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Research Article

Comparative Analysis of the European Regulatory Framework for C&D Waste Management

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This article presents a comprehensive analysis of construction and demolition waste (C&D waste) management in European Union (EU) Member States. The study utilizes official data and reports to assess the current C&D waste management status, revealing substantial disparities in recycling rates across countries, ranging from 100% to 24%. These variations emphasize the importance of knowledge sharing and collaborative efforts to improve C&D waste practices. The paper explores the complex factors influencing C&D waste management performance, offering a nuanced discussion of these dynamics. It provides a comprehensive set of practical strategies to address existing challenges, with a focus on reducing C&D waste sent to landfills or incineration. These recommendations align with the EU's commitment to sustainable resource management and the transition to a circular economy. The research's informed measures, driven by environmental responsibility and economic prudence, can significantly diminish C&D waste's environmental impact. Policymakers, environmentalists, and industry stakeholders can utilize these findings to develop and implement improved C&D waste management practices, promoting sustainability and resource efficiency across the EU. This research contributes valuable insights to the field of C&D waste management, offering a road map for improvement and highlighting the need for collaboration among EU Member States to create a more sustainable and resilient future.

1. Introduction

Construction and demolition waste (CDW) includes a wide range of materials such as concrete, stone, metals, wood, plastics, and more, and represents a significant portion of the overall waste stream [1–4]. The European construction industry plays a key role in both resource use and waste generation, accounting for half of the resources extracted and one-third of the total waste generated in Europe [1, 5]. At the same time, it makes a significant contribution to the economy, local employment, and overall quality of life [6, 7].

In recent years, the European Union (EU) has been faced with a growing challenge—the exponential growth of C&D waste [7, 8]. This increase in waste generation is inextricably linked to the flourishing construction sector and economic expansion in individual Member States [9, 10]. The spectrum of C&D waste includes materials from infrastructure construction, building construction, demolition of obsolete structures, and even minor renovation projects. While the management of such waste is critical, it becomes particularly complex during the disposal phase [11, 12]. A salient feature of C&D waste is that not all constituent materials are inherently designed for easy recycling; their primary intent is often geared toward durability and longevity rather than ease of separation [11]. This dual challenge presents a twofold problem: it hampers efforts to reduce C&D waste generation, and it impedes the recycling of this substantial waste stream. To make matters worse, illegal landfills are an ongoing problem that casts a long shadow by perpetuating soil and water contamination [13].

Figure 1: Topics covered by the questionnaires on regulations and procedures related to different stages. Source: self-generated content.

In addition, C&D waste management is influenced by the policies and frameworks at different levels, such as regulations, standards, incentives, and market demand [6, 14, 15]. Some EU countries have already developed and implemented policies leading to high-recycling rates of up to 90%, such as landfill taxes, mandatory recycling targets, green public procurement, and extended producer responsibility schemes [5, 16]. However, these policies need to be complemented by the measures to ensure the quality and safety of recycled materials and to prevent the generation of hazardous waste [10]. In conclusion, C&D waste management is a complex and multifaceted issue that requires a holistic and integrated approach. By adopting circular economy principles and practices, it is possible to improve the environmental and economic performance of the construction sector and contribute to the resource efficiency and climate change mitigation goals [2].

To address these pressing issues, Europe must move away from the conventional linear economic model and embrace the principles of a circular economy [1, 2, 10]. The circular economy revolves around the transformation of waste into valuable resources, breaking the link between economic growth and unsustainable resource consumption [2]. This transformative approach operates at multiple levels, encompassing individual products, urban environments, and entire nations, with the overarching goal of achieving sustainable development, environmental well-being, economic prosperity, and social equity for current and future generations [15].

As a result, the EU has made the management of C&D waste a priority within its circular economy strategy. While both the circular economy and the waste hierarchy aim to improve waste treatment efficiency and reduce environmental impacts, there has been limited discussion about integrating them [2, 17]. The EU's emphasis on waste prevention, recovery, and recycling serves as a global example, addressing resource constraints and global challenges such as resource depletion, pollution, climate change, and biodiversity loss. To address this multifaceted challenge and its environmental consequences, the EU has embarked on a mission to establish a harmonized regulatory framework. This framework aims to reduce waste production and promote the efficient use and recycling of existing residues. The CONDEREFF project, under the INTERREG Europe program, plays a pivotal role in coordinating EU-wide C&D waste management efforts, focusing on C&D waste [18].

Given its status as the largest waste stream in Europe and its inclusion in EU waste management plans [2], the evolution strategies of management practices serve as an ideal case study to examine C&D waste management practices in Europe. This study examines the specific practices and policies that have contributed to the remarkable C&D waste recovery rate in the EU and how these lessons can inform the development of more sustainable and efficient C&D waste management systems on a global scale. By emphasizing waste prevention, recovery, and recycling, the EU has set a valuable example for other regions grappling with C&D waste challenges in an increasingly resource-constrained world. In the context of global challenges such as resource depletion, pollution, climate change, and loss of biodiversity, there is an urgent need to move toward more sustainable societies. In this context, this research paper embarks on a comprehensive exploration of Europe's evolving waste management strategies and the unique challenges they face. At its core, the study aims to shed light on the importance of waste management within the broader context of sustainability. As waste generation becomes increasingly complex, our analysis focuses on different European countries, with a particular emphasis on understanding the intricate dynamics of waste, including mineral and recycled waste streams.

The primary objective of this study is to provide a comprehensive understanding of the dynamic landscape of C&D waste management strategies across Europe. It navigates the intricate tapestry of challenges and opportunities inherent in waste management, thereby enriching the ongoing dialogue on sustainable waste practices. What sets this study apart is its comprehensive examination of the shifting terrain of C&D waste management strategies in Europe, thoughtfully considering the increasing complexities as waste volumes continue to escalate. Furthermore, the present research aims to contribute valuable insights to the field of C&D waste management, fostering a deeper understanding of the multifaceted challenges and opportunities within this critical area. By addressing the pressing issues surrounding C&D waste management, we aim to pave the way for a more sustainable and environmentally responsible future for the C&D sector in Europe. Policymakers, environmentalists, and industry stakeholders may use these findings to develop and implement improved C&D waste management practices, promoting sustainability and resource efficiency.

2. Methods

This section provides an overview of the data collection sources for the C&D waste analysis, examining each stage of the process as shown in Figure 1. Official government websites from various countries were used, with data standardized for ease of comparison. In particular, the CONDEREFF project [19] played a key role in promoting resource efficiency and green growth by effectively managing C&D waste, stimulating demand for recycled C&D materials, and supporting sustainability and recycling in the construction sector. This project facilitated the identification of specific policy measures related to C&D waste generation, landfill treatment, recycling, and reuse [10].

Table 1: Survey and primary research carried out on Spanish territory.

Parameter analyzed	
Types of construction and demolition permits	Regulations requiring waste audits
Responsible public authorities	Legislation amending the European list extending or on-site classification of different types of waste
Removal of hazardous materials before demolition	Specific protocols for the identification and disposal of hazardous materials
Use of specific coding	Tracking of waste from origin to final disposal
Specialized C&D landfills	Landfill regulations
Waste management plans	Minimum C&D waste treatment and recycling requirements
Employee policies	Administrative permits for activities
The agency responsible for waste taxation and sanction procedures	Inter-administrative relationship in terms of regulation

Source: data collected and compiled by the research team [19].

Table 2: Partners involved in the CONDEREFF project.

Partners	Entity	Countries
UPV	Polytechnic University of Valencia (UPV)	Spain
RoT	Region of Thessaly (RoT)	Greece
AURA-EE	Auvergne-Rhône-Alpes Energy Environnent Agency (AURA-EE)	France
RRAPK	The Regional Development Agency of the Pardubice Region (RRAPK)	Czech Republic
ENEA	Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA)	Italy
LAZIO	Lazio Region (Lazio)	Italy
STYRIA	Styrian Provincial Government – Department 14 – Water Management, Resources and Sustainability (STYRIA)	Austria
ISW	Institute for Structural Policy and Economic Development (ISW)	Germany

Data sourced and compiled internally from CONDEREFF information.

To gain a comprehensive understanding of the situation, two types of surveys were conducted: one for the project partners directly involved and another for stakeholders. Together, these questionnaires provide insights into the current state, areas for improvement, and perspectives of individuals working in a field subject to evolving regulations [18]. The partner-focused questionnaires were designed to provide CONDEREFF project members with insights into each country's regulatory framework, the documentation required for C&D waste management, and the current situation.

This process aims to identify potential shortcomings or areas for improvement in the waste life cycle. The stakeholder questionnaire, on the other hand, is open to all interested parties and aims to gauge public opinion on the subject. This aspect of the process allows us to assess, among other things, the accessibility of information, the areas of focus, the depth of stakeholder understanding of various processes, and the potential for implementation of recycling and reuse regulations [18]. Table 1 provides examples of these surveys and their key questions, using data from the CONDEREFF project [19].

This survey highlights significant concerns across multiple sectors. A key issue is the lack of clearly defined regulations and commitment from authorities. In addition, challenges related to waste classification and management persist. Various approaches have been adopted to address these concerns, with a central focus on promoting the 3Rs (reuse, recycle, and reduce) principles of waste [20].

3. Results and Discussion

3.1. CONDEREFF Project. This project serves as an important basis for improving C&D waste management throughout the European Union (Table 2). As part of the INTERREG Europe programme, it aims to accelerate policy development in C&D waste management and improves resource efficiency in partner countries [18]. The main objectives of the project include supporting the establishment of policy frameworks, strengthening the capacity of public authorities to regulate C&D waste, improving public procurement practices, imposing landfill restrictions, improving recycling facilities, and promoting public awareness and acceptance. At its core, the project thrives on collaboration and cooperation among participants, including public authorities, C&D companies, agencies, and stakeholders. With eight partners from seven countries, it provides an ideal platform for sharing experiences and best practices in C&D waste management.

3.2. The Regulatory Framework in the EU. Construction waste in Europe is generated by two main activities: the demolition of existing buildings and the construction of new buildings. An analysis of the sources of waste in the

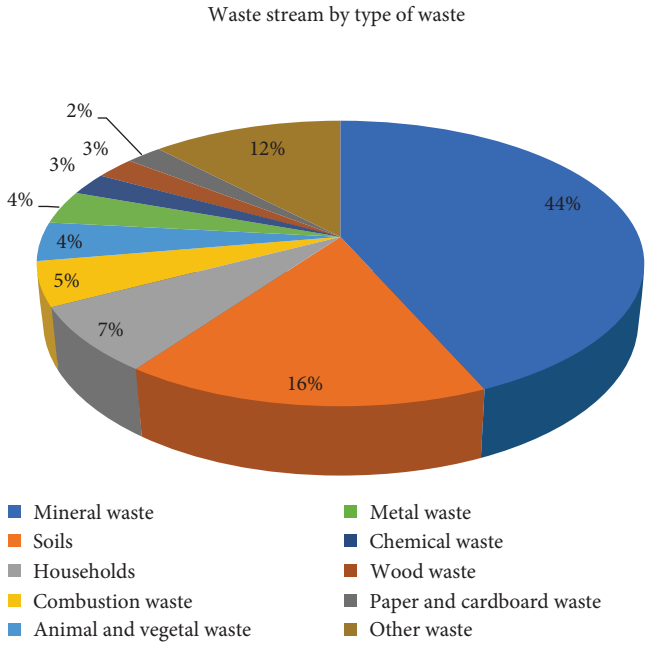

Figure 2: Percentage distribution of waste types within the waste stream. Data are independently sourced and compiled by EUROSTAT.

28 EU countries and Norway, based on Eurostat data, shows that 34% of waste comes from construction activities. Other significant sources include 27% from mining and quarrying, 11% from manufacturing, 9% from households, 3% from the energy supply chain, and 16% from various other sources [18]. These statistics highlight the significant contribution of the construction sector to overall waste generation. Further evidence of the sector's waste generation is provided by examining the types of waste generated. Figure 2 shows that mineral waste accounts for the largest share at 44%, while paper and cardboard accounts for only 2% of the total waste generated. This highlights the volume of waste generated and the need for effective management measures. As shown in Figure 1, the first step in managing C&D waste is to obtain a permit for the construction or demolition work. Following a comprehensive assessment, the waste must be classified according to the European waste list (Table 3). This list serves as the basis for classification and is supplemented by specific regulations at the national and regional levels.

After classification, waste shipments within the European Union are subject to Regulation (EC) No. 1013/2006, which governs cross-border shipments. For domestic shipments, individual countries oversee operations with continuous monitoring. The collected waste is sent to designated treatment or containment facilities by specific regulated procedures. Directive 1999/31/EC on the landfill of waste excludes inert waste suitable for restoration, conditioning, backfilling, or construction purposes from landfill (Article 3.2.2) and reserves specific landfill sites for inert waste only (Articles 4 and 6.d).

Directive 2008/98/EC establishes a legal framework for waste management in the EU, emphasizing the protection of the environment and human health. It stresses the importance of appropriate management techniques, waste recovery, and recycling to reduce pressure on resources and improve resource use. National authorities are required to develop waste management plans and prevention programs. In line with EU Directive 2008/98/EC, the EU requires that at least 70% of C&D waste be recycled, recovered, and reused by 2020. Member states are tasked with formulating Plan 10 and waste management legislation, including quality controls to ensure the usefulness of C&D waste. These EU protocols guide the management of C&D waste and assist administrations in formulating legislation that promotes the treatment of such waste as a secondary raw material.

Table 3: List of European waste categories.

European waste list C&D	
Concrete, bricks, tiles, and ceramics	Wood, glass, and plastic
Bituminous mixtures	Metals (including their alloys)
Soil (including excavated soil from contaminated sites), stones, and dredging spoil	Insulation materials and asbestos-containing construction materials
Gypsum-based construction material	Other construction and demolition waste

Data were collected and compiled independently from the CONDEREFF project.

3.3. Stakeholders. Stakeholders, individuals, or entities invested in the project, play a critical role in ensuring efficient project management, particularly for tasks related to C&D waste. Selecting the right individuals or groups to carry out these tasks is critical to ensuring proper procedures are followed. Criteria for identifying appropriate stakeholders are based on their interaction with the organization, the influence of their role, and the impact on project resources. Appropriate stakeholders typically include public administration, universities, research centers, C&D contractors, nongovernmental organizations (NGOs), and professional and industry associations.

The purpose of identifying stakeholders is to assess their understanding of the legislation, its impact on their activities, and how regulations can be adapted to improve recycling processes [21, 22]. Governments can provide incentives for the use of recycled C&D materials at different levels [6, 16]. The European Commission has long recognized the role of the construction industry in promoting environmental sustainability and employment. This highlights the need for future research to focus on the life cycle of materials, not only on the use of recycled materials but also on the regulations and guidelines that promote the design of buildings for efficient reuse at the end of their useful life. Additional measures at the national and regional levels, such as establishing standards for the use of recycled aggregates, can further advance sustainability efforts [23].

3.4. Results Achieved. The use of construction waste in our society has created several environmental, social, and health challenges. This waste category includes materials that are

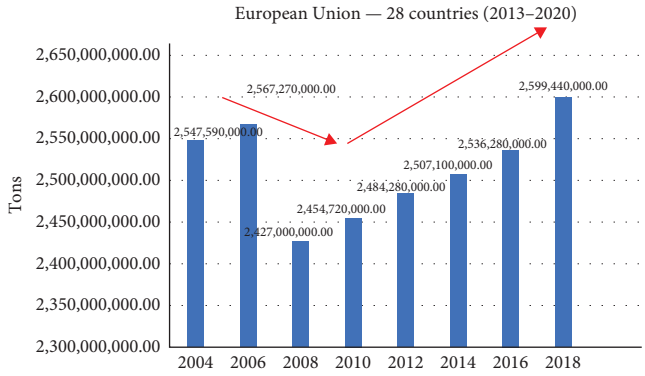

FIGURE 3: Total waste generation in the EU-28: data source—Eurostat.

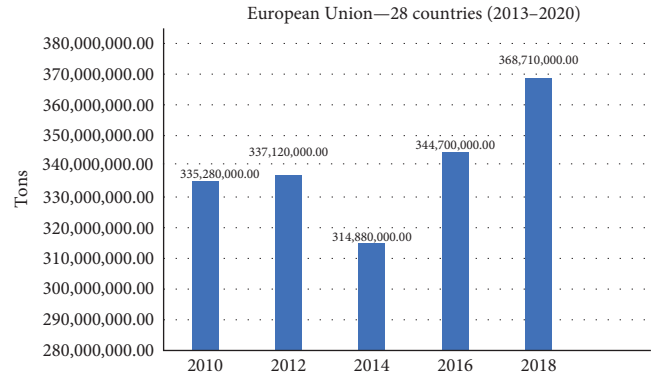

FIGURE 4: Mineral waste from construction and demolition. Data source: calculated internally using Eurostat data.

still in good condition but were not used in construction and can be recycled. Construction waste is a valuable source of renewable energy. Financing is a major challenge due to the significant costs associated with establishing solid waste management systems. Improved waste management has the potential to increase urban resilience to extreme weather events, preventing flooding, infrastructure damage, displacement, and disruption of livelihoods [23].

To understand trends in waste generation and management in the EU, it is important to consider the last 18 years, which have been marked by a production flow influenced by various factors, mainly economic [10]. As mentioned above, mineral waste accounts for 44% of total C&D waste generation. Consequently, this article is mainly based on data concerning the tons of this material produced and recycled. Figure 3 shows that from 2004 to 2018 (the most recent data available), waste production has increased, although not consistently or uniformly.

In 2004, a total of 2,547,590,000 tons of waste were produced. This upward trend was interrupted in 2008 when waste production fell to 2,427,000,000 tons, a decrease of 120,590,000 tons compared to 2004. It is worth noting that 2008 was one of the most severe economic crises in the last four decades, which had a significant impact on the construction sector. Since this production peak, the situation has gradually improved, reaching a total waste production of 2,599,440,000 tons in 2018.

When looking specifically at the production of mineral residues (see Figure 4), the figure remains significant, although they follow a slightly different production pattern compared to the overall material flow. As shown in Figure 4, the data span 10 years. In 2010, 335,280,000 tons were produced, with a decline to a low of 314,880,000 tons in 2014—a difference of 20,400,000 tons. In the following years, there seems to be a gradual increase, culminating in 2018 with 368,710,000 tons. This fluctuation in the production of mineral residues compared to the total production can be attributed to the different material uses and market demand during these years.

According to the Waste Framework Directive 2008/98/EC, the target for 2020 was to achieve a recycling rate of 70% for C&D waste [24]. Figure 5 illustrates how this target has not only been met but exceeded by many European countries.

Between 2010 and 2018, mineral waste recycling made remarkable progress, rising from 20% to a robust 80% in the most countries. Three countries, namely Ireland, Malta, and the Netherlands stood out in this regard, achieving a remarkable 100% recycling rate for mineral waste in 2018. This means that in these countries, all the waste generated will find a new use. It should be noted that these three countries differ significantly in terms of size and population, which means that the achievement of these outstanding results is not due to the inherent factors, but rather to the implementation of effective legislation and administrative measures.

While all the countries surveyed showed significant improvement in mineral waste recycling, three countries showed less favorable results. At the bottom of the ranking was Bulgaria with a recycling rate of only 24%. Slovakia followed with a slightly better figure of 51%. Norway rounded out the list, recycling only 63% of its total mineral residues (Figure 6).

Regarding the worst results, the authors noted that countries with very different structures and sizes cannot be solely responsible for such disappointing results. Instead, we can attribute these results to factors such as the widespread presence of illegal landfills in the case of Bulgaria [25] or the need for increased attention to proper end-of-life treatment to mitigate potential environmental pressures from C&D activities in Norway [26].

4. Policies Implemented in Different Countries

To gain a deeper insight into why certain countries outperform others and whether laws and regulations are the most effective means to achieve the goals set, we can examine a simpler scenario. By considering the CONDEREFF project and its participating countries, we can analyze the situation. Each country under consideration has its own set of regulations regarding the acquisition of execution permits and waste classification, as shown in Table 4.

4.1. Spain. In Spain, the regulations for obtaining a building permit include:

CTE (Technical Building Code): although it does not directly regulate the building permit, it establishes the necessary characteristics that a construction must have.

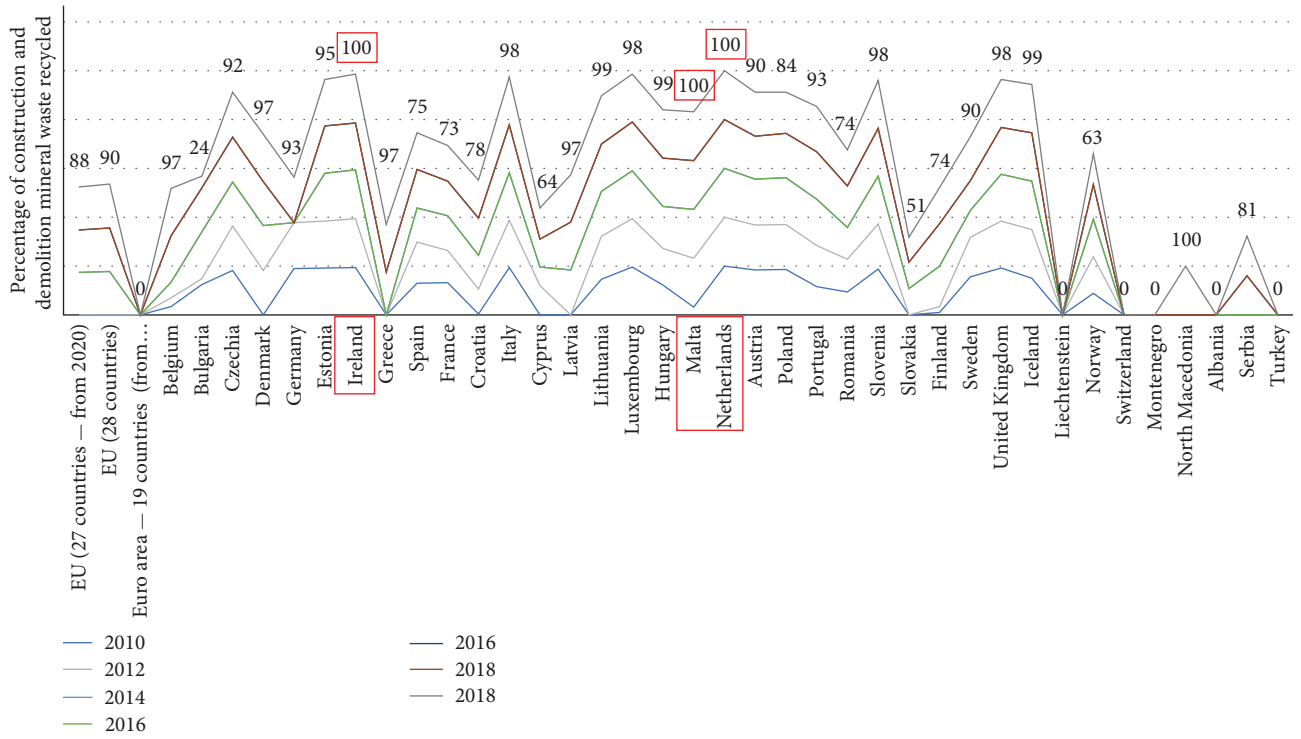

Figure 5: Percentage of mineral waste recycling from construction and demolition highlighting best practice. Data source: calculated internally using Eurostat data.

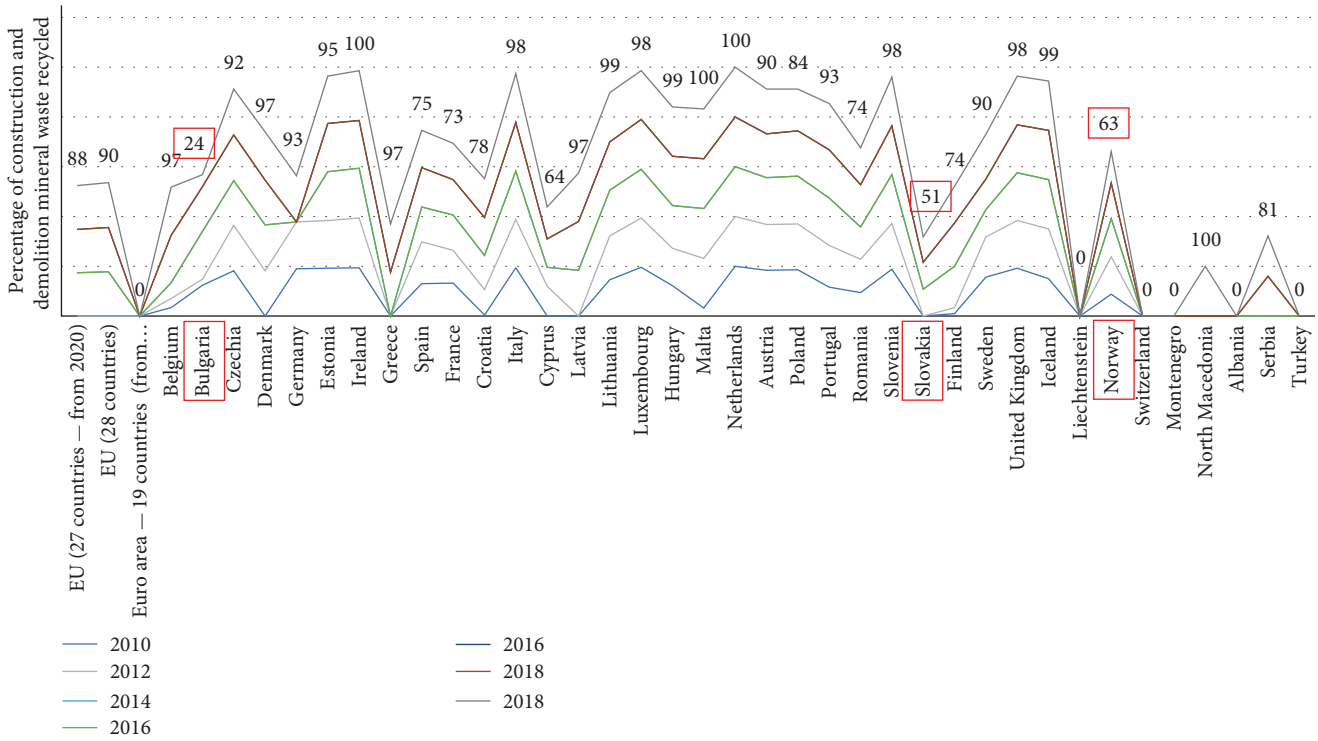

Figure 6: Percentage of mineral waste recycling in construction and demolition, highlighting suboptimal results. Data source: calculated internally from Eurostat data.

Table 4: Regulatory framework implemented in each country.

Country	Execution permit	Waste classification
Spain	CTE (Technical building Code) Municipal ordinances	LER Codes
Greece	54/38935/210.95	JMD 36259/1757/E103/2010
France	License to demolish RT2012 RT2020	Waste framework policies CDW regulations Pre-demolition standards
Czech Republic	183/2008 Sb 185/2001 Sb	185/2001 Sb 294/2005 Sb 383/2001 Sb
Italy	DpR 380/2001 Dlgs. 152/2006 D.Lgs. 112/2008 Lombardia regional law 16/07/2009 n13 Decree 133/2014 D.Lgs. 50/2016	D.LGS. 152/2006 DPR 120/2017 I.r. Lazio 27/98
Austria	ÖNORM B 3,151 Recycled construction material ordinance	List of waste ordinance
Germany	BauO LSA BauVorlVO BaustellV	AVV PCBAbfallV LAGA communication 23

Data were independently sourced and compiled from the CONDEREFF project.

Failure to comply with these criteria makes it impossible to obtain an execution permit.

Municipal ordinances: municipalities are responsible for issuing these permits. To obtain them, a mandatory waste management study is required. This study excludes reform projects or minor works.

4.1.1. Waste Classification. European legislation: LER codes C&D waste must be sorted into various categories, including ceramics, plastics, paper, glass, contaminated packaging, wood, iron, and aluminum. This sorting is usually done on-site before transportation, with each waste item assigned a code for future management. While on-site sorting is optional, C&D companies often choose to do it. Alternatively, another company may manage the sorting and charge for the service. Many companies in this sector also adhere to ISO 14001, which includes segregation and recycling as measures to improve environmental performance.

In the case of demolition, it is mandatory to remove hazardous materials from the building before demolition begins. These materials must be separated from other waste according to a specific protocol, usually carried out by specialized companies experienced in the hazardous materials removal.

4.2. Greece. In Greece, the regulations for obtaining an execution permit include:

54/38935/210.95: this regulation relates to the demolition process and requires waste audits in both C&D processes for permit approval. These audits are conducted by alternative management systems, often referred to as EPR schemes.

4.2.1. Waste Classification. Waste classification requirements are detailed in the following legislation:

JMD 36259/1757/E103/2010: this national legislation deals with construction, demolition, and excavation waste. It requires the separation of hazardous C&D waste from other types of waste. It also extends or modifies the European waste list. In the context of demolition, it is mandatory to remove hazardous materials from buildings before demolition begins. These materials must be separated from other waste using specific coding protocols.

4.3. France. In France, the regulations for obtaining a demolition permit are as follows:

License to demolish: this regulation establishes guidelines and criteria that must be met to obtain a demolition permit.

RT2012: this represents the thermal regulatory framework and serves as the national standard for the resource efficiency of buildings, covering aspects such as air quality, thermal insulation, and noise.

RT2020: this is the environmental framework and is expected to replace RT2012.

To obtain these permits, no waste audits are required in the construction processes, while a demolition audit is mandatory for buildings with a surface of more than 1,000 m^2 or which have hosted agricultural, industrial,

or commercial activities and which have been used as a storage, manufacturing, or distribution area for hazardous materials as described in article R. 4411-6 of the labor code. To carry out the inspection, the client will call upon a professional who has taken out a specific insurance policy for this operation. The professional must not have any relationship with the client or any company likely to carry out all or part of the project, which could compromise his independence and impartiality.

4.3.1. Waste Classification. Waste classification requirements are set out in the following legislation:

Waste framework policies: these policies are governed by the Energy Transition for Green Growth Act (LTECV) of August 17, 2015, the act of August 7, 2015 (NoTRE), and the Regional Plan for Waste Management and Prevention (PRPGD).

C&D waste regulations: these are regulated by the environmental code.

Predemolition standards: these standards are defined in Decree No. 2011-610 of May 31, 2011, relating to the diagnosis and management of waste resulting from the demolition of certain categories of buildings (currently under review). C&D waste must be sorted into the following categories: paper and cardboard, metals, plastics, glass, and wood. This sorting can be done on-site. In the case of demolition, the removal of hazardous materials from buildings before demolition is mandatory. These materials must be segregated from the other waste by an official protocol.

4.4. Czech Republic. In the Czech Republic, the regulations for obtaining an execution permit include the following:

183/2008 Sb: this relates to the construction law at the national level.

185/2001 Sb: this is the waste law at the national level.

Waste audits are generally not required for construction processes to obtain these permits. However, demolition is sometimes required and authorized engineers conduct these audits.

4.4.1. Waste Classification. The regulations on waste classification can be found in the following national-level legislation:

185/2001 Sb: this is the Waste Act.

294/2005 Sb: these are implementing decrees related to waste.

383/2001 Sb: these are additional implementing decrees related to waste.

Waste audits are generally not required for construction processes to obtain these permits. However, in some cases, particularly demolition, waste audits may be required. These audits are carried out by authorized engineers. Some regulations extend or modify the European waste list.

4.5. Italy. The regulations for obtaining a building permit in Italy include the following:

DpR 380/2001: this regulates the construction of buildings at the national level.

Dlgs. 152/2006: this law concerns environmental aspects and is of national importance.

D.Lgs. 112/2008: this law includes urgent provisions for economic development, simplification, competitiveness, stabilization of public finances, tax equalization, and Article 11, which deals specifically with the housing plans.

Lombardian Regional Law 16/07/2009 n13: this law focuses on extraordinary actions for the development and qualification of the architectural and urban heritage of Lombardy.

Decree 133/2014: addresses urgent measures related to the opening of construction sites, the construction of public works, digitization, bureaucratic simplification, hydrogeological stability, and the resumption of productive activities. It is of national importance.

D.Lgs. 50/2016: this is the national law on public procurement.

Local administrations generally grant construction or demolition permits for residential, industrial, and public infrastructure, with infrastructure authorization at the regional or national level. When applying for a C&D permit, waste audits or waste management plans are mandatory for the former, especially for the demolition of public buildings. For private interventions, these audits are optional, although there may be exceptions depending on the municipality.

4.5.1. Waste Classification. The classification of waste is regulated by the following standards:

D.LGS. 152/2006: environmental regulation at the national level.

DPR 120/2017: concerning excavated earth and rocks at the national level.

I.r. Lazio 27/98: this regulation is an example of regional regulations on waste. Such regulations may deviate from the guidelines established by European regulations, such as the European waste list.

Waste segregation is carried out on-site from the outset, using methods such as selective demolition or EER classification. Waste must be separated into hazardous, special, and general categories. Hazardous waste must be removed first according to the specific protocols. In all cases, waste must be coded using specific codes.

4.6. Austria. The regulations for obtaining a construction permit in Austria include:

ÖNORM B 3151: this standardizes the dismantling of buildings as a method of demolition.

Federal Law Gazette No. 181/2015, as amended: this refers to the Recycling Building Materials Ordinance.

To obtain these permits, an audit of the waste generated during demolition is always required, except for demolition projects with less than 3,500 m^3 of gross building volume or less than 750 tons of demolition material. For demolition projects exceeding 3,500 m^3 gross building volume, an external expert, or professional institute must perform the audit. If the demolition site has a gross building volume of less than 3,500 m^3 but contains more than 750 tons of demolition material, a qualified demolition specialist must perform the audit.

4.6.1. Waste Classification. The regulation on waste classification can be found in the following national legislation:

Federal Law Gazette No. 570/2003, as amended: this refers to the ordinance on the list of wastes. In addition, this regulation extends or modifies the European waste list. C&D waste must be separated into hazardous and nonhazardous waste, excavated soil, mineral waste, asphalt, wood waste, metal waste, plastic waste, and residual waste. This segregation can be done on-site. In the case of demolition, it is mandatory to remove hazardous materials from buildings before demolition. These materials must be separated from the rest using a regulated protocol and specific coding for this type of waste is mandatory.

4.7. Germany. The regulations for obtaining a building permit in Germany include:

BauO LSA: Building Regulations of Saxony-Anhalt. This operates on a regional level.

BauVorlVO: Ordinance on Building Plans and Building Inspection Requirements. Also applies at the regional level.

BaustellV: regulation on safety and health protection on construction sites. This is a national regulation.

To obtain these permits, an audit of the waste during both demolition and construction is required. Certified waste management companies carry out these audits.

4.7.1. Waste Classification. The regulation concerning the classification of waste can be found in the following national-level legislation:

AVV: regulation on the European waste register.

PCBAbfallV: ordinance on the disposal of polychlorinated biphenyls, polychlorinated terphenyls, and halogenated monomethyl diphenylmethanes.

LAGA-Merkblatt 23: implementation aid for the disposal of asbestos-containing waste.

C&D waste must be separated. This separation can be done on-site. In the case of demolition, it is mandatory to remove hazardous materials from buildings before demolition. These materials must be separated from the rest using a regulated protocol, and specific coding for this type of waste is mandatory. As a result of these different policies adopted in each country, five of the seven countries considered achieved a level of waste recycling higher than 90%. As seen in Figures 5 and 6, France produced 68,976,060 tons of mineral waste in 2018 but only 73% of it was recycled, the lowest value among the countries considered [27]. The amount of waste produced does not necessarily correlate with the level of waste recycled, as each country has its own policies and waste production volumes. For example, Greece produced only 1,145,016 tons of mineral waste in 2018, while Germany produced the highest amount at approximately 86,412,432 tons [27].

5. Conclusions

In recent years, the European Union has made significant efforts to improve waste management, particularly regarding C&D waste. However, these mandated targets are not being met uniformly across countries, and there are significant differences in the organization of waste management cycles. Challenges such as low-social inclusion rates and limited business incentives hinder the pursuit of effective waste management practices. In regions such as Seville, Madrid, or Valencia, recycling rates remain relatively low, mainly because the market for recycled materials has yet to expand in other parts of Spain and other European cities such as Berlin and Copenhagen.

As observed, countries such as Bulgaria and Slovakia have the lowest recycling rates in Europe, at 24% and 51%, respectively, for recycled mineral waste. This is mainly due to the lack of strict regulations at different stages of waste management, insufficient monitoring of enforcement, and insufficient efforts to address these issues. Conversely, higher recycling rates approaching 100% have been achieved in countries such as Ireland, Malta, and the Netherlands, where regulations are tailored to different waste categories. On average, 46% of C&D waste generated in the European Union is either reused or recycled. The data analyzed on waste generation and the responses from different regions underline the need for comprehensive legislation on C&D waste. Policymakers, environmentalists, and industry stakeholders may use these findings to develop and implement improved C&D waste management practices, promoting sustainability and resource efficiency across the EU. Furthermore, this research allowed to obtain valuable insights to the field of C&D waste management, offering a road map for improvement and highlighting the need for collaboration among EU Member States to create a more sustainable and resilient future.

Data Availability

Data for this research article are available in the references section.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Javier Cárcel and Fabiola Colmenero developed the methodology along with the preparation of the conceptualization and data curation; Javier Cárcel, Andrés Salas, Fabiola Colmenero, and Adolfo Preciado gathered and analyzed the data. Javier Cárcel, Fabiola Colmenero, and Adolfo Preciado also did the review and editing part; Javier Cárcel made the funding acquisition and Fabiola Colmenero, Fabiola Colmenero, and Javier Cárcel wrote the paper. All authors read and approved the final manuscript.

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