and effects in the medium-term (1–6 years after project closure) in the form of case studies. The information was provided by the coordinators of projects completed at least 1 year ago by replying to an email questionnaire. It was therefore a formative and qualitative evaluation. Conceptually, both outcomes and impacts and/or effects have been categorized according to three themes previously identified by Tuominen et al. (2011) as being relevant to European transport research and which we consider relevant to CBE, given the information provided in the previous sections of this article. These are: Strengthening industrial competitiveness (IndCo); Contributing to sustainable development (SuD); and Improving community and public policies (CPP). Also, each of them fits different

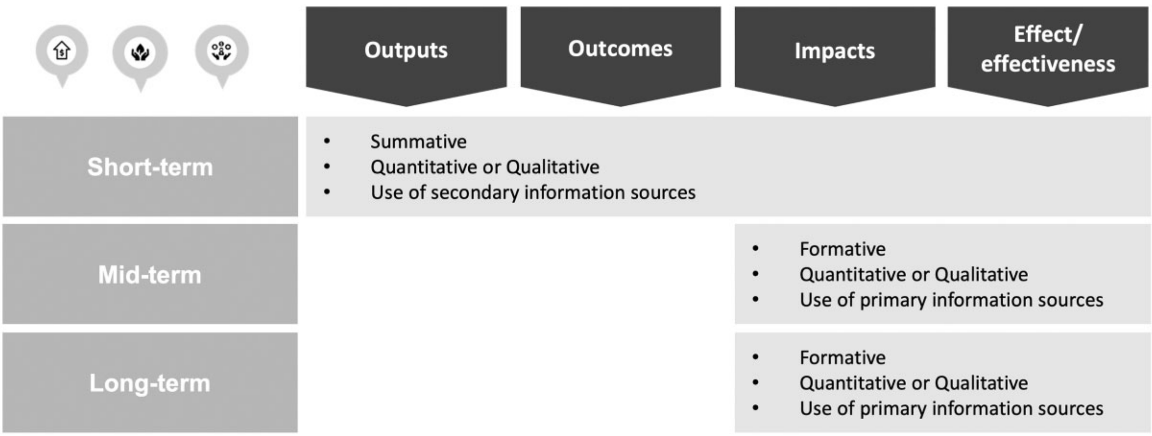

Figure 4. General framework for societal impact evaluation on CBE research based on the literature consulted.

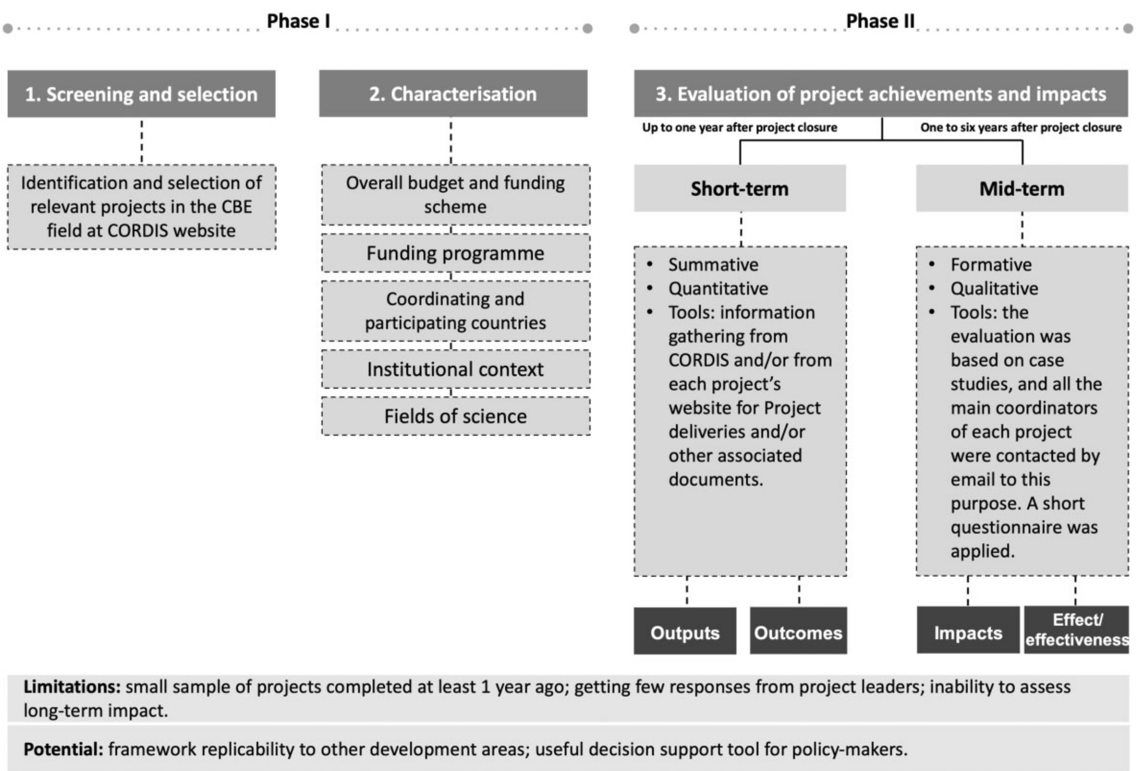

Figure 5. General methodological procedure adopted in the present study.

benefits, reinforcing its categorization. Specifically, IndCo entails social benefits, SuD entails environmental benefits, and CPP entails social benefits.

The long-term impact (over 6 years after project closure) has not been assessed as not enough time has lapsed since the end of relevant projects.

4. Results and discussion

4.1 Screening and characterization

Our research yielded 38 EC projects on CBE. The results are presented and discussed below. About half of the total number of projects identified are still ongoing. Of the remaining projects, most are already completed. Of these, 12 have been completed at least 1 year ago and were further analysed to assess their societal impact.

4.1.1 Funding programme

All projects are or have been funded by either FP7 or H2020. Specifically, the nine oldest projects have starting years between 2012 and 2014 and were funded by the FP7 programme. The remaining 29 projects, started from 2016 onwards, were funded by the H2020 programme. In fact, there are several factors that lead to a higher concentration of projects on CBE being funded by H2020. First, because the FP7 funding period (2007–13) ends 1 year after the emergence of the first European policies to encourage the CBE, namely the Strategy for the BE adopted in 2012. On the other hand, H2020, which ran from 2014 to 2020, not only followed on from that strategy, but already included specific initiatives, such as the call 'Industry 2020 in the circular economy' (under the work programme 2016–7), which supported European policies to encourage CE. Second, H2020 has been speeded up and simplified, cutting red tape. This can also be expected to have made it more attractive to potential applicants. Third, it was more accessible to institutes and universities, businesses, and above all more open to small business and international partners. Last but not least, the H2020 programme was bigger than FP7, which means more funding was available over its seven years duration.

4.1.2 Funding schemes and overall project budget

The overall budget assigned per project and the funding scheme distribution are depicted in Figures 6 and 7, respectively. The average budget for each project is around EUR 8 million. Two of these projects, namely BIOSKOH and AgriChemWhey, both of which are still running, stand out with a budget well above average, reaching EUR 30 million. Both projects are funded by the BBI-IA-FLAG (Biobased Industries—Innovation Action—Flagship) funding scheme, which supports closer-to-the-market activities. The lowest budget verified was in the order of EUR 100,000 and concerns projects mainly funded by Marie Sklodowska-Curie Individual Fellowships (MSCA-IF) and Coordination and Support actions (CSA) schemes. In general, the funding schemes are well distributed among typologies, with only a slight highlight for Innovation Actions (IA) (26%), followed by Research and Innovation Actions (RIA) (21%), CSA (16%), and MSCA (13%) in the H2020 programme. Concerning the FP7 programme, SMEs are targeted by both funding schemes present in the sample, the Collaborative Project targeting SMEs (CP-TP), and the BSG-SME-AG (Research for SME associations/groups).

The results show that from the point of view of project typology, CBE appears to be taking full advantage of the opportunities that the EC R&I programmes provide. Namely, regarding the different types of action, the sample collected is diversified with the presence of various funding schemes. In the case of BIOSKOH and AgriChemWhey projects, being funded by the BBI-IA-FLAG scheme, they are expected to present higher budgets. This is because from the point of view of the objective of the funding scheme itself, it aims to support the first application/deployment in the market of an innovation that has already been demonstrated. The BIOSKOH project aims to pave the way towards a Second Generation (2G) European CBE by developing the largest (110 kton) 2G biorefinery in Slovakia. Whereas AgriChemWhey will be the first major industrial-scale venture of a first-of-a-kind biorefinery that envisages to valorize more than 25,000 tonnes per year of excess whey protein and derivatives into bio-based value-added products. These are, therefore, large projects with very high TRLs that are already very close to the market. In essence, they represent innovative projects, with a very high degree of investment involved and a revolutionary concept. As for projects receiving lower budgets, between EUR 100,000 and 200,000, these are associated with CSA and MSCA funding schemes. While the CSA aims accompanying measures (standardization, policy dialogues, etc.) not covering research, the MSCA essentially intends to facilitate mobility of researchers for training and career development. This explains the lower budget related to these activities. Finally, in the

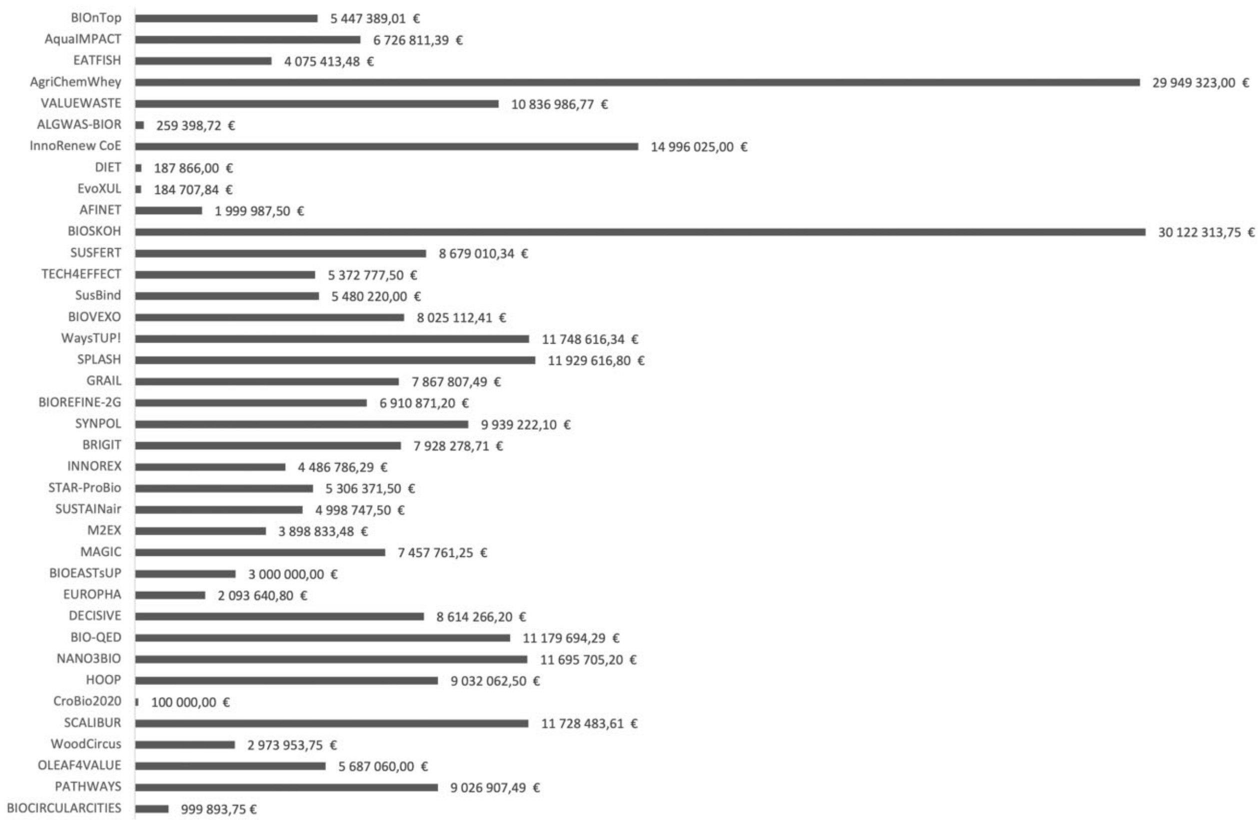

Figure 6. Overall budget per project.

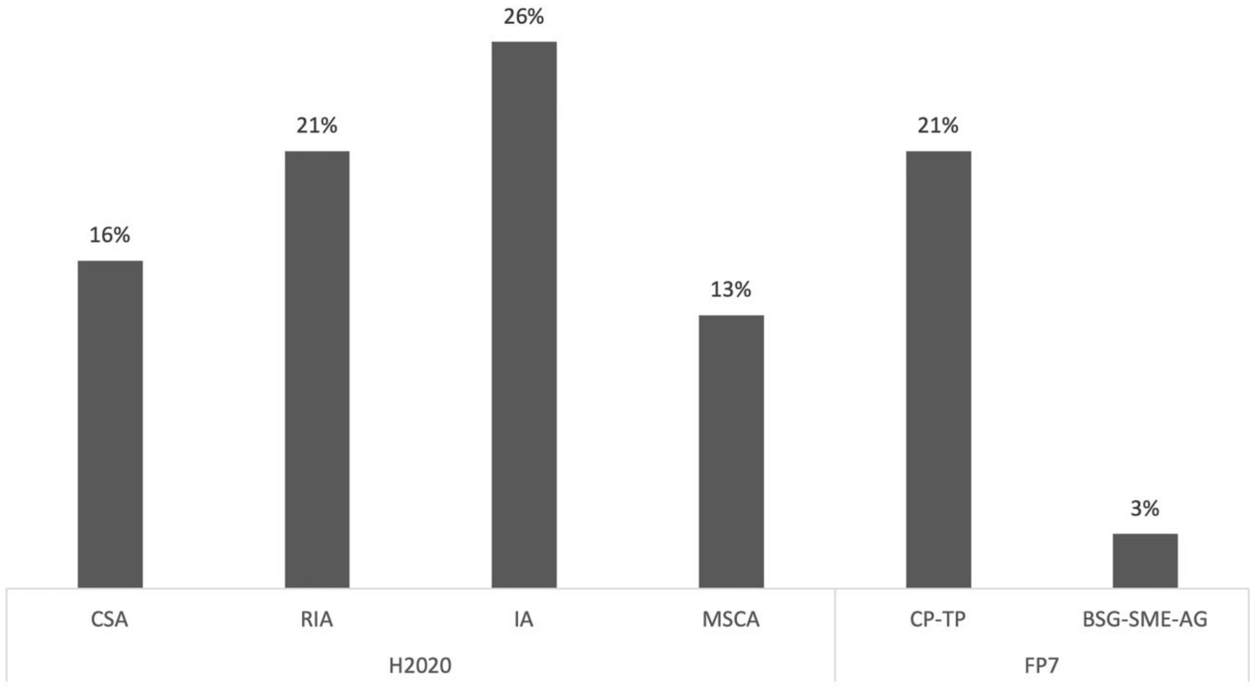

Figure 7. Predominance of the different funding schemes.

average budget figures, we find projects funded under the RIA funding scheme. This type of action focus on collaborative research projects tackling clearly defined challenges, which can lead to the development of new knowledge or new technology.

4.1.3 Coordinating and participating countries

The countries coordinating projects are depicted in Figure 8. It can be seen that Spain leads by far (39%), meanwhile the rest of the projects are almost evenly distributed among other European countries. The number of participations by country is depicted in Figure 9. In total, 37 countries are or have been participating in projects related to the CBE thematic area. As one would expect, most of these countries are European, with participation from countries outside of Europe, such as Chile, India, USA, and South Africa. Once again, Spain takes the lead also in the number of project participations (82). Germany comes next with 54 participations, followed by Belgium and Italy, both with 45 participations. The Netherlands, with 31 participations, and France, with 30, also stand out.

Although we did not get feedback from the contact persons of the Spanish projects, the results analysis allowed for some inferences to be made about what could be at the origin of the strong presence of Spain as project coordinator and/or participating in CBE-related projects. First, the encouraging dynamics, both at national and regional levels, that the Spanish authorities have developed. Spain has its own strategies for both BE and CE, launched in 2016 and 2018 respectively (Government of Spain 2018; Lainez et al. 2018). Besides, the Spanish Federation of Municipalities and Provinces (FEMP) has developed a 'Circular Economy Local Strategy Model', from which each municipality can develop its own sustainability programme, according to its needs and capacities (FEMP 2019). Second, the prestige of the coordinating entities. It should be noted that Spain has specialized entities with a very strong focus on CE, sustainability, and the development of sustainable products. A prime example, and coordinator of two of the Spanish projects of our sample, is AIMPLAS—Asociacion de Investigacion de Materiales Plasticos y Conexas. AIMPLAS is a technology centre, certified with the EFQM 500+ European seal of excellence. It has a vast experience in the plastics sector, focusing its activity on R&D + i activities to answer the challenges posed by society in relation to plastics in order to improve people's quality of life and ensure environmental sustainability. Third, the experience of the coordinating entities. For instance, the Agencia Estatal Consejo Superior de Investigaciones Cientificas (CSIC), which is also the coordinator of two of the Spanish projects in our sample, is the first Spanish organization by number of projects and economic return in the FP of the EU. At the European level, among public research organizations, the position is also remarkable, as it ranks third in terms of number of projects awarded (CSIC 2022). These figures and facts give an idea of the volume and importance of this institution at national and international level, which is an asset in the evaluation of each new submission and consequent eventual project participation.

In short, strategies for the CE, at national and local level, with the involvement of several partners from different sectors, as well as the existence of prestigious entities in areas such as sustainability and/or with extensive experience in presenting projects, may be setting Spain at the forefront of CBE when it comes to European FP projects.

4.1.4 Institutional context

The main activity type of participating entities is depicted in Figure 10. It can be observed that the private for-profit sector, mostly companies, is the one that participates the most (220 participations). Higher or secondary education establishments, as well as research organizations come next with 102

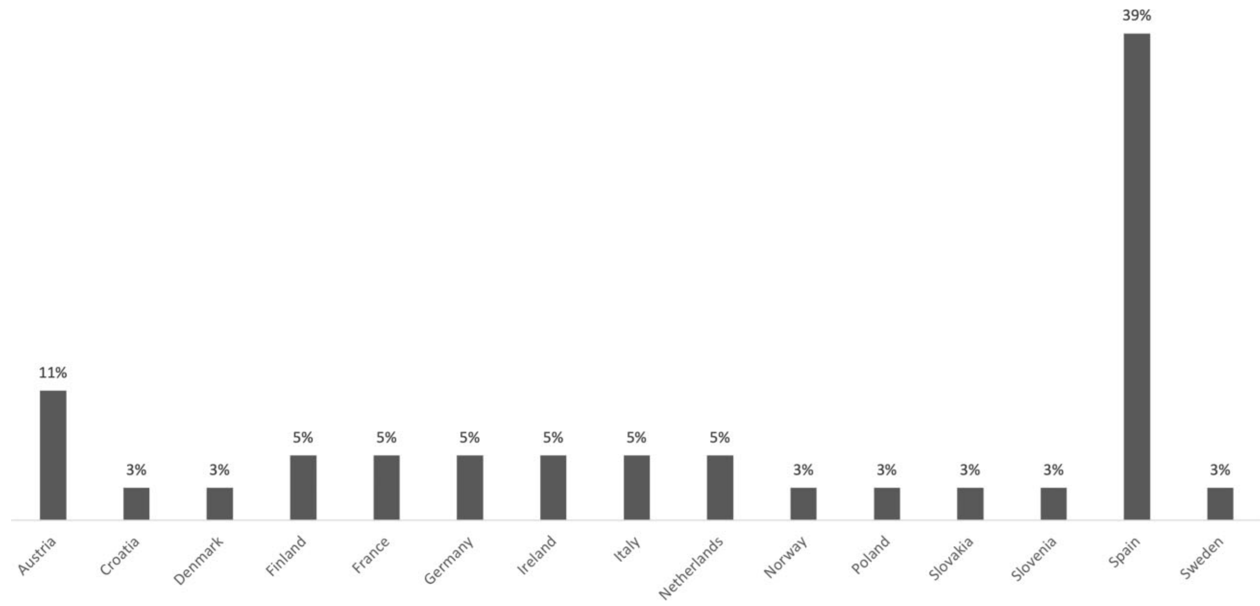

Figure 8. Distribution of projects by coordinating country.

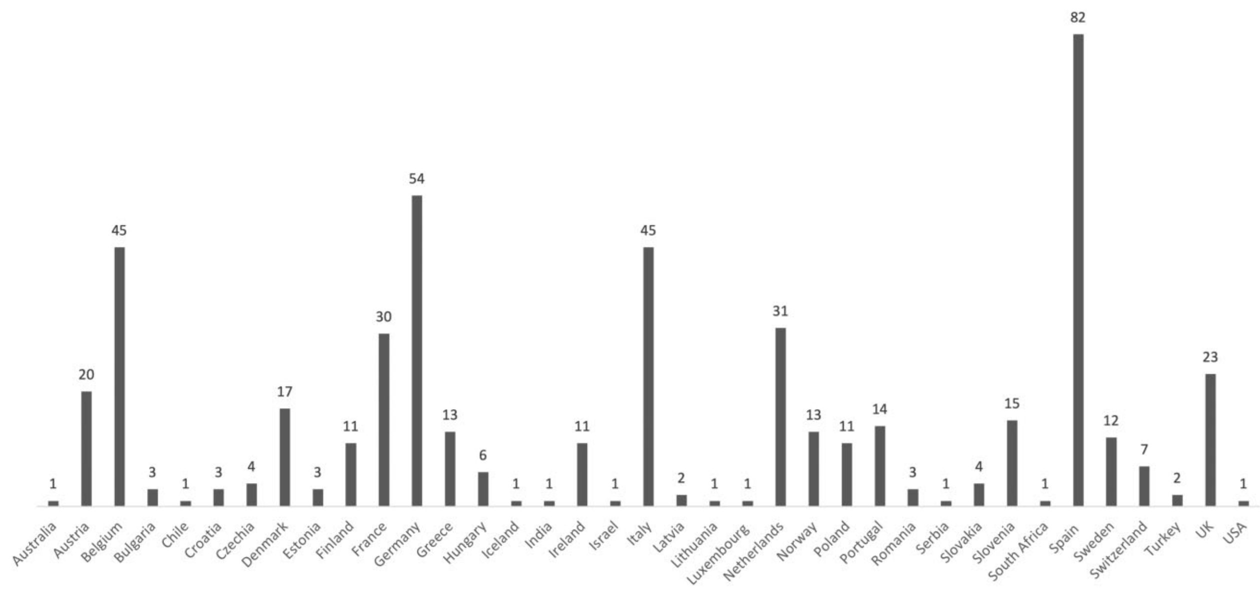

Figure 9. Number of participations per country.

and 90 participations, respectively. Public bodies have the lowest number of participations.

The results show that industry beats universities or research organizations by far when it comes to participation in European projects in the field of CBE. Again, the funder scheme may also be having some influence on this result. The prominence of the private sector can be explained by the fact that most calls are targeted at companies as a result of priorities set by the industrial sector itself. In addition, as a result of the simplification process, H2020 was easier to access for all type of entities, and especially more open to small businesses. This is not surprising taking into account that, for instance, H2020 was very focused on getting good ideas to market. Actually, industrial leadership, and investment in turnkey technologies and businesses in particular, was one of the three broad headings under which the R&I strategy of H2020 was grouped. However, getting closer to the market does not mean basic research is out in the cold. Universities and research organizations still have a very important participation. By coupling science and innovation, it covers a much wider range, from research to retail, delivering innovation from the lab to the market much faster, and making easier for the public and private sectors to work together in delivering new solutions for the challenges society faces.

4.1.5 Fields of science

The fields of science addressed in each project are depicted in Figure 11. By counting the number of times that each term is repeated in the fields of science classification of the analysed projects, it was found that, expectably, 'bioeconomy' was the most repeated, with 14 classifications. Next comes 'sustainable development' with six entries and 'commerce' with five entries. The agriculture sector, fermentation techniques,

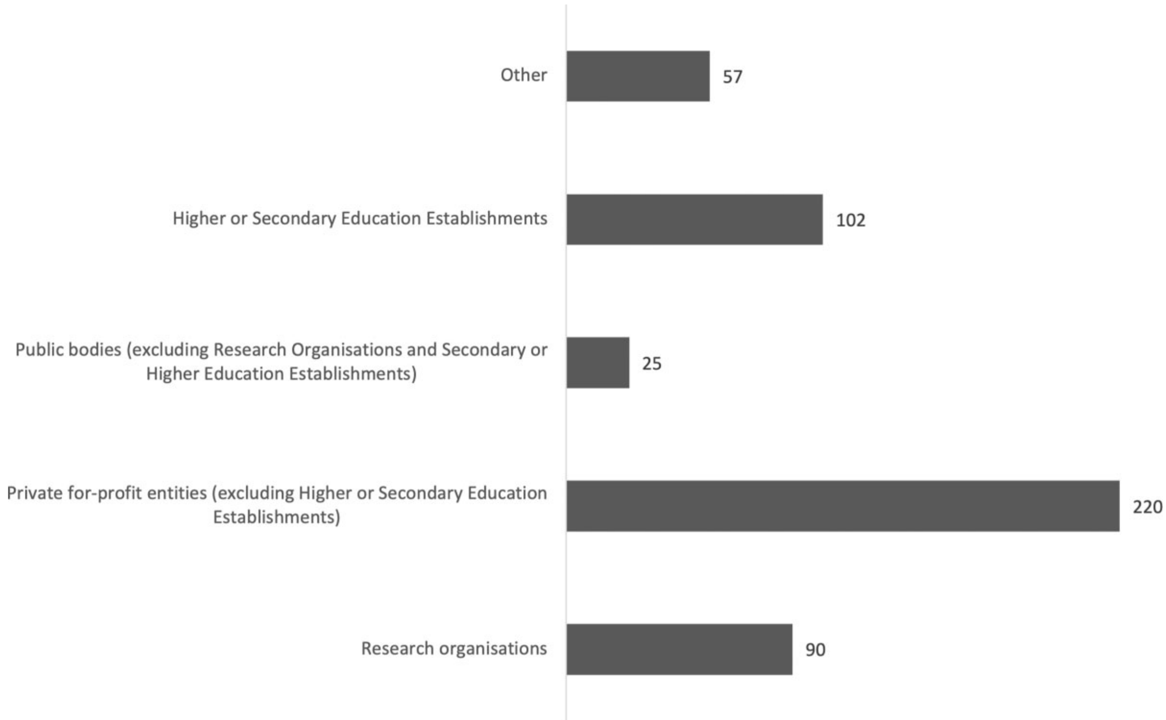

Figure 10. Main activity type of participating entities.

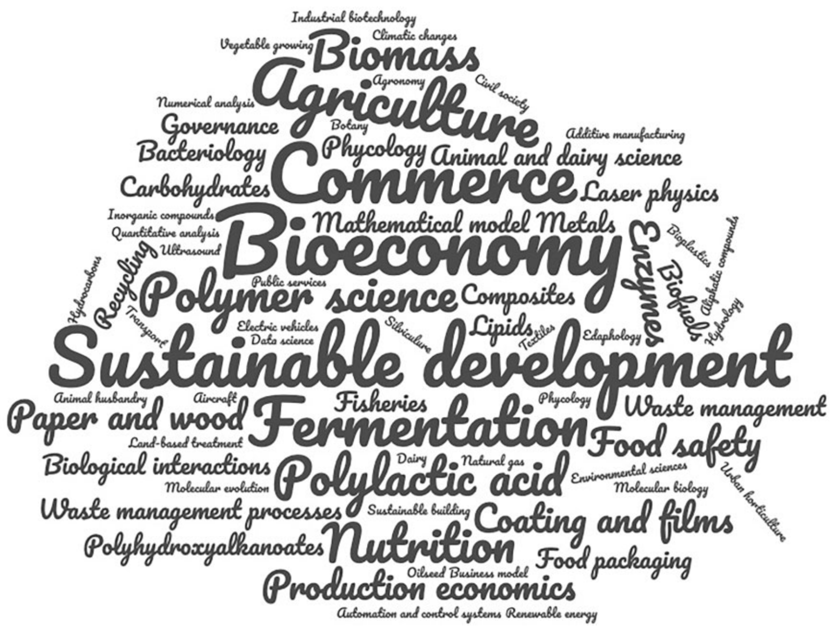

Figure 11. Word cloud of terms related to the fields of science addressed in the analysed projects.

'biomass', 'nutrition', 'polylactic acid', and 'polymer science' also feature prominently.

The prominence of a non-technology term like 'commerce' in a sample of mostly technology terms stands out. Being innovation one of the main mottos of the H2020 programme, one might think that these projects were designed accordingly, with a good market-oriented approach. Indeed, this might indicate that the translation of the project results to the economy was a key objective. However, whether this is supported by the existing evidence on the effects of the projects is what we will try to elaborate on below.

4.2 Evaluation of projects achievements and impacts

4.2.1 Short-term benefits

The evaluation of short-term benefits was summative and quantitative, assessing mainly outputs and outcomes. Thus, our sample of 12 projects completed at least 1 year ago was analysed for publications or other spill overs by looking at the results section of each project's page on the CORDIS website. From such analysis, we can conclude that, in the short-term, peer-reviewed scientific publications were the main outputs of the European projects in the CBE field (Table 2). Starting from the top of the table, projects are listed from the oldest, i.e. those that were completed longest ago, to the most recent. As we approach the bottom of the table, it is possible to glimpse a trend towards diversification in the type of outputs produced. For instances, the STARProBio project, funded under H2020, provided 11 datasets, evidencing the greater concern for data sharing, showing a transition towards the 'Open Access in Europe' stated by the H2020.

Regarding outcomes, a few contributions have been identified that fall under the three themes relevant to the CBE, namely:

i) *IndCo (or economic benefits)*—The market position of the Multi Rotation System technology, which Gneuss already serves, has been strengthened by the INNOREX project. It has demonstrated methods that enhance the production of bio-based polymers allowing for a large-scale production at a reasonable price.
ii) *SuD (or environmental benefits)*—The development of processes for the production of new biopolymers from highly complex biowaste using modern processing technologies, such as bacterial fermentation of syngas and pyrolysis, is a SYNPOL project contribution to SuD.
iii) *CPP (or social benefits)*—The elaboration of guidelines to overcome legislative barriers and foster product development and commercialization was achieved by the STAR-ProBio project.

4.2.2 Mid-term benefits

The mid-term benefits of European funding projects in the field of CBE were assessed by the use of case studies. Despite being labour-intensive and a craft rather than a quantitative activity, the case study method has been advocated as to be the 'state of the art' to measure the societal impact phenomenon (Bornmann and Marx 2014). Here, any impact other than the scientific one was considered, namely, those coded according to the three relevant themes previously selected (IndCo, SuD, and CPP).

Of the 12 projects completed at least a year ago, only half of them responded to the request for information. In general, none of these projects resulted in direct methodologies and/or products for the market. Nevertheless, interesting information was provided, which was analysed and is framed below in key themes relevant to European CBE research.

4.2.2.1 Strengthening IndCo

The project impact mentioned by more than one coordinator (INNOREX, BIOREFINE-2G), and which in our sample contributes most to IndCo, was the creation of scientific jobs in industry. In projects developed in partnerships between academia and industry, it is probable that, besides the expected transfer of knowledge and/or technology, scientists will also be transferred to the private sector. In this way, the industry benefits from a highly qualified workforce that surely contributes positively to the development of innovative strategies for the sector. In this way, industry benefits from highly skilled labour, while scientists see here an opportunity to develop their careers in industry, which it is not always easy to accomplish. With this transfer, the link between industry and academia is also promoted, facilitating communication channels and the continuity of collaborations, which often gives rise to follow-up projects, where knowledge is deepened (SYNPOL project). Last but not least, in one of the projects (SPLASH), a joint venture between participating companies was set up to facilitate the access of the product to the market, which is a clear boost to IndCo. This case study is explored in the text box below.

Text Box Case study—SPLASH

The SPLASH project focused on the development of a bio-based platform for sustainable polymer production using microalgae as a renewable raw material. At the end of the project, it could be concluded that substantial progress had been made in several domains. In the scientific domain, extensive knowledge was generated, for example as a result of detailed genetic analyses of the strains used (*Botryococcus braunii*). This boost in knowledge contributed, in the technical domain, to the improvement in the production of algae and the recovery of their products (hydrocarbons and polysaccharides), as well as to the improvement in their analysis and conversion of carbohydrates into building blocks and subsequently into polymers. In the commercial domain, a basis for the commercialization of hydrocarbon production with *B. braunii* was set-up. Last but not least, in the industrial domain, the necessary tools and technologies have been developed for the establishment of a new industrial sector of Industrial Biotechnology with algae and/or algal genes for the manufacture of industrial raw materials.

However, to the best of our knowledge, there are currently no companies using microalgae hydrocarbons or polysaccharides as renewable raw materials as a result of the project. Several reasons are thought to contribute to this. Despite various significant developments, the costs of the sugars produced by *B. braunii* are still too high. Furthermore, the separation of the sugars from the mixtures in order to act as substrate for polymers remains a critical step to be addressed. Although it could also be shown that implementing a route with a steam-cracking step would be suitable for cracking larger hydrocarbons into a gas phase rich in ethylene and propylene, the unexpectedly high nitrogen content (of 0.56 wt%) found in the hydrocarbon fraction (EHC) makes the industrial route from EHC to ethylene and propylene as platform chemicals unrealistic. It was thus concluded that it would be more favourable to concentrate on extracting the valuable chemicals from *B. braunii*, purifying and using them without modification, or with only slight modifications to the molecule structure. Still, in recent years, Avantium Chemicals BV, one of the companies that made up the project consortium, has developed the YXY® technology that starts from plant-based sugars to produce 2,5-furandicarboxylic acid, which can be polymerized into polyethylene furanoate (PEF). In October 2016, Avantium Chemicals BV and BASF SE formed a joint venture to commercialize the production of PEF, a 100% plant-based, recyclable and degradable plastic with superior performance properties compared to currently widely used petroleum-based packaging materials.

Table 2. The main outputs of EU-funded projects in the CBE field that were completed at least one year ago

Project acronym	Publications						Deliverables			Datasets	Software
	Peer-reviewed	Non-peer reviewed	Monographic books	Book chapters	Conference proceedings	Other	Documents, reports	Patent (filed or in preparation)	Open research data Pilot		
INNOREX	5										
BRIGIT	18										
SYNPOL	54										
EUROPHA	1										
SPLASH	7										
BIOREFINE-2G	10										
NANO3BIO	26							5			
GRAIL	10							5			
BIO-QED[a]	–	–	–	–	–	–	–	–	–	–	–
AFINET		2			14	279	15	3			1
DIET	6										
STAR-ProBio	28		1	2			21	5	1	11	

a No results available at CORDIS website.

4.2.2.2 Contributing to SuD

Contributing to SuD means meeting the needs of the current generation without depleting resources for the future. This is closely linked, in the light of the CBE, with innovating raw materials. For instances, the SPLASH project presented above, in addition to fostering IndCo, is also a good example of SuD impact. This is because the characteristics of PEF, the product marketed as a result of the joint venture, meets the demand of current generations for plastics without compromising fossil reserves. Another project with an impact in this area was SYNPOL. The project aimed to boost the sustainable production of new biopolymers from highly complex biowaste, e.g. municipal, commercial, sludge, agricultural, using modern processing technologies such as bacterial fermentation of syngas and pyrolysis. Although there are no spin-offs or other types of business activity originated from the project, during its execution, it was possible to contact companies outside the consortium that are currently leading related technologies (e.g. gas fermentation technology). An example is LanzaTech, Inc., a growing company using syngas (CO, CO_2, and H_2) for the industrial production of chemicals such as ethanol. A representative of the company has been invited more than once by the project to meet with the consortium to share knowledge and experience. This company has been leading the syngas fermentation process, connecting its bioreactors/fermenters directly to synthesis gas producing industries such as steel mills. In 2018, the cooperation between LanzaTech Inc. and Aemetics, Inc. gave rise to the first syngas fermentation pilot plant from biomass gasification. Nowadays, LanzaTech has four demonstration plants around the world that use innovative technologies to recycle carbon into valuable and sustainable new products (Ciliberti et al. 2020).

4.2.2.3 Improving CPP

The elaboration of guidelines to overcome legislative barriers and foster product development and commercialization was also mentioned, specifically in the work carried out under the European STAR-ProBio project. The overall objective of the project was to formulate guidelines for a common framework to promote the development of regulations and standards to support the implementation of business innovation models and market uptake of the bio-based products sector. In this regard, two institutes involved in the project, University of Rome Unitelma Sapienza and Technical University of Berlin, have launched the development of a pre-normative document in conjunction with UNI (the Italian standardization organization). The PdR (from the Italian Prassi di Riferimento) provides application guidelines for the environmental and social qualification of bio-based products, which includes sustainability assessments taking into account their life cycle. In fact, the novelty of STAR-ProBio project is evidenced by the fact that it goes beyond the traditional life cycle analysis of bio-based products by approaching the social life cycle (SLCA) as a tool for promoting the market uptake of bio-based products from a consumer perspective. Furthermore, it is an important contribution to the literature about social aspects (which tend to be under-investigated compared to environmental and economic aspects) of traditional life cycle analysis. By analysing the SLCA, it has allowed to assemble a set of social impact categories and indicators that should be considered in a social sustainability assessment of bio-based products to understand which social aspects may influence future demand and thus market acceptance (Falcone and Imbert 2018). As consumers play a crucial role in the market penetration of products, the study of the factors that influence their buying behaviour for bio-based products has been of particular interest. In this line, it has been revealed that certification has a significant impact on consumer preference for more sustainable products, even if it means a moderate increase in the price to be paid. As such, the continuous improvement of standards, certification schemes, and labels for bio-based products will contribute to strengthening their presence in the market (Morone et al. 2021).

5. Conclusions

This study provides an analysis of the societal impact of EU-funded projects related to CBE. To this end, a framework is proposed and used. Complementarily, a general characterization of EU-funded research projects that address the CBE is provided, in an attempt to understand how the priorities and guidelines of the EU in these matters are being followed-up.

In general, we can conclude that there are many approaches to assess research impact. However, the development of a successful evaluation framework must take into account three basic building blocks: (1) clear evaluation concepts; (2) contextual methodological approach; and (3) adequate data volume and types. All need to be adapted to each specific knowledge area and research context. In any case, mixed (qualitative/quantitative) approaches are often ideal, although more resource-intensive.

In the particular area of CBE, our findings suggest that European policies are working and paying off. The EU's concern to find innovative solutions, within CBE-related issues, that are increasingly 'marketable' is evidenced by commerce-related topics addressed in the projects analysed. As a result, companies are also being involved at an appropriate level, with industry outweighing universities and other research-performing organizations in terms of their participation in this type of projects.

From a practical impact standpoint, in the short-term, scientific publications continue to be the main output of this type of project. In addition, outcomes such as strengthening the market position of new technologies, producing innovative products from organic waste, and working on consumer acceptance of bio-based products were the main contributions to IndCo, SuD, and CPP, respectively. In the medium term, although it cannot be generalized, two out of six coordinators mention the creation of scientific jobs in industry, which together with a joint venture that was pointed out were the major impacts identified with contributions to IndCo. In addition, although indirectly, the commercialization of innovative raw materials (e.g. PEF) by the joint venture was also a mentioned impact with repercussions on SuD. Finally, the creation of documents that drive the improvement of public and community policies within the scope of biobased products was an evidenced impact with effect on CPP. Despite all the scientific and technological development that has taken place, the effective transformation of ideas into marketable products remains a major challenge, with the lack of economic viability and legislative barriers being identified as the main obstacles to be overcome. Factors such as the high price of raw materials or the development of very specific and little used methodologies are key challenges. Besides, recycling and resource recovery policies cannot exist if there is no capacity to introduce concepts of circularity, use of alternative materials and valorization of the assets that are already in the system. Thus, this study has as practical and policy implications the contribution of empirical evidence to the design of funding instruments that could make the most of CBE and enhance the transition to a sustainable economy.

As a final remark, it should be noted that the main limitation of this work lies in the restricted sample size of the project coordinators who answered the questionnaire. However, it represents the first attempt in the literature to assess the societal impact (in a short-, medium-, and long-term) of EU-funded projects in the CBE context. As future lines of research, it would be interesting not only to increase our sample by including the analysis of new projects, but also to continue to monitor some of these projects long enough to draw longer-term conclusions. Furthermore, the framework replicability to other research and development areas is an intended future line of action.

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References

Australian Research Council (2022) *ERA 2023 Benchmarking and Rating Scale – Consultation Paper* <https://www.arc.gov.au/excellence-research-australia/era-2023> accessed 16 May 2022.

Becker H. A. (2001) 'Social Impact Assessment', *European Journal of Operational Research*, 128: 311–21.

Bornmann, L. (2012) 'Measuring the Societal Impact of Research', *EMBO Reports*, 13: 673–6.

Bornmann, L., and Marx, W. (2014) 'How Should the Societal Impact of Research Be Generated and Measured? A Proposal for a Simple and Practicable Approach to Allow Interdisciplinary Comparisons', *Scientometrics*, 98: 211–9.

Brandão, A. S., Gonçalves, A., and Santos, M. (2021) 'Circular Bioeconomy Strategies: From Scientific Research to Commercially Viable Products', *Journal of Cleaner Production*, 295: 126407.

Brandão, A. S., and Santos, M. (2022) 'Rural Regions as Key Locations for the Circular Bioeconomy: Insights from the Northern Interior of Portugal', *Bioresource Technology Reports*, 17: 100955.

Carus, M., and Dammer, L. (2018) 'The Circular Bioeconomy – Concepts, Opportunities, and Limitations', *Industrial Biotechnology*, 14: 83–91.

CBE JU (2021) *Circular Bio-based Europe Joint Undertaking*. <https://www.bbi.europa.eu/about/circular-bio-based-europe-joint-undertaking-cbe-ju> accessed 16 May 2022.

Chai, S., and Shih, W. (2016) 'Bridging Science and Technology through Academic–Industry Partnerships', *Research Policy*, 45: 148–58.

Ciliberti, C., Biundo, A., Albergo, R., Agrimi, G., Braccio, G., de Bari, I., Pisano, I. (2020) 'Syngas Derived from Lignocellulosic Biomass Gasification as an Alternative Resource for Innovative Bioprocesses', *Processes*, 8: 1567.

Council Regulation (EU) 2021/2085 (19 November 2021) 'Establishing the Joint Undertakings Under Horizon Europe', *Official Journal of the European Union*, 427: 17–119. <http://data.europa.eu/eli/reg/2021/2085/oj> accessed 23 January 2023.

CSIC (2022) El CSIC se sitúa como la tercera institución en número de proyectos obtenidos del programa europeo de I+D+I Horizonte 2020, CSIC Communication <https://www.csic.es/en/node/2512373> accessed 12 May 2022.

D'Adamo, I., Falcone, P. M., and Morone, P. (2020) 'A New Socio-Economic Indicator to Measure the Performance of Bioeconomy Sectors in Europe', *Ecological Economics*, 176: 106724.

D'Adamo, I., Falcone, P. M., Imbert, E., and Morone, P. (2020a) 'A Socio-Economic Indicator for EoL Strategies for Bio-Based Products', *Ecological Economics*, 178: 106794.

D'Adamo, I., Falcone, P. M., Imbert, E., and Morone, P. (2020b) 'Exploring regional Transitions to the Bioeconomy Using a Socio-Economic Indicator: The Case of Italy', *Economia Politica*, 39: 989–1021.

D'Amato, D., and Korhonen, J. (2021) 'Integrating the Green Economy, Circular Economy and Bioeconomy in a Strategic Sustainability Framework', *Ecological Economics*, 188: 107143. https://doi.org/10.1016/j.ecolecon.2021.107143

Directive 2008/98/EC (2008) 'Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on Waste and Repealing Certain Directives'. *Official Journal of the European Union*, 312: 3–30. <http://data.europa.eu/eli/dir/2008/98/oj>

Directive (EU) 2018/2001 (2018) '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'. *Official Journal of the European Union*, 328: 82–209. <http://data.europa.eu/eli/dir/2018/2001/oj>

Directorate-General for Research and Innovation (2014) *Horizon Magazine: 30 Years EU Research Framework Programmes 1984–2014*. Special Issue March 2015. Luxembourg: European Commission Publications Office. <https://data.europa.eu/doi/10.2777/96026>.

Directorate-General for Maritime Affairs and Fisheries (2022), *BlueInvest: Commission and EIF Agree to Mobilise €500 Million with New Equity Fund for Blue Economy*. European Commission. <https://ec.europa.eu/oceans-and-fisheries/news/blueinvest-commission-and-eif-agree-mobilise-eu500-million-new-equity-fund-blue-economy-2022-03-28_pt> accessed 16 May 2022.

Directorate-General for Research and Innovation (2020) *Food 2030 Pathways for Action: Research and Innovation Policy as a Driver for Sustainable, Healthy and Inclusive Food Systems*. European Commission Publications Office. <https://data.europa.eu/doi/10.2777/104372>.

Earth Overshoot Day (2021) Past Earth Overshoot Days <https://www.overshootday.org/newsroom/past-earth-overshoot-days/> accessed May 16 2022.

ECBF, European Circular Bioeconomy Fund <https://www.ecbf.vc> accessed 16 May 2022.

ESIF, European Structural and Investment Funds <https://ec.europa.eu/info/funding-tenders/funding-opportunities/funding-programmes/overview-funding-programmes/european-structural-and-investment-funds_en> accessed 16 May 2022.

European Commission (2010) *Assessing Europe's University-Based Research: Expert Group of Assessment of University-Based Research*. Luxembourg: Publications Office of the European Union. <https://data.europa.eu/doi/10.2777/80193>

European Commission (2013) 'A new EU Forest Strategy: for forests and the forest-based sector', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2013) 659 final.

European Commission (2014) 'Innovation in the Blue Economy: Realising the Potential of Our Seas and Oceans for Jobs and Growth', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2014) 254 final/2.

European Commission (2015) 'Closing the loop – An EU action plan for the Circular Economy', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2015) 0614 final.

European Commission (2016) 'Clean Energy For All Europeans', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank, COM (2016) 860 final.

European Commission (2017a), *Review of the 2012 European Bioeconomy Strategy*. Luxembourg: Directorate-General for Research and Innovation, Publications Office of the European Union.

European Commission (2017b) 'Investing in a smart, innovative and sustainable Industry A renewed EU Industrial Policy Strategy', Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank, COM (2017) 0479 final.

European Commission (2018a) 'A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2018) 673 final.

European Commission (2018b) 'Monitoring Framework for the Circular Economy', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2018) 29 final.

European Commission (2019), 'The European Green Deal', Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2019) 640 final.

European Commission (2020a) 'A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2020) 381 final.

European Commission (2020b), 'EU Biodiversity Strategy for 2030 Bringing nature back into our lives', Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM (2020) 380 final.

European Commission (2021a) *Sustainable Development in the European Union – Monitoring Report on Progress towards the SDGs in an EU Context*. Belgium: Eurostat Statistical Books. Publications Office of the European Union.

European Commission (2021b) Common Agricultural Policy 2023–2027. <https://www.consilium.europa.eu/en/policies/cap-introduction/cap-future-2020-common-agricultural-policy-2023-2027/> accessed: May 16 2022.

Falcone, P. M., and Imbert, E. (2018) 'Social Life Cycle Approach as a Tool for Promoting the Market Uptake of Bio-Based Products from a Consumer Perspective', *Sustainability*, 10: 1031.

FEMP (2019) La Estrategia Local de economía circular, Federación Española de Municipios y Provincias <http://www.femp.es/comunicacion/noticias/la-estrategia-local-de-economia-circular> accessed 12 May 2022.

Global Footprint Network (2022) National Footprint and Biocapacity Accounts <https://data.footprintnetwork.org/?_ga=2.125032271.417188814.1648998850-1536533524.1648998850#/countryTrends?cn=5001&type=BCtot,EFCtot> accessed May 16 2022.

Government of Spain (2018) España Circular 2030. Estrategia Española de Economía Circular <http://www.miteco.gob.es/images/es/180206economiacircular_tcm30-440922.pdf> accessed 12 May 2022.

Higher Education Funding Council for England (2009), *Research Excellence Framework Second Consultation on the Assessment and Funding of Research*. Bristol, UK: HEFCE.

Joly, P. B, Gaunand A, Colinet L, Larédo P, Lemarié S, Matt M. (2015) 'ASIRPA: A Comprehensive Theory-Based Approach to Assessing the Societal Impacts of a Research Organization', *Research Evaluation*, 24: 440–53.

Kardung, M., and Drabik, D. (2021) 'Full speed Ahead or Floating around? Dynamics of Selected Circular Bioeconomies in Europe', *Ecological Economics*, 188: 107146.

Kokkinos, K., Karayannis, V., and Moustakas, K. (2020) 'Circular bio-Economy via Energy Transition Supported by Fuzzy Cognitive Map Modeling towards Sustainable Low-Carbon Environment', *Science of the Total Environment*, 721: 137754.

Lainez, M., González, J. M., Aguilar, A., and Vela, C. (2018) 'Spanish Strategy on Bioeconomy: Towards a Knowledge Based Sustainable Innovation', *New Biotechnology*, 40: 87–95.

LIFE Programme, European Climate Infrastructure and Environment Executive Agency. <https://cinea.ec.europa.eu/programmes/life_en> accessed 16 May 2022.

Mohan, S. V., Dahiyaab, S., Amulya, K., Katakojwala, R., and Vanitha T. K. (2019) 'Can Circular Bioeconomy Be Fueled by Waste Biorefineries – A Closer Look', *Bioresource Technology Reports*, 7: 100277.

Morone, P., Caferra, R., D'Adamo, I., Falcone, P. M., Imbert, E., and Morone, A. (2021) 'Consumer Willingness to Pay for Bio-Based Products: Do Certifications Matter?', *International Journal of Production Economics*, 240: 108248.

National Institutes of Health (2010) STAR METRICS: New Way to Measure the Impact of Federally Funded Research <https://www.nih.gov/news-events/news-releases/star-metrics-new-way-measure-impact-federally-funded-research> accessed 16 May 2022.

Naudet, P. M., and Marrazzo, G. (2021), *The Governance of Circular Bioeconomy*. Brussels: ACR+.

Pan, S. L., and Pee, L. G. (2020) 'Usable, In-Use, and Useful Research: A 3U Framework for Demonstrating Practice Impact', *Information Systems Journal*, 30: 403–26.

Recovery plan for Europe <https://ec.europa.eu/info/strategy/recovery-plan-europe_en> accessed 16 May 2022.

SIAMPI (2012) SIAMPI Approach <http://www.siampi.eu/642.bGFuZz1FTkc.html> accessed 17 May 2022.

Stegmann, P., Londo, M., and Junginger, M. (2020) 'The circular Bioeconomy: Its Elements and Role in European Bioeconomy Clusters', *Resources, Conservation & Recycling*, 6: 100029.

Taffuri, A., Sciullo, A., Diemer, A., and Nedelciu, C. E. (2021) 'Integrating Circular Bioeconomy and Urban Dynamics to Define an Innovative Management of Bio-Waste: The Study Case of Turin', *Sustainability*, 13: 6224.

The World Bank (2022) About World Development Indicators <https://datatopics.worldbank.org/world-development-indicators/about-world-development-indicators.html> accessed 16 May 2022.

Tuominen, A., Järvi, T., Hyytinen, K., Mitsakis, E., Lopez-Lambas, M. E., La Paix, L., van der Waard, J., Binsted, A., and Sitov, A. (2011) 'Evaluating the Achievements and Impacts of EC Framework Programme Transport Projects', *European Transport Research Review*, 3: 59–74.

Twproject (2022) Project benefits: what are they and how to manage them <https://twproject.com/blog/project-benefits-manage/> accessed 10 May 2022.

United Nations (2019) 'World Population Prospects 2019: Highlights', Department of Economic and Social Affairs, Population Division

(ST/ESA/SER.A/423)<https://population.un.org/wpp/publications/files/wpp2019_highlights.pdf> accessed 23 January 2023.

United Nations Environment Programme (2021) *The Role of Business in Moving from Linear to Circular Economies*. Nairobi: UNEP <https://www.unep.org/resources/publication/role-business-moving-linear-circular-economies>.

United Nations Statistics Division (2017) Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development. <https://unstats.un.org/sdgs/indicators/indicators-list/> accessed 16 May 2022.

Ward, J., and Daniel, E. (2005) *Benefits Management: Delivering Value from IS & IT Investments*. UK: John Wiley and Sons.

Williams, D., and Rank, A. D. (1998) 'Measuring the Economic Benefits of Research and Development: The Current State of the Art', *Research Evaluation*, 7: 17–30.

Yaremova, M., Tarasovych, L., Kravchuk, N., and Kilnitska, O. (2021) 'The Evolution of Circular Bioeconomy: A Bibliometric Review'. *International Conference on Sustainable, Circular Management and Environmental Engineering*, *E3S Web Conference*, 255: 01051. https://doi.org/10.1051/e3sconf/202125501051