

Review

Implementing the Circular Economy in the European Union and Spain: Links to the Low-Carbon Transition

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Abstract: This paper reviews and analyzes the process of the implementation of the circular economy in the European Union (EU) and Spain, and its links to the low-carbon transition. The EU implementation of the circular economy went through several stages. Since the adoption of the first action plan in 1993, the links between the circular economy and carbon transition goals have become intertwined. Recently, the EU approved the framework of new monitoring measures and indicators for the circular economy. The adopted actions have involved the adaptation of European legislation at the national level. Spain has participated in this process since 2017, when the Circular Economy Pact was signed. The subsequent approval of the Spanish Strategy for a Circular Economy in 2020 was developed, considering a close relationship between decarbonization and the circular economy. Lately, the circular economy implementation has been strengthened with the strategic project for economic recovery and transformation, linked to the recovery of COVID-19, and the roadmap for the sustainable management of mineral raw materials, with both documents including actions directly related to transforming the energy system. Data show that Spain has made significant improvements in the circular economy transition. However, Spain's vulnerability to externalities is greater than that of the EU as a whole.

Keywords: circular economy; Spain; European Union; policy and data evolution



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1. Introduction

Based on the statements of Boulding [1] and Pearce and Turner [2], which showed that a linear form of production could not be maintained in the long term, and that recycling was the only way to maintain the sustainability of the production system, the circular economy was considered crucial to address both environmental challenges and the dependence on certain production resources. The total amount of material consumed by humans already exceeds 100 billion tons per year, four times more than in 1970 and twice as much as the increase in population, according to the Circular Economy Report [3]. Moreover, in the last two years, this consumption has increased by 8%, while the reuse of resources has decreased by 5%.

In the European Union (EU), the concept and promotion of the circular economy has been gradually assimilated since the beginning of the 21st century. It is suitable to reduce the dependence on non-renewable resources to become less vulnerable to suppliers of essential raw materials and to promote economic growth and technological innovation [4]. In this sense, the Versailles Declaration of 2022, adopted by the European Council [5], stresses that raw materials are strategically fundamental to guarantee the autonomy and sovereignty of the EU. Meanwhile, the recent study by Carrara et al. [6] shows that the EU is dependent on many strategic resources (mainly from China), and that the EU (and other countries) demand for these materials will tend to grow significantly over time, with significant possibilities of the demand exceeding the supply. In addition, the energy transition will accelerate the demand for some of these materials, as they are needed for

the building blocks of renewable energy production. In this context, the EU has developed a strategy for the implementation and promotion of the Circular Economy Directive, as it could be part of the solution to the supply of scarce resources. According to the Cotec Report [7], this strategy has its crucial starting point in the adoption of the first EU Circular Economy Action Plan in 2015 [8].

Spain, as a member of the EU, participates in this process of promoting the circular economy. The Cotec Report [7] shows that Spain has significantly improved its promotion, especially since the approval of the National Strategy for the Circular Economy in 2020, which considers that the circular economy contributes to the achievement of a sustainable, low-carbon, resource-efficient and competitive economy [9]. However, there had been a previous process of circular economy assimilation that led to the approval of the document. Likewise, since the National Strategy, new legislation has been in place to promote the possibility of circular economic progress.

The aim of this paper is to provide a better understanding of how the circular economy is being implemented in the EU, and more specifically in Spain, and to identify the main measures that contribute to the development of a low-carbon economy. Starting from the concept of the circular economy, this paper reviews the phases the EU has gone through to promote circularity and its main achievements. The case of Spain is specifically studied. The comparison of Spain with the EU is relevant because, according to the conclusions of the report *Geography of the Circular Economy in the Regions* [10], Spain is one of the European leaders in the adoption of circular economy strategies.

This paper reviews and analyzes the process of the implementation of the circular economy in the EU and Spain, and its links to the low-carbon transition, carrying out a review of the measures adopted to this end. Therefore, the gap to fill, and the contribution of this paper, is the synthesis, organization and systematic presentation of these implementation and development measures for the EU and specifically in Spain, the revision of which has had no precedents so far.

The context in which it currently operates, the main results achieved and the challenges for the future are identified. To accomplish this objective, a scoping review was undertaken with the aim of synthesizing the most pertinent literature on the aforementioned topics. This synthesis includes recent reports on the circular economy in Spain, such as those produced by Cotec [7] and the European Environment Agency [11–13], among others. Likewise, the contents of the main strategies, plans and regulations approved by Spain and the EU to promote the circular economy is summarized. Its progress is also detailed.

In addition, an analysis of the evolution and current situation of the main indicators of the circular economy in Spain has been carried out, in relation to the EU, according to the EU monitoring framework.

This paper is divided into the following sections. After a brief methodological explanation in Section 2, Section 3 defines what the circular economy is and examines the means used to promote the implementation and development of the circular economy in the EU. Section 4 analyzes the adaptation of EU countries to the circular economy regulations. It details the current values and evolution of the main indicators. Section 5 analyzes the evolution of the measures used to promote the circular economy in Spain, analyzing their evolution and current situation. Finally, Section 6 concludes the review.

2. Materials and Methods

To conduct this study, a scoping review was undertaken for previous studies on the development, promotion and adaptation of the circular economy in the EU and Spain according to the purpose of this paper. Figure 1 shows a diagram of the search process and the analysis of the information.

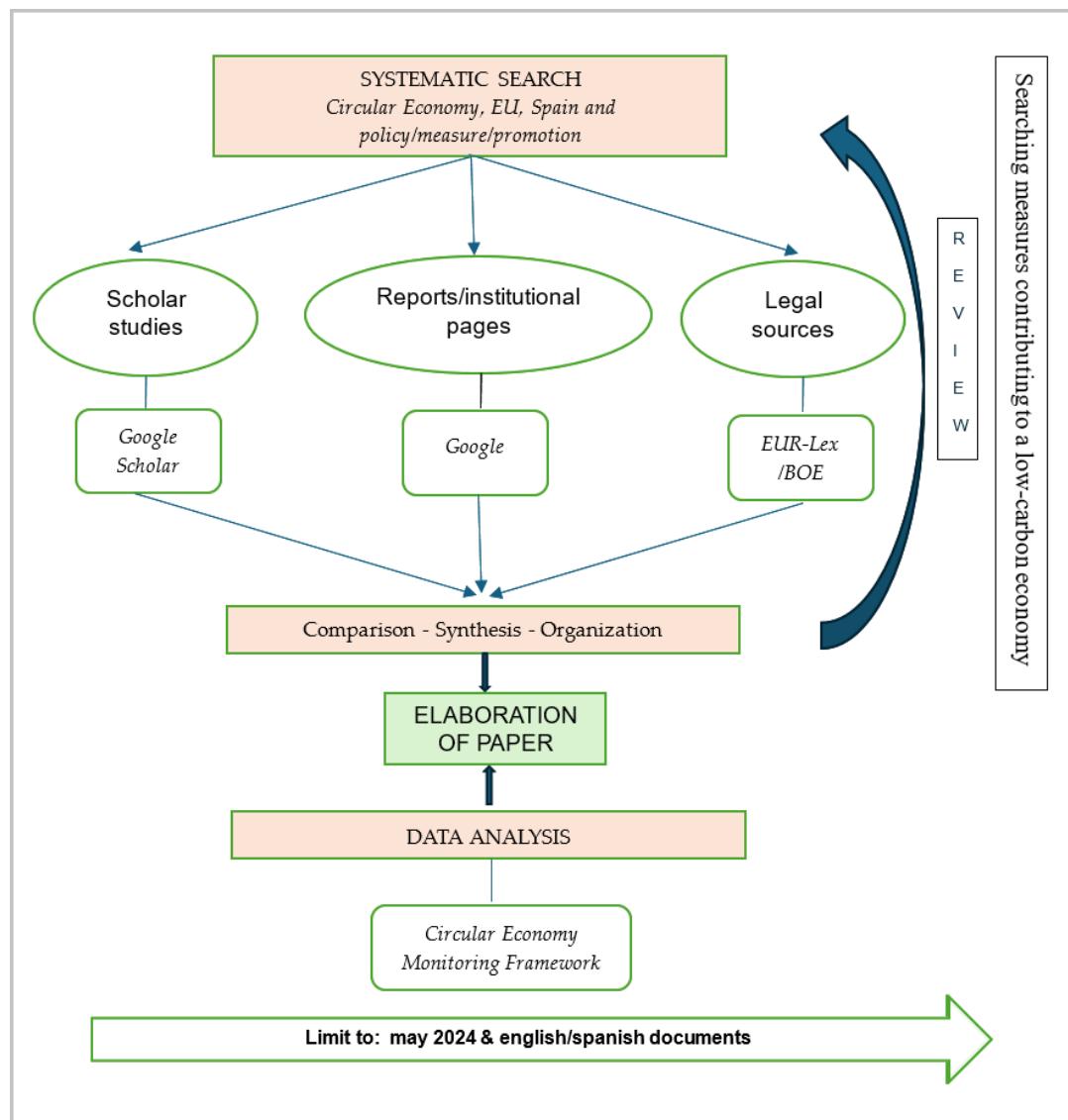


Figure 1. Diagram of the search process and the analysis of the information.

The search process was carried out in two main phases and according to the following three main search sources: Google Scholar, Google and sources of official legal publications (specifically the Official Gazette of the State of Spain—BOE—and the online gateway to EU law called EUR-Lex). The search in Google Scholar was aimed at locating previous academic studies on the subject. The search in Google was aimed at locating the official pages of the EU and the Spanish government that deal with the circular economy, and at locating reports of a different nature on this subject in the two geographical areas of study. The search in the sources of legal publications was aimed at compiling the regulations published both in the EU and in Spain on this subject.

In the initial phase of the study, a series of terms were introduced in the Google Scholar platform, as well as in Google and official legal sources in English and Spanish. The terms included in the search were as follows: “circular economy & EU & policy”, “circular economy & European Union & policy”, “circular economy & EU & measure”, “circular economy & European Union & measure”, “circular economy & EU & promotion”, “circular economy & European Union & promotion”, “circular economy & Spain & policy”, “circular economy & Spain & measure” and “circular economy & Spain & promotion”. In a second phase, further searches were conducted in the three aforementioned sources, employing more specific terms that were repeated in the previous studies, reports and regulations. These searches allowed us

to complete in detail the process of the adoption and promotion of the circular economy in the EU and Spain. Likewise, these subsequent searches focused on identifying the policies related to the decarbonization process, strengthening the search with the combination of words such as decarbonization, energy, renewable, low carbon and emissions.

These searches identified the academic studies cited in the references and mentioned and explained in this paper. Likewise, the main institutional websites containing information on the subject were located (for example, that for the CE in the EU, https://environment.ec.europa.eu/topics/circular-economy_en accessed on 30 May 2024), as well as some relevant reports, such as [3,4,7,9,11–13], among others. Finally, the regulations approved by the EU and Spain that deal with the subject of the analysis were located.

The search for information was carried out throughout the process in Spanish and English and was completed in May 2024. From these documents, the information was compared and grouped in time, the content was synthesized and the documentation was organized in time stages and actions taken, like that offered in some previous studies such as in [7,14–16]. Likewise, in this process, the information related to the decarbonization process was highlighted and analyzed.

In addition, the data provided by Eurostat [17] relating to the Circular Economy Monitoring Framework were used. Based on the data provided in this framework, a descriptive analysis of the evolution of the CE in Spain has been carried out in comparison with the EU, and its current situation has been assessed. This analysis was carried out in comparison with the data provided by previous studies.

3. The Circular Economy in the European Union and the Low-Carbon Economy

3.1. The Circular Economy Concept

According to Geisendorf and Pietrulla [18], the first references to the concept of the circular economy can be found in Boulding [1]. The author states that circular systems within the global economy are essential for the existence of humans on Earth in the future. In the same vein, Pearce and Turner [2] later argued that the linear economy was unsustainable and that its replacement by a circular system was inevitable. Along with these first mentions of the circular economy, the approval of some early laws related to waste can also be considered as the origin of the circular economy concept [18]. Among them, Andersen [19] cites the German Law on Waste Management of 1972.

Based on these concepts, the circular economy has been defined in multiple ways and without a clear definition. It has been interpreted as a business model that incorporates aspects of sustainable development [20] or an economy that encourages everyone to use resources in a more sustainable way [21]. One of the most recently used definitions of the circular economy is that by Kirchherr et al. [22]. After reviewing 114 previously used definitions, the authors defined the circular economy as an economic system that

“... is based on business models which replace the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, ... with the aim to accomplish sustainable development, ... to the benefit of current and future generations”

(Kirchherr et al., 2017: 224–5) [22].

Based on this definition, Figge et al. [23] highlighted four characteristics of the circular economy. First, there should be no need for the use of virgin resources; rather, their use should be in a closed loop. Second, the input and the output of the resources in the system should be the same. Third, the circularity of resources is supported by activities (recycling, remanufacturing, etc.) to which economic agents are committed. Finally, it is unlikely that resource circularity will develop autonomously.

Anyway, the wide number of definitions that can be found highlight that the concept of the circular economy may be challenging to define precisely. Following Milios [24] and Kumar et al. [25], practices for the circular economy are susceptible to be separated into the following two categories: those which boost reuse and extend the life of a product through

maintenance and refurbishments, and those that recycle the resources from used products to build resources that are as good as new. D’Adamo [26] raises that the circular economy model is required to construct a closed-loop cycle as a replacement for a linear system.

According to the European Commission [27], the linear economy continually increases its demands for scarce natural resources, making it essential to move away from the linear “take–make–use–dispose” model and transitioning to a regenerative growth model. In this sense, in a circular economy, the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimized. By using and consuming in a more circular way, we can substantially reduce the impacts of human economic activities on the environment and biodiversity.

Within this idea, the policy of promoting the circular economy acquires a special relevance, to allow economic development in a sustainable way over time. At the European level (and in Spain), these policies have been developed, especially since the second decade of the 21st century.

3.2. *Launching the Circular Economy in the EU*

At the beginning of the 21st century, the EU began to implement a series of short-term political and legal actions aimed at promoting a roadmap towards a circular economy [28]. This momentum had a first phase in the first decade of the century, which has tended to consolidate and expand since then, forming a legislative package that aims to promote this form of economy. At the EU level, general policies have been adopted and implemented, while individual countries have defined specific strategies that vary widely.

The framework in support of the circular economy in the EU has its origins in waste regulation. This regulation is supported by Articles 191–193 of the Treaty on the Functioning of the European Union [29], the VII Environment Action Program of 2013 [30], strategies and plans on waste and plastics and specific rules on the subject [14].

The first specific references to waste appear in the First Program of Action of the European Communities on the Environment (1973–1976) [31]. However, the use of clean technologies was not considered until the Fourth Environmental Action Program (1987–1992) [32]. In fact, it was under this program that the first Community Strategy for Waste Management was adopted [33], which already mentioned the promotion of waste reuse and the need to promote waste recovery. Later, starting with the Fifth Environmental Action Program in 1993 [34], a series of directives were adopted. These directives successively established plastic recycling targets, waste control instruments, measures to prevent waste generation and measures for the reuse of plastics. The following directives and strategies are worth mentioning: Directive 94/62/EC on packaging and packaging waste [35], Thematic strategy on the prevention and recycling of waste [36], and Directive 2006/12/EC on waste [37] and Directive 2008/98/EC on waste [38].

Of these directives, that of 2008 is a key regulation in the EU. It aims to harmonize previous legislation and address waste management. Its main points are as follows:

- It establishes a waste management hierarchy. It prioritizes prevention. It establishes preparation for reuse, recycling and recovery. Finally, it establishes disposal.
- It introduces the concept of Extended Producer Responsibility. This means that producers are responsible for their products, even after their useful life.
- It sets targets for recycling and waste recovery. Member States must achieve certain recycling rates for certain types of waste.
- It prohibits the elimination of waste in landfills (in a phased approach) and encourages the search for sustainable alternatives to waste disposal.
- It simplifies and harmonizes waste management legislation in the EU.

Later, in 2013, the Green Paper on a European Strategy on Plastic Waste in the Environment [39] was drafted and the VII General Union Environment Action Programme to 2020 was adopted [30].

3.3. Shifting the Focus to the Promotion of the Circular Economy in the EU

In 2014, the EU started to adopt a new approach to deal with waste issues by introducing the concept of circular economy [14]. In the European Commission's communication of 2 July 2014, entitled *Towards a Circular Economy: A zero waste program for Europe* [40], the Commission emphasizes the mode of production in Europe: a linear system of production consisting of the extraction of resources from nature, and production, consumption and disposal, which tends to negatively affect the competitiveness of the EU economy. Alternatively, it considers it appropriate to move towards a circular model that allows resources to be reused repeatedly, keeping them in the production chain at the end of their useful life. This economic system would make it possible to achieve significant benefits. Nevertheless, the Commission acknowledges that the transition to a circular economy system implies a change in the mode of production, which requires the creation of an appropriate regulatory environment. To this end, it proposes several measures. These include smart regulation, research and innovation and incentives. Furthermore, it is considered necessary to update waste policies to consider them as productive resources and to establish efficient resource use indicators.

Nevertheless, this proposal was withdrawn in favor of another communication that was issued in December 2015. It focused on the whole life cycle of products rather than waste reduction. That is, the production, the consumption, the disposal or the treatment of waste, the recovery of secondary resources from waste and the recycling of water. This action plan, called *Closing the Loop—An EU Action Plan for the Circular Economy* [8], was a crucial step in advancing the CE in Europe.

This plan consisted of a set of 54 measures which the European Commission considered essential for a successful transition from a linear to a circular economy in the EU over a five-year period. These actions addressed different aspects of product-related processes. These included the design, the production process, the use and the management of waste and residues, and the reuse of the materials they contain so to reintegrate them into the economy. The plan focused on the following five priority areas: plastics, food waste reduction, the management of strategic raw materials, the construction and demolition industry and the promotion of biomass and biological resources. It also emphasized a cross-cutting dimension, promoting innovation and investment at all stages of production and consumption.

For the first time, the Plan included several measures specifically designed to have a direct positive impact on the transition to a low-carbon economy. Table 1 shows the measures included in the 2015 Plan that contribute to this goal.

Table 1. Actions and measures in the Action Plan 2015 related to a low-carbon economy.

Actions Related to the Transition to a Low-Carbon Economy	From
PRODUCTION	
Develop a plan for product design, including the efficient use of materials	2015
Improve environmental auditing systems	2017
CONSUMPTION	
Analyze the use of environmental footprints	2016
WASTE MANAGEMENT	
Promote waste-to-energy conversion	2016
SECTORAL MEASURES	
Improve date labeling on food products	2017
STRATEGIC RAW MATERIALS	
Develop recycling standards for electronic equipment, batteries and similar products	2016
Improve the knowledge on the recycling of strategic materials	2017
BIOMASS AND BIOMATERIALS	
Improve diffusion and innovation of biomass cascade use	2018
Investigate the sustainability of bioenergy	2016
Analyze how the bioeconomy strategy contributes to the circular economy	2016

Source: own elaboration from COM [8].

According to Navarro [15], this communication was a decisive factor in the adoption of the circular economy. It was considered necessary to keep products and resources in the production cycle for the maximum length of time. It was also necessary to reduce the

production of waste and garbage. Therefore, with the efficient use of resources, the concept of production is transformed into a competitive model which takes care of the environment, and thus pursues sustainable development.

3.4. Consolidating the Circular Economy in the EU: Links to the Low-Carbon Transition

Since the 2015 Communication, several actions in the EU have strengthened the circular economy strategy. Firstly, three EU directives were presented in 2018 which aim to make progress in shaping the circular economy. The following advances have been observed in addition to a low-carbon economy:

- Directive (EU) 2018/850: amends Directive 1999/31/EC on the landfill of waste [41]. Its main objective is to reduce the amount of unused waste and to introduce more sustainable waste management practices. Included are stricter restrictions and conditions to reduce waste going to landfills and the promotion of more sustainable options such as energy recovery.
- Directive (UE) 2018/851: amends Directive 2008/98/EC on waste [42]. It is based on the need to improve waste management with the aim (among others) of promoting the circular economy, increasing the use of renewable energy, improving energy efficiency and reducing dependence on imported resources. These are necessary elements for the transition to a low-carbon economy. It introduces changes in waste treatment to promote recycling and reduce the reliance on landfills. It also establishes stricter rules for compliance, monitoring and reporting.
- Directive (EU) 2018/852: amends Directive 1994/62/EC on packaging and packaging waste [43]. It sets more ambitious targets for packaging recycling and reinforces the responsibility of producers in the management of packaging and packaging waste. Separate targets are set for ferrous metals and aluminum to increase aluminum recycling, thereby saving energy and reducing CO₂ emissions.

By implementing these changes, the EU is moving towards a sustainable economy and achieving strategic goals related to the efficient use of renewable resources. The amendments to these directives reflect the EU's commitment to a resource-efficient approach. This is essential to address current challenges related to the scarcity of strategic materials and climate change, while moving the economy in a more sustainable and responsible direction.

Secondly, 2018 also saw the publication of the Commission's Communication on a Monitoring Framework for the Circular Economy [44]. That is, the follow-up framework to the 2015 Action Plan [8]. For this monitoring, a set of ten indicators were established and grouped into the following four elements of the circular economy: production and consumption, waste management, secondary raw materials and competitiveness and innovation. Indicators directly related to transitioning to a low-carbon economy are not included.

Thirdly, also in 2018, the European Strategy for Plastics in a Circular Economy was approved [45]. This strategy highlights the importance of plastics, pointing out that 60% of plastic waste comes from packaging. In this context, the Commission's strategy proposes to recycle plastics and increase the demand for recycled plastics. It also considers encouraging and properly regulating the use of biodegradable plastics and promoting circular solutions.

In this process of the consolidation of the circular economy, it is also worth highlighting the European Green Deal [46]. This document contains a series of ambitious measures for the ecological transition which aim to adequately modify Community regulations with the goal of climate neutrality in 2050. These measures, which can be grouped into nine blocks, include one specifically related to the circular economy called Mobilizing Industry for a Clean and Circular Economy. This document highlights the need for a policy framework that stimulates the development of markets for circular and climate-neutral products, as industry presents a linear production model that generates 20% of greenhouse gas emissions. It includes a new Circular Economy Action Plan, legislative reforms on waste and initiatives to develop markets for carbon-neutral and circular products. The European Green Deal [46] was reinforced, shortly thereafter, by the European Parliament Resolution of 2020 [47], which sets out the need for a legal commitment to achieve climate

neutrality. In this regard, it is necessary to consider the role of infrastructures and markets in achieving the circular economy [48,49].

3.5. Recent Steps Towards the Circular Economy

During the COVID-19 epidemic, various circular economy actions were postponed, providing a more efficient, health-neutral response. Since then, the European Commission has taken significant steps to boost the CE in Europe, promoting sustainability and the responsible management of resources and waste. The following actions should be highlighted:

- Circular Economy Action Plan [50]. In February 2021, the European Parliament voted in favor of this Action Plan, highlighting the need to establish further measures to progress towards a clean, sustainable and circular economy by 2050. These additional measures include the implementation of new recycling laws, with more stringent measures and the definition of binding targets toward the reduction in the ecological footprint of material use to be achieved by 2030. The following three points of the plan should be highlighted:
 - Carbon-neutral economy: this highlights the commitment to reduce greenhouse gas emissions and the carbon footprint.
 - Sustainability and toxic substances reduction: this highlights the importance of minimizing the negative impact of the use of chemicals and hazardous substances in the supply chain.
 - Binding targets for 2030: this shows the EU's commitment to short-term action and accountability to achieve a circular economy.
- Package of measures. In March 2022, the European Commission launched the first package of measures to promote the development of the circular economy. The following main aspects include:
 - Sustainable products: measures to promote sustainable production and consumption. These include the following:
 - Measures focusing on eco-design, such as the introduction of a digital passport.
 - Measures to promote the repair of goods.
 - Measures to promote the circularity of production processes. The industrial emissions Directive should be updated to achieve the goal of zero emissions by 2050, especially those that promote circularity in production.
- Consumer empowerment: consumers are intended to be better informed and empowered to make sustainable product choices. In September 2023, an agreement was reached between the Council and the European Parliament on Directive (EU) 2024/825 on consumer empowerment for the green transition [51].
- The following actions in key sectors with high potential for circularity include:
 - Electronics and ICT. The adoption of Directive (EU) 2022/2380 on the common charger, in December 2022, is worth mentioning [52].
 - Cells and batteries and their waste. Regulation (EU) 2023/1542 on batteries and their waste promotes the internal market for batteries and accumulators [53].
 - Packaging. Measures are being developed to make packaging economically viable for recycling by 2030.
 - Plastics. The EU has been addressing the issue of biodegradable plastics and microplastics.
 - Textiles. The reduction in the environmental footprint of textiles is being promoted. The mandatory separate collection of textiles in households by 2025 is highlighted.
 - Construction and buildings. Energy efficiency and waste management in the construction of buildings are encouraged.
- Strengthening waste reduction: the EU is working towards achieving the objectives of the Waste Framework Directive (Directive 2008/98/EC) [38] and its amending Directive (EU) 2018/851 [42]. It is also working to reduce toxic substances, the use of

at least 25% of raw materials in internal recycling and to establish rules to improve internal and external trade in waste.

4. Adaptation of European Union Countries to Circular Economy Regulations: Transposition of European Regulations

4.1. Transposition of European Regulations in EU Countries

The successful implementation of the circular economy in the EU requires effective harmonized policies across Member States. As the EU has developed guidelines and regulations to promote sustainable and circular practices, Member States have worked to incorporate these principles into their national legal frameworks. To ensure a coherent and effective implementation of circular economy policies across the European Union, this transposition is key. Nevertheless, the diversity of legal systems and economic contexts has influenced the speed and the way each country has transposed these regulations, leading to differences in national approaches and priorities [54]. The uneven adoption of circularity can be observed in two ways. First, in adopting national circular economy strategies. Second, in implementing the relevant EU directives.

Regarding the adoption of national strategies, it should be noted that the first Circular Economy Action Plan [8] did not require the formulation of specific strategies. However, Member States were encouraged to develop such strategies, which eventually led many countries to adopt them. The report of the European Court of Auditors [54] shows that practically all EU countries have developed, or are in the process of developing, such a strategy at the national level. Specifically, Spain, Greece, Portugal, Ireland, France, Italy, Belgium, the Netherlands, Luxembourg, Denmark, Germany, Poland, Slovenia, Sweden and Finland have adopted such strategic documents to date. Similarly, Austria, the Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Lithuania and Latvia are in the process of preparing their respective national strategies. Finally, neither Croatia nor Cyprus have adopted, nor are they preparing, such documents. It should also be noted that some of these countries also have regional strategies, such as in the Region of Murcia.

The transposition of European directives also varies from country to country, although, in general, countries are meeting the transposition deadlines. Table 2 shows the transposition of EU directives, relevant to the circular economy, adopted during the first Action Plan.

Table 2. Transposition of EU directives on the circular economy.

Directives:	2018/849 (Batteries, Electronic Waste)	2018/850 (Landfill Waste)	2018/851 (Waste)	2018/852 (Packaging)	2019/771 (Sale and Purchase of Goods)	2019/883 (Ship Disp)	2019/904 (Plastics)
Austria	✓	✓	✓	✓	✓		✓
Belgium				✓	✓		
Bulgaria	✓	✓	✓	✓	✓		✓
Croatia					✓		
Cyprus	✓	✓	✓	✓	✓	✓	✓
Czech Republic	✓	✓	✓	✓			
Denmark	✓	✓	✓	✓	✓		
Estonia	✓	✓	✓	✓			✓
Finland	✓	✓	✓	✓	✓		
France	✓	✓	✓	✓	✓		
Germany	✓	✓	✓	✓	✓		✓
Greece	✓	✓	✓	✓	✓		
Hungary	✓	✓	✓	✓	✓		✓
Ireland	✓	✓	✓	✓		✓	
Italy	✓	✓	✓	✓	✓	✓	✓
Latvia	✓	✓	✓	✓	✓		✓
Lithuania	✓	✓	✓	✓	✓	✓	
Luxembourg					✓	✓	

Table 2. Cont.

Directives:	2018/849 (Batteries, Electronic Waste)	2018/850 (Landfill Waste)	2018/851 (Waste)	2018/852 (Packaging)	2019/771 (Sale and Purchase of Goods)	2019/883 (Ship Disp)	2019/904 (Plastics)
Malta	✓	✓	✓	✓	✓	✓	
Netherlands	✓	✓	✓	✓	✓		✓
Poland	✓	✓	✓	✓			
Portugal	✓	✓	✓	✓	✓	✓	
Romania	✓	✓	✓	✓	✓	✓	✓
Slovakia	✓	✓	✓	✓		✓	✓
Slovenia	✓	✓		✓		✓	✓
Spain	✓	✓	✓		✓	✓	✓
Sweden	✓	✓	✓	✓	✓		

Source: own elaboration based on European Court of Auditors [55].

4.2. Indicators of Circular Economy Adoption in the EU: Material Circulation Rate

The evolution of circular economy adaptation in the EU and its variation across countries is also visible in the evolution of the circular use rate indicator for materials. The Circular Economy Action Plan 2015 [8] called on the European Commission to monitor the plan. Since then, it has been the main tool to analyze and compare the performance of this type of economy in the EU and its Member States. The EU also used this indicator to quantify the Circular Economy Action Plan 2020 targets [50].

According to Eurostat [17], this indicator measures the share of recycled material reused in the production process in relation to total material use. Total material use is calculated as the sum of national material consumption and circular material use. The first value is obtained from the flow accounts of materials used in the economy. The second is calculated by approximating the value of waste recycled in domestic recovery facilities, adjusting for imported and exported waste.

Figure 2 shows the different levels and evolution of the value of the circular material use rate between 2010 and 2022. The circular material use rate measures the contribution of recycled materials to overall materials demand (expressed in percentage points). A large difference in country performance can be observed. The Netherlands is the country with the highest value (over 25% in 2010 and 2022), while, in 2022, Romania and Finland had the lowest values.

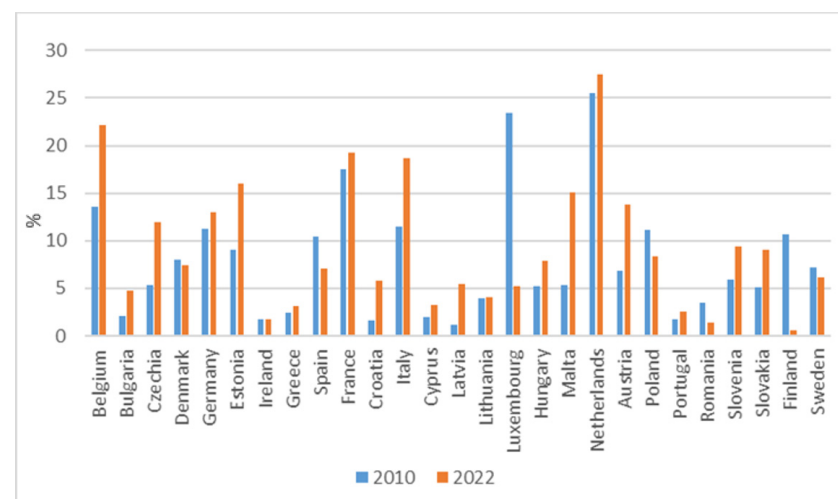


Figure 2. Circular material use rate: 2010–2022 (%). Source: own elaboration from Eurostat [17].

It should also be noted that the evolution between countries is very different. Some have experienced significant growth, such as Malta, Belgium and Italy, which exceeded 8 percentage points over the period, with overall growth rates of around 70–80%. Others, however, show very little growth. In fact, there is even a decline in the recycling rate. For

example, the rate declined by 18 percentage points in Luxembourg and by 10 percentage points in Finland.

4.3. Circular Economy Action Plan 2020 Indicators in the EU

Recently, in May 2023, the EU added several indicators to capture the focus areas of the EU circular economy, aiming to align with the objectives of the Circular Economy Action Plan 2020 [50]. This new monitoring framework is based on the priorities of the European Green Deal [46], the Sustainable Development Agenda [55] and the 8th Environmental Action Program [56]. These indicators are grouped into five groups, which are further subdivided into different indicators. The last group of indicators is directly related to the transition to a low-carbon economy. This group consists of four indicators on global sustainability and resilience. Table 3 summarizes the 27 indicators by group, according to Eurostat [17].

Table 3. New framework for monitoring the circular economy.

Group	Measure	Indicator	Definition
Production and consumption	Material consumption	Material footp. (tons. pc) Resource product. (2000 = 100) Green public procurement (not available yet)	Raw material consumption Materials directly used by an economy Public procurement procedures above the EU thresholds
	Waste generation	Waste generation (kg pc) Waste excluding major mineral wastes (kg/M€) Municipal waste (kg/pc) Food waste (kg/pc) Packaging waste (kg/pc) Plastic pack. waste (kg/pc)	Waste generated Waste generated related to production Waste collected by municipal authorities Food waste generated Packaging waste Plastic packaging waste
Waste management	Overall recycling rates (RRs)	RR of municipal waste (%) RR of all waste (%)	Recycled municipal waste/total municipal waste generated Recycled waste/total waste generated
	RRs for specific waste streams	RR of overall packaging (%) RR of plastic packaging (%) RR of waste of electrical equipment (WEE) separately collected (%)	Recycled packaging waste/all generated packaging waste Recycled plastic packaging waste/all generated plastic packaging waste WEE that enters the recycling for the reuse facility by the weight of all separately collected WEE
Secondary raw materials	Contribution of recycled materials to raw materials demand	Circular material use rate (%) End-of-life recycling input rates, aluminum (%)	Material recycled and fed back to economy/overall material use The % input into the production system coming from recycling
	Trade in recyclable raw materials	Imports from non-EU countries (kt) Exports to non-EU countries (kt) Intra-EU trade (kt)	Selected waste imported from third countries Selected waste exported to third countries Selected waste imported by EU Member States from another Member State
Competitiveness and innovations	Private investment, jobs and GVA related to circular economy sectors	Private investments (% GDP at current prices) Persons employed (% total employment) GVA (% GDP at current prices)	Gross investment in tangible goods in the recycling sector and reuse (RSR) Persons employed in RSR Value added at factor costs in RSR
	Innovation	Patents related to waste manag. and recycling (number)	Patents related to recycling and secondary raw materials
Global Sustainability and resilience	Global sustainability from circular economy	Consumption footprint (index 2010 = 100) GHG emissions from production activities (kg/pc)	Environmental impacts estimate GHG of all production activities in EU
	Resilience from circular economy	Material import depen. (%) EU self-sufficiency for raw materials, aluminum (%)	Imports/direct material inputs Independency from the rest of the world for aluminum

Source: own elaboration from Eurostat data [17].

Some of the most important and recent indicator values for the EU-27 and the EU Member States are shown in Figures A1 and A2 in Appendix A. The data for the EU as a

whole in 2020 show that the EU had a resource consumption of 15 tons per capita and an index close to 150 in the resource productivity indicator. In terms of waste generation, its value reached 500 kg/pc, with a value of 200 kg/pc in packaging waste. In addition, its recycling rate for all waste reached almost 60%, while that of municipal waste was lower, not reaching 50%. Figure A1 also shows that the weight of the circular economy sector in the EU was 2% both in terms of the employment and GVA.

Figure A2 shows that the EU-27 index value for the consumption footprint in 2022 is 109, while the GHG emissions from production activities is 6481 kg/pc. Finally, the high material dependency of some countries is remarkable. For example, only 11% of aluminum is self-sufficient. Globally, there are differences between countries for all indicators, without a common pattern. Therefore, these large differences from one country to another should be considered for the growth of the circular economy.

5. The Circular Economy in Spain and the Low-Carbon Economy

5.1. Evolution of the Legislation on the Circular Economy: First Steps

The first legislation in Spain related to the circular economy was Law 10/1998 [57], which aimed to prevent the generation of waste, implement the regulations to be applied to its treatment, promote its reduction and recycling and regulate contaminated soils. Subsequently, Law 22/2011 on waste and contaminated soils [58] replaced this law. The circular economy in Spain focused on waste with these laws.

Later, in 2017, in line with the EU's interest in the circular economy, the Ministries of Agriculture, Economy, Industry and Competitiveness, the European Commissioner for the Environment and 53 entities signed a covenant for a circular economy (Pact for a Circular Economy: The Commitment of Economic and Social Agents 2018–2020) [16]. Its objective was to promote the transformation of the linear economic model into a circular one. It also proposed 10 actions to achieve this goal. None of the actions mentioned in the document explicitly include progress towards a low-carbon economy. Nevertheless, the first action seeks progress in reducing non-renewable resource use, and actions 5 and 6 promote sustainable and responsible consumption. With this new focus, in May 2018, Royal Decree 293/2018 [59] was approved to reduce the consumption of plastic bags. This law marks the route of the treatment of plastic in Spain. Since then, plastic bags are charged to customers [60]. Additionally, a registry for manufacturers was also created.

5.2. Spanish Strategy for Circular Economy and the Circular Economy Action Plan 2021–2023 and Links with the Low-Carbon Economy

The strategic development of the new circular economy in Spain is focused on the Spanish Strategy for Circular Economy (SSCE) [9] and the 2021–2023 Action Plan [61]. The SSCE is the reference document for establishing the promotion of the circular economy in Spain, contributing to the achievement of a sustainable, decarbonized, resource-efficient and competitive economy [9]. This strategy lays the foundations for the implementation of a circular production and consumption system, minimizing the generation of waste and maximizing the recycling of products, materials and resources. The specific targets for 2030 included in the SSCE are to reduce material consumption relative to GDP by 30%, to reduce waste generation by 15% and food waste by 50% in households and 20% in production chains, to increase the reuse of municipal waste to 10% of its total value, to improve water use efficiency by 10% and, finally, to reduce GHG emissions to below 10 million tons of CO₂ equivalent.

The document identifies six sectors in which the integration of the circular economy is a priority (construction, agri-food, fisheries and forestry, industry, consumer goods, tourism and textiles) and eight lines of action (production, consumption, waste management, secondary raw materials, water reuse, awareness, research and employment). To evaluate the progress of the strategy's objectives, the indicators established by the EU are used. Moreover, the indicator for the share of the waste-related sector in greenhouse gas emissions is added.

Achieving the 2030 targets requires the implementation of triennial action plans. The first is the Circular Economy Action Plan 2021–2023 [61], published in May 2021. It addresses its objectives through five axes. The production axis seeks to integrate circularity throughout the product life cycle. The consumption axis aims to improve product labeling to help consumers identify the most environmentally friendly products. The waste management axis focuses on reducing waste generation and promoting waste management through recycling. The secondary raw materials axis promotes the introduction of secondary raw materials into the production cycle with guarantees and safety. The water reuse and purification axis seeks an efficient use of water through its reuse. Three lines of action are also addressed in the plan. The line of awareness and participation orients production and consumption towards products that are manufactured according to the criteria of the circular economy. The research, innovation and competitiveness line promotes investment in research for the development of competitive and innovative products in a sustainable manner. Finally, the employment and training line promotes workers' adaptation to change and employment in circular economy activities.

It is worth noting that several specific lines of action are directly related to the achievement of a low-carbon economy by focusing on relevant actions related to renewable energy. These actions include the development of a guideline for the establishment of environmental criteria to be considered in the dismantling and repowering of wind power plants, the implementation of a pilot project for the reuse of photovoltaic modules and lithium batteries for automotive applications and for domestic self-consumption and the adoption of the biogas roadmap. These measures are also part of the necessary proposals for the energy transition.

5.3. Other Key Documents for a Circular Economy in Spain and Decarbonization

In March 2022, the strategic project for economic recovery and transformation in the circular economy [62] was implemented, based on the extraordinary measures adopted to promote economic recovery following COVID-19 and the Next Generation EU Fund. The goal is to give a new impulse to the integration of the circular economy in Spanish industry. This strategic project foresees 18 instruments in two lines of action. The first line of action concerns the textile, plastics and renewable energy capital goods sectors. Thus, actions related to the third sector are directly related to the decarbonization process. In this sense, the strategic project emphasizes the need to accompany the penetration of renewable energies with an adequate treatment of the waste generated, specifying the actions to increase the circularity around the following three elements: the blades of the wind turbines, photovoltaic solar panels and batteries. The second line of action is horizontal action for the promotion of the circular economy in enterprises. It grants aid to promote the sustainability and circularity of production processes.

Later, *Law 7/2022* on waste and contaminated soils [63] was approved. This law, which replaces the Law 22/2011 [58], transposes the European Directives 2018/851 [42] and 2019/904 [64]. Its main objective is to promote the circular economy through the development of the following three main objectives: to regulate the legal regime of products in relation to their waste, to manage the prevention and production of waste and to regulate contaminated soils.

Finally, it is worth mentioning the roadmap for the management of mineral raw materials [65]. This document emphasizes that the transition process to a more sustainable economy, particularly the energy transition process, will reduce the dependence on fossil energy but will increase the demand for certain materials and raw materials. Therefore, it sets out the lines of action to guarantee the supply of strategic raw materials. These lines of action are formulated to contribute to the energy and digital transition and to promote the industrial independence of Spain from international markets. Thus, one of the priorities is to develop a list of strategic materials for the green industry. Specifically, the aim is to reduce dependency through the promotion of resource circularity, innovation, sustainable

domestic supply and the diversification of supply. To this end, it focuses on regulatory, sectoral, cross-sectoral and R&D instruments.

5.4. The Circular Economy in the Autonomous Communities

In Spain, basic environmental legislation is the responsibility of the national government. However, the Autonomous Communities are free to publish their own law on the circular economy. This decentralization of competences has led to the existence of different laws, strategies and plans in each of the Autonomous Communities.

The first region to have a circular economy law was Castilla-La Mancha. Although Law 7/2019 [66] is brief, with only nine articles, it shares similar objectives to Law 7/2022 [65], including the optimization of industrial organization and the promotion of the use of the carbon, water and ecological footprint indicator. Since this law, a significant development of rules and regulations has been observed in the Spanish regions [7]. In 2022, the Valencian Community passed Law 5/2022 on waste and contaminated soils for the promotion of the circular economy [67]. The Balearic Islands also has its own legislation on circular economy, Decree-Law 3/2022 [68], focused on the circularity of tourism. Other communities, such as Madrid and Andalusia, have approved their draft laws in 2023 [69,70]. In addition, several Autonomous Communities, such as the Basque Country, Castile and León, Navarre, Galicia, Extremadura, Catalonia, the Canary Islands, Asturias and Aragon, have strategies, agendas or plans, as shown in Table 4.

It should also be noted that municipalities have recently been involved in the promotion of the circular economy in Spain. Their interest has been growing since the signing of the Seville Declaration [71] in 2017, which marked the beginning of the commitment of cities and municipalities to move towards a circular production system. In fact, this declaration was signed by 231 local authorities, representing more than 20 million people. As a result of this interest, a local strategy for the circular economy was published in 2019 [72]. This strategy is divided into the following three main parts: the diagnosis, the municipal action plan and its monitoring. The actions are concentrated around the following five main goals: reducing the use of natural resources, improving water management, the sustainability of urban spaces, promoting sustainable spaces and practices and cross-cutting policies. Later, the Valladolid Declaration [73] was signed, highlighting the role that local institutions should play in promoting the circular economy and the need to promote the role of entrepreneurs.

Table 4. Instruments of the circular economy in the Autonomous Communities.

Autonomous Communities	Instrument	Year	Name
Andalusia	Strategy	2018	Andalusian Strategy for Circular Bioeconomy-Estrategia Andaluza de Bioeconomía Circular
Andalusia	Law	2023	Circular Economy Law-Ley de Economía Circular
Aragon	Strategy	2020	Aragón Circular Strategy-Estrategia Aragón Circular
Asturias	Waste Plan	2017	Strategic Waste Plan of the Principality of Asturias 2017–2024-Plan Estratégico de Residuos del Principado de Asturias 2017–2024
Balearic Islands	Waste Law	2019	Balearic Islands Waste and Contaminated Soil Law-Ley de residuos y suelos contaminados de las Illes Balears
Canary Islands	Strategy	2020	Canary Islands Circular Economy Strategy 2021–2030-Estrategia Canaria de Economía Circular 2021–2030
Canary Islands	Law	In process	Canary Islands Circular Economy Law-Ley de Economía Circular de Canarias
Cantabria	Roadmap	2020	Cantabria Roadmap 2030-Hoja de Ruta Cantabria 2030

Table 4. Cont.

Autonomous Communities	Instrument	Year	Name
Castile-La Mancha	Strategy	2021	Circular Economy Strategy of Castile La Mancha 2023-Estrategia de Economía Circular de Castilla La Mancha 2023
Castile-La Mancha	Law	2019	Castile-La Mancha Circular Economy Law-Ley de Economía Circular de Castilla-La Mancha
Castile and Leon	Strategy	2021	Castile and León Circular Economy Strategy 2021–2030-Estrategia de Economía Circular Castilla-León 2021–2030
Catalonia	Strategy	2021	Catalonia Bioeconomy Strategy 2023-Estrategia de Bioeconomía de Cataluña 2023
Catalonia	Strategy	2015	Catalan eco-design strategy for a circular and innovative economy-Estrategia Catalana de ecodiseño para una economía circular e innovadora
Catalonia	Strategy	2015	Catalan Strategy to Promote the Green Economy and the Circular Economy-Estrategia Catalana para promover la economía verde y la economía circular
Extremadura	Strategy	2021	Green Economy and Circular Economy Strategy-Estrategia de Economía Verde y Economía Circular
Galicia	Strategy	2019	Galician Circular Economy Strategy 2019–2030-Estrategia Gallega de Economía Circular 2019–2030
La Rioja	Strategy	2020	La Rioja Circular Economy Strategy 2030-Estrategia de Economía Circular de La Rioja 2030
Madrid	Law	2023	Community of Madrid Circular Economy Law Ley de Economía Circular de la Comunidad de Madrid
Murcia	Strategy	2017	Circular Economy Strategy of the Region of Murcia 2017–2030-Circular de la Región de Murcia 2017–2030
Navarra	Roadmap	2019	Agenda for the Development of the Circular Economy in Navarra 2030-Estrategia de Economía Agenda para el desarrollo de la Economía Circular en Navarra 2030
Basque Country	Strategy	2019	Circular Economy Strategy 2030-Estrategia de Economía Circular 2030
Valencia	Waste Plan	2019	Integral Waste Plan of the Valencia Region-Plan Integral de Residuos de la Comunitat Valenciana

Source: own elaboration from MITECO [74].

5.5. Key Data on the Circular Economy in Spain

Figures 3–6 show the evolution of the main indicators of the circular economy in Spain in relation to the EU according to the EU monitoring framework.

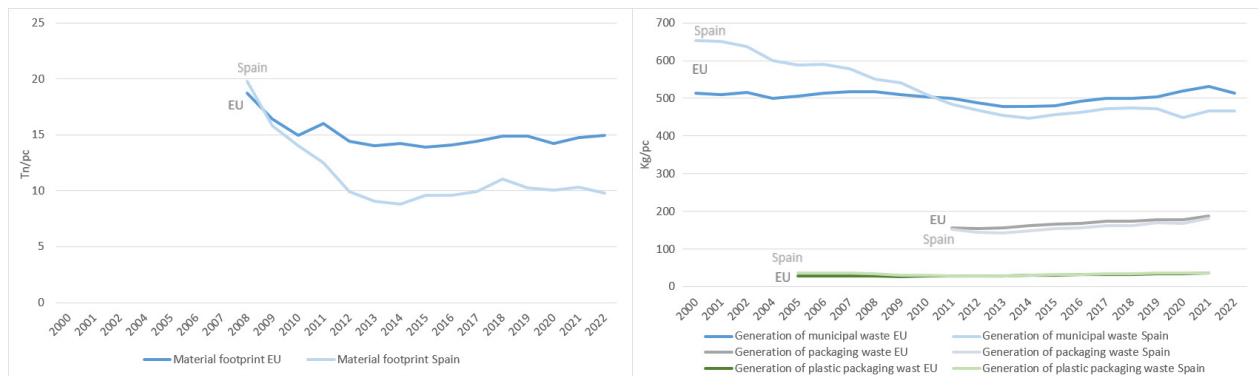


Figure 3. Circular economy indicators: production and consumption. Source: own elaboration from Eurostat [17].

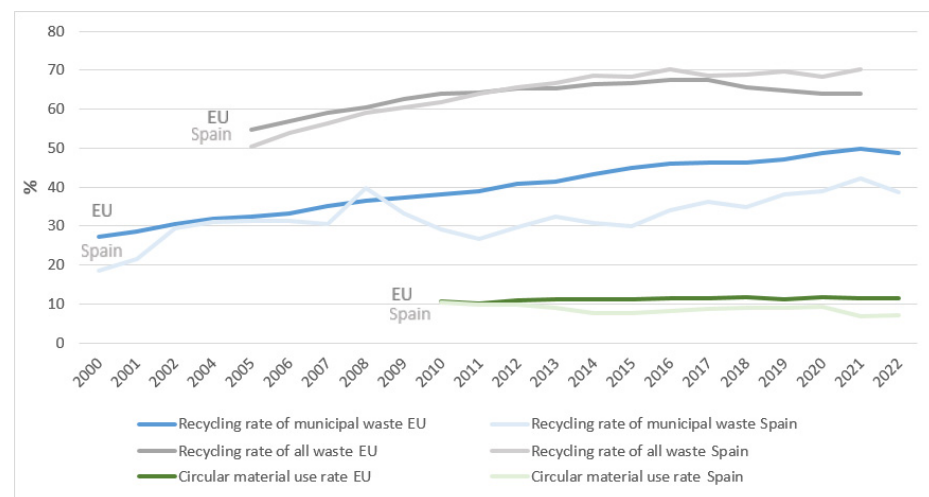


Figure 4. Circular economy indicators: waste management and secondary raw materials. Source: own elaboration from Eurostat [17].

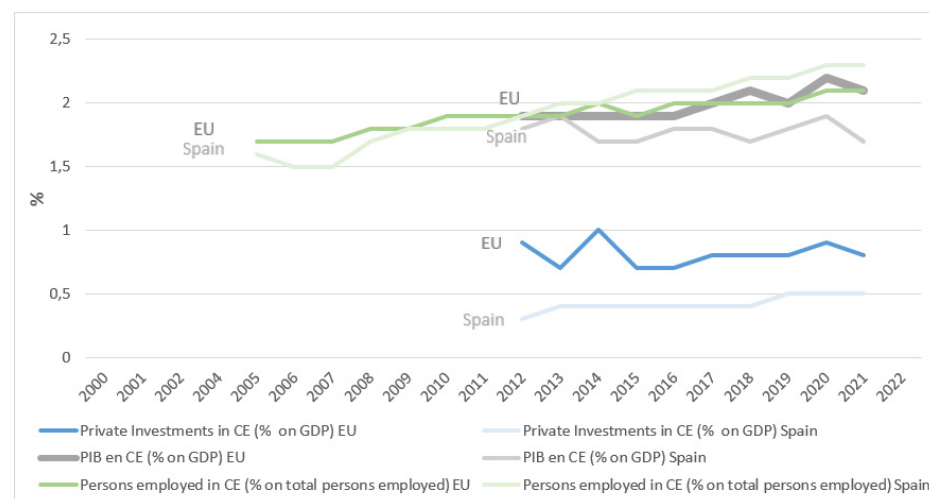


Figure 5. Circular economy indicators: competitiveness and innovation. Source: own elaboration from Eurostat [17].

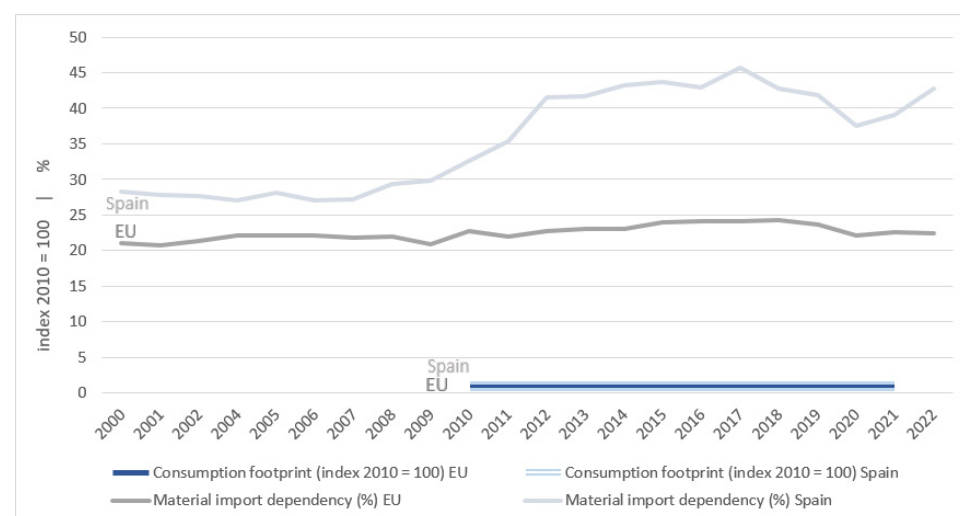


Figure 6. Circular economy indicators: sustainability and resilience. Source: own elaboration from Eurostat [17].

Figure 3 shows the production and consumption indicators linked to the circular economy. Both the consumption footprint and waste generation indicators are lower than in the EU. Moreover, the value of waste generation has decreased by 40% since 2004. This may be related to the decrease in chemical, textile and plastic waste [4]. However, there is an increase in packaging and electronic waste, which has doubled from 2009 to 2018. This increase, similar to the EU, may be linked to the digitalization of the economy and increased online sales.

Despite this good evolution in terms of waste generation, it is worth noting the decrease in the packaging recycling rate in recent years (Figure 4). Contrary to the stable value at the end of the period for the EU, Spain has decreased its value and returned to the values before 2010. On the other hand, the recycling rate of municipal waste is also lower than that of the EU. Despite a certain convergence to the EU values, since 2015, the decrease after the COVID-19 epidemic is more pronounced than in the EU. It also shows a low value for the material recycling rate, which also declined from 2020 onwards by 3 percentage points. The practically constant value of this indicator for the EU, and the decrease in its value for Spain, make it difficult to achieve the objectives set for 2030 in the Circular Economy Action Plan, which is to double its value in 2015 for the 2030 horizon.

Spain also presents negative data in terms of the relative economic importance of the sector. As shown in Figure 5, in 2021, these activities accounted for only 1.9% of GDP in Spain compared to 2.1% in the EU. Similarly, private investment in these sectors is lower than in the EU, although the difference has been decreasing over time. Despite these negative figures, it should be noted that Spain has higher employment values in the sector, with an upward trend. However, according to the Cotec Report [7], this value may be related to Spain's lower productivity in the sector; therefore, it may be necessary to improve the efficiency of the resources used.

Finally, Figure 6 shows the evolution of the indicators related to the sustainability and resilience of the sector. The consumption footprint is like that of the EU, with a constant value around index 1. However, the share of material imports in total imports is much higher in Spain, with a difference of more than 20 percentage points in 2022. The Spanish economy is therefore more vulnerable to foreign trade. This means that it is more important for Spain than for the EU to have a well-functioning circular economy that provides sufficient materials for the production chain without having to resort to foreign markets.

Even though Spain presents, in general terms, more negative values in circular economy indicators than the EU, it has significantly improved in its transition towards the circular economy since the implementation of the 2020 Circular Economy Strategy. The greatest progress has been made in terms of the reduction in the waste generated. In addition, resources are being mobilized to promote the circular economy through Next Generation EU Cotec [7] funds.

6. Conclusions

The implementation of the circular economy in the EU has its beginnings in the 21st century, although there are interesting precedents, such as the Fifth Environmental Program of 1993. Since then, some regulations have been developed, with a key regulation being the 2008 Directive, which aims to harmonize previous legislation on the subject. This strategy overlaps, at least in part, with the transition to a low-carbon economy.

In 2014, the EU started to adopt a new approach to waste issues, introducing the concept of the circular economy. The 2015 Action Plan was a decisive step in promoting the circular economy, setting out 54 specific measures affecting different aspects of product processes. Since then, the links between the circular economy and energy transition goals have become intertwined.

Following this plan, the implementation of the circular economy is being consolidated through the development of several directives that reflect the EU's commitment to the

efficient use of resources and the establishment of a framework for monitoring the objectives of the Action Plan.

This implementation process has involved the transposition of European regulations at the national level. However, the different legal frameworks of the Member States, and their different economic contexts, have led to an uneven adaptation. This is reflected in the adoption of different circular economy strategies (10 countries have not yet adopted them). This difference in legislation is also reflected in the different level and evolution of the rates of the circular use of materials, with the Netherlands being the country with the highest value and Romania and Finland being the countries with the lowest. In terms of growth, Malta, Belgium and Italy stand out with rates of 70–80%, while Luxembourg and Finland show setbacks.

In Spain, the first legislation related to the analysis of the circular economy is Law 10/1998 on Waste, later replaced by Law 22/2011. However, it was not until the signing of the Pact for a Circular Economy in 2017 that the transformation of the linear model into a circular one began. The approval of the Spanish Strategy for a Circular Economy in 2020 represents the adoption of the EU approach in this matter. It links the circular economy with the decarbonization process and the resource-efficient economy.

Lately, some other roadmaps have been established, such as the strategic project for economic recovery and transformation in the circular economy (linked to the recovery from COVID-19) and the roadmap, for the sustainable management of mineral raw materials. These documents were written to include actions directly related to transforming the energy system. Likewise, some Autonomous Communities have published and adopted specific laws, strategies and plans to promote a circular economy in their territories.

The development of these regulations has allowed Spain to significantly improve its transition to a circular economy. However, these improvements are insufficient to reduce waste generation and to implement more sustainable treatment methods. In addition, Spain presents insufficient data on the circular economy sector in economic terms, with values lower than the EU as a percentage of GDP and private investment. Likewise, Spain's vulnerability to externalities is higher than the EU, making the existence of a well-functioning circular economy and the availability of sufficient materials for the production chain and the energy transition particularly important.

This study shows the evolution of the implementation of the circular economy in the EU and Spain, identifies the main measures that contribute to the development of a low-carbon economy and analyzes in a descriptive way the indicators used to measure the degree of implementation of such an economy. This study is therefore limited to a descriptive overview. Therefore, it is not possible to draw conclusions about the effectiveness of the identified measures, nor to determine which of them allow for the further development of the circular economy. Given this limitation and the results of this study, future research could advance these goals in two ways. On the one hand, it may be useful to extend the study to the rest of the EU countries in order to compare how the circular economy is implemented in these countries. Secondly, it may be interesting to carry out analytical studies to assess the effectiveness of specific measures, both on the circular economy and on their impact on the development of a low-carbon economy.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

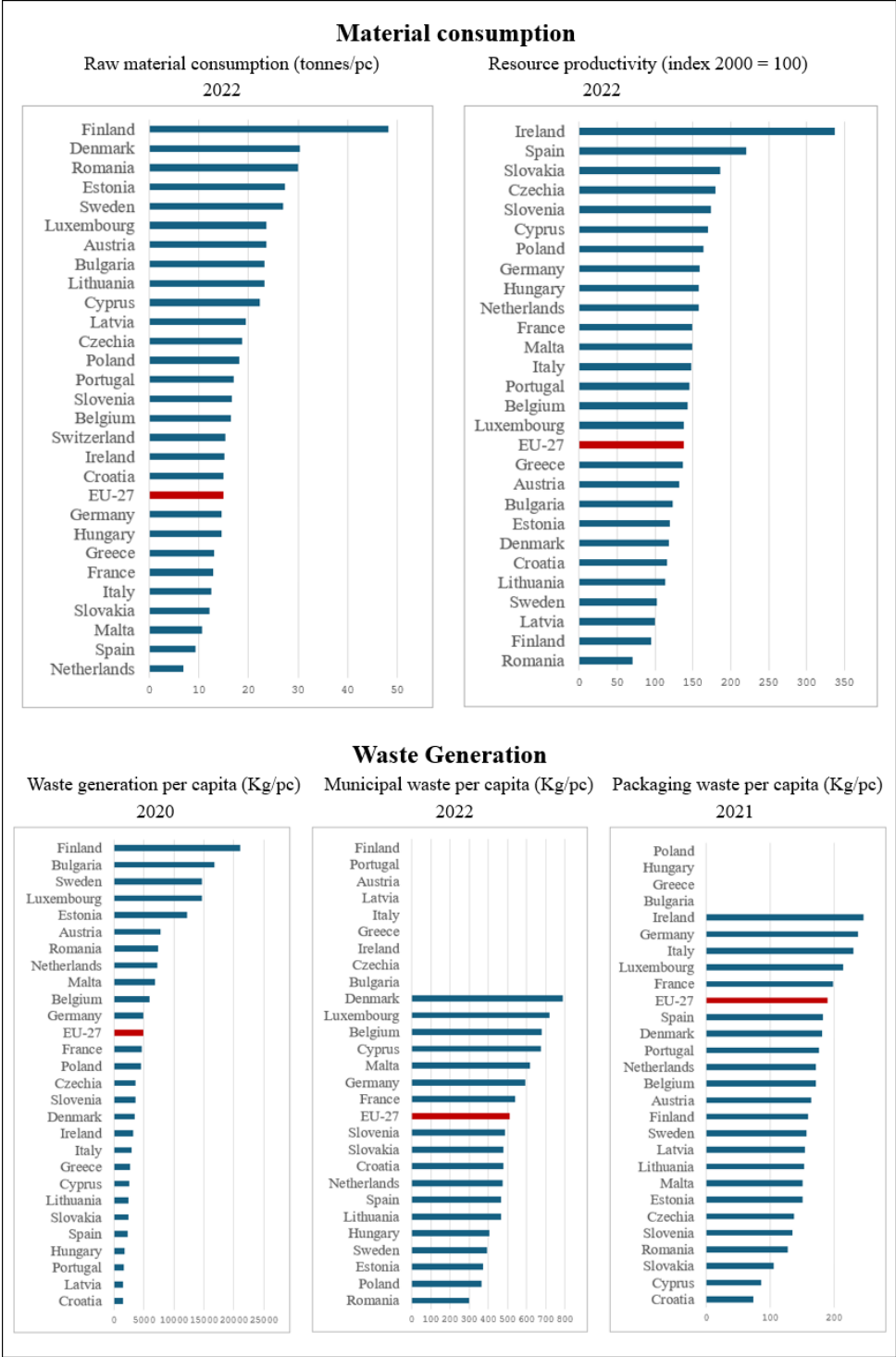


Figure A1. *Cont.*

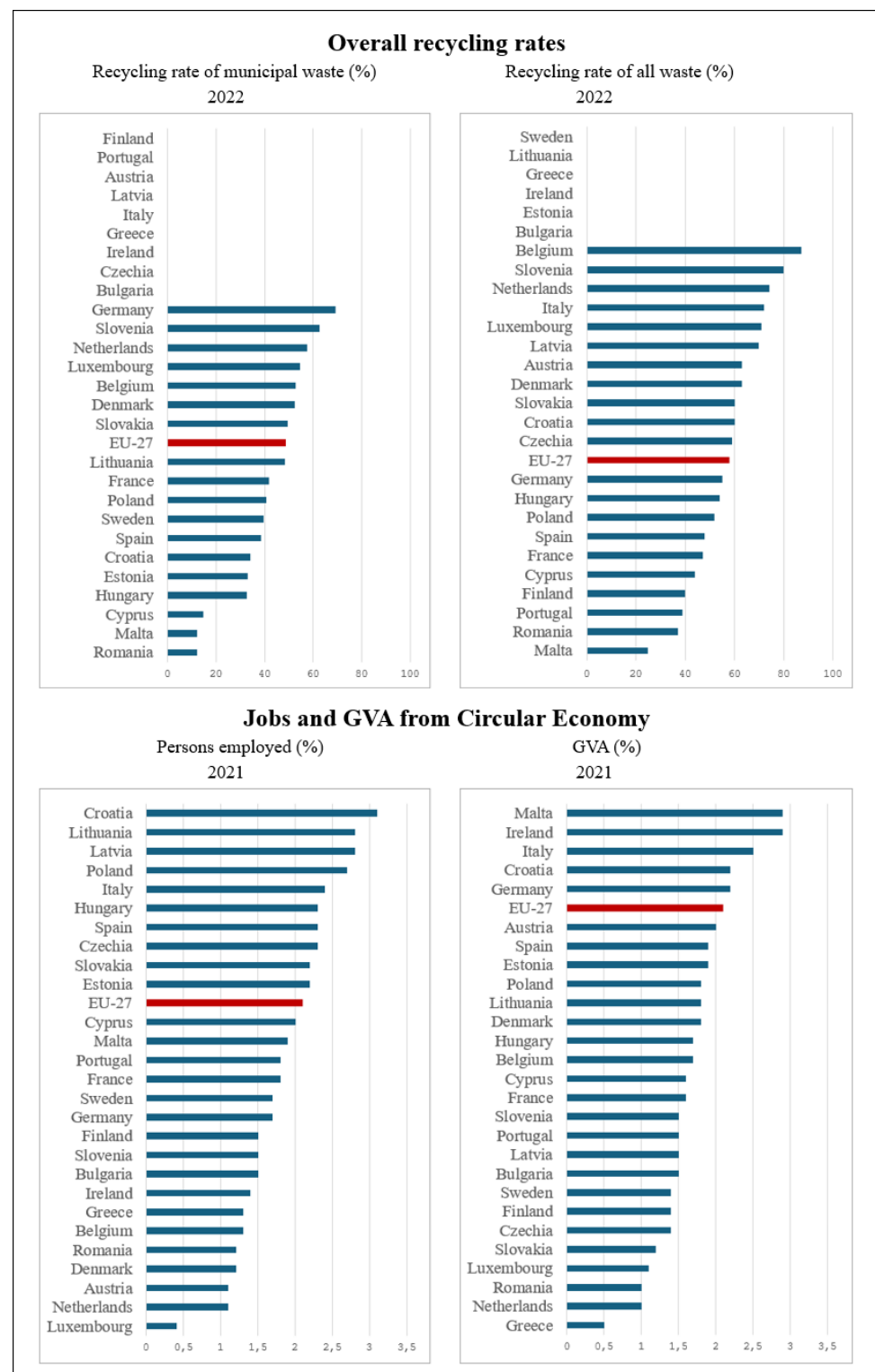


Figure A1. Production and consumption, waste management, and competitiveness and innovations circular economy indicators for the EU. Source: own elaboration from Eurostat [17]. Note: EU values are from 2020. When data are not available, the countries are shown with no representation.

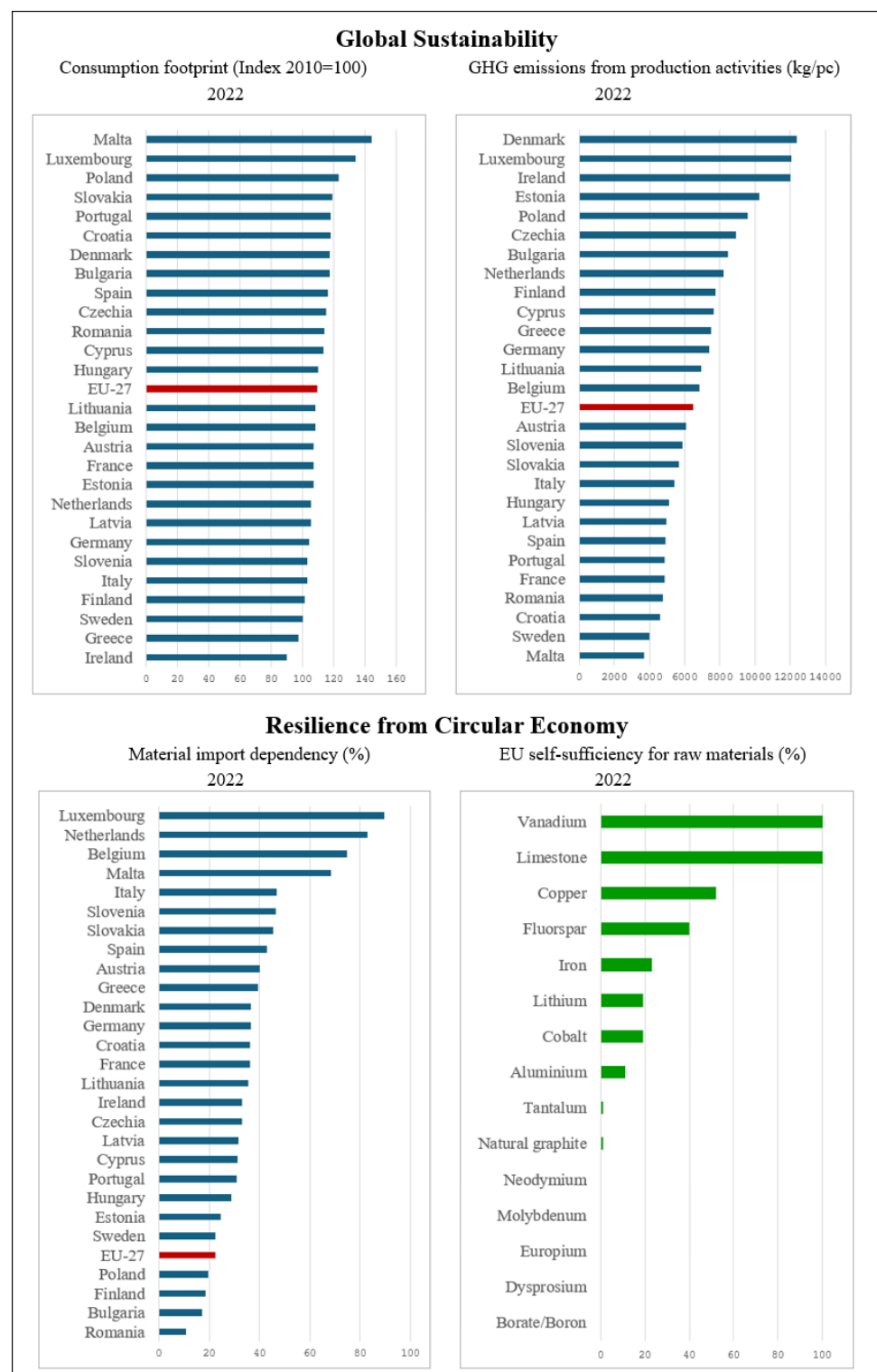


Figure A2. Global sustainability and resilience circular economy indicators for the EU in 2022. Source: own elaboration from Eurostat [17]. Note: EU values are from 2020. When data are not available, the countries are shown with no representation.

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