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ENVIRONMENTAL POLICIES, WASTE AND CIRCULAR CONVERGENCE IN THE EUROPEAN CONTEXT

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Abstract. This work explores the transition process towards a circular economic model in the European context. By placing the role of policies and waste as a focus of the debate, it first examines the possible effects that a stringent policy can generate and, secondly, how much waste and its management can influence the goodness of the transition process. By analyzing European data on major indicators of circularity, waste generation, and management, this paper attempts to provide a snapshot of the European situation and its different speeds along the transition path. In light of the recent development programs established by European institutions in the aftermath of the Covid-19 pandemic that strained the world economy, the trends show how program resources should be directed towards key sustainability sectors that can stimulate European countries towards a common circular pathway.

Keywords: Environmental policy; Circular Economy; Waste Management; Sustainability transition

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JEL Classifications: Q53, F64, E61

1. Introduction

During the last few years, concerns over the long-run effects of climate change and the pressures on ecosystem services in Europe have increased (EEA, 2019a). Although the European Union (EU) environmental policies have undoubtedly provided essential benefits, many European countries face urgent environmental issues due to global megatrends amplifying the environmental crisis, implying multiple environmental, societal and economic challenges (EEA, 2019b). The EU is experiencing numerous transitions linked to important demographic, technological, fiscal and financial structural changes that may affect the effectiveness of the long-term EU policy objectives to achieve a sustainable transition and decarbonization of EU's members during the first half of this century (EEA, 2019b). Therefore, a proper and effective ecological transition must be placed within a policy process that integrates different dynamics of sustainability and change (technological, fiscal, demographic, etc.),

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which may come into conflict, undermining the social acceptability of the sustainability transition itself (EEA, 2019b; Mazzanti and Pronti, 2021).

This systemic and multidimensional macro-perspective is embedded in the EU strategic macro-sustainability long-term strategy and related policy framework recently established by the European Commission (EC). European countries are undertaking the most important path toward an unprecedented ecological transition through the implementation of the Next Gen EU (NGEU), the European post-pandemic recovery program for EU's member states, which has the ambitious objective of restructuring the whole European socio-economic system (NGEU, 2022). The NGEU program is the largest public stimulus ever to the European economy to support reforms and investments to "make European economies and societies more sustainable, resilient and better prepared for the challenges and opportunities of the green and digital transitions" (NGEU, 2022). The post-pandemic recovery program is strictly linked to the European Green Deal (EGD), the EU Commission program for a total restructuring of the whole European economy toward a zero-carbon transition to be reached by 2050 (EGD, 2022). The EGD's main goal is to reach carbon neutrality for EU members by 2050, with an initial cut in carbon emissions by 50% from 1990s levels in 2030, and decoupling economic growth from resource use (EC, 2019; EEA, 2021).

Moreover, the EU is moving toward a digital transition of its members which is embodied in the communications "Shaping Europe's digital future" and "Europe's Digital Decade: digital targets for 2030", which jointly aim at improving the connectivity and digitalization of the public and private sectors to increase the EU's overall productivity (EC, 2021, 2020). The EU's Digital transition is strictly linked to the ecological transition. It will play a relevant role in supporting at the same time the achievement of the Green Deal objectives' in many different sectors as a key element for decoupling through increased productive efficiency and dematerialization of products into services to stimulate material circularity (FEEM, 2020, 2019). A widespread digitalization is an enabler of the 'Fourth Industrial Revolution' that can provide more integrated and efficient production processes, new jobs and economic growth (EEA, 2021). The NGEU has implemented the ecological and the digital transitions (known as twin transitions) with a total public expenditure of at least 37% of the Recovery and Resilience Facility (RFF) plans to support the green transition, and at least 20% to boost the digital transition (EC, 2022a; NGEU, 2022).

The recent public interventions carried out by the European Community represent an unprecedented opportunity for an epochal ecological and digital transformation of the whole European economic system toward a decoupled and sustainable system in which economic growth is materially efficient and detached from the production of waste. EU environmental policies, i.e. regulatory, economic and voluntary tools, may substantially contribute to fostering sustainability actions in production and consumption activities (e.g. eco-innovations, increasing resource and energy efficiency, circular economy) which can lead to the decoupling of economic growth from environmental depletion (Fusillo et al., 2020).

However, the effectiveness of EU policies for the ecological transition is difficult to monitor at this implementation stage, as they are still in progress and need an adequate framework for counterfactual analysis. But the need to understand the potential scenarios and effects of the new EU's policy framework is of extreme relevance, and the first step might be a descriptive analysis of the main trends that occurred in the recent past among EU countries.

The flow of waste treated in the EU domestic market (or abroad) represents a tool to monitor main trends to quantify the effects after the Rio Conference in 1992, which may be considered as the first steps on the path towards environmental transition taken by European countries (Marin et al. 2017). In turn, another aspect to be monitored to assess sustainability performances and ecological public objective achievements is how all the waste generated within the socio-economic system is reduced as avoided waste through reuse, recycling and the repair of goods.

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This last point is strictly linked to the concept of circular economy as a new productive model opposite to the predominant "take, make and dispose" paradigm more focused on regeneration, restoration of energy and materials and the resiliency of the productive system (de Jesus et al., 2021). This model is based on closing the loop of energy and materials used within the economic system through a structural change of the productive system as a whole (from the extraction to the end of use) to build long-term resilience, business opportunities and social benefits (Suchek et al., 2021).

The paper contributes to the scientific debate on waste management and circular economy, on the one hand, by providing a comprehensive description of the main EU legal framework on waste and circular economy, and on the other, by analyzing the most recent Eurostat data on waste and material flow at national level highlighting main macro-trends, in terms of waste management and circularity, occurred in the EU in the last 20 years. The work offers a detailed analysis of the EU policy framework and the main trends on waste and circularity of materials which can be used to qualitatively discuss the main weakness, strengths, and future scenarios of the EU in achieving the decoupling and sustainable transition goals decoupling and the main objectives of the sustainable transition of the NGEU and EGD programs.

The paper is structured as follows: Section 2 offers a short background on the interplay between Environmental policies, Waste management and the Circular economy concepts; Section 3 provides a background on the waste management policy framework at EU level, describing the most relevant normative linking waste management practices to the CE concept; in Section 4 are described the most relevant trends at EU level on waste and material flow; in Section 5 a discussion on the main trends, policy implications and potential scenarios is performed; finally the paper presents some concluding remarks highlighting the central point for the future research agenda and policy analysis perspectives.

2. Background

2.1 The role of environmental policies for sustainability

Decoupling assumes a crucial role in integrating economic, technological and environmental dimensions in sustainability and ecological transition. Decoupling can be defined as the general reduction of environmental impacts related to productive activities, either by considering the use of resources in production processes per unit of output or the reduction of the environmental effects (waste, pollution and other negative externalities) of each individual unit of output (UNEP, 2011). The decoupling process associated with the use of resources and emissions of pollutants is one of the key factors in describing the growth of social welfare and economic prosperity by limiting the environmental impacts, thanks to the processes of technical and technological innovation, in a sustainable development perspective (Lodi et al., 2020). A classic example describing decoupling at a macro level is the environmental Kuznets curve[1] which outlines the relationship between economic development and environmental impacts and has an inverted U-shape. According to this theory, supported by environmental and innovation policies, the overall environmental impacts decrease to almost zero (Grossman and Krueger, 1995; Stern, 2004). Measuring decoupling between the economic, and environmental dimensions at the national level is essential to monitor impact reduction processes and sustainability performance at EU level, but it requires considerable effort. Therefore, It will be increasingly relevant to analyze territorial dynamics of innovation and structural changes to understand the real effectiveness of environmental policies and regulations. Decoupling is strictly related to increasing material efficiency to reduce resource extraction and creating waste along the supply chain or at the end of the consumption process to guarantee long-term sustainability (Speck and Zoboli, 2017).

[1] From Nobel Prize winner Simon Kuznets who studied the relationship between economic development and inequality

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Environmental policies and regulations have a crucial role in the sustainability transition. They may act as a booster for structural change in the economy, reshaping the sectorial industry mix by stimulating improvements in the technological system and new combinations of domestic production and consumption process influencing the overall sustainability performances of the economic system (Speck and Zoboli, 2017). Stringent environmental policies may release twofold benefits: reducing environmental impacts and improving economic performances through greater eco-innovation due to higher competition (Costantini and Mazzanti, 2012; Porter and Linde, 1995). In this context, environmental innovations (Barbieri et al., 2016; René Kemp, 2010) are one of the most crucial enabling factors for the ecological transition by improving resource efficiency, reduction of materials extraction and the generation of waste (Speck and Zoboli, 2017). Nonetheless, environmental innovations can be hindered by a set of barriers such as financial constraints, high risks and organizational inertia (Ambec et al., 2013; Speck and Zoboli, 2017), which are especially strong in small and medium firms (SMES), that represents about the 93 per cent of the European total enterprises (Executive Agency for Small and Medium-sized Enterprises. et al., 2021).

The great public effort in terms of incentives in the forms of public policies and funds will help European firms to internalize part of the benefits of EIs, while reducing their innovation risks (Marin et al., 2015), and favoring a mass green technological change with important benefits for society at the same time (Popp et al., 2010). Technological change towards environmentally sustainable production models can lead to win-win situations in which environmental quality improvement and economic growth coexist by reducing the cost of achieving environmental objectives for society (Barbieri et al., 2016). This is well explained by the so-called 'Porter hypothesis' (Porter and Linde, 1995) which states that well-designed environmental regulations can translate into Pareto improvements leading to "innovation offsets" that can improve environmental performance and compensate for the additional cost of regulation. These are due to the increasing profits and competitiveness of the regulated sector that had obtained improvements in their products or their production processes compared to non-regulated ones (Ambec et al., 2013). Following Jaffe and Palmer (1997), one can identify mainly three different versions of Porter hypothesis: 1) "weak" which states that environmental regulations may spur innovation in general; 2) "narrow", indicating that flexible regulations have greater incentives for firms then prescriptive ones in terms of flexibility for compliance and 3) "strong" stating that innovation offsets may overcome regulatory costs increasing in an overall increase of competitiveness of a sector (or a nation) (Ambec et al., 2013; Jaffe and Palmer, 1997).

The 'Porter hypothesis' theoretical framework can be applied at micro- and meso-level considering firms or sectors respectively, alternatively, the Porter hypothesis may be tested at macro level considering regions and nations. Therefore, the analysis of the impact in a 'Porter hypothesis' view of the new EU green policy framework in terms of waste management and circularity would be remarkably interesting in terms of the potential domestic and international competitiveness of European countries. But this is extremely complicated for two main reasons. The first is that even if the 'Porter hypothesis' has a strong theoretical appeal, empirical evidence is unclear (Barbieri et al., 2016). Secondly, the difficulty of applying the 'Porter hypothesis' framework is even more complicated when one considers that this political process is still ongoing and counterfactual analyses are not possible.

2.2. Waste Management and Circular Economy

As Periathamby (2011) stated, waste represents a by-product of human activities investing in every aspect of social and economic life. The current aim of the European Union is to find a strategy to promote waste prevention and apply a waste management hierarchy. According to van Ewijk and Stegemann (2016), the Waste Hierarchy (WH) concept originates from prioritizing reduction, recycling, and reuse of waste over treatment or disposal. In 2008, the WH principle was included in the Waste Framework Directive 2008/98/EC (WFD) (European Parliament and Council, 2008). It was subsequently transposed into the national law of European Union (EU)

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Member States. The European WFD defines the waste hierarchy as the priority order of operations to be followed in waste management: prevention, preparing for reuse, recycling, other recovery (including energy recovery), and disposal. In 2015, the Circular Economy Strategy from EU COM/2015/0614 (EU Commission, 2015) defended the role of waste management based on a waste hierarchy as the way to lead to the best overall environmental outcome and to get valuable materials back into the economy. Although there are attempts to quantify waste operations by a single indicator, there is still no shared consensus (Pires and Martinho, 2019), nevertheless, WH is present in all national and international regulations as a tool to promote the implementation of the Circular Economy (CE). Despite the concept of CE has been extensively investigated by the current literature, for the CE a commonly accepted conceptual framework does not exist yet, and CE builds its strength based on several concepts developed since the late 20th century[2]. It shares, for example, the tentative idea of surpassing the current open-ended economy by relating to Boulding's idea of a spaceman economy. CE also calls for the application of integrated, productive processes in line with the industrial ecology of Frosch and Gallopoulos (1989). Later on, the CE concept was combined with different notions, e.g. clean production (de Jesus et al., 2018; de Jesus and Mendonça, 2018; Kalmykova et al., 2018), product-life extension, material efficiency (Rashid et al., 2013), product- service systems (Stahel, 1982), Cradle-to-Cradle (McDonough and Braungart, 2002). Many relevant definitions embrace the holistic dimension in which the CE concept lies. Among the others, the Ellen MacArthur Foundation recognizes CE as an industrial economy that is restorative by intention; aims to rely on renewable energy; minimizes, tracks, and eliminates the use of toxic chemicals; and eradicates waste through careful design (Ellen MacArthur Foundation (2013), p. 22). The EU Commission, in turn, defines CE as an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and waste generation is minimized (p. 2). Against this background, it emerges that CE strives for a new approach based on minimizing resource use and waste accumulation by creating continuous cycles of materials. The current linear model indeed exceeds the environmental capacity. So, as the availability of resources and the regenerative capacity of renewable sources are depleted, multiple economic consequences will emerge, such as increasing prices, materials shortage or dependence. Given these assumptions, recycling is typically referred to as one of the strategies of the WH to move from a linear to a circular economy (Alaerts et al., 2019). Still, as Iacovidou et al. (2017) pointed out that the recycling rate is not a measure of the goodness of the overall waste operations quality, efficiency, and sustainability, since it can show only the waste that is re-entering the economy. It represents only a segmented indicator.

As Mazzarano et al. (2021) state, the waste role is more ambiguous in a circular economy where actions range from waste prevention to allowing waste production as a source of material and resources. This ambiguity generates a sort of duality in the common view: on the one hand, a stringent environmental policy - could improve the overall environmental quality by increasing the level of eco-innovation and implementing in this way the CE; from another hand, decreasing waste production could mean reducing the amount of waste that - in such a way- is the feed of the circular model increasing the intrinsic value of waste and making it even more attractive to countries where the policy is not stringent. What emerges is that maintaining the current stock of resources constantly became, therefore, a challenge. The WH recognizes prevention as the first step of environmental strategies and policies (Mazzanti et al., 2022), reducing waste and recycling human activities' by-products. Overall, the approach of CE regards: A) reduce new resources' extraction, favour efficient exploitation, and prioritize renewable materials; B) extend products' life through practices, e.g. of, repair, remanufacturing and reconditioning; C) valorize waste through recycling and integrated production process.

2.3 The EU Policy Framework on Waste and Circular Economy

The European Green Deal (EGD), introduced at the end of 2019, represents Europe's comprehensive strategy for a sustainable future (European Commission, December 2019). It serves as a long-term roadmap to transform the EU economy into a carbon-neutral by 2050, and resource-efficient. Due to its complexity, many new policies and

[2] In their work, Kirchherr et al. (2017) have identified 114 different definitions of CE

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measures have been issued at both EU and national levels. Among the others, in March 2020 a New CE Action Plan (COM(2020)98 final) was proposed, by underlying the pivotal role of CE in scaling up the transition toward zero carbon emission, the decoupling of economic growth from resource use, while guaranteeing competitiveness and social just (European Commission, 2020).

From a CE perspective, resources must remain in the cycle for as long as possible by minimizing the need for new raw materials extraction and waste accumulation into landfills. Indeed, current patterns of production and consumption put tremendous pressure on the ability of the environment to continue providing its services for the foreseeable future. This means a progressive degradation of natural biodiversity and the impossibility of guaranteeing development for present and future generations, which lies precisely in maintaining the quality and quantity of natural capital stable (Dasgupta, 2021).

To meet the demands of a new circular model, the European Union has worked to ensure more sustainable waste management in recent years. This concerns the development of a new vision, no longer aimed at the correct and safe management of waste into landfills, but at preventing waste generation, preserving the value of waste, and putting it back into the production cycle. In accordance, recent literature has recognized the central role of waste management in supporting environmental sustainability and the development of a circular economy. Specifically, numerous studies on the subject (e.g. Stahel, (2016); Fellner et al., (2017); Aghbashlo et al., (2019); Zeller et al., (2019)) have confirmed that more efficient resource management and the reduction of waste produced cannot prescind from the design and implementation of new waste management systems. For instance, as pointed out by Stahel (2016)and Ranjbari et al. (2021), while mainstream WM is aimed at preventing waste from being dispersed in nature by minimizing costs of collection and disposal, differently in a circular economy perspective, WM systems should process waste to favour its reinjection in the economy, hence avoiding new virgin materials' extraction.

As Chioatto and Sospiro (2022) highlight, in the last twenty years, EU has framed a comprehensive regulatory action aimed at shifting WM practices, based on end-of-stream solutions, to SWM systems focused on strengthening the relation between waste treatment and resource recovery (See Table 1 for a summary of the main EU Directives on waste). Specifically, to enable the reintegration of waste as a resource within the economic cycle». For this purpose, the waste hierarchy concept has been placed at the heart of the plan to achieve more sustainable waste management within Member States. The waste hierarchy provides an order of priority in waste management, and as Fig. 1 shows, waste prevention is the most preferred option, followed by reuse, recycling, recovery and ultimately disposal. Focusing on municipal waste, in the First 2015 CE Package, the EU has revised the main directives on waste, Dir 2008/98/EC (waste), Dir 1999/31/EC (landfill), Dir 94/62/EC (packaging), that were definitively amended on the 30/5/2018 with the new Dir 2018/851, Dir 2018/850, and Dir 2018/852.

For this purpose, the EU has set different MW management targets that Member States have to achieve by developing effective systems of waste-separated collection. For instance, by 2020 the reuse and recycling of waste materials (such as paper, metal, plastic and glass) from households shall be increased to a minimum of overall 50% by weight, and by 2025, the preparation for reuse and recycling of municipal waste shall be increased to a minimum of 55%, 60% and 65% by weight by 2025, 2030 and 2035 respectively. In addition, MSW landfilled should be reduced to less than 10% of the total MSW generated by 2035 (Directive 2018/851). Monitoring activities are, therefore, fundamental to understanding where we stand in the transition from WM to SWM to CE, which means what effect European policies have had and what obstacles need to be corrected.

First, it is essential to identify and analyze SWM performances that member states have achieved since the WFD came into force. Next, understand whether efforts and achievements are taking place homogeneously across the different states, thus whether policies can trigger a convergence process that allows for a transition that is not only circular but also equitable. In relation to this, recent studies have shown that the WFD has produced positive

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results in increasing recycling rates and decreasing landfilling. However, the transition path appears heterogeneous within EU countries.

Among others, Marin et al. (2017) Castillo-Giméneza et al. (2019a) and Castillo-Giménez et al. (2019b) revealed that there are still significant differences in the treatment of MSW: Northern and central EU countries report high recycling and incineration rates, however, Mediterranean and Eastern countries still dispose of large amounts of waste in landfills. Furthermore, despite these efforts and major improvements in waste management, the total amount of waste generated has not significantly reduced. Still, all EU economic activities generate 2.5 billion tonnes of waste, and households produce nearly half a tonne of municipal waste on average. In addition, the presence in certain EU countries of low recycling rates and low-quality recycles highlights the need for more efficient waste collection systems. For this reason, the EU Commission is revising the WFD to align waste management with the waste hierarchy and comply with the polluter pays principle European Commission (2020).

On the other side, it should be questioned and monitored, as Fellner et al. (2017) pointed out, whether increasing quantities of recyclable materials also effectively translate into increased secondary raw materials used by EU firms. Indeed, strengthening waste policy cannot effectively transition to a circular model. In this case, it is essential that, where waste management effectively saves resources that would otherwise be discarded, there are systems for feeding secondary materials back into new production cycles, thus saving new extractions of virgin materials. This requires overcoming the challenges connected with secondary raw materials' safety, availability, performance and cost, which hinder the creation of a well-functioning market able to compete against primary resources. Secondly, firms must be able to integrate secondary raw materials into their production processes and thus increase their share of the total resources used to manufacture goods. In this concern, the New CE Action Plan plans to introduce requirements for recycled content in new goods, preventing the mismatch between secondary raw material demand and supply. The EU plans to double its circular material use rate in the coming decade. Besides this, the Plan further foresees waste reduction targets and clarifies actions to favour reuse, repair and recycling. In addition, the Critical Raw Materials Strategy aims to support research and innovation on critical raw materials, significantly improving collection rates, recycling efficiency, and recovery and extending producer responsibility for these materials.

Table 1. EU legal framework on waste and circular economy.

	Objective	**Targets**
Waste Framework Directive (Directive 2018/851 of the European Parliament and the Council on amending Directive 2008/98/EC on waste)	Creates a legal framework for treating waste in the EU, intending to protect the environment (reduce raw material extraction and enhance resources' use) and human health. For this purpose, it favours recovery and recycling techniques.	• Set minimum requirements for **extended producer responsibility schemes** • Strengthen rules on **waste prevention** • Set **municipal waste targets:** by 2025, at least 55% of municipal waste by weight will have to be recycled. This target will rise to 60% by 2030 and 65% by 2035. • By 1 January 2025, **separate collection of textiles** and **hazardous waste** generated by households • By 31 December 2023, **biowaste** should be collected separately or recycled at source
Landfill Directive (Directive 2018/850 of the European Parliament and of the Council amending Directive 1999/31/EC on the landfill of waste)	Introduces more stringent requirements (technical and not) to prevent or reduce as much negative impacts (e.g. on surface water, groundwater, soil, air or human health) from waste landfilling.	• **Restrictions on landfilling**: from 2030 all waste that is suitable for recycling or other material or energy recovery • **Municipal waste landfilled** should be limited to 10% by 2035 • Introduces **rules on calculating** the attainment of **municipal waste targets** • Requires EU countries to create an effective **quality control and traceability system** for municipal waste landfilled
Packaging and Packaging Waste Directive (Directive 2018/852/EC 2018/852 of the European Parliament and the Council amending Directive 94/62/EC on packaging and packaging	Introduces more stringent measures, on the one hand, to prevent the production of packaging waste, and on the other, to better manage packaging residual through reuse, recycling and other forms of recovering packaging waste, in line with circular economy objectives.	• By 31 December **2025**, at least **65% by weight of all packaging waste must be recycled**. Includes targets per material: − 50% of plastic − 25% of wood − 70% of ferrous metals − 50% of aluminium − 70% of glass, and − 75% of paper and cardboard. • By 31 December **2030**, at least **70% by weight of all packaging waste must be**

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waste).		**recycled**. Includes targets per material: − 55% of plastic − 30% of wood − 80% of ferrous metals − 60% of aluminium − 75% of glass and − 85% of paper and cardboard.
Batteries Directive (Directive 2018/849 of the European Parliament and of the Council amending Directives 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment).	It aims at reducing the amount of hazardous substances dumped into the environment (e.g. mercury, cadmium and lead). First, it ban the placing on the market of certain batteries or accumulators with a mercury or cadmium above a fixed threshold. Secondly, it boost the increase of collection rates, reuse and recycling of waste batteries.	• **Prohibits batteries:** − containing more than 0.0005% by weight of mercury − containing more than 0.002% by weight of cadmium • Encourages end-users to discard spent batteries **at collection points** in their vicinity or to take them back at no charge by the producers • **Producers** (or third parties acting on their behalf) **have to bear the net cost** of collecting, treating and recycling industrial, automotive and portable batteries
WEEE Directive (Directive 2012/19/EU of the European Parliament and of the Council on waste electrical and electronic equipment (WEEE) (recast 2018/849/EC))	Encourages sustainable production and consumption. Specifically, it aims to prevent the creation of waste electrical and electronic equipment (WEEE), promote WEEE recovering practices (i.e. reuse, recycling), and favour the recovery of valuable secondary raw materials.	• Provides a **categorization of WEEE** (e.g. small and large equipment temperature exchange equipment, screens, lamps and small IT and telecommunications equipment) • Foster **cooperation between producers and recyclers** to design electrical equipment which can be reused, disassembled or recovered • Reduce the **unsorted WEEE disposal** in municipal waste • Ban the disposal of WEEE collected separately that has not been properly treated • Set a **minimum annual WEEE collection rate**: a target for collection of 85% of the total WEEE generated.
End-of-Life Vehicles Directive (Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of-life vehicles)	Establishes measures to prevent and reduce waste from end-of-life vehicles (ELVs) and their components through the promotion of their reuse, recycling and recovery.	• Manufacturers must ensure that **new vehicles** are: − reusable and/or recyclable to a minimum of 85% by weight per vehicle − reusable and/or recoverable to a minimum of 95% by weight per vehicle. − avoid the use of hazardous substances (e.g. lead, mercury, cadmium and hexavalent chromium) • Manufacturers, importers and distributors shall guarantee **collection systems for ELVs** and, whether technically feasible, used parts from repaired cars. • Manufacturers must meet all, or the majority, of the costs involved in delivering an ELV to a waste treatment facility.
Waste Shipment regulation (Regulation (EC) No 1013/2006 of the European Parliament and of the Council of 14 June 2006 on shipments of waste)	It controls waste shipment in compliance with environmental protection the provisions of the Basel Convention and the revision of the OECDs' 2001 decision on the control of transboundary movements of waste addressed to recovery operations.	• Parties involved in waste exchanges shall ensure that waste is managed in an **environmentally sound manner** • **Exports to non-EU countries** of waste for disposal are prohibited • Exports for **recovery of hazardous waste** are prohibited (except for those directed to countries to which the OECD decision applies) • **Imports from non-EU countries** of waste for disposal or recovery are prohibited, with some exceptions.

Source: Own elaboration

Fig. 1. Waste Hierarchy
Source: EU WFD

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3. Main trends on waste and circularity of materials

3.1 Data description

In this section, the main trends observed in terms of CE and waste management in European countries are shown. The data employed are from several Eurostat datasets focused on material circularity and waste management at EU level, considering both members and not members states. The main databases used in this paper are the Material flows and resource productivity and the Waste database from Eurostat. That database have been recently updated and offers a vital picture at macro level on material and waste management strategies at the country level, covering a timeframe of twenty years from 2000 to 2020. Data have been elaborated and ranked through Excel sheets, tables and graphs to give a clearer interpretation to the reader on the main trends that occurred among European selected countries in the last twenty years. By doing this, our analysis offers an introductory depiction of the results obtained in terms of decoupling and circularity in Europe. The trends analysis considers different aspects detailed in the sub-sections below.

3.2 Material Flow Accounts

These indicators are part of the Economy-wide material flow accounts (EW-MFA), a multi-purpose information dataset which provides an aggregate overview of the material flows within European countries' economies. The EW-MFA provide a rich empirical database for numerous analytical purposes; the indicators used in this analysis are: the Domestic Material Consumption per capita, the national Resource productivity, the Material import dependency and the Circular Material Use rate. All of those are expressed in different forms (e.g. total quantity, percentage, value, or quantity of waste per capita). As stated by Eurostat, the EW-MFA database covers solid, gaseous, and liquid materials, except for bulk flows of water and air (EW-MFA, 2022).

3.2.1. The Domestic material consumption per capita

The Domestic Material Consumption (DMC) is the most relevant indicator informing on material use by a given economy used in the literature for quantitative analyses on the circularity and material efficiency at the macro level (Bianchi et al., 2020). Combined with other socio-economic variables it can provide important information in terms of socio-metabolism (Krausmann et al., 2008) of an area with indications of the interactions and the coupling between society and the environment (Bianchi et al., 2020; Fischer-Kowalski et al., 2011). DMC is defined as the total material directly used in an economy equal to the domestic extraction plus the imports for inputs minus the exports of material extracted (EW-MFA, 2022). In this paper is used the DMC per capita as a measure of resource coupling of the economy for each domestic resident, and it represents all the net material extracted for productive purposes within a country per inhabitants[3]. It can be considered as an interesting measure of socio-metabolism to observe potential decoupling occurred over time. DMC per capita is based on the EW-MFA which considers the overall material inputs into national economy in tonnes per capita. EW-MFA covers all solid, gaseous, and liquid materials, except water[4] and air.

The average of DMC for the EU27 in the last twenty years did not change much, staying stable 15 Tonnes per capita. Still, data show important heterogeneities among countries with different trends over time. The majority of countries considered shown a stable level of DMC per capita, such as Belgium (15 Tonnes), Sweden (22 Tonnes) and Finland (34 Tonnes), even if with some dispersion over the timeframe considered. On the other hand, some countries shown a descending trend of DMC per capita, suggesting the decoupling of their economies or a general reduction of material extraction, whereas others showed an increasing trend of DMC per capita. Those showing a critical decreasing level of DMC are: Italy, Ireland, Spain, Iceland and Greece, with an overall reduction of the

[3] For the 'per capita' calculation of the indicator the average population is used (the arithmetic mean of the population on 1st January of two consecutive years) (EW-MFA, 2022).

[4] Water embedded in products is included (EW-MFA, 2022).

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DMC per capita larger than 30 per cent[5] . Increased efficiency of material explains this use both domestic and from an increase in the imports of materials which both indicate a decoupling of domestic economic activities or otherwise, by a rise in exported extracted materials to other countries.

Conversely, other East European countries have experienced a substantial increase in DMC per capita over the last twenty years, especially those which experienced higher levels of economic growth such as Poland (+25 percent), Bulgaria (+65 per cent) and Romania (+275 percent). This may also depend on the overall growth of economic activities after the beginning of the last century in Easter Europe due to cheap labour costs, which attracted an essential flow of investment from Western countries (Bianchi et al., 2020). Sweden is the only non-Eastern European country that experienced an increase in DMC per capita, with a total variation in the timeframe of +22 per cent. Figure 2 is shown the trend of a set of selected European countries from 2000 to 2020.

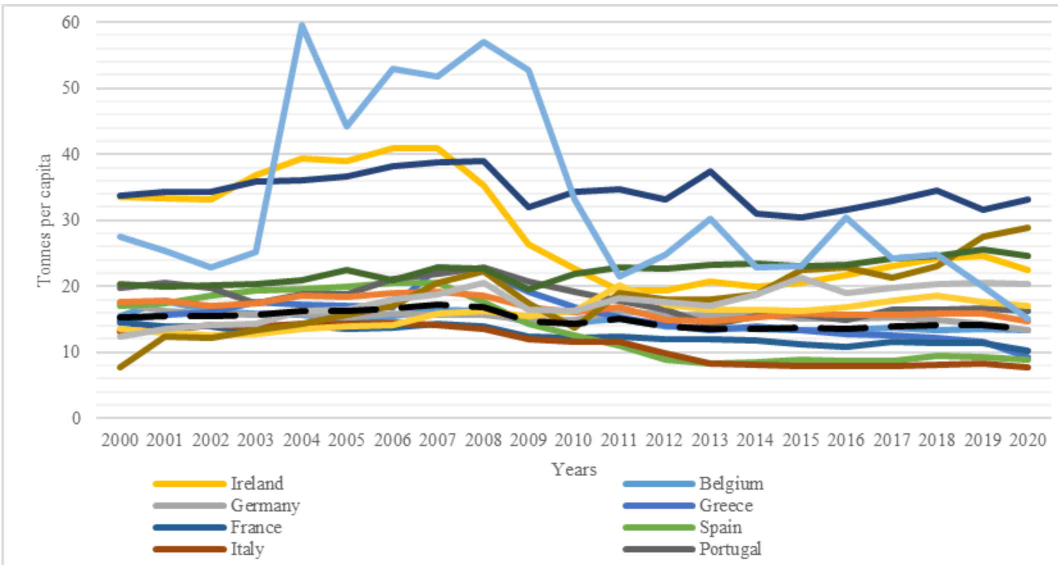

Fig. 2. DMC per capita (Tonnes per capita) for selected European countries and EU27 from 2000 to 2020.
Source: authors' elaboration on EW-MFA (2022) data.

3.2.2. The Resource productivity indicator

The resource productivity indicator is part of the EW-MFA (EW-MFA, 2022) data from Eurostat, and it is calculated as the ratio of gross domestic product (GDP) over domestic material consumption (DMC) using various units of measurement. This indicator reflects the GDP generated per unit of resources the economy uses, which can be presented alongside labour or capital productivity (EW-MFA, 2022). In this work, we used the resource productivity indicator expressed in terms of GDP in current prices expressed in purchasing power standard (PPS)[6] (Eurostat, 2022a) per Kilogram of DMC to remove differences in relative purchasing power across countries to increase comparability (Figure 3) and using the resource productivity with index the year 2000[7] to show the development of aggregates excluding inflation (Figure 4).

[5] It has been calculated considering the overall variation rate between 2000 and 2020.

[6] PPS is a fictional currency unit which considers purchasable parity among countries. The same amount of goods and services can be bought in each country. PPS are derived by dividing any economic aggregate of a country in national currency by its respective purchasing power parities (Eurostat, 2022a).

[7] Index, 2000=100 (based on GDP in chain-linked volumes normalized to 2000 prices) (EW-MFA, 2022)

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European countries generally experienced increased resource productivity during the period considered. On average, the EU27 countries show a value of 1.67 PPS per Kilogram of material extracted over the twenty years, with an overall variation of +86 per cent. As above, significant heterogeneities are evidenced among European countries in terms of value created, with best-performing countries showing average values above 2 PPS per Kilogram, such as Italy, Spain, Belgium and France. In contrast, all the other set of countries considered showed values higher than 1, indicating value creation (values above 1 evidence GDP greater than DMC, therefore a more significant value creation than material extraction). Only Romania, Bulgaria, Poland, Estonia and Finland (those last four are not presented in Figure 3) have shown values lower than 1, indicating a higher level of extraction than GDP, suggesting inefficiency in the use of resources.

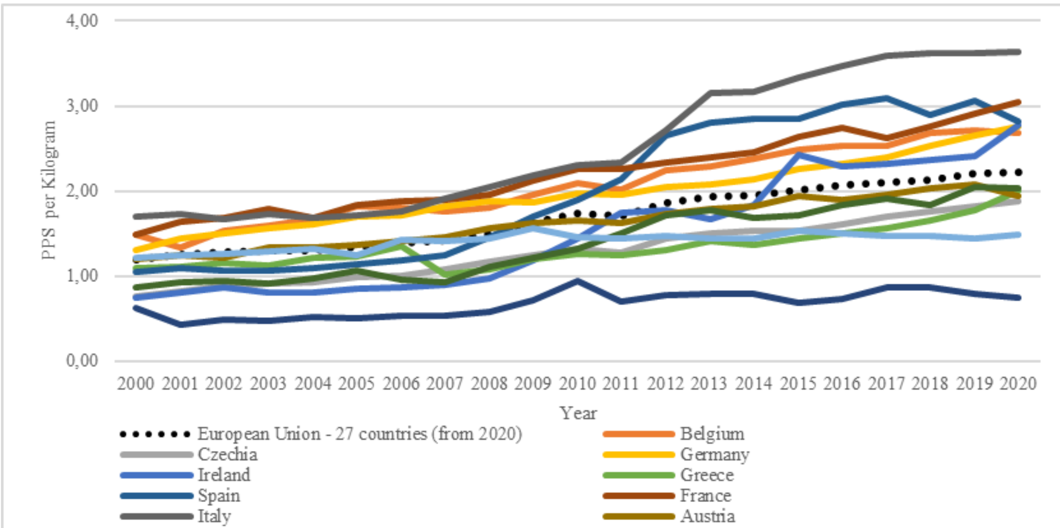

Fig. 3. Resource productivity in PPS per Kilogram of materials for selected European countries and EU27 from 2000 to 2020.
Source: authors' elaboration on EW-MFA (2022) data

In general, in terms of growth, all European countries had shown a positive growth rate of resource productivity, indicating that the GDP increased more than DMC and suggesting a partial decoupling, but not considering the potential outsourcing of material-intensive extraction and processing abroad (Bianchi et al., 2020). Figure 4 evidenced a positive increase in the resource productivity indicator compared to the year 2000, representing the baseline. Only Romania, as evidenced above, had experienced decreasing performances in resource productivity, suggesting a low level of efficiency in resource use.

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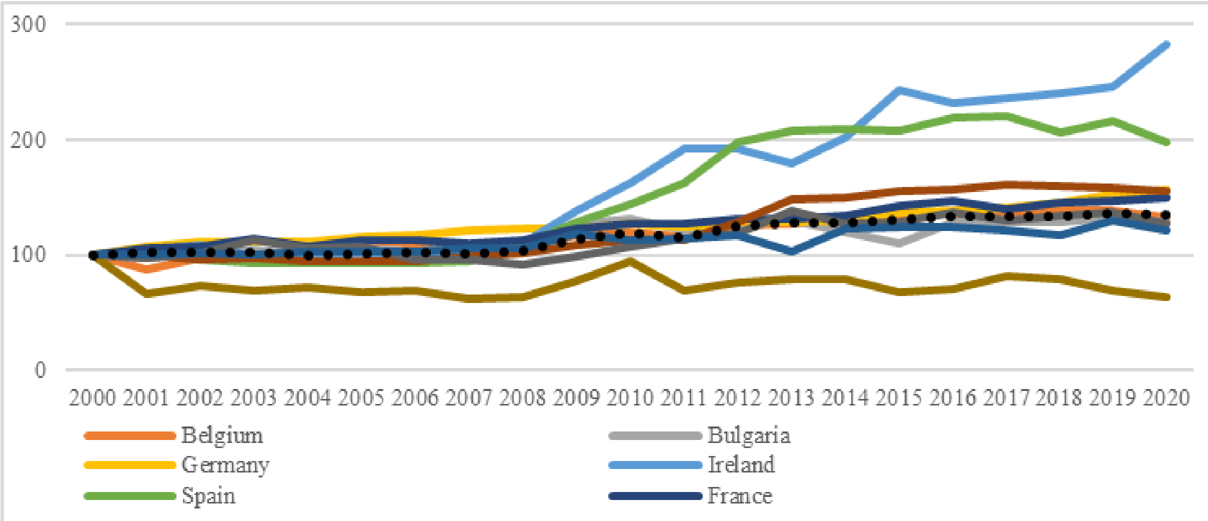

Fig. 4. Resource productivity with index=2000 for selected European countries and EU27 from 2000 to 2020.
Source: authors' elaboration on EW-MFA (2022) data

3.2.3. the Material import dependency indicator

The material import dependency indicator is also part of the Eurostat EW-MFA dataset (EW-MFA, 2022). It is computed as the ratio between imports and direct material inputs (DMI) which indicates the direct input of material into the economy both from direct extraction and from imports[8] (EW-MFA, 2022). It is expressed in the percentage of total imports on the DMI, and it indicates the importance of imports in meeting domestic material needs, value around zero indicate that a country does not rely on imports for its internal material needs, while values close to 100% indicate that no domestic extraction occurred and that the country totally on imports of materials from abroad to satisfy its material needs. The graphs in Figure 5 show the material import dependency indicator considering the total material[9] processed within a country for a set of selected countries.

The average rate for EU27 countries is an import material dependency ratio of 23% along the time frame considered but with high variability among countries with values larger than 70% for the Netherlands and Belgium and around 20% for Romania, Poland and Bulgaria. Overall, during twenty years since 2000 the indicator remained stable for many countries (an increase of the ratio of less than 50%), indicating that the structure of how materials are processed within European economies did not change over time. Nonetheless, some countries increased substantially their dependency from imports on materials for their domestic productions with an overall increase of the indicator in the timeframe considered, such as Czechia (+55%), Greece (+79%), Poland (+64%) and Slovenia (+64%). The only countries that experienced a reduction of the indicator are Romania (-31%), Sweden (-17%) and Bulgaria (-1%). In contrast, all the others remained stable with an average growth of 23% along the timeframe considered.

Those above may suggest that within the EU, not many improvements have been made in terms of self-sufficiency of material use, but anyway, this indicator does not reveal the origin of the materials, therefore it may

[8] DMI includes all materials of economic value and available for use in production and consumption activities. It is calculated as the sum of domestic extraction plus physical imports: DMI = DE + IMP. Where DE is the total amount of domestic extraction of material extracted within a country from the natural environment direct to other processing activities into the economy, and IMP indicates imports of products in their simple mass weight (EW-MFA, 2022).
[9] The total physical imports in relation to direct material inputs for all the materials processed within the economy considering Biomass, Metal ores, Non-metallic minerals and Fossil energy materials extracted domestically or imported (EW-MFA, 2022)

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also reflect an increase in the internal exchanges of materials within Europe itself in during the timeframe considered.

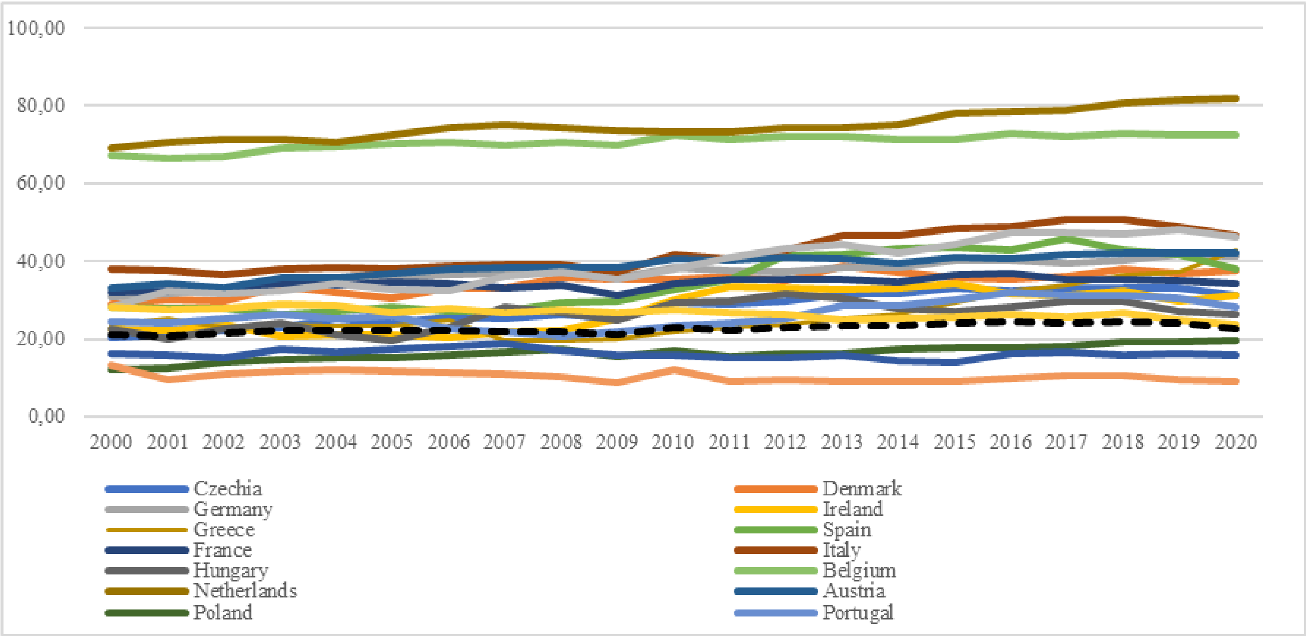

Fig. 5. Material import dependency indicator for selected European countries and EU27 from 2000 to 2020.
Source: authors' elaboration on EW-MFA (2022) data.

In terms of single materials, the indicator aggregated at EU27 country level, shows that, on average, material dependency on material imports related to metal ores and fossil fuel energy materials is the most important (Figure 6). Metal ores show an average of 59% over time, even if the dependency in the period considered has been reduced by -21% from 2000 levels. Whereas, for fossil energy materials, the time average of the material import dependency indicator is 61%, with an increase in the overall time frame of 21% from 2000. On the other hand, the average values for biomass and non-metallic materials are 11% and 3%, respectively, with an overall variation rate of 26% and 19%.

These elements evidence the structural dependence of many European countries on imported fossil energy materials and metallic materials. On the other hand, they highlight an essential independence for relying on biomass and non-metallic materials. This reflects the weakness of the natural endowments of European economies in terms of strategic input materials for manufacturing and the industry (both heavy and non-heavy), indicating that structural changes in terms of reliance on inputs for production may be needed in the future and that the twin transition of the European economy may go in this direction. Moreover, the lower reliance on imports for biomass highlights the strong independence of Europe for food, timber and other natural resources strategic for food security.

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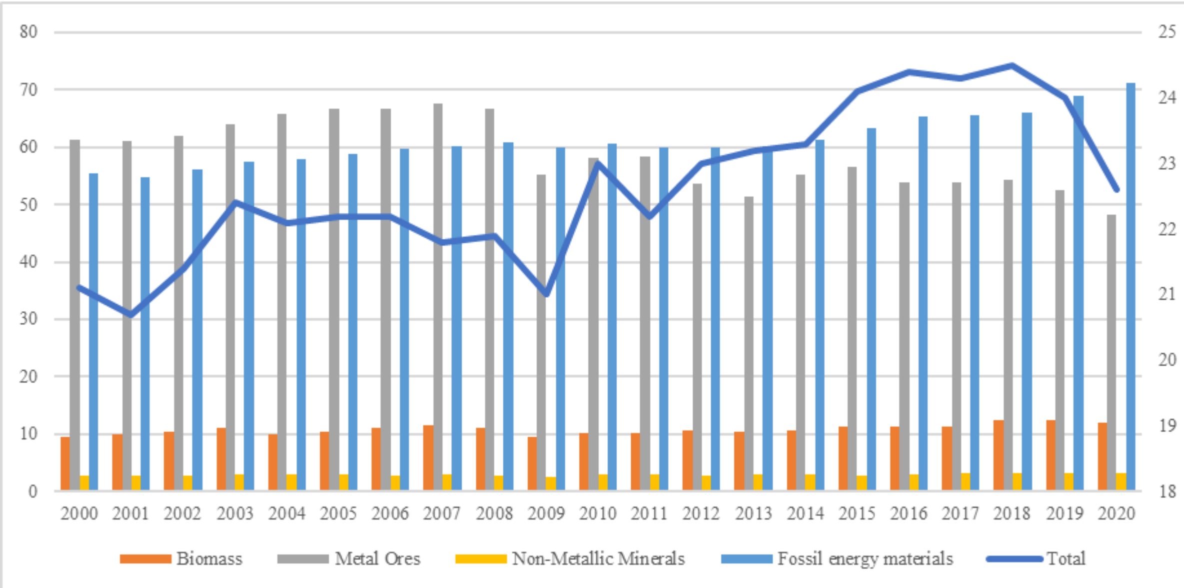

Fig. 6. Material import dependency indicator of Biomass, Metal ores, Non-Metallic minerals and Fossil energy materials for EU27 from 2000 to 2020.
Source: authors' elaboration on EW-MFA (2022) data.

3.2.4. The Circular Material Use rate

The circular material use rate, or circularity rate, is part of the material flow accounts of Eurostat (Eurostat, 2022b). The circularity rate is a proxy of circularity in European economies. This indicator measures the saving extraction of primary raw materials as the share of material recycled and fed back into the economy on the overall material use in a country's economy. It is computed as the ratio of the circular use of materials (U) to the overall material use (M), this last one is calculated as the DMC plus the circular use of materials in the economy (M = DMC + U)[10] (Eurostat, 2022b). A higher circularity rate value suggests that more secondary materials are substituting primary raw materials increasing the overall circularity of the economy and reducing at the same time the impacts primary material extraction on the environment (Eurostat, 2022b).

The graph in Figure 7 shows the trends of circular rate for EU27 and selected countries along the horizon 2010-2020. Some countries are well above the EU27 average of the period (11%), with good performances of circularity in their economies, such as France, Belgium and Italy, respectively with 19%, 18% and 17% of circularity rate. The best performer is the Netherlands, with an average circularity of 28%. On the other hand, many other countries are performing less than the EU27 average such as Slovenia and Finland with a circularity rate of 9% and Denmark showing an average rate of 8%. The worst average performers over the period are Bulgaria with a circular rate of 3%, Portugal and Romania with 2%.

In figure 8 is shown the circular rate divided into a class of materials. The figure shows a more or less constant level of circularity among different classes of materials with high-levels of circularity rate around 24% for metal ores, 15% for non-metallic minerals and 9% for biomasses. Fossil energy materials show the lowest rate of

[10] The circular use of materials (U) is approximated by the amount of waste recycled in domestic recovery plants (RCV_R) minus imported waste destined for recovery (IMPw) plus exported waste destined for recovery abroad (EXPw). RCV_R is approximated by the amount of hazardous and non-hazardous waste treated in recovery plants excluding amounts used for energy recovery and backfilling (recovery operations R2 to R11 as defined in the Waste Framework Directive 75/442/EEC). European statistics on international trade in goods (ITGS) approximate the net imports of waste destined for recycling (Eurostat, 2022b). The circularity rate (CMU) is equal to: CMU=U/M= ((RCV_R-IMPw+EXPw))/(DMC+(RCV_R-IMPw+EXPw))

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circularity with a 2% average rate along the timeframe considered. The static performances on circularity rates suggest that there have been no noticeable structural, technological changes in terms of material recovery in the last decade and that the most important gaps to be reduced concern fossil energy materials.

Table 2 and Figure 9 shows the ranking of EU members in 2020 regarding circularity. The best performer is the Netherlands, Belgium, France, Italy and Estonia, reflecting the historical trends. In contrast, at the bottom of the ranking, a part of Romania and Bulgaria are also Latvia the 22nd place, Portugal at the 24th and Ireland at the 25th place in the European ranking. Again, these data highlight the strong heterogeneity among European countries in terms of circularity and material strategies. This evokes an essential element of diversity, suggesting that implementing directives in different countries leads to different results.

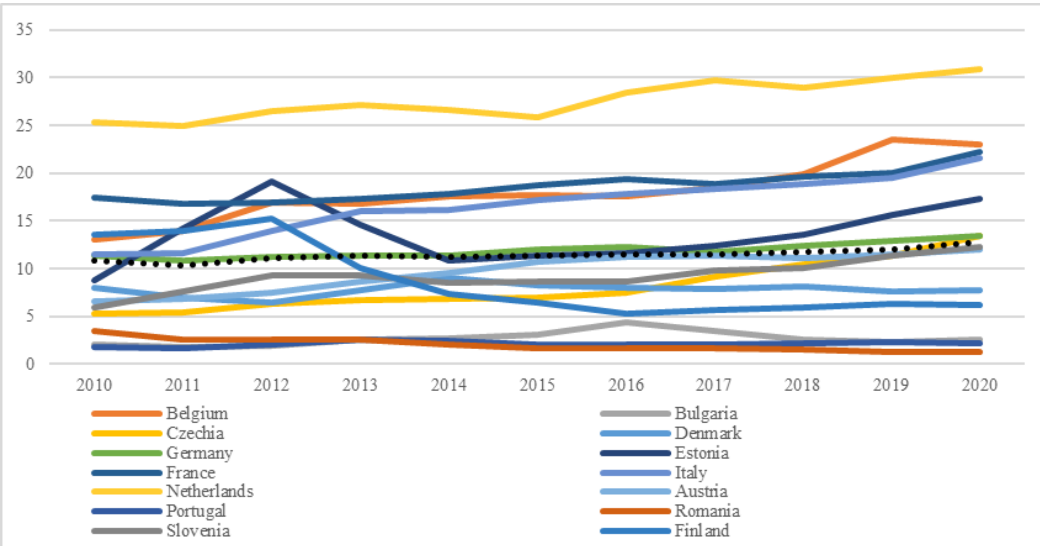

Fig. 7. The circularity rate for selected European countries and EU27 from 2010 to 2020.
Source: authors' elaboration on Eurostat (Eurostat, 2022b) data.

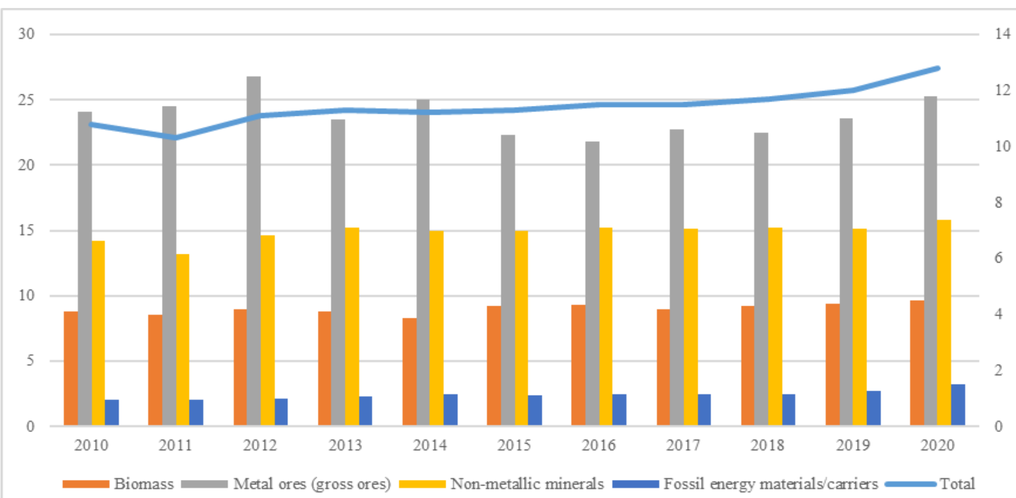

Fig. 8. The circularity rate for the EU27 by different type of materials: Biomass, Metal Ores, Non- metallic minerals and Fossil energy material from 2010 to 2020.
Source: authors' elaboration on Eurostat (Eurostat, 2022b) data.

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Table 2. Circularity index ranking in 2020.

	Country	Circularity index
1	**Netherlands**	31
2	**Belgium**	23
3	**France**	22
4	**Italy**	22
5	**Estonia**	17
6	**Luxembourg**	14
7	**Czechia**	13
8	**Germany**	13
9	**Slovenia**	12
10	**Austria**	12
11	**Spain**	11
12	**Poland**	10
13	**Hungary**	9
14	**Malta**	8
15	**Denmark**	8
16	**Sweden**	7
17	**Slovakia**	6
18	**Finland**	6
19	**Greece**	5
20	**Croatia**	5
21	**Lithuania**	4
22	**Latvia**	4
23	**Bulgaria**	3
24	**Portugal**	2
25	**Ireland**	2
26	**Romania**	1

Source: Eurostat

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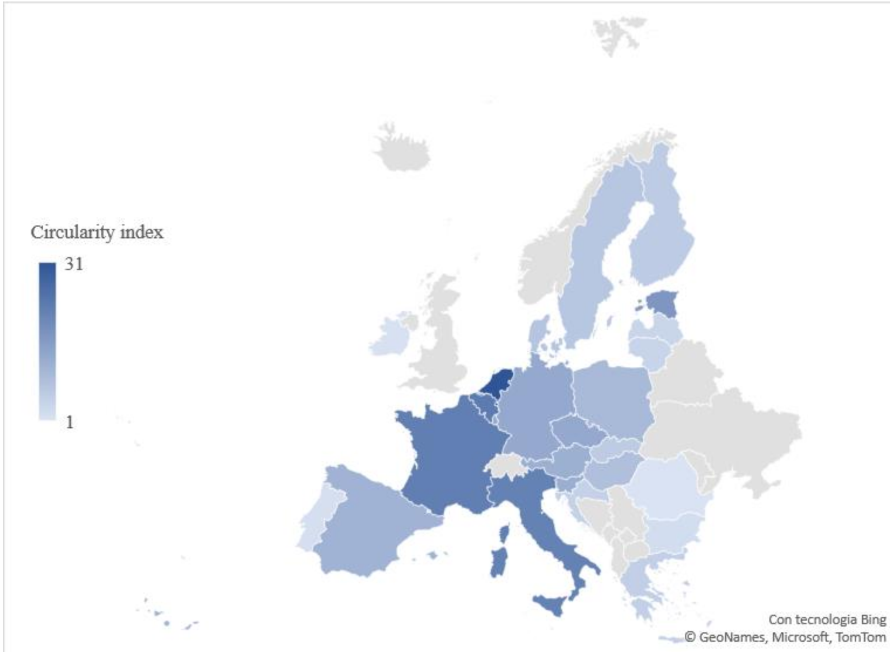

Fig. 9 Circularity index map in 2020.
Source: own elaboration on Eurostat data

3.3 Waste Management in the EU

To have a general picture of waste management in Europe, we employed the Waste database of Eurostat (Eurostat, 2022c). We focused on waste generation relying on the data from Eurostat on Municipal waste by waste management operations. We considered waste generated per capita divided into non-households and household waste generation to enhance comparability among countries.

This data is part of the Resource Efficiency Scoreboard (2022b), which illustrates the progress towards increased resource efficiency of Member States in the EU. This dataset covers between 2004 and 2020 generation of waste per inhabitant of all the European countries, excluding major mineral wastes, dredging spoils and contaminated soils (2022d). Municipal solid waste is not included and is exposed later on.

The data on waste generation remain mainly stable along the timeframe considered, with an average of 1.7 Tonnes per capita of waste produced at EU27 level without evident signal of reduction in waste production among countries, apart from Finland, which reduced its waste generation -43%, as did Hungary and Romania both by -41% and Austria by -34% (Figure 10). Just a few countries slightly increased their waste generation between 2004 and 2018; the most remarkable changes occurred in Bulgaria, Poland and Germany, with an increase of 42%, 38% and 27%, respectively.

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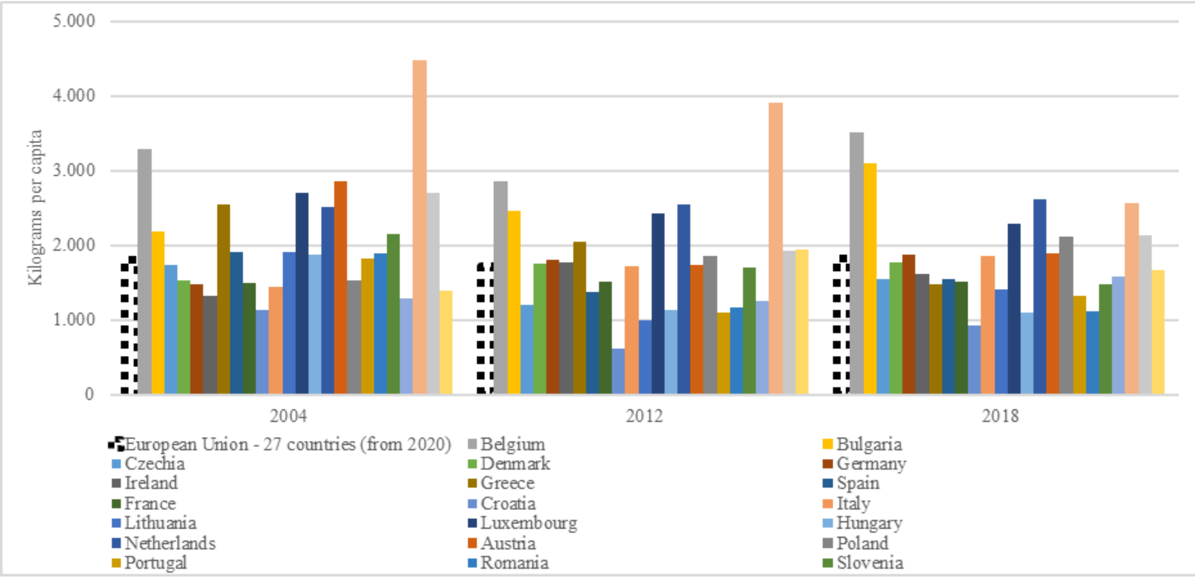

Fig. 10. Waste generation per capita in Tonnes of waste excluding MSW composition from 2004 to 2018 for EU27 and selected countries.
Source: Authors' elaborations from Eurostat (2022c).

Then we analyzed general trends of municipal solid waste (MSW), which can be considered as the waste produced principally by households[11] and collected by or on behalf of municipal authorities and disposed of through the waste management system (EW-MFA, 2022). Also, the total waste generation per capita for MSW has been stable among European countries. Still, the mix in the waste treatment operation evidenced some changes with an increase in the recycling of materials, a reduction in incineration and the disposal in landfills. Figure 11 shows the composition of MSW by treatment as an average of the EU27 members. In contrast, Figure 12 depicts the general trend of the EU27 average of incinerated and recycled waste per capita. In this last figure, it is possible to observe the reversal trends between the declining level of incineration and the increasing level of waste recycling.

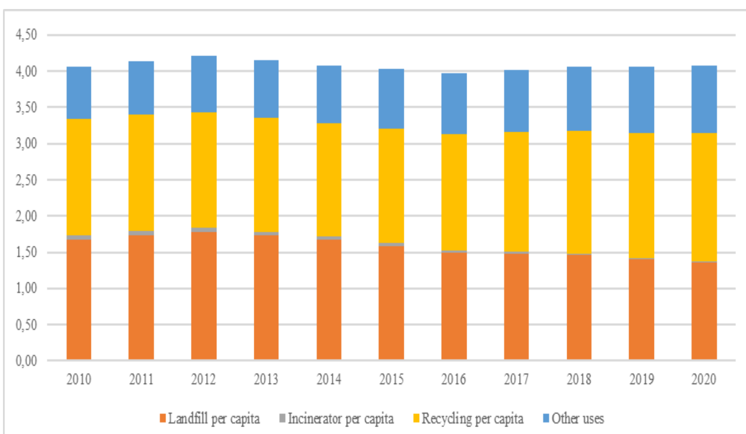

Fig. 11. Total MSW per capita composition from 2010 to 2020 in Tonnes of waste divided between: Landfill, Incineration, Recycling and Other uses. Values as average for EU27 member states.
Source: Authors' elaborations from Eurostat (2022c).

[11] Similar wastes from sources such as commerce, offices and public institutions are included. The amount of municipal waste treatment is reported for incineration (with and without energy recovery), recycling, composting and landfilling. Wastes from agriculture and industries are not included

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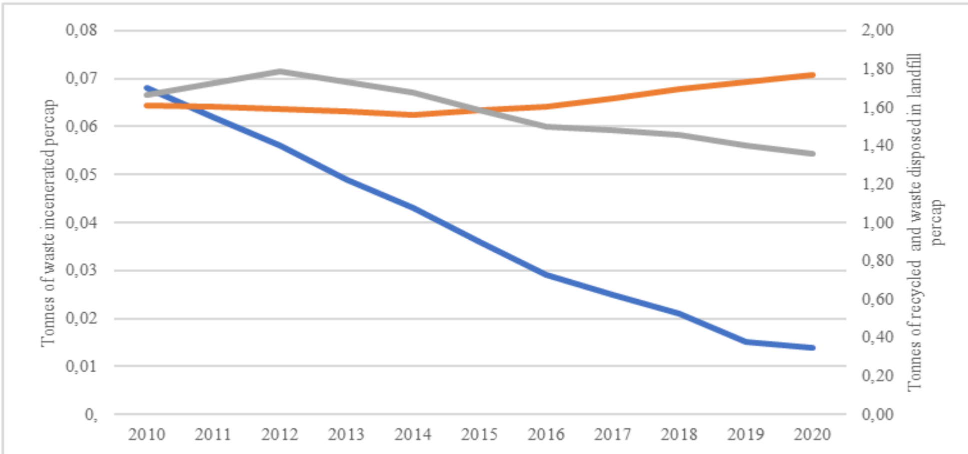

Fig. 12. Trend of incinerated and recycled waste per capita in Tonnes of waste from 2010 and 2020. Values as average for EU27 member states.
Source: Authors' elaborations from Eurostat (2022c).

According to Figure 12 the incinerated waste per capita at EU27 level fell from 0.07 Tonnes of waste per capita in 2004 to 0.014 Tonnes per capita in 2020. On the other hand, the level of recycled waste per capita at EU27 level increased from 1.61 Tonnes per capita in 2004 to 1.77 Tonnes per capita. Whereas the quantity of waste disposed in landfill per capita only slightly decreased along the timeframe passing from 1.67 Tonnes per capita in 2004 to 1.36 Tonnes per capita in 2020.

Individual European countries show important heterogeneities in terms of waste treatment. The amount of waste landfilled has been substantially reduced over time, especially for Denmark, Italy, Greece and Ireland, by -84.66, -69.73, -64.35 and -50.64 Tonnes per capita, respectively. Some countries experienced the opposite path, with an increase in landfill waste per capita between 2010 and 2020, such as Finland +50.71, Poland +27.87 and Romania 14.14 Tonnes per capita.

This general pattern of reduction of landfilled waste is also confirmed by the trend of recycled waste per capita, shown in 13 for a selected set of European countries. The figure shows a general convergence path towards around 2 Tonnes of waste recycled per capita, with a slight increase in all the countries between 2010 and 2020. The only exception is Finland which experienced a general reduction in the amount of recycled waste per capita falling from 5.4 in 2010 to 1.98 Tonnes per capita in 2020. This is also confirmed by the Recycling rate shown in Figures 14, 15 and 16 for two different subsets of countries. The indicator measures the share in percentage of recycled municipal waste in the total municipal waste generation, including material recycling, composting and anaerobic digestion (Eurostat, 2022c). Figure 15 shows the convergence trends towards the 'best-performing countries' for selected Western European countries, while Figure 16 depicts the same convergence path for Eastern and Mediterranean European countries. The two figures clearly show a difference in the convergence process between Western and Eastern Europe. The convergence in recycling rate growth occurred at a relatively constant path between 1998 and 2020 for Western countries; conversely, Eastern countries experienced a strong convergence path with the critical rate of recycling growth along the same timeframe passing from a meagre rate of recycling (around 0) towards the highest levels of recycling rate in Europe. For instance, Italy and Slovenia reached 2019 a rate recycling level above 50% as the best-performing Western countries.

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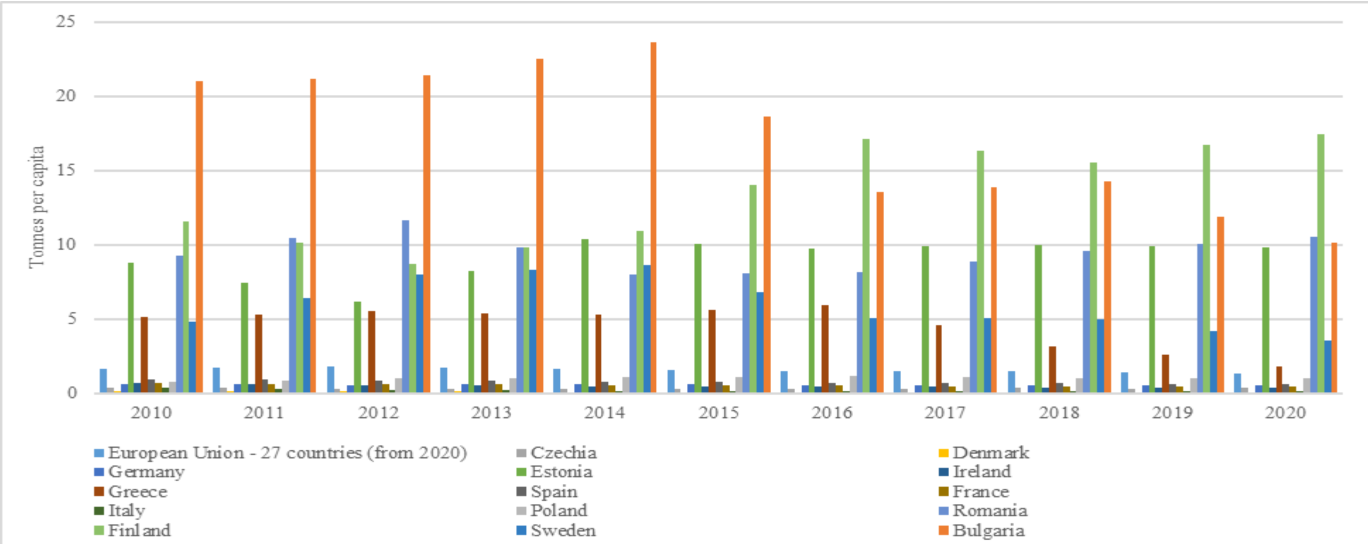

Fig. 13. Waste in landfill per capita for selected set of European countries from 2010 to 2020.
Source: Eurostat

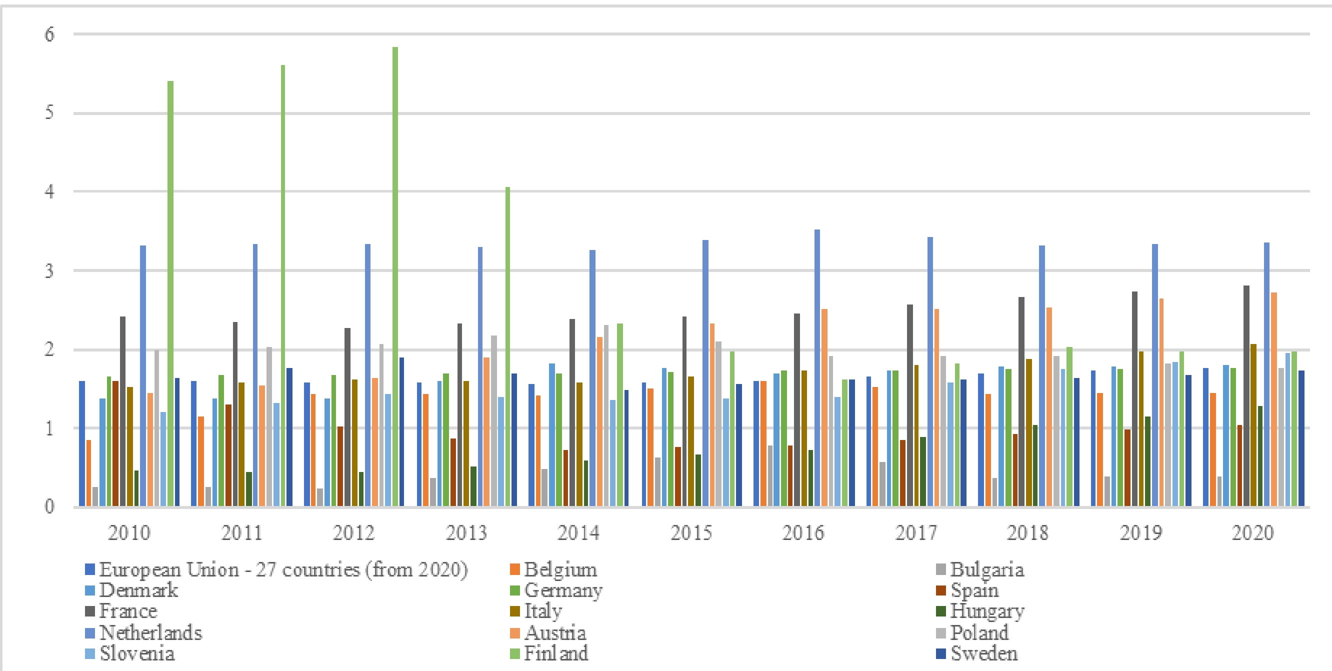

Fig. 14. Recycled Waste per capita for selected set of European countries from 2010 to 2020.
Source: Eurostat

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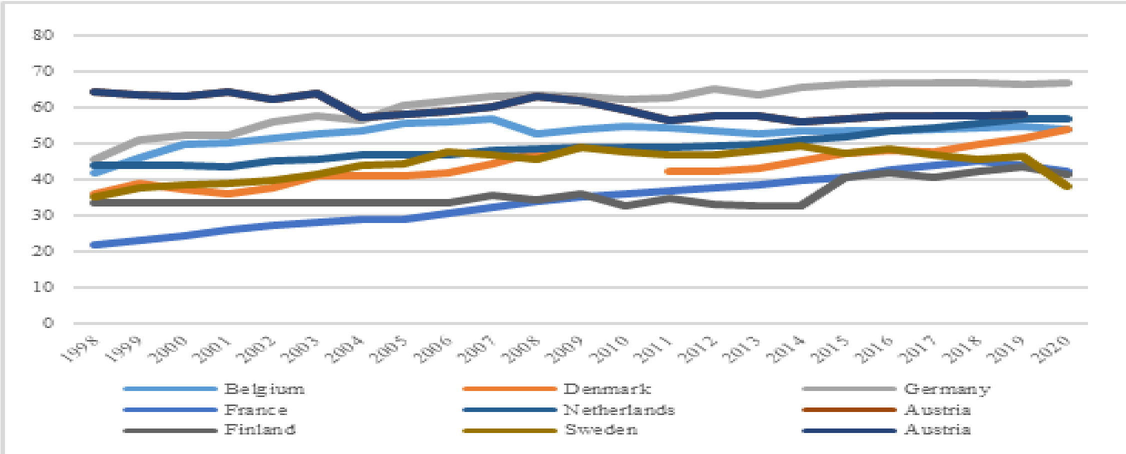

Fig. 15. Recycling rate of Western European Countries between 1998 and 2020.
Source: Eurostat

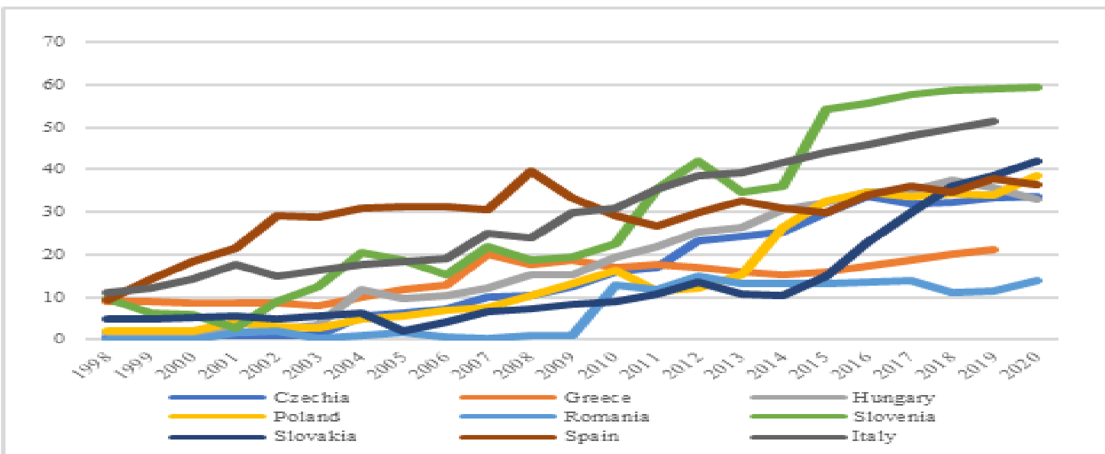

Fig. 16. Recycling rate of Eastern and Southern European countries between 1998 and 2020.
Source: Eurostat

Conclusions

The global order and challenges of the contemporary world are putting a strain on all economies. Governments and institutions strive for change, and an ever-stronger push towards sustainability.

For this reason, efforts are being concentrated on implementing recovery programmes that during (and after) the Covid-19 pandemic aim to support recovery sustainably. Programmes such as NextGenerationEU aim to invest in environmentally friendly technologies, introduce greener vehicles and public transport, and make our buildings and public spaces more energy efficient. Indeed, the energy crisis 2022 has put the world economy at a turning point, making it clear that the development and growth model followed so far is no longer viable. The transition towards a more sustainable economic, social and environmental model has put several issues on the scales, and the shift towards a circular economy is undoubtedly one of the most debated topics on which

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governments and experts are focusing their attention. As discussed extensively throughout this paper, the economic literature (Kirchherr et al., 2017; McDonough and Braungart, 2009) has recognized the CE as a regenerative economic model, which proposes different business models to close the loop. In this context, a leading role is played by waste. CE offers a model in which waste does not exist, each product is designed to become something else once it reaches the end of its useful life (EMF 2013), and environmental policies and regulations are key in improving economic performance while reducing the environmental impact.

Monitoring this transition is a challenging task. Indeed, analyzing trends in waste and materials is one of our available tools. Following the WH we can have an idea on waste prevention, reuse and recycling by studying the trends related to the material flows, resource productivity and recycling. By doing this, it is possible to observe how heterogeneous the European countries are, which - although sharing a policy framework set by the European institution - show different convergence speeds. As the DMC and Circularity Material Use Rate analyzed above suggests, the average for the EU27 in the last twenty years did not change much, but data show significant heterogeneities among countries with different trends over time.

The same heterogeneity is visible also exploring the trend of resource productivity, which highlights different performances, especially looking at the differences between Western and Eastern EU countries that show a higher level of inefficiency in the use of resources. This indicates that radical technological innovation in terms of circularity and efficiency, which may have fostered a structural change in the EU by decoupling the economy from the natural system, has not occurred in the last two decades. As Porter's hypothesis suggests, this could also be the effect of delays in policy implementation that result in a reduction in economic performance. In addition, within the EU, few improvements have been made in terms of material use self-sufficiency. Indeed, what emerges quite clearly is the structural dependence of many European countries on imported fossil energy materials and metallic materials.

By analyzing trends in waste and circular material use, strictly related to implementing circular strategies, the marked difference and heterogeneity between the European countries becomes even more evident, reflecting a different geographical location and industrial structure.

Such a varied situation between different European countries is undoubtedly an obstacle to transition, especially if we look at the implementation of a circular economic model that implies deep links between different economies. By its conceptualization, the CE requires close contact between countries that must dialogue to exchange secondary raw materials (real or potential through waste recycling) and work together to create a model that can regenerate itself and ensure sustainable growth. The need for policies that can converge European countries towards the same results at the same speed is becoming increasingly apparent. Therefore, harmonizing EU members' national strategies can increase the likelihood of a successful European circular transition. These harmonized strategies can include standard policies, incentivizing tools, and monitoring methods to be shared among EU members, including some convergence mechanisms to help laggards converge towards best-performing countries.

The pattern of change in the EU over the last two decades is clear regarding waste management. A general reduction in the amount of waste generated has occurred among EU countries, with landfilling and incineration being replaced by recycling. Still, it has happened languidly over the last two decades. Also, in the case of waste management, a marked heterogeneity among a cluster of countries has been evidenced in this work. Again, it is emphasized that although the EU regulatory framework on circularity and waste management has clear objectives, the overall results of the European ecological transition plan are highly dependent on national implementation strategies and therefore, harmonization, cooperation and convergence mechanisms are needed.

The role of waste management in transitioning to the circular economy still needs to be determined. If on the one hand, waste reduction is imperative to achieve circularity; on the other hand, waste generation represents the 'raw material' for reuse activities (Mazzarano et al., 2021). The general concept of the circular economy could thus get trapped in a 'no-waste production system', which in reality needs waste for socio-economic activities, failing to self-sustain the system itself. Therefore, a deeper understanding of the interconnections between these two dimensions is needed, and further studies should go in this direction.

This paper introduced the topic of environmental policies in the European Ecological Transition Plan framework, trying to highlight an even closer link between policy, waste and CE, which represent three pillars of environmental transition. The general legal framework has been discussed after introducing some basic concepts of the Circular Economy and environmental policies. Then the main trends in terms of material use, circularity and waste management were examined using a descriptive and graphical visualization of data from the Material flows and resource productivity and the Waste database of Eurostat. We are aware that this contribution needs to be more comprehensive. Still, this exploratory study will help further analysis of the circular economy at the European level to contribute to the realization and implementation of a genuine ecological transition in Europe.

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