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Policy measures to promote reuse and high-quality recycling of construction and demolition waste

Problem analysis; state-of-play in the EU; exploration of policy options; and recommendations for consideration in future Circular Economy policy

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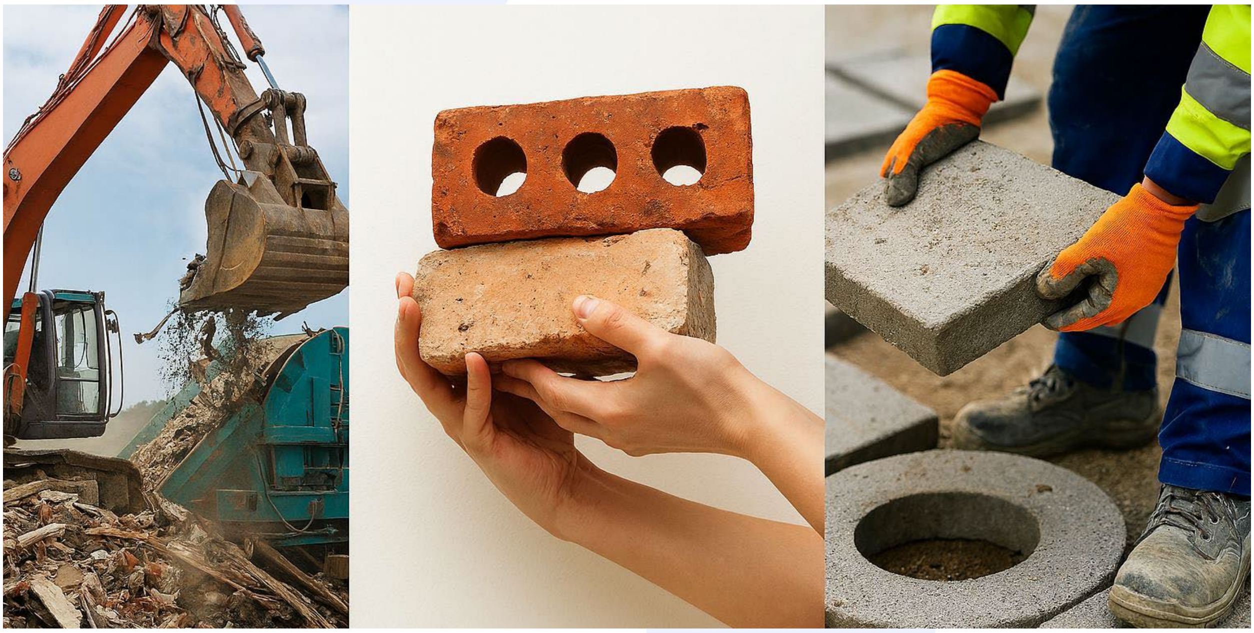

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Contents

Abstract

The European Union (EU) has made progress in managing construction and demolition waste (CDW), but more needs to be done to promote preparing for reuse and high-quality recycling. The scope of the current study is the universe of policy measures intended to reduce waste, increase recycling, and achieve cost savings in CDW management in the EU. This study serves to define the state-of-play in the EU and winnow the universe of policies to those that are most promising given current technological and market conditions. Based on analysis of the policies with the highest potential positive impacts, the Joint Research Centre (JRC) recommends considering eight targeted actions at the EU level and ten additional targeted actions at the national and local levels to improve CDW reduction, reuse, and recycling. These policy measures range from legally binding rules to soft regulation and include measures such as extending producer responsibility, promoting selective demolition, and harmonising landfill charges. The measures require further in-depth impact assessment if promoted. The current study offers reliable evidence based on quantitative/qualitative analyses that provide new empirical data and results for use in future impact assessments.

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Executive summary

Policy Context

The European Union's (EU) policy objectives for construction and demolition waste (CDW) are twofold, (i) to ensure that CDW is managed in an environmentally sound way, and (ii) to reap the full potential of CDW for the transition to a circular economy. The objectives are vital to achieving a circular economy because CDW accounts for almost 40% of all waste generated in the EU. The Waste Framework Directive (WFD) sets specific objectives for CDW, including a 70% recovery target by weight, promoting selective demolition, and reducing waste generation. While the 70% recovery target has been reached at EU-wide level, with an average of 89% of the mineral fraction recovered in the EU-27 in 2022. Therefore, this report focuses on analysing the problem drivers of inefficient CDW management that persist across the EU. It also reports on the current outcomes and implementation of policy measures in Member States (MS) to explore possible actions at EU level to address the ongoing challenges in CDW management.

Scope of the Study

This study serves to define the state-of-play in the EU and winnow the universe of policies to those that are most promising given current technological and market conditions. The scope of the current study is the universe of policy measures intended to reduce waste, increase recycling, and achieve cost savings in CDW management in the EU. The report develops reliable evidence, new data, and qualitative and quantitative analyses focused on real-world cost and effectiveness evidence. Its recommendations for further consideration and monitoring individual policies support rather than replace future impact assessments. The purpose of this report is to inform future EU policy goals that may be further articulated in detailed impact assessment processes according to the EU Better Regulation Guidelines and Toolbox.

Key Conclusions

The key conclusions of this report are as follows:

- The two main problems in the management of CDW are the **increasing volumes** of CDW due to the overall growth in the economy and urbanisation, and the **insufficiently circular outcomes** of CDW treatment due to a wide range of economic (e.g. CDW economic value, except for ferrous and non-ferrous metal, is typically low) and non-economic (e.g. cultural barriers and lack of skills and knowledge on reuse and recycling techniques) and market barriers for all individual fractions. The increasing volumes of CDW are linked to primarily linear building processes that generate waste and pollution and to the challenges associated with waste minimization (e.g. via reuse and preparing for reuse) or with prevention (e.g. via design). Further, the increasing volumes of CDW are linked to insufficiently circular outcomes that impede competitive pricing of secondary materials and hinder the development of robust secondary materials markets for all CDW fractions, particularly non-metals. These issues could be partly addressed with policy interventions on CDW, which is the scope of this analysis.
- The high reported recovery rate of the mineral fractions of CDW is 89% across MSs disguises to some extent the observation that most recovery is achieved by ‘low-quality’ recycling and backfilling. This may also be inferred by the currently low level of incorporation of secondary materials, mainly recycled aggregates, in high-quality construction product applications (e.g. structural and non-structural concrete). The **low levels of reuse and high-quality recycling** of CDW (beyond its mineral fraction) are a

result of underlying causes that are likely to persist without intervention at the EU or Member State (MS) level. Harmonisation of effective practices for CDW management across MSs is necessary to increase interoperability, and to help grow secondary material markets.

- There are many existing MS policies and good practices aimed at reducing the problems generated by CDW through improved construction practices and increasing the (preparation for) reuse and recycling of CDW, which can be effective in improving reuse and recycling rates for selected materials and the overall quality of recycling. They include 'hard' (legally binding) rules of the so-called 'command-and-control' type, 'soft' regulation, education and information (awareness), and economic instruments, as per the 'EC Better Regulation' nomenclature.

- The analysis carried out in this study suggests that a possible policy initiative aiming to increase the circularity of CDW should come in the form of a combination (i.e. a policy package) of regulatory, economic, and awareness measures. Recommendations for considering specific measures such as:

    - Extended Producer Responsibility (**EPR**) schemes, whereby sellers of products pay for their products' waste collection and treatment.
    - **Pre-demolition audits** and **selective demolition** that increase recovery, separation, and recycling of materials from construction; and
    - Pay-As-You-Throw (**PAYT**) that charges waste generators by volume and sorted versus unsorted waste they generate, thus incentivizing reduction and recycling.

  The recommendations are based on the relative low cost of these measures (relative to the cost of waste management overall or to the cost of construction) and environmental and economic benefits estimated in this preliminary analysis (via life cycle assessment and costing, when possible).

- It is important to acknowledge that the estimated benefits from reuse and recycling hinge on the crucial assumption that a market for secondary materials is established (i.e. that secondary materials are absorbed into new products, thus replacing corresponding primary materials). It is also important to acknowledge the role of complementary measures to facilitate the implementation of the mandated measures (notably, ensuring that a market for the secondary materials exists), avoid unintended consequences or loopholes, and create synergies.

Main Findings

The main findings of this report are as follows:

- At current market conditions, the economic value (market price) of many CDW streams, except for metals, is generally too low to facilitate widespread circular outcomes. This is mainly due to uncompetitive pricing of secondary compared to primary products, as external costs are not accounted for in the latter, the difficulty of deconstruction and separation, as well as transport costs for mineral waste streams.

- The most widely applied regulatory instruments across the MSs for CDW are broadly interpreted landfill bans, product standards and certifications, while the most widely used economic instruments are landfill taxes / fees, followed by resource taxes. Extended producer responsibility (EPR) has been adopted by France and the Netherlands and green public procurement (GPP) implemented by Italy. The MSs where the widest range of assessed regulatory instruments are already implemented are the Netherlands and Belgium, according to our analysis.

- It is important to consider instruments aiming to reduce non-compliant disposal at the policy design stage, not just through enforcement, but also with a view to establishing the right incentives for proper disposal. Non-compliant CDW disposal - with lower overall costs - is a part of the problem in some regions. While more evidence is required on this aspect, a few scientific studies and preliminary data gathering by non-governmental associations flag the issue.
- The assessment of selected policy measures for circular CDW management suggests that EPR schemes, taking cues from the existing French EPR scheme for CDW, can be a promising cost-effective measure at both macroeconomic level (limited effects are anticipated on overall construction project costs and the affordability of housing) and at the micro-material level (limited effects on the waste management costs). This is the case since only relatively small price increases would be expected (relative to the overall construction project costs and to the overall cost of waste management), while environmental benefits can be generated by recycling, assuming a market for the separated materials exists. The implementation of a CDW EPR scheme in France is a real-world experience with pros and cons that can inform practice at the EU level.
- Pre-demolition audits and selective demolition are two policy measures considered as complementary. According to the assessment carried out here, they could be considered for an EU-level mandate since the costs (in the range of ca. EUR 0.2€/t - 2€/t of CDW for pre-demolition audits, and around 10-25% additional cost of selective rather than conventional demolition) appear limited, thus not a barrier to implementation, whereas benefits from recycling outweigh the costs assuming a market for the separated materials exists. Pre-demolition audits and selective demolition are closely linked to design measures that favour the adaptive reuse of existing buildings and design for deconstruction. Under these conditions, the analysis supports the consideration of an EU-level mandate.
- Waste management fees (a broad range of instruments covering EPR fees, landfill and incineration taxes, and other discarding fees) are generally considered current good practice and a necessary background condition. New waste management fees and mandates such as landfill bans remain best practices; however, they may inspire a minority of consumers to dodge increased costs through littering. For example, landfill bans, which are regulations not a fee or strictly economic instrument, do not necessarily equate to achieving optimal reuse and recycling (thus environmental) outcomes, as the waste management system would likely move to the next-cheapest management option. This study found that a direct correlation between the level of a landfill tax and the rate of recycling cannot be demonstrated with the data available to date. The study observes that illegal dumping or poorly managed landfilling can occur in the presence of high disposal charges. It is therefore recommended to further investigate advanced waste management charging instruments, such as PAYT, potentially coupled with a deposit, that could be used to support the refinement of longstanding but rudimentary instruments such as landfill taxes and bans.
- Overarching EU-level targets with a focus on preparing for reuse and recycling may be an efficient policy measure, if part of a broader policy package. While the analysis confirms that economic and environmental benefits are expected if targets are achieved, this result only holds on the condition that a market for secondary materials exists, which may not be the case for all MS. Due to its weight, many CDW fractions are not traded over long

distances. Achieving recycling targets can be challenging. Therefore, the technical and economic feasibility of such targets needs to be assessed at MS level, as it differs across the 27 EU MS.

- The study lists other complementary measures that facilitate the achievement of the objectives of increased preparing for reuse and high-quality recycling, such as requirements for a digital passport, recycled content, and operating marketplaces. It further suggests specific 'next steps' in terms of research to complement this study and inform future impact assessments.

Related and Future JRC Work

This report builds on previous JRC work on CDW management, in particular 'Background data collection and [life cycle assessment] LCA for CDW management' by Damgaard et al. (2022) and 'A techno-economic and environmental assessment of CDW management in the EU' by Cristóbal García et al. (2024). These reports synthesise and quantify the environmental impacts It is focused on providing an overview of the policy measures available to foster preparing for reuse and high-quality recycling, while reducing the generation of CDW.

Parallel and future JRC studies focus on End-of-Waste, design for recycling, and GPP criteria. The End-of-Waste technical proposal for CDW criteria is scheduled for June 2026. GPP criteria towards circularity and material efficiency for buildings are discussed in Ranea Palma et al. (2024). The environmental and socio-economic effects of a broader set of circularity measures, beyond waste management, applied to the EU cement and concrete sector (e.g. effects on gross value added, employment, and trade) can be consulted in Walker et al. (2025a and 2025b).

Quick Guide

For policymakers and stakeholders, this report provides the following:

- A review of current problems and challenges in CDW management and their main drivers.
- An overview of the EU's CDW policy objectives and the current state of CDW management in the EU.
- Identification and analysis of the effectiveness and applicability at the EU and MS levels of 22 priority policy measures based on highest potential impact.
- Identification of data gaps for future policy analyses.
- Recommendations for EU- and MS-level policy and management actions to address the challenges and opportunities presented by CDW.

For researchers, this report provides the following:

- A comprehensive review of the current knowledge on CDW management and the circular economy encompassing 43 policies.
- New empirical data (i.e. stakeholder input, literature review, cost data, analysis of real-world effectiveness).
- A framework for future research on CDW management and the circular economy, highlighting the need for further analysis of the economic and environmental impacts of CDW management scenarios and the development of decision-support tools for CDW management.

1. Policy outlook for action at EU level

This section will give a general introduction to the policy status of construction and demolition waste (CDW) in the EU-27.

1.1.EU policy objectives

The main objectives for the CDW stream at European Union (EU level) are twofold. First, the EU aims to ensure that CDW is managed in an environmentally sound way that also does not harm human health. Second, reaping the full potential of CDW will contribute to the transition to a circular economy. Under the Waste Framework Directive (WFD), CDW is a priority waste stream. It sets the following objectives:

- "Member States shall take measures to promote selective demolition in order to enable removal and safe handling of hazardous substances and *facilitate re-use and high-quality recycling* by selective removal of materials, and to ensure the establishment of *sorting systems* for construction and demolition waste *at least for wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic and plaster*." (WFD, emphasis added)
- by 2020, the preparing for reuse, recycling and other material recovery of non-hazardous CDW (excluding naturally occurring material defined in category 17 05 04 in the list of waste) shall be increased to a minimum of 70% by weight; and
- reduce waste generation.

The monitoring of the recovery target (i.e., 70% by 2020) is based on the treatment of the mineral fraction of CDW. In 2022, in the EU27 on average 89% of the mineral fraction was recovered, suggesting that this target was on average widely achieved. Small variations in inter-MS's CDW recovery and recycling rates reported in Eurostat are partially related to different reporting conventions.

1.2. EU policy and financing instruments

The Commission guides CDW management through binding and non-binding EU policy, guidance and financial instruments. Policy instruments, such as the WFD separate collection targets, are binding. Also, there are policy measures designed to improve CDW management attached to EU spending. For example, the current proposal for the 2028-2035 Multiannual Financial Framework that includes a dedicated 35% climate and environment target to support climate resilience and strengthen circularity[1], providing a strong basis for investments in the circular economy, nature restoration and water resilience. In addition, the "Do no significant harm" (DNSH) criteria to carry out the circular economy objectives applied to infrastructure investments funded by the Recovery and Resilience Facility (RRF) and Cohesion Policy without. Detailing the extent of EU funding for construction projects that must meet the DNSH criteria is beyond the scope of this study. However, the DNSH requirements are binding.

The End of Waste (EoW) criteria under development as well as existing CDW-relevant EoW criteria are aimed at promoting the single market for secondary materials. So far, CDW relevant EoW criteria exist for iron, steel and aluminium scrap (see Council Regulation (EU) N° 333/2011), glass cullet (see Commission Regulation (EU) N° 1179/2012), and copper scrap (see Commission Regulation (EU) N° 715/2013). EoW sets the same rules for selling recovered materials as products rather than waste for all MS.

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[1] https://ec.europa.eu/commission/presscorner/detail/en/qanda_25_1848

In 2018, the Commission introduced non-binding guidelines for CDW Management to foster the circular economy for CDW from the construction industry perspective. The 2024 "EU Construction & Demolition Waste Management Protocol", an update of the 2018 version, outlines key processes, including pre-demolition audits to identify hazardous materials and re-use potential, selective demolition for safe waste segregation, and transparent waste logistics."2 The guidance presents waste prevention best practices for the assessment of CDW generating projects.

1.3.Relevant EU preparatory work and tools

The EU has been working on increasing the circularity of CDW in the last decades. This is a non-exhaustive list of scientific studies, policy-oriented preparatory studies, and tools. Please note that there are many other initiatives that are not highlighted here. For a more detailed and up-to-date information on the European Commission's initiatives on CDW see [Construction and demolition waste - European Commission.]

- Level(s)[3] is a voluntary reporting framework to improve the sustainability of buildings. Using existing standards, Level(s) provides a common EU approach to the assessment of environmental performance in the built environment, throughout the whole lifecycle. Specifically, Level(s) indicator 2.2 for CDW offers, to "promote and allow users to systematically plan for the reuse, recycling or recovery of elements, materials and wastes via the segregated collection of CDW during construction, renovation and demolition activities"[4].
- Study on techno-economic and environmental assessment of construction and demolition waste management in the European Union (Cristóbal García et al., 2024)
- Study on circular technologies in construction (Jenet et al., 2024)
- Environmental and socio-economic effects of construction and demolition waste recycling (Caro et al., 2024)
- Study on taxonomy of design for deconstruction (Pristerà et al., 2024a)
- Study on using recycled aggregates in concrete (Nuno Pacheco et al., 2023)
- Study on EU End-of-Waste criteria of construction and demolition waste (JRC ongoing).
- Study on the development and implementation of initiatives fostering investment and innovation in construction and demolition waste recycling infrastructure (European Commission, 2018a).
- Report on the management of construction and demolition waste in the EU (Monier et al., 2011).
- Report on supporting environmentally sound decisions for construction and demolition waste management (Joint Research Centre, 2011).
- Study on Environmental and socio-economic effects of the Circular Economy transition in the cement & concrete sector (Walker et al., 2025a; Walker et al., 2025b).
- Study on Environmental and Socio-Economic effects of the Circular Economy transition in the aluminium sector (Albizzati et al., 2025)

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[2] The EU Construction & Demolition Waste Management Protocol (2024 updated edition) eu_construction__demolition_waste_management_protocolET0224753ENN_IyxMKELqLpGkiQcRrhsvvGZrFro_108376 (1).pdf

[3] https://ec.europa.eu/environment/eussd/buildings.htm

[4] 20201013 New Level(s) documentation_2.2 C&d waste_Publication v1.0.pdf

1.4.Summary: Policy outlook for action at EU level

In general, practices fostering diversion from landfill are being efficiently implemented in the EU. Also, the combination of hard and soft regulations like binding recycling targets for CDW and the voluntary initiatives like Level(s) and the 2018/2024 voluntary guidance "EU construction & demolition waste management protocol including guidelines for pre-demolition and pre-renovation audits of construction works"[5] have made a positive impact. Notwithstanding the achievement of diversion from landfill, **the low levels of reuse and high-quality recycling are a result of underlying causes and drivers** that are likely to persist without intervention at the EU or Member State (MS) level. Today's CDW problems, as defined in Section 2, are economic and non-economic market barriers that impede competitive pricing of secondary materials with primary materials and hinder the development of robust secondary materials markets for CDW fractions, particularly non-metal fractions. There is significant variety amongst MS regulatory frameworks for CDW.

[5] https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en; (2024 revision at: https://op.europa.eu/en/publication-detail/-/publication/d63d5a8f-64e8-11ef-a8ba-01aa75ed71a1/language-en)

2. CDW management: problem analysis

This section will describe aspects of current CDW management that are recognised as problematic by relevant actors (NGOs, EU Environmental Agency, OECD, etc.), industry stakeholders, and academic literature, e.g., because of environmental damages, unnecessary loss of material, general inefficiencies.

Essentially, the questions this section aims to address are:

- What are the **problems related to CDW** (that would need to be addressed by specific policy)?
- What are the **problem drivers** underlying these problems?
- **Who are the actors** whose behaviour would need to change to address these problems?
- **What** could be done to influence these behaviours, and **how** could it be done most efficiently and effectively?

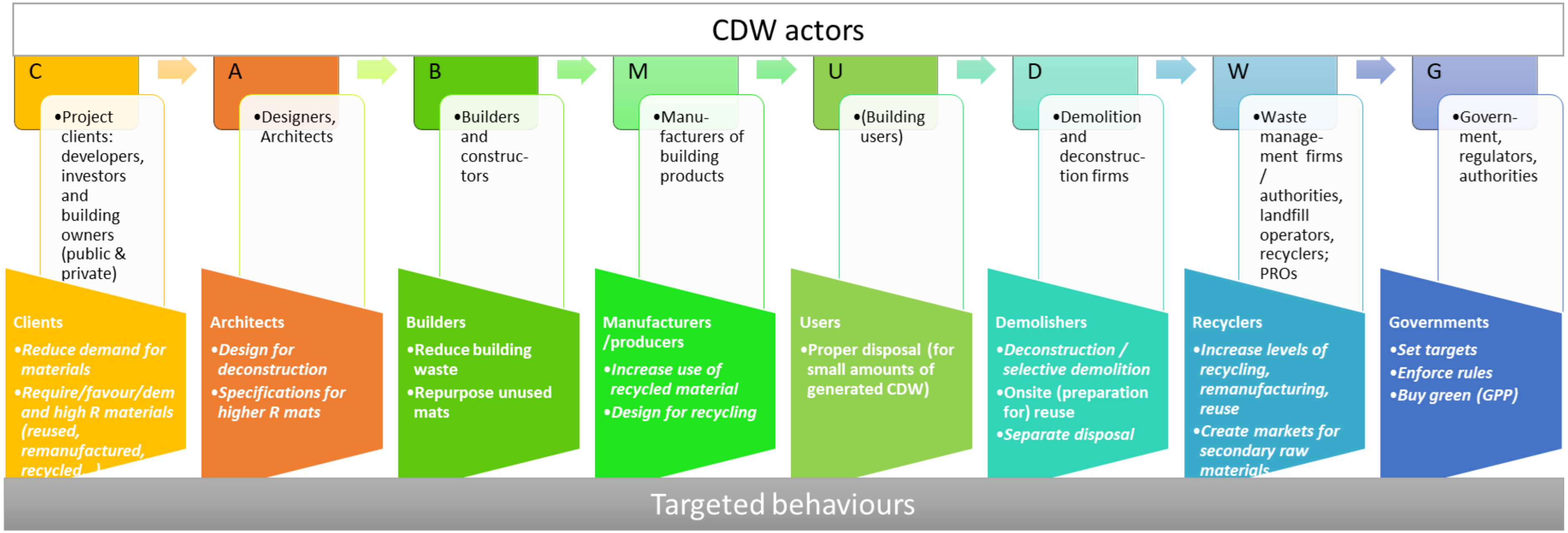
2.1. Addressing the problems: potential solutions, behavioural interventions and policy measures

2.1.1. Stakeholders/Actors analysis: identifying the players

Our analysis identifies eight different categories of stakeholders in the building and construction value chain, whose behaviour influences the generation and treatment of CDW and who are therefore potential targets of policy to address CDW issues. Figure 1 summarises the targeted behaviours to be encouraged/discouraged by policy measures for the following stakeholder groups:

- Developers, investors and building owners; project clients (private and public).
- Designers, architects.
- Constructors and builders.
- Manufacturers of construction products.
- Building users.
- Deconstruction and demolition firms.
- Waste management firms / authorities, landfill operators, recyclers; Product Responsibility Organizations (PROs).
- Government, regulators, authorities.

Figure 1. Categories of stakeholders in the building and construction value chain and target behaviours to be influenced by policy measures. This *conceptual* graphic presents the roles and behaviours of CDW actors at a highly summarised level. For example, the targeted behaviours concerning digital tools and other applications available to designers and builders such as BIM and resource efficiency decisions are included in "design". Further, the targeted behaviours of governments are highly summarised as set targets, enforce rules, and buy green (green public procurement). Note, "materials" is abbreviated to (mats) in the graphic.



Source: Own elaboration.

Of these eight categories of stakeholders, the category of "building users" not otherwise falling in the other categories, e.g. building owners, are typically residential tenants, or users of professional-use buildings, and are not found to have a directly relevant impact on CDW generation in the context of normal use. Therefore, this category is of lower impact, and therefore lower priority as target for CDW policy and only the other seven categories are further analysed in the report.

2.1.2. Changing actors' behaviour by changing market conditions

Progress on higher level management of CDW in accordance with the Waste Hierarchy is at a standstill. CDW recycling (i.e., mineral fractions) is mostly used for road construction and filling, while the remaining fractions (other than metals) are mostly disposed of in landfill or incinerated. Also, the rate of recovery and recycling amongst MSs varies greatly (although this may partly be due to new definitions for reporting waste statistics). See Cristóbal García et al. (2024) for more details. JRC scenario analysis indicates that a change of the current situation - backfilling, incineration, and landfilling - towards more circular outcomes, by promoting preparing for reuse and recycling, would maximise potential environmental and economic benefits. JRC analysis suggests that the percent of the total CDW generated that could be potentially sent to recycling could be as high as 97% (as a weighted average, when including the 'mixed mineral and mixed CDW' fraction; 83% otherwise; see Cristóbal García et al. 2024).

2.1.3. Environmental impacts of better CDW management

The consequences of not managing CDW as a circular system is low resource efficiency, pollution and greenhouse gas emissions. Improper disposal of CDW can lead to environmental pollution and harm to human health. Under current practices, CDW is a consequence of linear extraction of natural resources destined for disposal at the end-of-life, with more linear extraction to replenish stocks. Environmental burdens are created at resource extraction, processing, and disposal. Society is exposed to potentially harmful impacts such as greenhouse gas (GHG) emissions and air pollution.

A circular system that uses CDW to replenish stocks through reuse and recycling can mitigate resource extraction and waste disposal's environmental burden and decrease GHG emissions. By using recycled materials, the demand for virgin resources is lessened, aligning with the principles of a sustainable and circular economy. Moreover, the recycling sector can generate employment and drive economic development through new recycling infrastructure and technologies.

The recent JRC study examined the environmental outcomes of scenarios for business-as-usual versus improved CDW management (Cristóbal García et al., 2024). The study concluded that "preparing for reuse and recycling are the options incurring the highest GHG savings, when assuming the use of best-performing available recycling technologies. The highest GHG savings are achieved for preparing for reuse and recycling metals. Landfilling (or incineration when applicable) incurs the highest GHG burdens for all individual material fractions except for wood and mineral wool waste." (Cristóbal García et al., 2024). The expected results of Commission action on policy measures on CDW are, broadly speaking, less human-induced pressure on natural systems and less pollution. The GHG reduction results of the high-level recycling scenario in Cristobal Garcia et al., 2024 are worth restating here.

- "the fraction with the highest GHG emission saving potential is the summed inert fraction (bricks, ceramics and tiles, glass, concrete) totalling 27.9 Mt of CO_2-eq. Concrete could contribute with 6.6 Mt CO_2-eq. at a total cost of EUR 6.5 billion (marginal cost of EUR 1 kg^{-1} CO_2-eq.)."
- "Plastics (EPS and PVC) could contribute with 0.2 and 1.6 Mt CO_2-eq. savings respectively, and metals with 2.8 Mt CO_2-eq. (2.0 Mt CO_2-eq. for aluminium and 0.8 Mt CO_2 eq. for steel, both largely recycled already). Overall, accounting for the total (non-hazardous) CDW from buildings, soil and dredging spoil generation (131 Mt, 444 Mt, and 79 Mt, respectively; totalling 652 Mt), the MRP [Max Recycling Potential] scenario could lead to a total reduction of ca. 34 Mt CO_2-eq. using 2020 waste generation figures and a net cost saving of ca. EUR 2.9 billion."

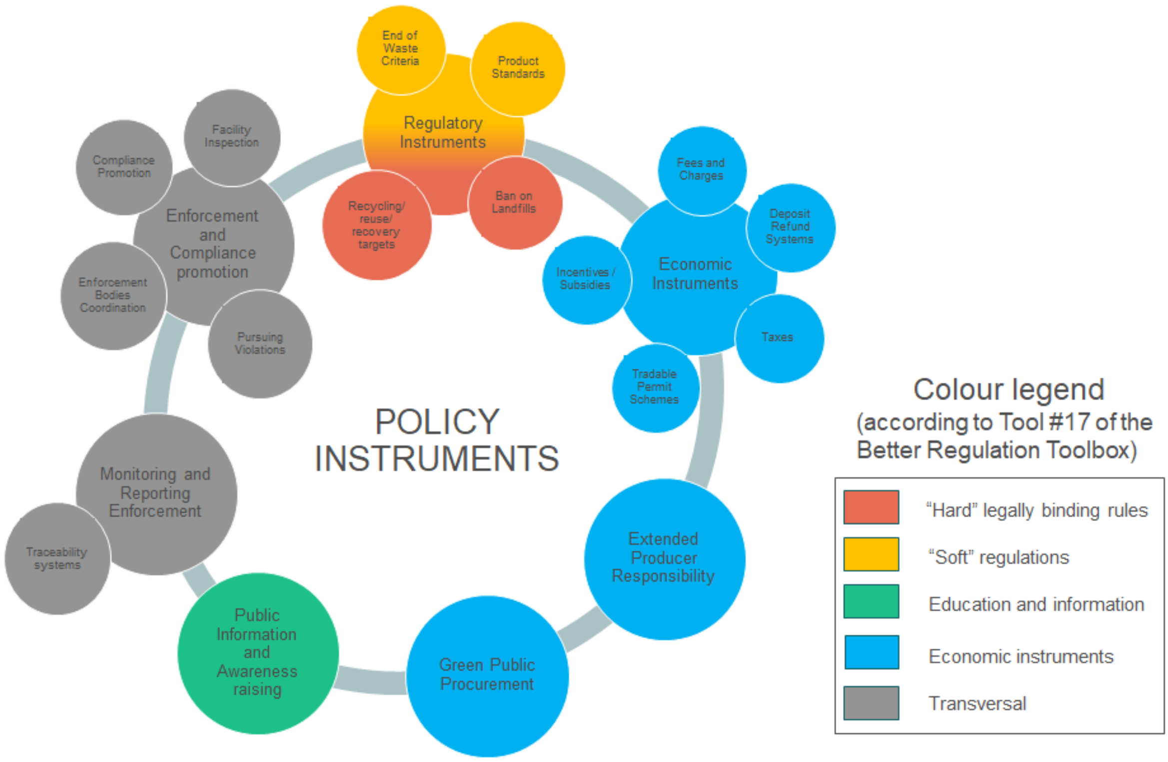
— "Excluding soil and dredging spoils, for which cost savings are considered very uncertain, the GHG saving potential is ca. 33 Mt CO_2-eq. at a cost of EUR 6.3 billion"

2.1.4. Policy interventions

The problems identified above, and underlying behaviours can be addressed using a range of policy solutions at local, regional and MS level, in the framework of policy driven at EU level, which is the focus of the present report.

There are different definitions and classifications for policy instruments applicable to waste management in the literature. The current study follows the OECD classification system in the publication "Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews" (OECD, 2019). The policy instruments are grouped in seven clusters, i.e., regulatory instruments, economic instruments, extended producer responsibility, green public procurement, monitoring and reporting, and enforcement and compliance. Besides, Tool #17 of the 'Better Regulation' Toolbox (European Commission, 2023a) categorises those instruments in four categories, i.e., 'hard' – legally binding rules, 'soft' regulation, education and information, and economic instruments. Figure 2 presents an adaptation of the clusters proposed by the OECD including the alignment with EU 'Better Regulation' Toolbox in the colour legend. This is a general classification system that applies to all kind of wastes generated in the EU. However, all the policy instruments shown in Figure 2 might not be applied to CDW.

Figure 2. Classification of policy instruments adapted from OECD. In the colour legend the classification according to the Tool#17 of the EU 'Better Regulation' Toolbox.



Source: Own elaboration based on OECD (2019 - Box 4.1. Examples of good practices for policy instruments) .

2.2.Summary: CDW Management problem analysis and drivers

This section explored the key drivers shaping today's CDW problem, including its scale, pervasiveness in the EU, expected persistence, the key stakeholders, and finally, the expected results of better CDW management on society. Figure 3 provides a high-level graphical summary of the CDW problem tree, as well as avenues for potential policy solutions.

To summarise the key insights of this chapter, as depicted in Figure 3:

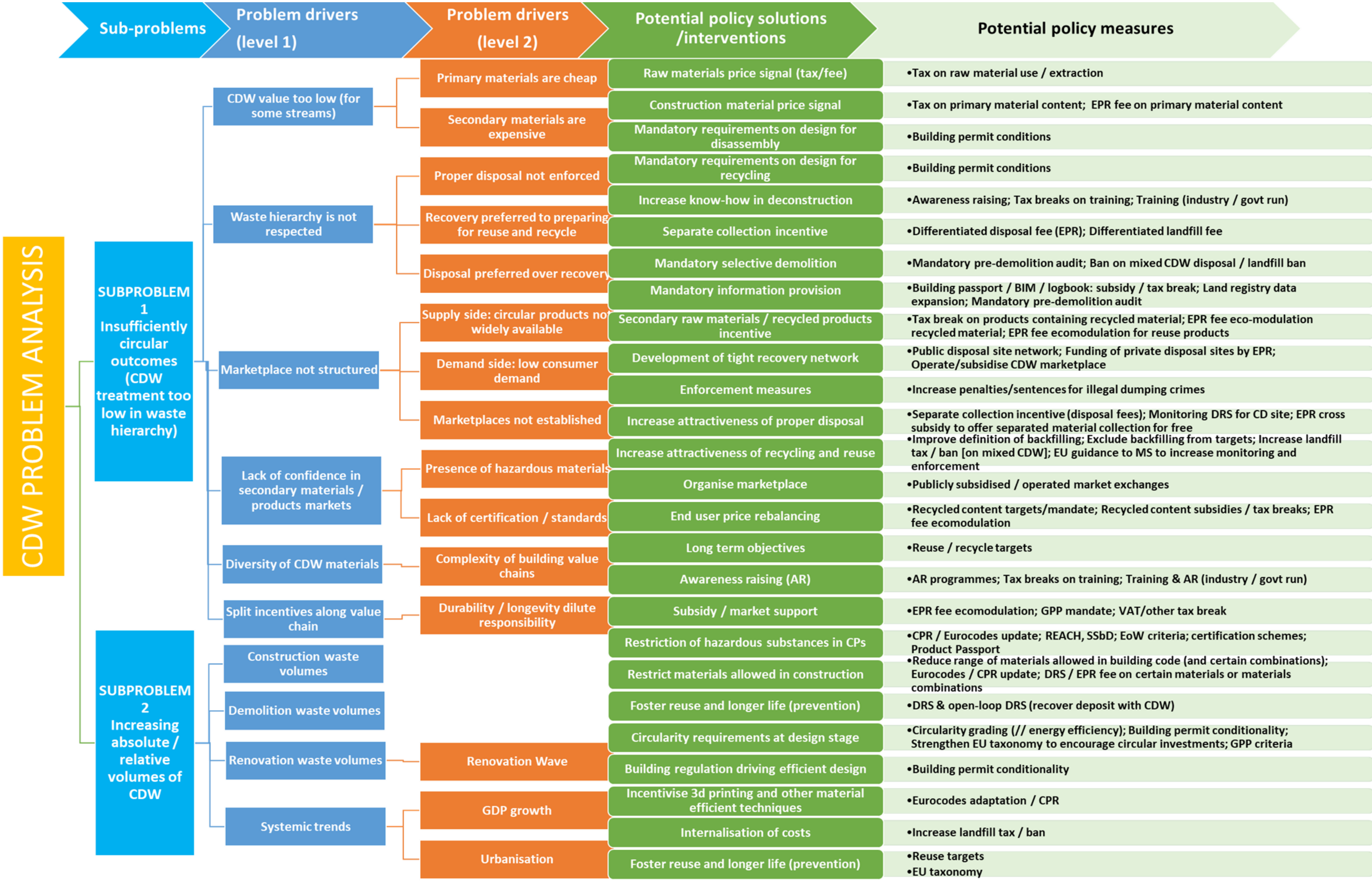
- CDW is a growing waste stream.
- CDW is not being processed in an environmentally efficient manner.

This results in the following "social costs" issues:

- Waste recovery to backfilling or to mixed aggregates is the most common practice.
- There is still room to capture more materials that are lost to landfill or illegal disposal.
- CDW materials are currently negative-value or very low-value waste, which economically restricts their transport and trade.
- Secondary materials markets do not exist or function well except for high-value metals, inhibiting recycling and reuse.

The root causes of the CDW problem are several types of market failures, including unpriced externalities, as well as the increasing volume of construction / renovation / demolition (a megatrend in Europe), and the complexity of the construction industry. See Annex 1 – Table A1 for details.

Figure 3. CDW problem analysis summary. The problem tree is presented in a simplified version. *Source: Own elaboration.*



3. Review of current and best practices in CDW policy

This chapter reviews and assesses policy instruments currently in force (or planned) in MSs but also provides a broader perspective with examples of non-EU countries. In addition, the chapter discusses an example of a novel policy, which is aid to sustainable design and the EU research and development programs that aim to improve CDW reduction, reuse, and recycling.

3.1.EU Member States' current implementation of policies for CDW

Table 1 shows a summary of the implementation status of the policies identified for CDW within the EU MSs. These instruments and legislative initiatives are categorised and further discussed in the following sections (3.1.1 to 3.1.8). The **regulatory instruments** assessed are End-of-Waste criteria, landfill bans, product standards and certifications, targets beyond WFD and backfilling definition (meaning whether the MS has further defined / clarified the WFD 'backfilling' definition). The most applied regulatory instruments across the MSs are landfill bans at 70%, when counting the 4 countries (Belgium, Finland, Malta, Netherlands) with explicit CDW landfill bans and the 15 additional countries with broader MSW landfill bans that may apply to CDW. Product standards and certifications (59%) and backfilling definition (44%) have wide application. The MSs with the highest application of regulatory instruments are Netherlands (5 out of 5) followed by Belgium (4 out of 5).

Landfill tax / fee, PAYT, resource tax, deposit-refund system (DRS) / Advance Discarding Fee (ADF), and EPR are the **economic instruments** considered. Landfill tax / fee, is applied in over 90% of countries. PAYT - DRS / ADF for CDW is the least implement. Apart from DRS / ADF (as is implemented by Spain[6]), landfill tax / fee, resource tax and incentives / subsidies are all applied by Belgium, Czechia, Denmark, Estonia and France.

Extended Producer Responsibility (EPR) is only implemented by France and the Netherlands (8% of all MS) while **Green Public Procurement (GPP)** only applies to Italy (4%). Austria, Belgium, Denmark, Estonia, France, Germany, Hungary, the Netherlands, Poland, Portugal, Slovenia and Sweden implement both CDW **traceability systems** as monitoring and reporting enforcement and **pre-demolition audits** as compliance promotion enforcement.

The Netherlands, Denmark, and Flanders region in Belgium have been identified as front-runners as they stand out due to their well-rounded policy frameworks for the handling and treatment of CDW. The policies enacted in these countries have therefore been assessed in detail, to establish what best practices look like when applied effectively (see Box 1).

[6] The DRS as implemented in Spain is described in detail later. Arguably, one could conclude that the system as implemented in Spain could be rather classified as a sort of PAYT system (a sort of anticipated deposit-fee for correct waste management).

Table 1. Summary of the status of the analysed **policy instruments identified for CDW** within the EU Member States. A green shaded box means implemented. Orange shading refers to planned measures (including voluntary measures). Red shading means not implemented / not planned. Grey means insufficient information / not searched. [The colour code for the landfill ban column is different: green is for countries with explicit CDW landfill bans; orange means countries with a landfill ban on MSW that may apply to CDW or with planned landfill bans.]

EU MS	Regulatory instruments					Economic instruments					GPP	Aid / subsidy	Monitoring and Reporting	Enforcement and compliance
	EoW criteria	Landfill bans	Product standards and certif.	Target beyond WFD	Backfilling definition	Landfill tax / fee	PAYT	Resource tax	DRS / ADF*	EPR			Traceability systems	Pre-demolition audits
Austria	Red	Orange	Green	Red	Red	Green	Red	Red	Red	Red	Red	Grey	Green	Green
Belgium	Green	Green	Green	Green	Red	Green	Red	Green	Red	Orange	Red	Green	Green	Green
Bulgaria	Red	Red	Grey	Green	Green	Green	Red	Green	Red	Red	Red	Grey	Red	Green
Croatia	Red	Orange	Grey	Red	Green	Red	Red	Green	Red	Orange	Red	Grey	Red	Green
Cyprus	Red	Orange	Orange	Red	Red	Orange	Red	Green	Red	Red	Red	Green	Red	Green
Czechia	Orange	Orange	Green	Green	Red	Green	Red	Green	Red	Red	Red	Green	Orange	Green
Denmark	Red	Orange	Green	Green	Red	Green	Red	Green	Red	Orange	Orange	Green	Green	Green
Estonia	Red	Orange	Green	Green	Red	Green	Red	Green	Red	Red	Red	Grey	Green	Green
Finland	Orange	Green	Green	Green	Red	Green	Red	Red	Red	Red	Red	Green	Red	Green
France	Green	Orange	Green	Green	Red	Green	Red	Green	Red	Green	Red	Grey	Green	Green
Germany	Red	Orange	Green	Red	Green	Green	Red	Red	Red	Red	Red	Grey	Green	Green
Greece	Red	Red	Grey	Red	Green	Green	Red	Red	Red	Red	Red	Grey	Orange	Red
Hungary	Red	Orange	Green	Red	Green	Green	Red	Green	Red	Red	Red	Grey	Green	Green
Ireland	Green	Red	Green	Green	Red	Green	Red	Red	Red	Red	Red	Grey	Red	Green
Italy	Green	Red	Green	Red	Green	Green	Red	Green	Red	Red	Green	Grey	Orange	Green
Latvia	Red	Red	Grey	Green	Red	Green	Red	Green	Red	Red	Red	Grey	Red	Red

EU MS	Regulatory instruments					Economic instruments					GPP	Aid / subsidies	Monitoring and Reporting	Enforcement and compliance
	EoW criteria	Landfill bans	Product standards and certif.	Target beyond WFD	Backfilling definition	Landfill tax / fee	PAYT	Resource tax	DRS / ADF*	EPR			Traceability systems	Pre-demolition audits
Lithuania														
Luxembourg														
Malta														
Netherlands														
Poland														
Portugal														
Romania														
Slovakia														
Slovenia														
Spain														
Sweden														
Application rate by EU Member States	5 out of 27 (19%)	19 (green/orange out of 27 (70%)	16 out of 27 (59%)	11 out of 27 (41%)	12 out of 27 (44%)	25 out of 27 (93%)	1 out of 27 (4%)	13 out of 27 (48%)	1 out of 27 (4%)	2 out of 27 (8%)	1 out of 27 (4%)	8 out of 27 (30%)	12 out of 27 (44%)	22 out of 27 (81%)

Source: Own elaboration.

Note: Public information and awareness have not been included in the table since it is a very diffuse action, and it is present in all countries in different ways. Specific examples are mentioned in section 3.1.8. Similarly, marketplaces (especially through digital platforms) have not been included in the table since they are implemented everywhere at MS and EU level – see section 3.1.3.

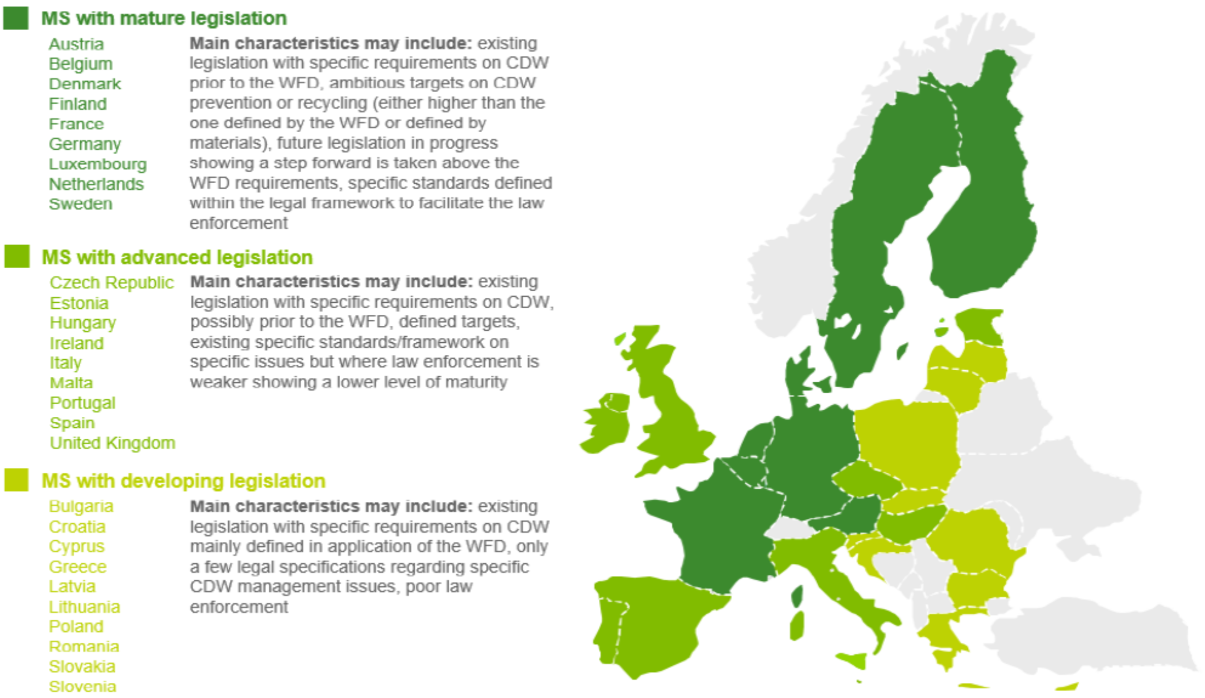
**DRS / ADF refers to Deposit Refund System and Advance Discarding Fee respectively. See sections 3.1.2.1.2 and 3.1.2.1.3.*

3.1.1. Regulatory instruments

A suitable framework of regulations to govern key aspects of waste management is of paramount importance for the environmentally sound management of CDW and especially to foster reuse and recycling. The OECD (OECD, 2019) identified four key elements of waste regulatory frameworks to ensure an environmentally sound and economically efficient management: i) an adequate **regulatory and enforcement infrastructure at the different governmental levels**, consisting of legal requirements such as **authorisations / licenses / permits, or standards;** ii) **practices and instruments** enabling competent authorities to **monitor waste facilities, control waste activities, and carry out enforcement**; iii) ensuring that facilities operate according to **best available techniques**; iv) an environmental **liability regime** for facilities to ensure adequate measures to prevent environmental damage.

The EU general waste regulatory framework is structured around one main piece of legislation, namely the WFD 2018/851, and is complemented with the Regulation on the shipments of waste (Regulation EU 2024/1157 amending EC 1257/2013 and 1013/2006) and two waste regulations on waste treatment operations for incineration (Directive 2000/76/EC) and for landfilling (Directive 1999/31/EC). However, as shown in Figure 4, the CDW legal framework for all MSs does not present the same level of maturity. According to the analysis of Sönmez & Kalfa (2023) based on European Commission (2017), all 27 MSs have transposed the WFD and present CDW management plans. However, only 4 of 27 present specific regulations for CDW management. Concerning sorting and collection, 16 out of 27 present national/regional sorting obligations and 13 out of 27 present national/regional separate collection obligations (being however mandatory in all 27 MSs the separate collection and management of the hazardous fraction of CDW).

Figure 4. In 2017, most EU Member States had already achieved a "mature" or "advanced" level of maturity of legal framework regarding CDW.



Source: European Commission (2017)

It is not the scope of this section to analyse all legal frameworks in detail, but instead, the existing waste regulatory framework within **three front-runners (i.e., The Netherlands, Denmark, and**

Flanders region in Belgium) is explained more in detail in Box 1 to give an idea of best practices. An overview of the existing policies and laws on CDW management of several EU countries (the Netherlands, Italy, Austria, Germany) and other non-EU countries (UK, Japan, China, South Korea) can be found in Ma et al. (2023). Further subsections analyse in detail specific regulatory instruments.

Box 1. Waste regulatory frameworks of the three identified front-runners

The Netherlands

In the Netherlands, the Environmental Management Act (01/05/2004) (Dutch Government - Ministry of Housing Spatial Planning and the Environment, 2004) defines an integrated approach to environmental management and outlines the role of government at its various levels (from the municipal to the national). It also establishes the necessity for the Ministry of Infrastructure and Water Management to draw up a National Waste Management Plan once every six years at least (Dutch Government - Ministry of Infrastructure and Water Management, 2017b), setting out the policy for waste management in the country. The current plan, LAP3, covers the period 2017-2023, with the goal of promoting the transition to a circular economy. The LAP3 is structured in two main sections: the policy framework and the sector plans, which refer to 85 specific waste streams[7], among which mixed construction and demolition waste, stony material fraction, gypsum, aerated concrete, roof material, wood, flat glass, and stone wool. The sector plans define minimum standards with regards to treatment options for these waste fractions, regulate their imports and exports and establish whether preparation for reuse and/or recycling is feasible, at least in principle. The cost of treatment is also described in some of the material-specific sector plans; based on the estimated costs, treatment options may vary.

Several policies have been developed addressing another regulatory aspect relative to the construction sector (and its waste production); namely, the need to apply for permits at various stages of a building's life. The Building Decree of 2012 (Wahlström et al., 2019) defines the technical regulations representing the minimum requirements (in terms of health and safety, usability, energy efficiency and environment) with which all structures need to comply; it is therefore a fundamental piece of legislation at various stages of the building's life cycle (construction, refurbishment, demolition). Crucially, it also defines the procedure regarding pre-demolition audits: demolition permits are not required; however, a notification, containing information on the nature and amount of waste materials, their discharge destination, the demolition plan and the asbestos inventory, should be sent when the concerned structure is expected to produce more than 10 m^3 of demolition waste. This decree is expected to be combined with the Energy Performance of Buildings decree into the Living Environment decree in 2024 (Boddaert et al., 2023). While the Building Decree focuses on technical requirements and standards, the General Provision Act Wabo defines the rules for granting the All-in-one Permit for Physical Aspects, needed to build or renovate. The permit provides permission for three main types of activities: building permission, planning and zoning permission and environmental permission. The requirements for each sub-permit are found in different laws, including the aforementioned Building Decree 2012 (Sanders, 2015).

Some changes might come into effect in 2024, when the Environment and Planning Act will be implemented. This act combines twenty-six laws, with the goal of simplifying the permit application process, and its main rules are elaborated in four decrees, among which the Environment Buildings Decree (Dutch Government - Ministry of the Interior and Kingdom Relations, 2021). The Environment Buildings Decree contains rules on the safety, health, sustainability and usability of construction works, and refers to the use of CE markings for construction products, the construction product regulation, and the permit requirements for buildings.

[7] https://lap3.nl/sectorplannen/sectorplannen-1-85/

On the construction side, the Green Deal Timber Construction should be implemented starting in 2025 in the Metropolitan Region of Amsterdam, meaning that 20% of all new housing projects will have to be built with wood or other biobased materials. This agreement should lead to an expected annual CO_2 emission reduction of around 220 000 tons (AMS, 2021) and might significantly change the CDW composition in coming years. At the country level, the Raw Materials Agreement was signed in 2017, in connection with the Circular Netherlands in 2050 program (Dutch Government - Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs, 2016). The agreement is not specific to the construction sector, but it does include it. Its goals are to ensure that the raw materials in existing production chains are used efficiently; that when new raw materials are needed, they are, where possible, sustainably produced, renewable and widely available; and that products are designed with an eye to circularity. As for the Circular Netherlands in 2050 program, it involves the definition of transition agendas for a set of priority sectors, among which the construction sector (and specifically housing; offices and industrial buildings; concrete viaducts and bridges; road surfaces). The program centres around a series of actions aimed at promoting the transition towards a circular economy: reducing raw material use (narrowing the loop), substituting raw materials, extending product life (slowing the loop) and high-grade material processing (closing the loop). Where the construction sector in particular is concerned, the actions to be undertaken involve building efficiently and using fewer primary materials; designing and building in such a way as to extend the lifetime of the product (thus reducing the need for materials); using adaptive construction; reusing building materials and components or, when that is not an option, adopting high-grade recycling practices; implementing circular design practices; developing and using alternative materials, characterised by a lower environmental impact. Specific interim objectives, to be achieved by 2030, have been laid out, starting with a 50% reduction in the use of primary raw materials (acting across different sectors).

Targets specific to the construction sector include at least 10% of binding agents and 20% of other raw materials (except asphalt granulate) becoming of alternative origin (secondary or renewable materials), where road surfaces are concerned; a 50% reduction in annual CO_2-eq emissions (from 107 to 53 Mt CO_2-eq/year) in the Civil Engineering & Utility Construction and the Ground, Water and Road Construction sectors (Transition Agenda Circular Economy, 2018). Cost-related information can be found in Table 40 (Budget consequences of policy under Article 21) in "National Circular Economy Programme (2023-2030)" and in section 5 - The required investments of "Transition Agenda - Circular Construction Economy" (Transition Agenda Circular Economy, 2018).

Denmark

In Denmark, a National Strategy for Sustainable Construction[8] was developed in 2021. The plan has five focus areas: climate-friendly construction, durable buildings, resource efficiency, energy efficiency, and digitally supported construction. Its goals include the reduction of the environmental impact of buildings, to be assessed using a Life Cycle Assessment (LCA) approach; the adoption of a Life Cycle Costing (LCC) perspective, to be achieved by integrating the LCCbyg tool with BIM, the improvement of health and indoor climate in buildings. The preparation for the introduction of CO_2 emission limits is also part of this plan and is finalised in the New Building Regulations[9]. According to these regulations, as of 2023 an LCA must be performed for most new buildings, for an occupancy permit to be granted. Buildings with an area exceeding 1 000 m^2 must also adhere to a limit of 12 kg CO_2-eq per m^2 per year; this value will be progressively lowered until 2030.

Where the end of life in particular is concerned, waste management is regulated by the Danish Waste Regulations: according to article 35, municipalities must ensure that CDW is reused, recycled, or used in another material recovery process, and article 63 states that construction and demolition companies must separate the following categories of waste: stone, brick and tile, concrete, metal, mixed mineral, plasterboard, mineral wool, earth and soil, asphalt, mixed concrete and asphalt (Barth & McKinnon, 2023).

[8] https://scandiconnect.se/scandinavian-markets/sustainable-construction/
[9] https://greensurvey.dk/onewebmedia/New%20building%20regulations.pdf

As is the case for the Netherlands, a Danish Circular Economy Action Plan, with the built environment as a focus area, has been developed (Barth & McKinnon, 2023; Danish Government - Ministry of Environment of Denmark, 2021). The action plan is constituted of 129 initiatives, many of which are also included in Climate plan for a green waste sector and circular economy (2020), Strategy for Green Public Procurement (2020), National Strategy for a Sustainable Built Environment (2021), Strategy for circular economy (2018) and Action Plan on Plastics (2018). Where the construction sector is concerned, the action plan involved an update to the building regulations, to include sustainability-related elements (this was carried out in 2022, with the New Building Regulations mentioned above); the introduction of increasing climate footprint limits for buildings for the period 2023-2029 (this was also done in the New Building Regulations); the further development of the existing Danish LCA and LCC tools for buildings into design tools (scheduled for 2024); the introduction of requirements relative to standardised demolition plans (with the consequent boosting of selective demolition); the establishment of limits for the content of problematic substances in recycled brick and concrete; the improvement of the traceability system for CDW. The measures developed in the action plan propose to encourage the design, production and use of resource-efficient, reusable products; target products containing critical raw materials, to prevent their becoming waste; and reduce waste generation. Specific targets and indicators, relating to CO_2-emissions, material footprint, Ecolabels, circular material use rate, climate footprint of public procurement, waste management indicators, etc., are described in Table 1 (Targets and indicators in the Action Plan for Circular Economy) in "Action Plan for Circular Economy (2020-2032)" (Danish Government - Ministry of Environment of Denmark, 2021)

Region of Flanders

In the region of Flanders (Belgium), the framework legislation on waste management and material cycles is the Waste and Materials Decree of 2012, together with its implementing regulation, VLAREMA (EEA, 2016b; European Commission, 2016b). They focus on sustainable material management, adopting an outlook that considers products along their entire life cycle chain and promoting waste prevention.

The years between 2014 and 2020 were also covered by the Material Conscious Building in Circuits policy program, which proposes a framework to support cooperation between the authorities and various stakeholders within the construction sector, with the goal of boosting sustainable material management and, more specifically, minimising the use of primary raw material, reducing the design footprint of building products and bolstering the implementation of modular and flexible construction techniques. In particular, a voluntary demolition inventory for smaller buildings is promoted, to be used as a basis for selective deconstruction (EEA, 2016b; FCRBE Project, 2019).

3.1.1.1. End of waste criteria

End of waste (EoW) is a legal instrument to facilitate the transition from waste to product, and thus by extension facilitate the conditions for a circular economy (Johansson, 2023). EoW criteria are rules that establish the point in the recovery process at which quality material can drop their waste status and enter recycling markets.

These criteria are defined by techno-economic-environmental assessments that verify material safety and the existence of a market for candidate end of waste materials. Four general conditions are drawn for waste which has undergone a recycling or other recovery operation and thus will be considered to have ceased to be waste if it complies In Article 6 of the WFD: i) the substance or object is to be used for specific purposes; ii) a market or demand exists for such a substance or object; iii) the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and iv) use of the substance or object will not lead to overall adverse environmental or human health impacts.

Article 6(3) of the WFD grants MSs the authority to formulate their own guidelines for determining when waste no longer carries its waste status within a specific waste category, based on the broader criteria mentioned before. However, these national EoW criteria can only be established if the relevant waste category lacks specific EU-level regulation, as outlined in Article 6(2) of the directive. Currently, EU-level EoW criteria do not exist for CDW, although some mineral CDW fractions have been identified as priority stream for further EU-wide EoW criteria development along with plastic waste, textiles and rubber (Orveillon et al., 2022). Article 6(4) specifies that in the absence of community-level criteria, MSs may individually decide on a case-by-case basis that certain treated waste no longer requires the waste designation.

As reported in the EU project CINDERELA[10] some countries have established EoW criteria for the use of SRM obtained from the valorisation of CDW and industrial waste or by-products, namely as aggregates. **Italy** in Decree N. 205/2010 has included EoW criteria for aggregates made from CDW for paving roads (in Italian "granulato da conglomerato bituminoso") and in Decree 5/4/06 n.186 there are EoW criteria for CDW (e.g., the conditions for construction waste to be considered as SRM). The objective of this regulation is the environmental benefit and the added economic value of transforming waste into a valuable resource. The regulation should contribute to reducing the consumption of raw materials and the amount of waste to be disposed of, thereby promoting a more sustainable and efficient use of resources. In **the Netherlands**, a regulation introduces EoW criteria that apply to recycled aggregates from stony waste, Regulation No IENM/BSK-2015/18222 of February 5, 2015 (European Commission, 2017 - Country factsheets)[11]The requirements focus both on the waste that is accepted, such as the prohibition of tar asphalt in the recycled aggregates, and on the production process of the recycled aggregates (i.e., the producer must have a process control system in place). In **Flanders (Belgium)**, in the Materials Decree of 2012 (named VLAREMA) some specific criteria are developed for recycled granulates derived from CDW (FCRBE Project, 2019). In **Ireland**, the National End-of-Waste Decision EoW-N001/2023 by the Environmental Protection Agency (EPA) establishes criteria determining when recycled aggregate resulting from a recovery operation ceases to be waste. The criteria allow for the replacement of virgin aggregates with recycled aggregates in uses such as general fill, road construction, railway ballast and other non-structural uses. The criteria regulate the quality of waste inputs, the recovery processes and treatment techniques used to process the waste, the specified uses and restrictions on use. In addition, a verification sample must be taken from each batch of recycled aggregates produced and tested to ensure that the criteria have been met. The criteria apply to aggregates recycled from construction and demolition waste, including soil, stone, concrete, bricks, and ceramics. The latter along with glass and tiles are the CDW accepted to produce aggregates to be used in road building in **France**. The French EoW regulation provides an approach to assess the environmental acceptability of alternative materials produced from CDW and industrial waste or by-products for road construction usage specifying that they must be capable of being implemented under the conditions and with the same equipment as the natural materials they replace. For excavated soils, criteria deviate from the ones in the WFD since the excavated soil if not contaminated can be used in earthmoving programs (i.e., between sites) whenever they satisfy geotechnical and geological/environmental parameters.

Finally, other countries and regions are making efforts to include EoW criteria in their legislation. **Finland** is currently in the process of preparing national EoW criteria for concrete waste. The Government Decree (858/2018) applies to manufacturers who have an environmental permit for concrete waste crushing operations and contains paragraphs on different topics such as the pre-treatment and recovery of concrete waste, sampling instructions to examine the environmental suitability of the material, use and storage instructions for the recovered material. In the Walloon region (**Belgium**), new legislation is under development that will allow Federations to try to create an EoW criteria for recycled aggregates and for excavated soils. **Czechia** is planning to develop

[10] https://www.cinderela.eu/

[11] Country factsheets - https://environment.ec.europa.eu/topics/waste-and-recycling/construction-and-demolition-waste_en

criteria for certain materials and waste streams, to clarify when a material should be classified as by-product and when it can cease to be waste (European Commission, 2017 - Country factsheets).

For the remaining MS it is unclear when and how the waste can obtain the status of product / SRM. Therefore, a clarification / development of an EU-wide regulation could be helpful. Recently, a project named “Background Data Collection for Future EU End-of-Waste (EoW) Criteria of Construction and Demolition Waste (CDW) – GROW/2022/OP/0015” (Reetsch et al., 2024) was commissioned by the European Commission in order to collect and analyse data and background information on CDW / by-product streams. The data and information collected is used to generate a priority list for EoW criteria for the waste / by-product streams identified: aggregates, concrete, asphalt, bricks, wood, gypsum, insulation plastic (PUR / PIR / EPS), insulation mineral (stone wool / glass wool), building products for reuse (e.g., windows and doors), and plastics (PVC for rigid plastic pipes / window frames). Furthermore, the CINDERELLA research project proposed a harmonized approach for EoW protocol (including lab and field tests, parameters to be assessed, limit values, etc.) for the use of SRM obtained from the valorisation of CDW as aggregates[12].

To meet the EoW criteria, it is likely that the CDW will need to undergo waste treatment for the handler to obtain a permit from the competent authority (Article 23 of the WFD). However, MSs have the option to exempt waste recovery options from the need for permits (Article 24 of the WFD), which can facilitate reuse by reducing the administrative burden required. In these cases, MSs shall set rules for the types and quantities of waste that may be covered by an exemption and the method of treatment to be used (Article 23 of the WFD). As MSs are required to keep a register of establishments subject to exemptions (Article 26 of the WFD), there is still some administrative burden to CDW handlers even in this case.

3.1.1.2. Standards and Certifications

Certifications ensure the compliance of systems, processes, products, services and people with the requirements **set by international norms and standards** that must be complied by professionals, companies and public organizations. Certifications are issued in various product sectors by a third-party body accredited pursuant to ISO/IEC 17065, ISO/IEC 17021-1, ISO/IEC 17024, whose independence with respect to the object to be certified – whether it is a good or service or an organization – is verified and attested by the **accreditation body** of each individual MS.

The compliance assessment of a product concerns only some characteristics of the object, particularly those contained in the reference standard or technical specification in a specific market, industry or region. This may be a mandatory requirement due to a potential risk to the end-user, or a voluntary exercise which provides a unique selling point for the product. In general, a product certification process can be broken down into the following stages:

- Application – to a competent entity approved for product certification.
- Evaluation – the product is tested in an accredited lab by a competent testing entity as per the relevant standard or regulation.
- Review and attestation – after testing (and factory audit, as required), the resulting outcomes (test reports, factory audit reports, corrective actions taken, as needed) are reviewed. Once conformance to the standard/regulation is confirmed, a certification decision

[12] https://www.cinderela.eu/The-project/Reports/D5.5-End-of-waste-criteria-protocol-for-waste-used-as-aggregates

is taken. If approved, a certificate of conformity, or a license, can be granted for use as a product certification mark.

- Surveillance – once certification is granted, the product and the manufacturing facility is periodically checked and visited, to ensure that the product still meets the qualification criteria required at the time that the certificate/license was granted.

Once the product satisfactorily passes these stages, the product may now bear the certification mark, and the consumer now knows it has met the requirements of the relevant standards. Because of the evaluation of the manufacturing process of a product, the positive judgment and confidence in its conformity extends over time. Through the certificate, the manufacturer or supplier can demonstrate to the market its ability to obtain and maintain the conformity of the products manufactured.

Product standards can play a role in encouraging the shift to a circular economy. Under the construction products regulation (European Union, 2011), there is a set of EU harmonised standards, available since 2016 (after reviewing the versions introduced in 2004), for the use of several products that can appear within the CDW, e.g., aggregates or flat glass (Henrotay et al., 2016). EU standards are developed through one of the EU standards organisations, namely the EU committee for standardisation (CEN) or the EU committee for electrotechnical standardisation (CENELEC).

For CDW, the use of recycled aggregates (RA) as a SRM for the concrete industry is particularly relevant for the EU circular economy objectives and shows great potential since i) the sector of construction aggregates is the largest non-extractive industry worldwide concerning material use, ii) concrete plays a central role in construction being the most widely used building material in the world, iii) incorporation ratios of RA in concrete in the range 5-60% depending upon application are technically-sound (Pacheco et al., 2023). However, it should be noticed that Pacheco et al. (2023) argue that current regulations are not a limiting factor preventing the increased market uptake of RA by the concrete industry (i.e., the maximum incorporation ratios of RA allowed in regulations are much larger than the current market uptake), suggesting that the barriers are mainly elsewhere (market, sector logistics/practices and consumer awareness, etc.).

Focusing on the field of natural, recycled and manufactured aggregates, the technical committee CEN/TC 154 is devoted to the standardisation by specifying aggregate performance characteristics, sampling and methods of testing. For example, EN 12620 “Aggregates for concrete” and EN 13139 “Aggregates for mortar” cover physical and chemical properties of aggregate across a range of uses. EN 12620 also provides standards for the physical and chemical properties of recycled aggregates from CDW. EN933 provides a set of separate standards addressing the geometrical properties of aggregates. Other standards (produced by other technical committees, i.e., CEN/TC 104), are focused on the concrete products and define the maximum allowable incorporation ratio of recycled aggregates in concrete (EN206 “Concrete – Specification, performance, production and conformity”).

However, despite having the above-mentioned harmonised EU standards for applications which are mandatory in all EU MS, there can be differences at MS or even regional levels since these regulations are typically made at the country level, with some exceptions of regulations with regional validity (Pacheco et al., 2023). For example, for the maximum allowed quantity of RA for structural concrete, Pacheco et al. (2023 - Table 9) give an overview of standards / national laws and the values by country. According to the authors, the maximum allowed amount of RA spans from 5% (for low demanding exposure classes of France) to 60% (for non-demanding structural concrete and moderate quality RA of Italy).

The information included in this section has been collected for all EU MS. Some examples of existing national product standards or laws concerning CDW related products, mostly focused on, but not limited to, concrete and recycled aggregates are included.

Austria has a norm for recycled building materials (ÖNORM B 3140) whose aim is to improve the suitability of the waste to produce recycled building materials. The regulation contains provisions on the further treatment of CDW and covers a wide range of end uses that sets requirements for RA for unbound and hydraulically bound applications as well as for concrete from 2020.

Belgium has in place standards for sustainability assessment of buildings using a life cycle approach. Besides, there are standard recycling specifications for road works in the 3 regions (European Commission, 2017) and a standard for concrete (NBN B 15-001) that states the maximum RA incorporation ratio and the limitations.

Cyprus has standards for recycled CDW to be marketed, but they are not mandatory. **Czechia** has standards for the quality of recycled construction materials (Zákon č. 22/1997 Sb). In many countries there are standards that state the maximum RA incorporation ratio in the concrete (Pacheco et al., 2023 - Table 9) such as **Denmark** (DS 2426), **France** (NF EN 206-1/CN), **Germany** (DIN 1045-2), the **Netherlands** (NEN 8005), **Sweden** (SS-137003), or even national laws or specifications such as **Italy** (Ministry Decree NTC:2018), **Portugal** (National specification LNEC E471) or **Spain** (Royal Decree EHE-08).

According to the European Commission (2017 - Country factsheets), **Estonia, Slovakia** and **Hungary** have also standards for RA, **Finland** implements procedures related to CE marking of recycled products while the sustainability standard of **Ireland** is applicable for public roadwork only.

At MS level, and at EU level building-level requirements that rely on the use of **building sustainability certification** is mainly a voluntary best-practice but on some occasions, it is mandatory for a public tender. In the **UK**, public procurements of local authorities and municipalities often require a certain level of BREEAM. The BREEAM identifies specific criteria for circular economy, not only for the 'use of reused / recycled materials' and the 'reuse / recycling of CDW', but also regards 'design for disassembly', the 'design for adaptability', and 'pre-demolition audit'. Similarly, in **Denmark** many public buildings ask for the sustainability certification (generally DGNB) to be a 'manifest' of sustainability of the building stock. In the **Netherlands**, it is important to highlight the work done by the DGBC (Dutch Green Building Council) on the proposed improvement of BREEAM-NL (New Construction and Refurbishment and Fit-Out based). The proposal gives six additional indicators about: 'Design for reassembly', which requires de / re-mountable connections for products, and 'Knowledge development and sharing' which requires building materials passports and buildings' specific 'disassembly guidelines'; and nine improvements about 'maximizing amounts of reused materials and renewable materials' (Giorgi et al., 2022). **Italy** presents some reference practices: UNI/PdR 88:2020, useful for verifying the recycled / recovered / by-product content, declared by an organization for its product, and UNI/PdR 75:2020, which defines an operational methodology for selective deconstruction that favours the recovery (recycling and reuse) of CDW. Further,

Whereas EU-level GPP criteria for building design and construction that are relevant to CDW are voluntary, there are specific mandatory GPP requirements in legislation such as the Energy Performance of Buildings Directive and the Construction products regulation. Also, the EU taxonomy applies to funding for infrastructure including the construction of new buildings and building renovations.

3.1.1.3. Landfill ban

A **Landfill ban** is one of the most effective and most common policy instruments for increasing CDW recovery rates according to European Commission (2017). Landfill bans (broadly interpreted) have been implemented in 17 out of 27 EU MSs[13]. However, landfill bans are generally applied to municipal solid waste (MSW) (CEWEP, 2021) and – depending on how they are defined – may also apply to some fractions of CDW. Table 1 reports all countries with any landfill ban (even if not specifically applying to CDW). Countries with explicit CDW landfill bans are noted in green. Countries with a landfill ban on MSW that may apply to CDW or with planned landfill bans are assigned the colour orange.

For example, in **Austria** and many other countries, restrictions apply to waste with total organic carbon (TOC) higher than 5%, and it is possible that CDW contains high organic materials quantities above that level (mostly in the fines fraction) depending on the sorting and collection process. In **Czechia**, the Legislation no. 352/2014 introduces a landfill ban planning that from 2024, landfilling or energy recovery of recyclable, recoverable and mixed municipal waste will not be allowed anymore (European Commission, 2018a). In **Cyprus**, according to the recently amended landfill regulations, it is now banned to landfill waste that has been separately collected to prepare for reuse and recycling, and by 2030, it will be prohibited to landfill any waste suitable for recycling or recovery, excluding waste for which landfilling is the best environmental option (EEA, 2022a).

Other countries such as **Belgium (Wallonia and Flanders)** impose restrictions on separately collected waste and untreated waste that directly apply to CDW (it is forbidden to landfill the mixed fraction of CDW directly) (European Commission, 2017). In **the Netherlands**, a landfill ban is in place (*Decree for Landfill and Waste Disposals Bans*, 1995) (Scharff, 2014) that, while it does not focus exclusively on CDW (it includes over 60 waste streams), it does concern several relevant CDW streams: mixed CDW, stony materials, roof waste (e.g., tar, bitumen), wood, metals, paper and cardboard, plastic, glass (European Commission, 2018a). Specific reference to CDW landfilling is in place in **Finland** (that entered into force on January 1, 2020) (CEWEP, 2021), and in **Malta** where landfilling clean inert CDW is banned (instead it is diverted to quarries for backfilling) (European Commission, 2017).

3.1.1.4. Backfilling definition

As mentioned before, the management of CDW in the EU is regulated by the WFD that recognises backfilling as a recovery operation. Specifically, backfilling falls under "other recovery" as an operation in which waste replaces other materials to fulfil a particular function but without being prepared to fulfil that function through recycling or preparation for reuse operations nor returning to the economic material cycle. The amended WFD of 2018 introduced a revised definition of backfilling that reads "backfilling means any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes". This is stricter than the earlier definition in Commission Decision 2011/753/EU (European Commission, 2011), which reads "backfilling means a recovery operation where suitable waste is used for reclamation purposes in excavated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials".

According to the European Commission (2017), 12 out of 27 EU MS apply the backfilling definition within their national boundaries (see Table 1). However, there are still some reporting issues concerning treatment categories due to the different interpretation of backfilling among MSs (see

[13] Meaning additional restriction on different streams additionally to the requirements of Directive 1999/31/EC on the landfill of waste (Art. 5): liquid wastes; explosive, corrosive, oxidising, highly flammable or flammable wastes; hospital and other clinical wastes; whole used tyres; any other type of waste which does not fulfil the acceptance criteria determined in accordance with Annex II of the Directive.

examples in Cristóbal García et al. (2024). Thus, it can be argued that further clarity or guidance on backfilling reporting would be beneficial (Cristóbal García et al., 2024).

3.1.1.5. Targets beyond the WFD

Several MSs have proposed targets beyond the EU-wide target of "**by 2020**, the preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of **non-hazardous construction and demolition waste** excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be **increased to a minimum of 70% by weight"** included in the WFD (see Table 2) (RE4 Project, 2017a). The overview in Table 2 also includes countries setting specific targets on excavated soil or whenever they include those materials within the target (i.e., differently from the WFD, which does not include 'natural occurring material' within the 70% recovery target). Note that there is a lot of ambiguity when transposing the WFD to national laws on the terms recovery and recycling (e.g., to the authors, it is not clear if countries like Denmark and Finland, when referring to recycling targets consider only recycling and not recovery).

In some countries, targets on CDW management are articulated as landfill restrictions or targets on landfilling. As an example, **Spain** imposes a landfill **restriction** since 2020 of a maximum of 30% of non-hazardous CDW (that is in line with the WFD target of recovering 70% of CDW) and maximum of 10% of excavated soil and rocks over the total volume of natural excavated materials (Spanish Government – Ministry of the Agriculture Food and Environment, 2015).

Table 2. Specific EU national targets on CDW. Note that the EU WFD target for 2020 in relation to CDW management consists of recovering a minimum of 70%, excluding naturally occurring material (e.g., notably soil). Data extracted from the European Commission, (2017 - Country factsheets) and the RE4 Project (2017).

Country	National target CDW	National target for excavated soil
Belgium	Regional targets: -Flemish: Recycling 75% (2000) -Brussels: Recycling 90% (2020 – Nonbinding) -Walloon: Recycling 87% (2010)	-
Bulgaria	Specific targets for recovery of materials from non-hazardous CDW by materials by 2020: - Concrete – 85% - Bricks and tile/ceramics – 70% - Wood – untreated – 80% - Glass – uncontaminated – 80% - Plastics – excluding packaging – 80% - Metals – 90%	
Czechia	The recovery/recycling of 75% (by weight) of CDW produced by 31/12/2012	The target includes the use of uncontaminated soil and stones for re-cultivation and landscaping
Denmark	Maintain a high recycling rate (at least 70%) by 2020	-
Estonia	75% recovery (2020)	-

Finland	At least 70% by weight of the CDW is used in production other than as energy or fuel.	-
France	WFD target (2020) - 70% CDW recovery and recycling	The target does not excludes naturally occurring material
Ireland	WFD target (2020) – Also 85 % recovery by 2013 (voluntary construction industry initiative)	Regional plans include recovery of soil and stone in the target.
Latvia	75% recovery (2020) established in Latvian regulation n.598 of the Cabinet of Ministers establishes	-
The Netherlands	95% recovery of CDW	Soil waste included in the calculation
Spain	WFD target (2020) - 70% CDW recovery and recycling	Soil and stones (17 05 04) used in earthworks and restoration, backfill: Objectives: 90% by 2020

Source: Own elaboration.

3.1.2. Economic instruments

Economic instruments used in waste policy adjust the market dynamics of product design, use, and waste management such that higher echelons of the waste hierarchy are preferred, i.e., waste prevention, reuse, and recycling is made more attractive to the relevant actors than e.g., landfill and incineration disposal options. Economic instruments can be effective and efficient policy measures for the prevention, minimisation and sound management of waste, including CDW. Fees and taxes for example could assist governments in recovering the cost of waste management and to internalize the environmental and human health costs (i.e., supporting the polluter pays principle), but they may also have “unintended” consequences. Fundamentally, economic instruments can be used for encouraging behavioural changes necessary to achieve waste policy objectives (OECD, 2019).

Economic instruments on waste (whether CDW or otherwise) are well-studied and based on a robust conceptual framework (OECD, 2019; Porter, 2002 among many others). The EEA (EEA, 2023a) provides an overview of economic instruments for municipal waste, which principles are applicable also to other waste streams such as CDW. From a regulatory perspective, economic instruments are already the object of established guidelines under the WFD: Annex IVa of the WFD sets out a (non-exhaustive) list of 15 measures to be considered as economic instruments; however, most are voluntary, and not all are strictly speaking economic in nature.

From a general perspective, CDW constitutes for its majority a material with low economic value. If separated into material fractions, some of those might acquire a positive value, while others will remain unwanted; this is compounded (as discussed above in 2.1.3.1) with the bulkiness and high costs of transport which rapidly erode any value. The role of economic instruments is therefore to ensure that negative environmental outcomes do not arise due to this low or even negative value triggering low-cost disposal options; for instance, illegal dumping (cf. 2.1.3.2).

Theoretically, introducing a charge for CDW management is in line with the polluter-pays principle and, economically, helps cover the cost of treatment. However, it also risks driving unwanted behaviour to escape that fee, typically leading to illegal disposal or other creative behaviours from the waste holder, but not necessarily the most environmentally beneficial outcome.

In the rest of this work, and at the most general level, this type of charge is called 'waste management fee' (WMF)[14], i.e., a charge borne by a waste handler to cover the full cost of managing the waste. These fees can take a broad variety of forms, such as: discarding fees, applied to the waste generator or waste handler who discards waste; disposal fees, such as landfill taxes or incineration fees; "Pay-As-You-Throw" schemes, etc.

The acquis of EU waste legislation recognises the difficulty of a straightforward charge on waste discarding by the waste generator, as this reduces the incentive for compliant behaviour of the holder of negative-value goods at the time and place of discarding, considering there might be more economically attractive options (see discussion in 2.1.3.2). One of the solutions adopted for instance in the end of life of vehicles or in the waste from electrical and electronic equipment (WEEE) context, is the **"free take-back"** principle: the charge is incurred at an earlier point in the value chain / lifecycle of the product and discarding itself is made "free".

In the context of CDW, these lessons learnt from other waste streams could be translated into effective economic instruments adapted to the nature of CDW streams. For instance, as analysed in the review of the EPR scheme set up in France (see section 3.1.2.1.4), **separated fractions can be discarded for free** but mixed CDW incur a WMF (like unsorted municipal waste in some PAYT schemes).

Therefore, it could even be worth envisaging a model where discarding is not linked to a charge, a positive contribution (discarding is rewarded by a payment), as discussed by the OECD (OECD, 2004). Two issues therefore arise the source of the funding for such a monetary flow, and the potential negative consequences of reward discarding (disincentivising waste reduction, and worse, the potential of payments for stolen goods). These issues are discussed further in the coming sections. Also, the practicalities of charging for discarding in the form of an ADF which may take several forms ("eco-contribution", returnable DRS fee, advance disposal charge, EPR fee, etc.) are discussed.

3.1.2.1. Environmental charges

Environmental charges increase the cost of polluting products or activities and thereby discourage their consumption or production; as such, they are an example of Pigovian charges, which aim to internalise externalities and implement the polluter-pays-principle. In waste policy, taxes and fees are used to internalise the full costs of waste treatment and disposal, making more environmentally harmful treatment methods more costly. Theoretically, incentivizing actors to use more environmentally beneficial alternative treatment methods such as reuse and recycling. For CDW and MSW, typically landfill and incineration taxes are applied (OECD, 2019). In general, environmental taxes, for statistical purposes, include energy taxes, transport taxes and taxes on pollution (e.g., landfill taxes) and resources (EEA 2023a).

3.1.2.1.1. Landfill taxes / fees

Landfill taxes / fees (fixed or progressively increasing), are widely used levers to disincentivise landfilling and, ideally, promote CDW recovery and recycling. In total, 25 EU MSs have a CDW landfill tax / fee (Table 1). Only Croatia and Cyprus do not have it, but according to the EEA (EEA, 2022a) for the latter a tax is planned to be applied from 2024 onwards. Landfill taxes have been extensively studied as part of the EU's portfolio of environmental policies aimed at increasing recycling (EEA, 2023a).

The following section describes the landfill taxes / fees related to mixed CDW and in some cases to specific fractions for each MS. The data refer to the most updated taxes / fees and are expressly

[14] A clarification diagram for WMFs is presented in the "List of abbreviations and definitions" section.

reported either as a tax or as a fee or as a combination of the two instruments, according to the source listed in Table 3.

The distinction between the terms "tax" and "fee" is not harmonised and sometimes unclear among the different literature sources consulted, indicating a lack of uniformity in terminology in the field. Therefore, in the summary presented herein and in Table 3, the term "tax" means a charge collected by the tax authority of the MS or regional tax authority and the term “fee” refers to the payment to the landfill operator at the local level, i.e., "tipping fee” or "gate fee”. Taxes and fees can both be applied in the same MS to the same truckload of CDW. Most sources used in this research focus on the environmental taxes collected at the national level rather than local or regional level disposal / incineration fees. Therefore, a limitation of this study is that local fees are likely under-reported.

Table 3. Overview of landfill taxes and fees across the EU27.

Member State	**Landfill Tax or fee (T or F)**	**Rate**	**Reference**
Austria	T	From 9.20 €/t to 87€/t. (inert)	(European Commission, 2017 - Country factsheets) (Luciano et al., 2022)
Belgium	T	Brussels Capital Region: > 20 €/t (inert) Flanders: > 12.73 €/t (inert) Wallonia: > 7.23 €/t (soils with max 5% of stones) > 85.96 €/t (land sorting with 5 to 30 % of inert waste)	(European Commission, 2017 - Country factsheets)
	T	Flanders: > 11.67 €/t (inert) Wallonia: > 5 €/t (inert)	(Luciano et al., 2022)
Bulgaria	T	14.3 €/t	(European Commission, 2017)
	T	From 0.25 €/t to 17.5 €/t	(RE4 Project, 2017a)
Croatia	-	No landfill tax in place, a general fee is applied only for hazardous waste based on the produced and unprocessed not exported hazardous waste and the waste characteristics.	(European Commission, 2017 - Country factsheets)
Cyprus	-	No landfill tax in place. but a tax is planned to be applied from 2024	(EEA, 2022a)
Czechia	F+T	19 €/t and 225 €/t (hazardous mixed CDW)	(European Commission, 2017 - Country factsheets)
	F+T	From 6 €/ton to 225 €/t	(RE4 Project, 2017a)
Denmark	T	63 €/t (inert)	(Luciano et al., 2022)
	T	64 €/t	(European Commission, 2017 - Country factsheets)
Estonia	T	29,84 €/t	(European Commission, 2017 - Country factsheets) EU, 2021
	T	12 €/t (inert)	(Luciano et al., 2022)

Finland	T	55 €/t (sorted CDW) From 100 €/t to 170 €/t (unsorted CDW)	(European Commission, 2017 - Country factsheets)
France	T	40 €/t (non-hazardous mixed CDW)	(European Commission, 2017 - Country factsheets)
	F	From 2.90 €/t to 7.10 €/t (inert)	(Luciano et al., 2022)
	T	61 €/t (planned to increase to reach 65 €/t in 2025)	Taxe Générale sur les Activités Polluantes (TGAP), 2023
Germany	F	From 8 €/t to 148 €/t	(European Commission, 2017 - Country factsheets)
Greece	T	40 €/t	(European Commission, 2017 - Country factsheets)
	T	10 €/t (inert)	(Luciano et al., 2022)
Hungary	T	38.4 €/t	(European Commission, 2017 - Country factsheets)
	T	28 €/t	(European Commission, 2017)
Ireland	T	75 €/t	(European Commission, 2017 - Country factsheets) (RE4 Project, 2017a)
Italy	T	10 €/t	(European Commission, 2017)
	T	From 1 €/t to 10 €/t (inert)	(RE4 Project, 2017b)
	T	From 10 €/t to 50 €/t From 1 €/t to 10 €/t (inert)	(Luciano et al., 2022)
Latvia	T	13 €/t	(European Commission, 2017)
Lithuania	T	30.41 €/t (inert)	(European Commission, 2017 - Country factsheets)
	T	7.14 €/t (inert)	(European Commission, 2017)
	T	5 €/t	EU, 2021
Luxembourg	F	From 1.24 €/t to 12.39 €/t (inert)	(European Commission, 2017 - Country factsheets)
Malta	F	20 €/t (non-hazardous mixed CDW)	(European Commission, 2017 - Country factsheets)
Netherlands	T	13 €/t	(European Commission, 2017 - Country factsheets)
	T	107.49 €/t 16.79 €/t (inert)	(Luciano et al., 2022)
Poland	F	From 2.7 €/t to 38.7 €/t	(European Commission, 2017 - Country factsheets)
Portugal	T	4.3 €/t (inert)	(European Commission, 2017 - Country factsheets) (RE4 Project, 2017a)
Romania	T	4.5 €/t	(European Commission, 2017 - Country factsheets)
Slovakia	F	6.6 €/t	(European Commission, 2017 - Country factsheets)
Slovenia	T	19.2 €/t	(European Commission, 2017 - Country factsheets)

	T	11 €/t 2.2 €/t (inert)	(Luciano et al., 2022)
Spain	T	From 5 €/t to 40 €/t	(European Commission, 2017 - Country factsheets)
	T	40 €/t	(European Commission, 2017)
	T	From 1 €/t (Navarra) to 25.20 €/t (Madrid) From 10 €/t to 20 €/t (inert)	(RE4 Project, 2017a)
	T	Catalonia: > 12.4 €/ton (21.6 €/t if biowaste not collected at source) Castilla y Leon: > 7 €/t (20 €/t for potentially recoverable waste) > 3 €/t (inert) Madrid: > 3 €/m^3 (inert) Murcia: > 3 €/t (inert)	(Luciano et al., 2022)
Sweden	T	54 €/t	(European Commission, 2017 - Country factsheets)
UK (ex-EU)	T	Standard Rate £96.70/t Lower Rate £3.10/t	(Eunomia & European Environmental Bureau, 2022)

Source: Own elaboration.

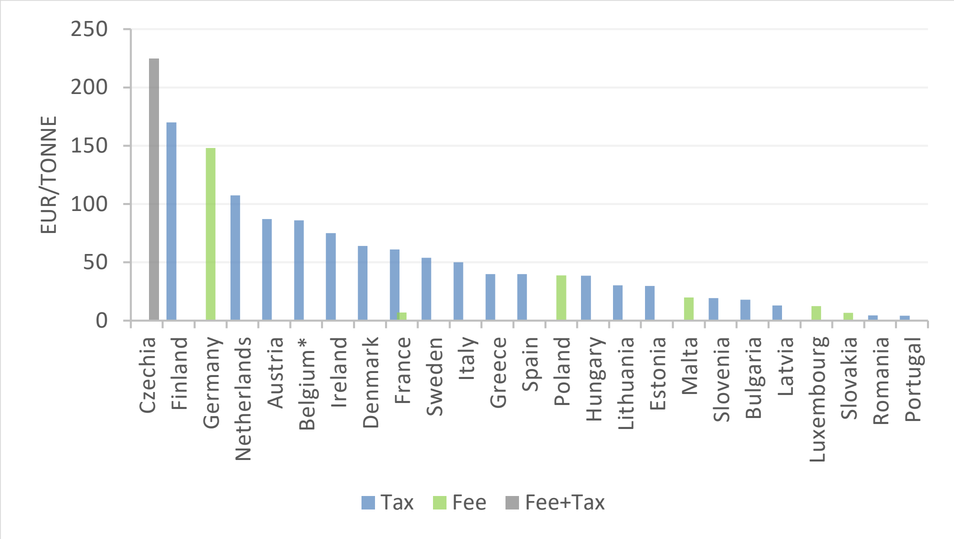
Table 4 shows the summary of the minimum and maximum landfill tax / fee rates for CDW (and / or inert waste) across EU MSs, and Figure 5 shows the maximum landfill tax / fee by MS.

Table 4. Summary of the minimum and maximum landfill tax/fee rates across EU Member States.

Landfill Tax or fee (T or F)	**Minimum**		**Maximum**	
	Country	**Value (€/t)**	**Country**	**Value (€/t)**
T	Bulgaria	0.25	Finland	170
F	Luxembourg	1.24	Germany	148
F+T	Czechia	6	Czechia	225

Source: Own elaboration from Table 3.

Figure 5. Maximum landfill tax / fee rates within EU Member States.



Source: Own elaboration from Table 3.
*Notes: *tax rate refers to Wallonia.*

In the **Netherlands**, a landfill tax, which is referred to in the legislative documents as a waste disposal charge, was introduced in 1995, repealed in 2012 and then reinstated in 2014. As of 2016, the tax applied to both landfilling and incineration, and as of 2019 it also included waste generated in the country and exported abroad. The tax has increased over the years, reaching 107.49 € per ton (Luciano et al., 2022). Between 2014 and 2018, the revenue from the waste disposal charge (tax) came close to 100 million €; in 2019, the revenue was 205 million € (European Commission, 2021 - Country factsheet).

Austria represents a good practice, according to a recent review by Luciano et al. (2022). The current landfill tax "ALSAG" ranges from 9 to 87 EUR/tonne and helps channelling a high percentage of the CDW stream towards the recycling facilities.

The **French** landfill tax (TGAP) is made up of two elements: a tax on the operation of the landfill site and a tax depending on the quantity of waste received and the environmental impacts of the site. Both separate collection and recovery of waste into SRM did not benefit from the application of landfill taxes in France. The Landfill tax is low compared to other MSs, which does not encourage building firms to favour recycling and recovery over landfill (Luciano et al., 2022). Furthermore, France is one of the countries in Europe with no tax on inert waste landfill (European Commission, 2017 - Country factsheets), but only inert gate fees (i.e., charges set by the operators of the landfills for the provision of the service, that cover their costs and profit). General landfill taxes, around 25 €/t in 2019, will keep increasing progressively up to 2025, to reach 65 €/t, a high level in comparison with EU average (ca. 38 EUR/tonne; see Caro et al.; 2024 or Cristobal Garcia et al.; 2024). This rate would give clear advantage to recycling activities in line with other countries with similar landfill taxation levels, e.g., Netherlands and Denmark.

In **Spain**, there are many differences in landfill taxes on inert CDW, according to the municipality, but the taxes are generally very low (between 1-3 €/t; Table 3).

In **Italy** the landfill taxes are applied on a regional level and all regions must implement them. Law 549/1995 defines the upper and lower level of the tax for inert waste, including waste from the mining, extractive, building and metalworking sector (1.03-10.33 €/t). Italy is at present in the process of implementing the revised European Waste Directives, so this issue is going to be reviewed.

3.1.2.1.2. Pay-As-You-Throw (PAYT) and other waste management fees

Waste management charges (taxes, fees etc.) generalise the concept of disposal / discarding taxes (generally carried over from the end-of-life stage up the value chain) and send price signals which aim to promote more environmentally favourable options.

As discussed above, a key aspect of waste management fees is the combination of (a) actor and (b) behaviour that they target in the value chain, which largely determine their effectiveness and efficiency. Targeting the waste generator at the time of disposal is typically "too little, too late" (too little because the charge cannot be too high to avoid risks of non-compliance, but then the incentive effect is lost; and too late because the waste has already been generated and other options are less feasible at that stage, e.g. waste reduction). Therefore, waste charges should aim to transmit the price signal upstream in the value chain when the actors are less likely to evade the fee and the portfolio of options higher up the waste hierarchy is broader.

One example of applying this principle is to levy a charge on products at point-of-sale, rather than waste. This is the case of "eco-contributions" levied in France on electrical and electronic equipment (EEE) to help cover the costs of WEEE management, and more recently on construction products (in this case, part of a broader EPR scheme) to help cover the costs of CDW management. Other examples include Advance Discarding Fees or differentiated discarding fees Pay-As-You-Throw (PAYT).

PAYT is a scheme in which waste fees paid by users are modulated according to the amount of waste delivered to the waste management system. This creates a direct economic incentive to recycle more and to generate less mixed and/or residual[15] waste. It is usually implemented for municipal waste, mainly for residual waste but also for organic and bulky waste.

The idea explored here is to mimic a model already common for waste charging at the household level for municipal waste, where it is simply referred to as PAYT: a differentiated Waste Management Fee is charged to waste generators according to the waste streams that they generate, the level of separation, and the amount. Typically, dry recyclables (in the separate or commingled fractions practiced by the local authority) are collected at zero charge while mixed waste incurs a fee proportional to the volume (weight) delivered to the waste management system.

The system examined below extends the PAYT concept to CDW disposal and treatment.

Parameters of PAYT systems

<u>Fixed vs variable:</u> In the case of municipal waste, there are two broad PAYT pricing models, namely the one-component model that relies on a single fee for the citizen that can be fully variable with no fixed amount, and the multi-component model that combines fixed and variable rates (Ukkonen & Sahimaa, 2021). The fixed rates usually cover the necessary expenses of the waste management system, while the variable rate is proportional to one of the following variables: the weight of the waste, the volume of the waste, the number of containers used, or the frequency with which the containers are collected and the composition of the waste, with higher fees for mixed residual waste.

In case of setting up a PAYT system for CDW, a similar approach could be adopted, i.e., a fixed (or zero) fee corresponding to a *de minimis* amount allowed (per construction project, or per

[15] Mixed waste is household municipal waste that contains recyclates improperly separated (such as recyclable glass or paper) and 'residual waste'. 'Residual waste' strictly-speaking is household waste without recyclates included (i.e. the share of household waste that is not subject to sorting and, thus, subsequent recycling).

household), with additional charges when over a certain amount of mixed waste is discarded. This is in practice already the case in many countries for household CDW: a small volume of waste is accepted at local civic amenities sites (CAS) when delivered by citizens (with some checks on e.g., residence or identity to avoid opening a loophole for larger deliveries by professionals). For example, in Warsaw, Poland, the amount of 1 m^3 can be delivered at the selective waste collection point (SWCP) free of charge once per month from a given owner of a residential property[16].

Proportional to volume: The core principle of PAYT is to modulate the fee according to the weight / volume of waste being discarded. The basic model consists of free take-back for separated waste fractions whereas a charge is due on mixed CDW.

Depending on the specific markets and expected value to be recovered from a separated fraction, a negative fee may be more realistic for some fractions. For instance, once separated into a fairly pure fraction, it is likely that metal scrap from CDW will be marketable at a nonzero (positive) price. If waste managers want to be able to capture this fraction, they may have to pay for it to compete with other recycling actors. As for MSW (where the waste management system counts on valuable recyclables to partly cross-subsidise the treatment of other fractions and ensure the overall balance), frequent revaluations of fees based on market prices will be necessary to ensure economic viability. This will also be easier as part of a subsidised scheme (paid for by government funds) or an EPR scheme (paid for by PROs).

Household CDW: Regarding household CDW, a PAYT system could be implemented specifically, i.e., for CDW arising from minor do-it-yourself renovation, construction and demolition works carried out independently in the households. The removal of this kind of waste is usually based on households communicating with municipalities, as this waste must be collected in appropriate containers (including big-bags and metal containers) that can be removed and delivered to the CAS by either an external company or by the owner himself. However, the authors could not find information about existing PAYT schemes for household CDW in the EU. It is common that municipalities impose caps on the quantities of CDW that citizens can deliver in the CAS for free.

According to the European Commission (2017 - Country factsheets), only **Luxembourg** reports a PAYT scheme (at least under this denomination), and **Latvia** has identified the lack of PAYT schemes as obstacle to sustainable CDW management (lack of deterrents aimed at landfilling).

3.1.2.1.3. Resource taxes

Resource taxes are environmental taxes levied on the extraction and / or use of non-renewable resources to capture external costs, encourage more prudent use of natural resources, and promote the search for sustainable alternatives. Resource taxes relevant to CDW often focus on mined materials for all purposes, and for aggregates, including sand, gravel, and/or crushed rock. Table 5 presents an overview of resource taxes identified in this research from a variety of sources. Taxes on primary aggregates (including sand, gravel and / or crushed rock) are implemented in Denmark, Sweden, Belgium (Flanders) and Italy (on a regional level) (Legg et al., 2008). The rest of the countries shown in Table 5 implement general mining or extraction taxes (also known as royalties) that are levied in exchange for access to publicly owned resources (mining on public lands). A more detailed picture of how MSs are implementing this policy (or one with elements related to it) is provided in Annex 2.

[16] https://www.collectors2020.eu/wcs-cdw/warsaw-pl/

Table 5. Resource taxes and royalties in the EU Member States.

Member State	Resource tax / royalties	Reference
Belgium (Flanders)	No value found	(LNE, 2015)
Bulgaria	No value found	(UN, n.d.)
Croatia	**0.41 € per m^3** (sand) – (ca. **0.2 € per tonne** assuming 2 tonne per m^3) **0.55 € per m^3** (gravel) - – (ca. **0.27 € per tonne** assuming 2 tonne per m^3)	(OECD, 2024a)
Cyprus	**0.4 € per tonne** for any quarry material, cement and lime **1.71 € per thousand bricks** **1.03 € per thousand tiles**.	(Republic of Cyprus, 2012)
Czechia	**3.6–36 € (or CZK 100–1000) per km^2 per year.** Additional charge (calculated as a proportion of the sale price on the market is 2 % for construction stone and 3 % for sand and gravel, and up to 10% of other mineral resources). Total figure is roughly about **0.1 € (CZK 3) per tonne** of an aggregate material**.**	Legg et al. (2008)
Denmark	**0.7 € (5 DKK) per m^3** (ca. **0.35 € per tonne** assuming 2 tonnes per m^3) for extracted raw material including stones, gravel, sand, clay, limestone, peat and topsoil.	(Andersson, 2004)
Estonia	**0.75 – 1.42 € per m^3** (clay) – (ca. **0.4 – 0.7 € per tonne** assuming 2 tonne per m^3) **0.6 – 2.43 € per m^3** (gravel) – (ca. **0.3 – 1.2 € per tonne** assuming 2 tonne per m^3) **0.98 – 2.94 € per m^3** (limestone) – (ca. **0.5 – 1.5 € per tonne** assuming 2 tonne per m^3) **0.42 – 1.64 € per m^3** (sand) – (ca. **0.2 – 0.8 € per tonne** assuming 2 tonne per m^3)	(OECD, 2017, 2024a)
France	**0.22 € per tonne** for 2024.	(République Française, 2020)
Hungary	**1.8 € (HUF 700) per tonne** of graded sand, graded sandy gravel and natural sandy gravel **2.3 € (HUF 900) per tonne** of graded gravel **52 € (HUF 20 000) per tonne** of cement.	(OECD, 2018)
Italy	In 2014, the tax increased to **0.70 € per m^3** (ca. **0.35 € per tonne** assuming 2 t per m^3 density).	(RE4 Project, 2017)

Member State	Resource tax / royalties	Reference
Latvia	With effect from January 1, 2017, taxes on natural resources include, but are not limited to: **0.86 € per m³** of soil (ca. **0.54 € per tonne** assuming 1.6 tonne per m³) **0.21 € per m³** of sand, gravel, dolomite (ca. **0.13 € per tonne** assuming 1.6 tonne per m³)	(Taukačs et al., 2018)
Lithuania	**0.51 – 0.86 € per m³** (clay) – (ca. **0.25 – 0.4 € per tonne** assuming 2 tonne per m³) **0.84 € per m³** (limestone) – (ca. **0.4 € per tonne** assuming 2 tonne per m³) **0.38 – 0.48 € per m³** (sand) – (ca. **0.2 – 0.24 € per tonne** assuming 2 tonne per m³)	(FOES, n.d.; OECD, 2024a)
Sweden	**1.58 € (SEK 15) per tonne** of gravel	(OECD, 2014, 2024a)

Source: Own elaboration.

3.1.2.1.4. Deposit-refund systems (DRS)

A deposit-refund systems (DRS) is an economic instrument that usually require buyers to pay a (generally small) deposit when buying a product, to be refunded when it is returned to a collection point after use. DRSs significantly increase the capture rate and thereby the reuse / recycling of containers covered by deposits. It is considered best practice to increase the use of (also reduce the decline of) refillable containers to reduce littering and to avoid harmful chemicals being released into the environment (RE4 Project, 2017b). Within the EU, DRS has been employed mostly for fast-moving consumer goods with a short lifecycle, such as drink containers, i.e., bottles and metal cans, and the captured containers can be used either for reuse (refill) or recycling (Albizzati et al., 2023). However, the principle can be applied to other products such as batteries, tyres, automotive oils or shipping pallets.

The **application of DRS to CDW** would be different from the one applied to drink containers. In the context of construction products and materials, which have very long lifecycles inside the built environment, DRS as such seems impracticable. However, an 'open loop' DRS system could be envisaged, whereby deposit paid upon purchase of a construction product can be reclaimed if an equivalent construction (leftover), or (selective) demolition material can be returned, once appropriate return conditions for equivalence have been set. For instance, loads of recovered bricks could be used to reclaim the deposit paid on new bricks if they meet certain quality and purity requirements (e.g., cement content).

One immediate difference with products whose lifetime is short (or even, finite) is that there is a structural imbalance between the quantities of new materials being put on the market and the quantities of waste collected. By way of illustration, the market for construction materials in the EU in 2021 represented about 2.4 billion tonnes[17], while around 850 million tonnes of CDW were collected that year, or about a third of the volume. While this allows to spread the cost of waste

[17] in 5.4 tonnes per capita 2021 x 443.2 M residents according to Eurostat

management over a wider collection base (with a 3-fold factor), this needs to be considered and accepted across the value chain, to avoid perceptions that the scheme is being operated as a pyramid scheme.

3.1.2.1.5. Refundable Advance Discarding Fee

The concept of using a *deposit* can be extended from the product side (DRS) to the waste side. The conceptual principle remains the same: as waste is often a negative-value good, there is a risk that the waste will be disposed of illegally to escape the cost of waste management. In the case of DRS, the charge is borne by the consumer that purchases a product. In the case of advance disposal fees, it is charged on waste volumes, but at the time of planning of construction or demolition, when the potential waste generator is "captive" and unlikely to escape the fee (as it is otherwise administratively tied to compliance with licensing obligations for the works).

One such model for CDW has been successfully used in **Spain** (Solís-Guzmán et al., 2009 - note that the authors refer to the model as a DRS). Known as the Alcores waste management model, as it was piloted in Alcores, Seville. The national decree (Real Decreto 105/2008) that regulates the production and management of CDW since February 1, 2008 (Spanish Government – Ministry of the Presidency, 2008) mandates the deposit. The decree requires the building developers to pay a deposit before any building or demolition permit is awarded by the Town Hall. The amount of the deposit depends on the type of work involved and the volume of waste estimated (based on the surface area / size of the building site, demolition activities, typology of the building, and packaging). To get the deposit refunded, the developer must present to the Town Hall a certificate of correct management from the treatment plant showing that the waste has been disposed of in an authorised facility and that the amount of waste delivered by the developer is in line with the estimate on which the deposit was based. **The refundable advance discarding fee model intends to** encourage waste reduction at the point of design of the rehabilitation or construction, **prevent illegal dumping** (up to 60% of CDW in the years prior) **and encourage proper disposal (in line with the waste hierarchy)** (Solís-Guzmán et al., 2009).

Two key features of the Advance Discarding Fee stand out:

- Local policy: It has inherently been developed as a *local* solution. In the absence of e.g., a national extended-producer responsibility scheme (which is another way of sending a price signal even more upstream), imposing a fee at local level provides a feasible solution to address local waste issues, increase control on waste generation and provide localised behavioural incentives. This is attractive for local policy makers as it does not require coordination at regional / national or even EU level and can therefore be put in place relatively easily. However, there are also spillover risks (e.g., if a municipality controls construction sites within its jurisdiction, but nearby municipalities don't, there is still a risk that less-controlled waste from neighbouring communities will also be dumped on the territory subject to the ADF).
- Green licencing: Administratively, the ADF rests upon the existence of processes used for issuing building permits (planning permission, licencing). The existing experience from Spanish municipalities shows that it is possible to use the licencing process to introduce incentives (they can be more or less compulsory, i.e., strict conditionalities vs. additional fees or even pre-emptive / refundable fees as here) to orient behaviour in the building sector. This opens a range of possibilities for policies directed towards the improvement of

environmental impacts of buildings in general, and for CDW management. Such innovative policy instruments could for instance cover:

- o planning requirements incentivising the reduction of waste at project design stage.
- o planning requirements requiring the submission of a waste management plan, reflecting the waste hierarchy.
- o planning requirements with a modulated licencing fee based on waste amount and quality.

By sending the incentive signal (or in the case of ADF, price signal) early in the licencing process, municipalities can not only ensure good coverage and capture of the targeted waste generation but also incentivise behaviours earlier in the building project where more structural waste-reduction decisions can be made (e.g., refurb vs demolish-and-rebuild).

3.1.2.1.6. Extended producer responsibility schemes (EPR)

Extended producer responsibility schemes (EPR) or product stewardship schemes represent a mix of policy instruments such as take-back requirements, recycling targets, and producer fees (OECD, 2019). EPR schemes extend the "polluter-pays" principle to a "producer-pays" principle: whenever a product is sold (causing environmental impacts in its whole life cycle, including end-of-life), then not only the purchaser of the product (who will eventually discard it) incurs a cost, but also the manufacturer or seller who profits from selling it. The idea is to establish incentives at the product design phase to reduce lifecycle impacts.

An EPR is a fee-based cradle to grave approach to product responsibility or liability. The party that manufactures and/or places a product on the market for sale and directly benefits from its purchase is charged a fee to pay for society's costs for collection, treatment, and disposal with the best environmental outcomes. In essence, producers pay for the proper disposal of their products after consumers' use. EPRs are designed for products that pose specific waste management challenges and environmental risks due to the products' hazard or volume.

In general, the administrative functions of an EPR fall on the producers and retailers and are carried out more efficiently by a producer responsibility organization (PRO). These include tracking the volume of products sold, collecting the fees from producers and paying the fees to the waste management operators or the governments incurring the costs of waste management. From the consumer's point of view, the cost of the product is increased by the amount of the fees. The increased cost is a market price signal reflecting the environmental "burden" of the product.

In addition to managing wastes at the end of the useful life cycle, EPRs can influence the start of a product's life cycle by incentivising sustainable design and alternatives that reduce the environmental "burden" of the product through advanced "eco-modulation" of the EPR fee. Producers who use less resources to produce their products, such as less / lighter weight packaging or produce less-polluting products than the norm, pay lower EPR fees. Normally, the rules regarding eco-modulation are agreed by the PROs and there are different levels of eco-modulation (Laubinger et al., 2021). The ability to create market price signals is one of the reasons that EPRs are widely used environmental policies.

EPR in the construction sector is challenging. Adhering to the EPR is difficult within the construction sector as buildings are long-term and complex assets. In comparison to other sectors, challenges to an effective EPR in the construction value chain include the following points (OECD 2016):

- The final product in construction is the building, which is made up of many sub-products.

- Each building design is flexible and project specific with multiple decision-makers for both the product and the eventual waste management. The decision makers include, but are not limited to the architect, the firms constructing the building, the user, the firms demolishing, and the regulators.
- The decision-making takes a long period of time, and manufacturers may not have any say in the practical use of the product.
- The uncertainty in design, installation, geographical area and other conditions is high and influences the life span of construction products and are unknown by the manufacturer.
- The lifespan of construction products and buildings is long. A building could be in place for 60 years or 200 years. Finally, due to the aforementioned reasons, the producer of a building component may not be administratively or temporally close to the end-of-life of the product (building or component).

The OECD and other institutions provide several documents and guidelines on the key factors, to facilitate their use. The Prevent Waste Alliance offers an EPR toolbox that defines **the key enabling factors of an EPR, such as clear roles and responsibilities, PROs, a register of products, tracking financial flows between parties, and an established legal framework**[18].

Despite the challenges, research indicates that EPR schemes can be applied to two complementary waste streams within the construction sector: residual and unused building materials, and CDW of an entire building (Brown et al., 2023). Further, municipalities and MS are experimenting with EPR schemes for building components and products.

An example of EPR on residual and unused building materials is the general binding agreement (Algemeen Verbindend Verklaring or AVV) for flat (insulation) glass existing in **the Netherlands**. The programme started on a voluntary basis and is now a binding financial contribution for post-consumer collection, sorting and treatment (Brown et al., 2023) of glass, and contributes to reducing the energy demand for production[19].

For CDW from an entire building, there are some examples across MS that apply EPR to CDW or at least to materials found in CDW such as concrete or wood. **France** introduced an EPR for construction products or materials in the building sector in the Law on Anti-waste and Circular Economy (AGEC Law issued in 2021) starting from January 1, 2022 (Ministère de la Transition écologique, 2022); see Box 2.

[18] EPR Toolbox - Prevent Waste Alliance (prevent-waste.net)

[19] Recycling of end-of-life building glass - Glass for Europe

Box 2. EPR scheme in France

The **French law** on Anti-waste and Circular Economy (AGEC Law issued in 2021) imposes new waste management obligations, as part of an EPR as of January 1, 2022, to all producers of building products and materials (BPM) in the construction sector, requiring them the adhesion to an approved eco-organisation and the payment of the eco-contributions to them based on the quantities of product put on the market. Thus, the eco-organization systematizes the management of waste from their end-of-life products. This applies to all companies within the BPM sector including manufacturers and distributors, both French and importers.

It refers to "*products and materials, including wall, floor and ceiling coverings, that are intended to be incorporated, installed or assembled permanently in a building or used for the facilities related to its use located on its site, including those related to vehicle parking, and with the exception of products and materials used solely for the duration of the construction site*". It excludes products and materials used only for the duration of the worksite, products and materials of public work, and excavated land.

BPMs are differentiated in two categories. Category 1 includes BPM consisting predominantly of minerals such as concrete and mortar or contributing to their preparation, lime, limestone, granite, sandstone and lava stone types, terracotta or raw, slate, bituminous mixture or combination of bituminous mixing (excluding bituminous membranes), granulate, ceramics. On the other hand, Category 2 includes other BPM consisting predominantly by mass of metal, wood, plaster, plastic, bituminous membranes, glass wool, rock wool, as well as mortars, coatings, paints, varnishes, resins, preparation and processing products, including their container, carpentry with glass, glazed walls and related construction products, and construction products of plant, animal or other material not listed in herein.

In the order of 10 June 2022 containing specification for the eco-organizations, individual systems and coordinating bodies of the EPR for BPM in the construction sector, certain objectives for collection, recycling, reuse and valorisation are defined as follows in Table 6 and Table 7 (ADEME, 2021):

Table 6. Objectives set for the French EPR.

Category	Collection		Recycling		Recovery		Reuse	
	2024	2027	2024	2027	2024	2027	2024	2027
Cat. 1	82%	93%	35%	43%	77%	88%	2%	4%
Cat. 2	53%	62%	39%	45%	48%	57%	2%	4%

Table 7. Specific recycling objectives, by material, for the French EPR.

Material	Concrete	Metal	Wood	Plaster	Plastic	Glass
2024	60%	90%	42%	19%	17%	4%
2027	60%	90%	45%	37%	24%	18%

Source: (ADEME, 2021).

In **the Netherlands**, the already cited Dutch National Circular Economy Programme aims, among other things, at increasing producer responsibility (through measures such as quality assurance, certification, etc.), and suggests the development of pilot projects for this purpose (Dutch Government - Ministry of Infrastructure and Water Management, 2023). Furthermore, there exist voluntary EPR schemes for concrete (Green deal Duurzaam Beton)[20] and for sustainable forest management (Green deal Duurzaam Bosbeheer)[21].

Denmark does not have any legal EPR scheme related to construction materials. However, since 2011 it has a certification system for sustainable buildings in place, the so called DGNB (European Commission, 2018a) that increase producer responsibility. Similarly, **Belgium** does not have an EPR scheme related to construction materials, but it has voluntary EPR schemes for specific materials such as PVC from construction and thermoplastic pipes (European Commission, 2018a).

Croatia does not have an EPR scheme related to construction materials, but for statistical purposes, the Croatian Environmental Agency gather data on CDW generation through the EPR databases for waste producer / owners generating more than 2000 kg per year that should pay the prescribed management fees.

In **Ireland**, the possibility of implementing an EPR scheme for CDW was examined, and finally discarded due to the complexity (it is composed of several by-products and there are several economic agents in the management) as part of the Review of Producer Responsibility Initiative in Ireland published in 2014 (European Commission, 2017).

3.1.2.2. Overview of economic instruments

Several economic instruments are used along the whole building value chain to encourage CDW reduction and better CDW management to reduce its impacts. Table 8 summarises the authors' reflections on the effects of the main economic instruments. The box colours reflect qualitative assessments of the contributions of each economic instrument towards desired and undesired policy objectives according to the waste hierarchy, i.e., whether the instruments tend to have an effect towards an improvement (light or bright green) or could possibly have the unintended effect of illegal dumping (light red), other factors being equal. Grey boxes indicate no significant impact on the effect in the respective column. For example, a landfill ban enhances recovery bright green, but a minority of actors could illegally dump (light red). The assessment aligns with Albizzati, et al. (2023) and Ernst & Young (2020). A further discussion of these economic instruments is found in Section 4.

[20] https://www.greendeals.nl/sites/default/files/downloads/GD030-Verduurzaming-betonketen.pdf
[21] https://bewustmethout.nl/

Table 8. Overall review of economic instruments.

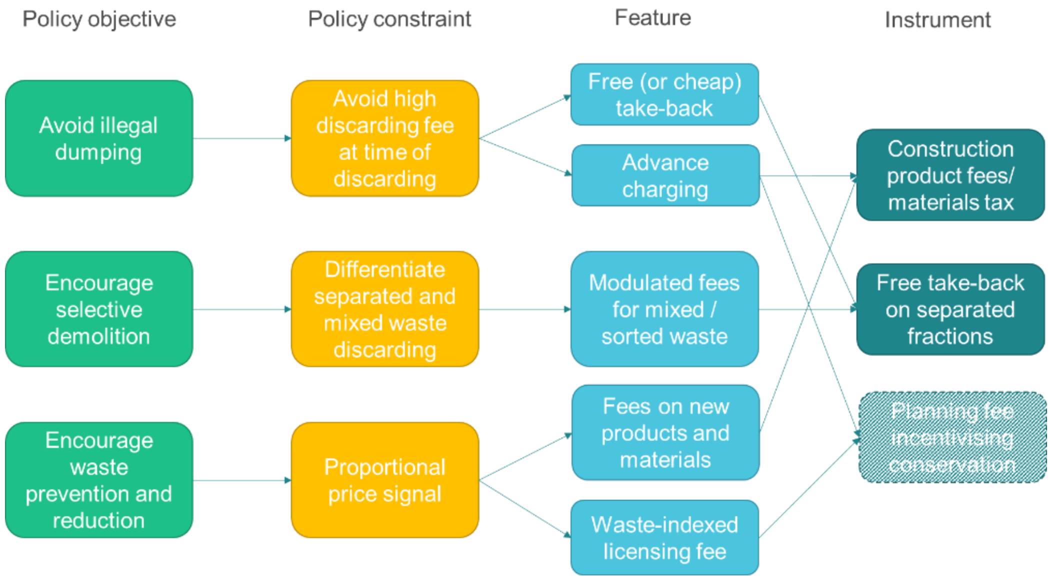
Economic Instrument	Actor	Lifecycle stage	Effects					Comments / unintended effects
			Risk of Illegal Dumping**	Discourage Landfilling	Encourage Recovery & Sorting	Recycling and Higher Quality Recycling	Reduce Waste Generation*** Reduce Material Consumption	** Cost increases for legal waste management, risk illegal dumping. *** Reduces waste generation and consumption, but effect depends on enforcement, public awareness, availability of alternative waste management, and context. According to Eurostat, construction industry waste (excluding major mineral waste) grew by 12.5% between 2004 and 2020 (Eurostat, 2023b). Eurostat data show that between 2012 and 2022, the total waste generated including major mineral wastes has remained around 5,000 kg per person.
Landfill tax / fee	Waste generator	Disposal	**				***	Price signal for waste generators and market and defers societal costs that all taxpayers would otherwise pay.
Advance discarding fee	Waste generator	Planning					***	Based on Spain's example.
Discarding fee	Waste generator or handler	Discar-ding	**				***	Most common format in Europe for households that hire contractors to carry out construction works.
Free takeback / separated	Waste generator or handler	Discar-ding					***	Free disposal of separated wastes facilitates sorting, recovery, and higher quality recycling by municipalities.
Free takeback / mixed	Waste generator	Discar-ding					***	May discourage dumping but does not follow polluter pays principle and imposes total treatment costs on society at large.
Takeback with financial reward / separated	Waste generator	Discar-ding						Encourages collection and bring-in of recyclables. May incentivise theft to collect payment.
Primary resource tax								Clear price signal to market that encourages resource efficiency and makes recycled materials more price competitive with virgin materials.
Product fee	Builder	Product purchase						Product level fee for fully virgin materials at point of sale internalises societal costs.
Eco-modulated product fee	Builder	Product purchase						Lower or zero fees for recycled content, durability, recyclability, etc., creates price signal to market that encourages resource efficiency and perhaps makes recycled materials more price competitive.
Open-loop DRS (product fee + paid takeback /	Waste generator + builder	Product purchase + discar-ding						Price signal that increases value of CDW to spur market.

Economic Instrument	Actor	Lifecycle stage	Effects					Comments / unintended effects
			Risk of Illegal Dumping**	Discourage Landfilling	Encourage Recovery & Sorting	Recycling and Higher Quality Recycling	Reduce Waste Generation*** Reduce Material Consumption	** Cost increases for legal waste management, risk illegal dumping. *** Reduces waste generation and consumption, but effect depends on enforcement, public awareness, availability of alternative waste management, and context. According to Eurostat, construction industry waste (excluding major mineral waste) grew by 12.5% between 2004 and 2020 (Eurostat, 2023b). Eurostat data show that between 2012 and 2022, the total waste generated including major mineral wastes has remained around 5,000 kg per person.
separated waste)								
PAYT (free separated takeback + discarding fee)	Waste generator	Discar-ding	**					Cost of end-of-life CDW management is paid by generators following polluter pays principle, whilst those who incur cost of separation such as selective deconstruction have reduced costs.
EPR (Product fee + PAYT)	Waste generator + builder	Discar-ding + product purchase	**					Approximates end-of-life costs for each material, creating an increase in the price/value of CDW fractions.
PAYT + resource tax	Waste generator + builder	Discar-ding + product purchase	**					Attempts to "level the playing field" between virgin and recycled / more sustainable options at resource extraction and waste disposal stages.
Eco-modulated EPR (eco-mod. product fee + PAYT)	Waste generator + builder	Discar-ding + product purchase	**					Approximates End-of-life costs for each material, creating an increase in the price/value of CDW fractions. Lower costs for recycled content, durability, recyclability, etc.
(Eco-modulated) product fee + PAYT with ADF	Waste generator + builder	Planning + discar-ding + product purchase						Administratively complex.

Source: Own elaboration.

As illustrated in Table 8, no single instrument can effectively address the various impacts along the value chain. Some instrument combinations may provide more effective solutions, albeit at the expense of increased administrative complexity. Figure 6 illustrates the rationale behind the use of specific instruments and how they could potentially be combined to develop more efficient charging schemes for CDW.

Figure 6. Rationale and features for the use of economic instruments.



Source: Own elaboration.

3.1.3. Marketplaces for CDW

A waste marketplace refers to commercial transactions between economic actors to buy, sell, and trade products and services relevant to CDW. Markets are formal and informal and some sectors such as aluminium and steel recovery and trade are highly developed. For some CDW fractions, private and public platforms (online and in the real world) enable companies to provide information about their CDW products to potential buyers.

These CDW-focused marketplaces have sprung up (with and without government support) because of the specific nature of trading CDW products for reuse and recycling. First, CDW products suitable for reuse can be unique or of limited quantity. For example, if a historic building is dismantled, the stairwell(s) or decorative fixtures may be unique items that are of interest to architects, collectors, and builders. Second, the regular supply chains from producer to retail sale do not apply. For example, the products may still be on the deconstruction / dismantling building site and for a limited time. Perhaps, buyers need to assume the cost of dismantling and/or shipment. Third, the items may need cleaning and refurbishment before reuse, i.e., bricks, wooden desks, or shelves. Fourth, the volume of components slated for reuse may need to be stored in a warehouse or depot to allow for their reuse or recycling as they are not able to be stored on site. Because of these characteristics marketplaces require significant coordination, networking, and active participation of companies. Traditional CDW marketplaces maintain a physical space where the products are stored and exhibited. Marketplaces facilitate commercial transactions between companies, fostering the reclaim and reuse of building materials.

Digital marketplaces are very diverse in content and form across the EU (i.e., from online catalogues to simple downloadable spreadsheets). They are run by private companies, associations or even public actors. The project Digital Deconstruction[17] analysed 41 digital trading platforms for reclaimed construction materials in the Netherlands, Belgium, Luxembourg and France. The results show that most platforms only publish ads coming from the administrators, with open access less common. While completely digital platforms without warehousing are becoming more common, most of the platforms still have a warehouse and / or showroom. Finally, Digital Deconstruction concluded that the marketplaces are not a unique service for the organizations providing them. The CDW product marketplace may not be their main source of income. In summary, private and government funded websites and warehouses that facilitate CDW reuse are available in many locations in Europe. However, they are not routinely integrated into construction industry supply chains.

3.1.4. Green public procurement (GPP)

At EU level, the Commission published in 2016 common EU green public procurement (GPP) criteria that can be incorporated into a public procurement procedure to reduce the environmental impact of a purchase for office buildings' design, construction and management (European Commission, 2016a). The use of these criteria is voluntary and for each criterion there is a choice between two ambition levels: **core criteria** "are designed to allow for easy application of GPP, focussing on the key area(s) of environmental performance of a product and aimed at keeping administrative costs for companies to a minimum", and **comprehensive criteria** that "take into account more aspects or higher levels of environmental performance, for use by authorities that want to go further in supporting environmental and innovation goals".

Thus, for the demolition and site preparation works, under technical specifications, there are core criteria that set a **minimum of 55% by weight** (80% in the comprehensive criteria) of the non-hazardous waste generated during demolition and strip-out works, and excluding excavations and backfilling, that shall be **prepared for reuse, recycling and other forms of material recovery**. This shall include: (i) Timber, glass, metal, brick, stone, ceramic and concrete materials recovered from the main building structures; (ii) Fit-out and non-structural elements, to include doors and their frames, flooring, ceiling tiles, gypsum panels, plastic profiles, insulation materials window frames, window glass, bricks, concrete in the form of blocks and precast elements, steel rebars. Besides, the criteria (both as core and comprehensive criteria) specify that the contractor shall carry out a **pre-demolition audit** to determine what can be reused, recycled or recovered.

Concerning **waste prevention**, for the construction of the building or major renovation works, under technical specifications the core criteria set that waste arising during construction and renovation, and excluding demolition waste, shall be less than or equal to 11 tonnes per 100 m^2 (7 tonnes per 100 m^2 in the comprehensive criteria) gross internal office floor area.

These GPP criteria for office buildings have been recently reviewed (Donatello et al., 2022; Ranea Palma et al., 2024) enlarging the scope not just to office buildings, but also to schools and social housing, as also recommended in Foster et al. (2020) that proposes an expansion of the EU procurement guidance for office buildings to include mixed-use and residential. Note that in principle, the same proposed criteria, that are generally aligned with the Level(s) framework of indicators (Dodd et al., 2021), could be also used in other types of public buildings or in the private sector. Thus, concerning CDW management, the revision proposes in the technical specifications **core criteria targets** of **90% reuse on site** or within 2 km radius of all non-hazardous excavation waste (i.e., soil and stones) (being 100% in the comprehensive criteria), **90% diversion from landfill** of all non-hazardous CDW (being 100% in the comprehensive criteria), **70% reuse, recycling or material recovery of all non-hazardous CDW** (being 90% in the comprehensive criteria specifying that 70% shall be reuse or recycling of all non-hazardous CDW; i.e., limiting other forms of recovery). The improvement potential that can be achieved via technical specifications in EU GPP criteria as described by Ranea Palma et al. (2024) is very high.

In general, the uptake of GPP criteria in procurement seems to be lower than 40% in most MSs (European Commission, 2017), being the front-runners Belgium, Denmark, the Netherlands and Sweden. However, those numbers refer to all product groups (not just construction) and to all EU core GPP criteria (not just CDW management). According to Luciano et al. (2022), 23 MSs out of 27 have adopted a National GPP Plan but only Italy has **mandatory** minimum environmental criteria for construction and buildings. According to Sönmez & Kalfa (2023), GPP criteria for CDW have been applied in 11 MSs out of 27.

Currently, the **EU Taxonomy** (European Commission, 2023c) also considers targets for CDW from new construction, demolition and renovation activities for demonstrating a significant contribution to a circular economy. There are two types of targets that apply to the **construction of new buildings,** the **renovation of existing buildings**, and the **demolition and wrecking of buildings and other structures** as shown in Table 9. The first one sets the **minimum percentage** (by mass in kg) **of the preparing for reuse or recycling** of the non-hazardous construction and demolition waste generated on the construction site, excluding backfilling. This excludes naturally occurring material referred to in category 17 05 04 in the European List of Waste established by Decision 2000/532/EC. The second one is the **limitation of primary raw materials use** (measured by mass in kg), expressed as a maximum % of the material coming from primary raw material, for the **combined total** of **concrete, natural or agglomerated stone**, for the **combined total of brick, tile and ceramic**, for the **combined total of glass and mineral insulation**, for **metals**, and for **gypsum**.

Table 9. Targets contained in the EU taxonomy concerning CDW management and use of primary material for new buildings, renovation of existing buildings, and demolition/wrecking of buildings and other structures.

		Construction of new buildings	**Renovation of existing buildings**	**Demolition and wrecking of buildings and other structures**
Preparing for reuse or recycling target		At least 90%	At least 70%	At least 90% Alternatively, at least 95% of the mineral fraction and 70% of the non-mineral fraction of the non-hazardous demolition waste is separately collected and prepared for reuse or recycled
Limitation of primary raw material use	combined total of concrete, natural or agglomerated stone	max of 70%	max of 85%	NA
	combined total of brick, tile and ceramic	max of 70%	max of 85%	
	combined total of glass and mineral insulation	max of 70%	max of 85%	
	metals	max of 30%	max of 65%	
	gypsum	max of 65%	max of 83%	

Source: Own elaboration.

According to the CONDEREFF[22] project, **Italy** has been the only EU country that made **the green public procurement minimum environmental criteria (MEC) for public buildings** (D.M. 24/12/2015 and update with D.M. 11/10/2017) (including the criteria on reuse of CDW material) **mandatory** for the construction of public buildings, both in new construction and renovation of existing buildings, pursuant to the new Procurement Code (D.lgs. 50/2016). However, recent studies point out that the implementation rate of GPP MEC for buildings is still low - around 18% on average in main cities in 2020 (Luciano et al., 2022).

In **the Netherlands**, a voluntary, non-legally binding **Dutch** Demolition Code has been established, which can be applied by contractors and customers in procurement procedures (European Commission, 2018a). The Dutch Ministry of Infrastructure and the Environment has developed a methodology relevant for infrastructure projects, whereby they use the Most Economically Advantageous Tender approach, with the inclusion of sustainability criteria; the public procurement is relevant at the stage of tendering and pre-tendering and is based on the principles of balance and e-procurement. The Dutch model is based on the use of two instruments: a CO_2 emission and an environmental impact assessment tool. The latter, DuboCalc, is an LCA-based tool which calculates the Environmental Cost Indicator (ECI) value. The ECI is then transformed into a monetary value. The contracting authority will select the tender with the lowest combined price and ECI value (OECD, 2016b).

A sustainable procurement webtool (MVI-tool) was also developed in the Netherlands, with the goal of enabling the authorities to easily identify appropriate Sustainable Public Procurement criteria (FCRBE Project, 2019).

Furthermore, the *Dutch concrete agreement* of 2018, signed by the government and fifty construction companies, with the goal of fostering cooperation and transparency in the concrete value chain and increasing the demand for green concrete, requires that sustainability criteria are included in tenders. It also sets specific sustainability goals to be achieved by 2030: a 29% CO_2 emission reduction with respect to 1990; 100% high-value concrete reuse and recycling within the construction sector; improvements in terms of sharing knowledge and education; a net positive value of natural capital (i.e., increased biodiversity following the extraction of sand and gravel) (Cramer, 2021). From an economic perspective, the aforementioned Dutch *National Circular Economy Programme* also includes provisions promoting circularity in public tenders and subsiding circular business models starting from 2030 (Transition Agenda Circular Economy, 2018).

Denmark promotes in the previously mentioned Danish Circular Economy Action plan the development of quality standards for green procurement, establishing the need for all public procurement to be eco-labelled by 2030; it also includes a provision for green procurement training (EEA, 2023b).

3.1.5. Direct aid, subsidies and support programmes

Another important policy instrument are **subsidies and grants for developing and commercialising new recycling technologies, techniques and activities**. In particular, the EU Recovery and Resilience Facility (RRF) as well as several Horizon research grants focus on strategic industries such as building and construction, as well as energy intensive production processes such as steel and cement. These products are important elements of the building and construction environmental footprint that would benefit significantly from increased recycling efficiency.

[22] https://projects2014-2020.interregeurope.eu/condereff/

On the other side, the extensive **training and skill development** sponsored by MS and the EU and their evaluation are beyond the scope of the current report. There is a detailed list of government supported circular construction skills in the EU portal BUILD UP[23]. Further information can be found at the website of the Commission's Large Scale and Regional Skills Partnerships under the Pact for Skills for the Construction industry[24].

Subsidies may be used to encourage better waste management practices, waste reduction and investments in improved waste management infrastructure, and may take the form of direct subsidies or tax exemptions / reductions. Government subsidies have a clear impact on the CDW recycling supply chain (e.g., on the pricing of new building material products or on the CDW remanufacture products). The government can adjust the subsidy rate, which can affect the decision-making behaviour of stakeholders in the supply chain (Han et al., 2022). In certain cases, these incentives are articulated in the form of direct tax reductions for reconstruction activities, or indirectly through tax deduction of labour costs (The World Bank, 2022).

We only found limited information on subsidies and incentives aimed at CDW prevention, recycling, and reuse. Thus, this summary is not exhaustive. This section provides an overview of the examples identified in this research.

In **Belgium**, both in the Brussels Capital region and the Walloon region, the Government provides subsidies to non-profit or social organizations that are active in the area of reuse and preparation for reuse including CDW (European Commission, 2017 - Country factsheets). Besides, Belgium has introduced a reduced value added tax rate of 6 % for demolition and reconstruction activities (The World Bank, 2022).

In **Czechia**, the operational programmes of the Ministry of Environment in 2016 foresee selective subsidies to support waste collection, sorting and treatment facilities, which may be up to 85% of the total eligible project expenditure – exceptionally up to 100% for some nature conservation measures (applicable to bio-waste, metal, residual waste and other household waste – note that Czechia misses a proper definition of CDW) (RE4 Project, 2017b).

The **Netherlands** have introduced and tested for years material passports for buildings that contain information on all their parts, and the Government has introduced tax incentives for developers who register material passports (Nordic Council of Ministers, 2014).

According to the European Commission (2017), **Denmark** provides economic support through loans for refurbishment and use of recycled material; **Malta** promotes economic incentives through lower tax for restoration of old buildings instead of demolition; **Romania** fosters incentives for economic operators to choose recycled over natural resources; **France** encourages financial Incentives to waste prevention and management projects. One such initiative is a result of the French Anti-waste law. The French Solidarity Reuse Fund "will guarantee that 5 % of the fees collected via Extended Producer Responsibility (EPR) schemes covering re-usable waste streams (such as textiles, furniture and WEEE) are used to finance re-use and preparing for re-use activities conducted by social enterprises"[25]. The dismantling and refurbishment before sale of built in furniture, wood, WEEE, and bricks are a few examples of reusable building elements that benefit from subsidies to scale up the markets for reuse and remanufacture.

In **Estonia** there are strong financial incentives for encouraging recycling and recovery of CDW over landfilling (RE4 Project, 2017a) and subsidies through the Estonian Environmental Investment

[23] https://build-up.ec.europa.eu/en/resources-and-tools/articles/skills-development-eu-building-sector
[24] https://pact-for-skills.ec.europa.eu/about/industrial-ecosystems-and-partnerships/construction_en
[25] https://www.rreuse.org/wp-content/uploads/France-to-create-a-Solidarity-Re-use-Fund_Final.pdf

Centre for demolition projects that include detailed planning for the sustainable management of CDW and for the appropriate treatment of asbestos-containing CDW (European Commission, 2017).

As an example of indirect tax deduction that affects CDW, **Sweden** introduced in 2016 a deduction of 50% (named RUT tax deduction) on labour costs for home repairs and maintenance in order to support product lifetime extension and thus reduction of CDW (The World Bank, 2022).

3.1.6. Monitoring and reporting and traceability systems

Monitoring and reporting are key elements for an effective waste management with the ultimate goal of robust data collection and potentially support and boost circularity practices (Luciano et al., 2022). Monitoring and reporting are enabling measures. It is assumed that all implemented policies are enforced.

Despite the release of the OECD Recommendations on Material Flows and Resource Productivity, which note the importance of data on materials flows, both within and among countries, progress on strengthening this information basis has been limited. The lack of reliable data to target policies and measures, and to monitor their effects has been an obstacle (OECD, 2015).

Information systems and digital passports can provide detailed waste information and tracking and represent a key tool for policy action towards the circular economy. **Building pass / passports and digital building logbooks or building renovation passports: although the definitions vary, the core principles of waste reduction and increasing materials entering secondary markets are present in all these traceability concepts.** The BAMB (buildings as material banks) concept was explored as a collection of resource efficiency measures facilitated by traceability by the Horizon 2020 project of the same name between 2015 and 2019, BAMB[26]. Digital passports, for example, is one of the key "best practices" introduced in some countries as part of a building material information system to monitor the existing materials and it is kept with the building's documentation throughout its entire life cycle.

The "digital building logbook" including a "building renovation passport" was introduced into the EU Energy Performance of Buildings Directive (EPBD) (European Union, 2024a). Herein, the digital building logbook is defined as "'a common repository for all relevant building data, including data related to energy performance such as energy performance certificates, renovation passports and smart readiness indicators, as well as data related to the life-cycle GWP, which facilitates informed decision making and information sharing within the construction sector, and among building owners and occupants, financial institutions and public bodies". The renovation passport is defined as "a tailored roadmap for the deep renovation of a specific building in a maximum number of steps that will significantly improve its energy performance." A 2022 study on MS implementation plans for the EPBD showed that the majority of MS had already begun plans for policies and actions on deep renovations including building renovation passports. The directive and its logbook and renovation passport introduce a potential new possibility for traceability for building CDW.

The directive states that the building renovation passport option should be made available as a voluntary component of the digital logbook in all MS by May 2026. If owners chose to do so, the renovation passports can be completed concurrently with the mandatory energy performance certificate. This is specifically relating to the construction, and demolition wastes from deep renovations because the renovation passports should include, "(g), prevention and high-quality treatment of CDW in accordance with Directive 2008/98/EC, in particular as regards the waste hierarchy, and the objectives of the circular economy;". **The WFD is directly applied in the**

[26] https://www.bamb2020.eu/

voluntary building renovation passports that will be made available in every MS by 2026. This new policy action will raise the availability of waste information in the EU.

Prior to the revisions to the EU Energy Performance of Buildings Directive, 15 EU MSs present traceability systems specifically related to CDW at different levels of implementation. Well-established traceability systems that can be found in many MSs based on the information from Luciano et al. (2022) and the European Commission (2017) are cited below.

In **Austria,** the Federal Waste Management Plan sets the building pass along with other measures for the prevention of CDW. The Austrian traceability system is already well established: the Austrian "Abfallwirtschaftsgesetz" (Waste Management Act), in force since 2011, binds waste owners and treatment plants to register the typology, quantity, origin and location of waste, including hazardous waste, which must be reported. All waste data are then transmitted to the Electronic Data Management System, thus ensuring a comprehensive data collection (Luciano et al., 2022).

In **Belgium,** the non-profit CDW management organisation "Tracimat" has developed a traceability system, in order to provide quality assurance for Flanders recycling companies handling materials obtained through selective demolition (FCRBE Project, 2019). Furthermore, in the Flanders region, the movement of excavated soil must be registered into a national database for a cost of € 0.05/m^3 of soil. By doing so, costs related to landfill tax and waste transport are avoided with a saving of €2/m^3 of soil. However, generally, Belgium suffers from a lack of harmonisation of data collection across regions (European Commission, 2017).

France has introduced an effective traceability system for CDW named Démoclès[27] as reported in the EU Interreg Project CONDEREFF (Annex 3, Table A2) (Luciano et al., 2022).

Germany presents a robust methodology based on data from treatment facilities and an independent quality assurance test, carried out before releasing the data in the IT network. CDW recycling plants report the quantities of waste to the statistical offices of the Lander they belong to, which share the statistics with the Federal Statistical Office, with the whole process undergoing a quality control verified by external organizations (Luciano et al., 2022).

The Netherlands performs numerous cross checks with other data sources to ensure data robustness. Furthermore, a Container Service App was implemented for private and professional ordering of CDW containers which allowed the recycling of the 86% of the collected waste (European Commission, 2017).

Estonia presents a well-developed Waste Register database and produces robust estimates thanks to administrative data (i.e., waste factors are used to extrapolate the data to enterprises that do not have a permit, and double counting is avoided through specific algorithms).

Denmark has in place a waste data collection system for estimating waste from waste treatment facilities and waste collectors.

Hungary relies on a robust methodology to estimate data from non-replying units and for enterprises that have no obligation to report their data. It relies on two different organisms responsible for the quality of the data sets and the data quality control.

Poland checks the coherence between the reported national data and the official data presented by Eurostat and has in place a robust methodology for waste generation data (i.e., data are collected based on permits and licenses through the Integrated Waste Management System).

[27] https://www.democles.org/

Portugal imposes the obligation to report data regarding CDW through the SIRAPA portal and has robust validation tests performed to ensure internal coherence and time-series consistency, and combination of data from waste generators and waste operators to increase coverage of waste treatment data, correct some reporting mistakes and reduce double counting.

Slovenia covers 100% of reporting units for CDW treatment data from advanced web surveys.

In **Sweden,** the Swedish Transport Administration has developed a materials database for the trading of, and information concerning, excavated materials.

In the remaining countries, despite having traceability instruments, a need for improvement in the CDW sector has been identified. Thus, in **Czechia** there is a traceability system, but stakeholders highlight that a more rigorous control of CDW records is necessary, as well as an improved database and platform (Luciano et al., 2022), because the co-existence of two separate and inconsistent information systems for waste data has lead to duplications, gaps and discrepancies in the information database (European Commission, 2017). In **Italy**, the SISTRI traceability system is no longer operational. The Decree Law December 14, 2018 n. 135 has introduced the National electronic register for the traceability of waste, managed directly by the Ministry of the Environment, which has not been fully applied yet. In **Greece**, a specific CDW tracking system exists with the obligation of the officially licenced CDW management systems to report data through an annual survey combined with administrative data sources for cross-checks (European Commission, 2017). However, the system is not widely used, since CDW recycling facilities are not widespread across the country yet, though their number is increasing and will allow a more detailed tracking and data collection in the future (Luciano et al., 2022).

3.1.7. Enforcement and compliance promotion

Waste audits are important instruments to promote enforcement and compliance of policy objectives on CDW reuse, preparing for reuse and recycling since they provide information about the nature and volume of materials generated during demolition works. The European Guidelines for the waste audits before demolition and renovation works of buildings (i.e., pre-demolition audits) (European Commission, 2018b) represent the starting point for the implementation of audits across MSs and provide recommendations on how to assess resources available prior to demolition or renovation works. Well-performed pre-demolition audits have proven to positively influence data quality, legislation and market conditions, contributing to improve CDW recycling quality and quantity (Luciano et al., 2022). The implementation and application of the pre-demolition audits depend on each EU MS, and according to the (European Commission, 2017), a pre-demolition audit is already mandatory in several MSs, and in some cases it is only mandatory at regional level or only for hazardous CDW as reported by Spišáková et al. (2021).

In **Belgium,** a pre-demolition inventory is required in the three regions (Brussels Capital Region, Flanders and Wallonia). The Flemish legislation VLAREMA provides instructions on how to perform pre-demolition audits, which are only mandatory for buildings with specific characteristics (European Commission, 2016b). Similarly, in **Finland** and **France**, pre-demolition audits are only mandatory for certain categories of buildings. **Luxembourg** also requires a pre-demolition inventory to support selected collection of each material and corresponding treatment in line with waste hierarchy.

Bulgaria includes the pre-demolition audits through plans for management of CDW. **Hungary** includes pre-demolition audits through demolition plans as requirement deriving from the Government Regulation 312/2012 (XI.8). The plan must include demolition technology, outcomes of the building inspection including whether any asbestos and other hazardous materials is found within the building.

Czechia, in the Building Act 183/2006, requires a pre-demolition audit as a condition to give the permission for demolition of buildings by regional/local authorities. However, it lacks the criteria for the quality of the pre-demolition audit that can vary from a very quick inspection and vague description to very detailed ones (European Commission, 2017 - Country factsheets).

The Netherlands request a demolition licence with a pre-demolition audit for buildings in which more than 10 m^3 waste is released. **Portugal,** through the waste management legislation, stipulates that pre-demolition audits are stipulated in the case of demolition or renovation of public buildings or public infrastructures (Oberender et al., 2024).

In **Sweden**, pre-demolition audits are mainly focused on health aspects (identification of asbestos) and hazardous wastes. Similarly, **Ireland** requires to take all necessary steps to identify presumed asbestos-containing materials at a premises or place of work before commencing demolition, removal or maintenance work at that premises or place of work (Article 12 of S.I. No. 386 of 2006 and S.I. No. 589 of 2010). Furthermore, demolition work on a building does not start until asbestos and asbestos-containing materials are removed and a suitable plan of work is drawn up and submitted to both the environmental and health & safety authorities (Article 15 of S.I. No. 386 of 2006). Finally, asbestos must be identified as a particular risk in the preliminary health and safety plan which is developed by the Project Supervisor for Design Process (S.I. No. 291 of 2013). In **Germany**, pre-demolition audits are, until now, mandatory only following the detection of harmful substances arising due to the obligation to evaluate the risk and adopt safety measures when workers may be exposed to hazardous materials (Oberender et al., 2024).

In addition to the countries mentioned above, Spišáková et al. (2021) report that pre-demolition audits are mandatory also in **Italy** and **Malta**, and only for hazardous CDW in **Poland**, **Slovenia**, **Austria, Croatia, Cyprus, Denmark** and **Estonia**. It is important to note that, despite being mandatory in many MSs, there is a limited application in some of them. For example, in **Spain,** even if mandatory, it is not widely implemented, due in part to lack of monitoring and controls (European Commission, 2019).

In **Greece, Latvia, Lithuania, Romania and Slovakia,** there is no legislative obligation of pre-demolition audits (Spišáková et al., 2021).

3.1.8. Public information and awareness raising

Some of the main barriers to implement a sustainable and efficient waste management are related to social behaviour, lack of motivation or knowledge on recycling options, and cultural norms. Along with regulatory and economic instruments, the so-called social instruments (also referred to as behavioural nudges) such as public campaigns can play an important role to overcome those barriers and change people's attitudes and actions (Cristóbal et al., 2022). Besides, social instruments might be very effective in achieving the desired outcome when other instruments are inappropriate or undesirable (Jevrić & Ćipranić, 2023).

Adams et al. (2017) analysed the awareness level of circular economy (that includes the topics of waste prevention and management) in the construction sector in the UK and concluded that at an industry wide level (comprising researchers and consultants, contractors, clients, product manufacturers, demolition contractors, designers, government representatives and trade associations covering building products) there was a general lack of awareness. This conclusion is also shared by the impact assessment of the review of the national waste management legal framework in 2011 (D.L. 73/2011) in Portugal (Sharp et al., 2019). The study from Adams et al.

(2017) also analysed circular economy enablers and awareness raising campaigns, as well as the best practice case studies, and concluded that they were considered very important among the sector members.

Raising awareness about the impact of construction site waste and providing education on proper waste management practices are crucial for community engagement. This can be achieved through **public campaigns, workshops, and informative resources**. **Technological advancements** (e.g., waste recycling apps) can also play a significant role in improving waste management practices in construction sites, enhance community participation and spread valuable information to foster prevention, recycling and sound CDW management. Finally, **educational programs** at different levels for waste management can increase awareness, enhance knowledge and skills and foster community engagement and involvement.

Best practice in awareness-raising is to effectively encourage waste prevention, reuse and recycling behaviour within the waste collection catchment area, and to incentivize community participation in waste reduction. Even if, as stated by Ramos et al. (2023), strategies/measures at local scale (i.e., relationship between municipalities and micro and small construction companies) are key to achieve the major objectives of CDW management and circularity in the construction sector, strategies/measures at higher level (i.e., regional, national and European) or through EU funded projects (such as CONDEREFF, CITYLOOPS) can also be helpful to achieve the overall goals (Annex 3, Table A2). Examples of best practices from the plethora of different initiatives and measures to raise awareness throughout all EU MSs are shown below.

At **EU level**, there are many initiatives to raise awareness about waste and loss of materials in the economy. One of the most recognised ones is the **European week for waste reduction (EWWR)** that encourages all Europeans, and not only, to carry out awareness-raising actions about sustainable resource and waste management during a single week in November every year since 2009. For example, during the edition of 2022, the Reincarnate project participated in the EWWR to raise awareness of the need to transform the construction sector into a circular one promoting circular economy practices for CDW including extended use, reuse, and recycling[28].

The **EU project** CITYLOOPS[29] investigates innovative analysis and solutions that include awareness-rising campaigns for promoting a transition to a circular economy for CDW and organic waste in seven European cities in five EU MSs and Norway. In the same line, the CONDEREFF project[30] delineates awareness-raising actions relevant to CDW recycling capacity in several regions of seven EU MS.

In **Slovenia**, the EU LIFE project ReBirth[31] aims to increase and improve the recycling of industrial and construction/demolition waste for use in the construction sector by means of communication and open dialogue activities aimed at raising awareness on these recycling possibilities at national, regional and local level. The channels of communication would be open to professionals, state and local authorities, and the public, with different topics such as legal issues around the correct disposal and recycling of waste, the economic opportunities around the growth of new environmental goods and services, and dissemination of best practices in other EU countries (e.g., green public procurement, environmental taxes and charges).

[28] https://www.reincarnate-project.eu/reincarnate-participates-in-the-european-week-for-waste-reduction/
[29] https://cityloops.eu/
[30] https://projects2014-2020.interregeurope.eu/condereff/
[31] https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE10-INF-SI-000138/promotion-of-the-recycling-of-industrial-waste-and-building-rubble-for-the-construction-industry

In **Belgium (Flanders)**, the EU LIFE project C-MARTLIFE[32] will implement the Flemish Waste Management policy, and one of the main aims is to **support communication**, management and **replication of successful environmental solutions** and practices, and developing solutions to increase the recycling rate with closed loops for CDW, as well as other waste fractions.

At national level, there are also some examples of social instruments embedded with the regulations. In **the Netherlands**, there are several initiatives which either focus on, or at least include, activities aimed at raising awareness and sharing knowledge, particularly where circularity is concerned. Thus, circularity is the focus point of the aforementioned *National Circular Economy Programme*, which includes provisions aimed at increasing the use of material passports and **creating local networks** to enable high-grade reuse (Dutch Government - Ministry of Infrastructure and Water Management, 2023). The *Raw Materials Agreement* which, as mentioned before, was developed in connection to the circular economy programme, lists as one of its goals the **promotion** of new ways of consuming (Dutch Government - Ministry of Infrastructure and Water Management, 2017a). Another example is the previously mentioned *Dutch Concrete Agreement* that sets as one of its 2030 targets increasing social capital by "**improving and sharing knowledge, innovation and education**" (Cramer, 2021).

In **Denmark**, some initiatives include sections relative to sharing knowledge or raising awareness. As an example, the previously mentioned Danish *Circular Economy Action Plan* includes among its measures **supporting exchange platforms** for construction materials and products (EEA, 2023b).

In **Belgium (Brussels)** the Regional Programme for Circular Economy (PREC) that ran from 2016 to 2020 (Gouvernement de la Région de Bruxelles-Capitale, 2016), has included engagement with construction professionals, including designers and contractors. Different working groups have been established to set actions, for example, on training. The BAMB project[33] recognise the implementation of the PREC as an example of awareness raising among professionals (Sharp et al., 2019). In **Belgium (Flanders)**, the Flemish government, in conjunction with the Public Waste Agency of Flanders (OVAM), developed the *Flanders Materials Programme* (VMP), with the goal of working with a variety of stakeholders to identify solutions for waste and materials management, with a focus on waste prevention (EEA, 2016b).

3.2. Non-EU countries' current implementation of policy instruments for CDW

The previous section analysed the waste management frameworks and the current implementation of policy instruments within the EU. It is important to also analyse the situation in other countries outside the EU to identify best practices that, in case of not being present in the European context, might be evaluated for future implementation. An overview of the waste management framework of some countries outside the EU has been reported by Sakai et al. (2011) (i.e., US, Japan, South Korea and China) and Ma et al. (2023) (i.e., UK, Japan, South Korea, China). This section focuses on the UK, Japan, and the USA.

3.2.1. United Kingdom

The United Kingdom (UK) officially left the EU on January 2020 after 47 years as a MS, and for that reason the legal framework is very similar to the other EU countries, due to the required alignment

[32] https://webgate.ec.europa.eu/life/publicWebsite/project/LIFE19-IPE-BE-000008/circular-material-approach-on-residual-waste-targets-and-a-litter-free-environment
[33] https://www.bamb2020.eu/

with the EU environmental acquis. Besides, according to the assessment of the level of maturity of legal frameworks in EU MSs conducted by the European Commission (2017) (note that UK was still a MS then), UK presented an **advanced legislation on CDW**. The WFD was transposed into national law in 2011 within the four different regions of UK (i.e., England, Wales, Scotland and Northern Ireland), as well as the landfill directive. Herein the main policy instruments present in UK are reported (note that when differences between regions exists, they will be highlighted) according to RE4 Project (2017), the European Commission (2017 - Country factsheets), and OECD (2022).

Concerning regulatory instruments, the UK established **EoW criteria** in 2011 for several materials such as iron, steel and aluminium scrap or glass cullet. For other materials in CDW, the producer, in a voluntary process to avoid the material is classified as waste, must undertake an EoW test by either complying with a Quality Protocol or carrying out an EoW Test Assessment. CDW relevant Quality Protocols in England and Wales include for example aggregates from inert waste, flat glass, waste plasterboard and non-packaging plastics. In Scotland, the Scottish Environment Protection Agency does not automatically recognise the validity of the mentioned Quality Protocols (European Commission, 2017 - Country factsheets). The UK has **no specific bans on CDW landfilling**. Concerning **CDW targets**[34], England, Northern Ireland and Scotland rely on the target imposed in the WFD, meanwhile Wales set a target of 90% preparing for reuse, recycled or recovered by 2019/20 by weight for all non-hazardous CDW excluding naturally occurring materials of category 17 05 04 in the list of wastes, and a proposed waste prevention target of 1.4% per year on the CDW to 2050. Further targets are set for Wales for reducing the percentage of construction and demolition waste landfilled in Wales, as a percentage of the 2007 baseline, by 50% by 2015-16, and by 75% by 2019-20 (Welsh Government, 2015). There are also targets for certain materials such as plasterboard (i.e., long term objective of zero plasterboard waste sent to landfill by 2025, as well as increase the recycling of new construction plasterboard waste to 50% by 2015) in industrial agreements and partnerships[35], and for concrete (i.e., increasing the proportion of recycled/secondary aggregates as a % of total aggregates to 25% by 2012).

Concerning economic instruments, a **UK landfill tax** (that applies to England, Wales and Northern Ireland) was introduced in 1996 and has reached a value of £96.7 per tonne standard rate and £3.1 per tonne lower rate, being the latter paid on wastes such as rocks or soil (i.e., inert or inactive waste). The UK landfill tax is collected by the Government department. A longstanding instrument is the **aggregates levy**, introduced in the UK in 2002 that applies to commercially extracted sand, gravel and rock, including imports with the main aim to reduce quarrying impacts on the environment and increase recycling in construction. Originally, the rate was £ 1.6 per tonne of aggregate, but it rose to £2 per tonne in 2009 and has not increased since.

In the UK, the **EPR** is recognised as an important concept and its waste management policy is based on the principle of shared responsibility (Sakai et al., 2011). For construction and demolition related wastes, there is an EPR for plasterboard, insulation and ceiling tiles. Instruments like SmartStart in the UK promotes **on-site inspection and assessment** of waste management at most building sites (Villoria Sáez & Osmani, 2019).

As an example for **monitoring and reporting enforcement**, CL:AIRE, that is a charity, has developed a voluntary framework named "Definition of Waste: Code of Practice" (DoW CoP) that helps industry assess whether excavated materials can be classified as waste or not, whether treated excavated material can cease to be waste for a particular use, and how to reuse excavated materials sustainably. This framework imposes an administrative declaration fee depending on the volume of soil being reused. Thus, for less than 50 000 m^3, the fee is approximately 400 €. This

[34] Additional targets exist from join industry and Government that intends to "halve CDW to landfill by 2012 based on a 2008 baseline", as well as other industry targets with many construction companies for diverting CDW from landfill within some construction projects e.g., Olympics. Trade bodies tasked their members further targets to ensure a reduction of materials sent to landfill.

[35] Ashdown 2 Agreement

increases to approximately 575 € for volumes up to 150 000 m^3, and over 1 000 € for volumes above 150 000 m^3. Furthermore, a "volumetric fee" of approximately 0.03 € per m^3 is applied for volumes over 1 000 m^3.

3.2.2. Japan

Japan is one of the world's front-runners in terms of **waste policy framework**, actual recycling rate and advanced recycling technologies and initiatives to address the challenge of CDW (including excavated soil). The basis for the legal framework dealing with CDW is grounded on several pieces of general legislation. Namely, the Waste Disposal and Public Cleansing Act (1971) that requires waste treatment by not only municipalities but also businesses; the Law for the Promotion of the Effective Utilisation of Resources (1991) prioritises both waste minimisation and rational use of natural resources fostering the 3Rs initiatives; the Basic Environment Law (1993) that was enacted to comprehensively and systematically promote policies for environmental conservation; and the Basic Law for Establishing a Sound Material-Cycle (2001) to promote comprehensively and systematically the policies for the establishment of a society in which the consumption of natural resources will be reduced along with the environmental load to the greatest extent possible, by preventing or reducing the generation of wastes. There is also a specific piece of legislation focused on CDW: the Construction Materials Recycling Act (2000) aiming at recycling and reuse of prospected construction materials with a view to ensuring efficient use of resources (Sakai et al., 2011).

Up to date, Japan **has not elaborated EoW criteria**. However, there are several **standards on different recycled products** related to CDW. Japan has enacted (between 2005 and 2007) a set of regulations and guidelines aiming to deal with the application of recycled aggregate for concrete class H (general purpose concrete), M (concrete for piles, foundation beams, steel pip filling) and L (not requiring high strength and durability such as levelling concrete) (JIS A 5021:2018, JIS A 5022:2018, and JIS A 5023: 2018, respectively) (Advanced Construction Technology Center, 2019). In addition, excavated soil waste utilization standards were introduced in 2006, focusing on recycling of waste soil. This standard concerns classification of recycled products, together with their quality control and applications (Ma et al., 2021).

Japan has **not imposed landfill bans** since waste management methods differ from the EU and other countries. The whole system relies on waste-to-energy technology and in 2018 the incineration of MSW in Japan accounted for around 80% of all municipal waste and landfilling was around 1%. **CDW are accepted in specific inert waste landfills** along with the disaster wastes that is an important issue in this country (Katsumi et al., 2021). The quantity of CDW landfilled has decreased by 84% between 2002 and 2018, being a 3% of the total CDW generated.

The Construction Materials Recycling Act obliges the construction contractor to sort specific CDW by type at the construction / demolition site and established clear and reasonable recycling **targets** (in some cases including reduction) **on specific CDW**. The minimum recycling target for 2018 was established as 99% for **asphalt** and **concrete**, 95% for **wood** (including reduction), 90% for **construction sludge** (including reduction), 80% for **excavated soil**, and 60% for **mixed CDW** (including reduction) being most of them already achieved by 2012 (MLIT, 2019 - page 188). The 2024 target value described in the "Material Reuse and Recycle Promotion Plan in Construction Works 2020—Towards Recycling with an Emphasis on Quality" is maintained for asphalt and concrete at 99%, and the values for wood and sludge are increased to 97% and 95%, respectively. Since the utilization ratio of excavated soils is currently 79.8% and the amount of excavated soil used at construction sites has increased up to 89% in 2018, the 2024 target value is maintained at 80% (Sumikura & Katsumi, 2022). Furthermore, all major branches of Japanese industry, including construction, also adopt voluntary action programmes that include quantitative targets and timelines concerning, for instance, control of GHG emissions and the reduction, reuse and recycling of waste (OECD, 2010).

By 2014, there was a **landfill tax** on industrial waste (referring to waste generation from business activities) that applied in 27 (of 47) prefectures, and one city (Sasao, 2014). Three types of taxation are employed at the prefecture level: **Type A** (used in two prefectures) directly tax waste generators based on their direct transport to landfills or to intermediate treatment facilities, except recycling facilities, a quantity of 1000 yen (10 $ or 7.4 €[36]) per tonne of waste plus an additional tax rate depending on the environmental impact of the final disposal (e.g., 100 yen (1 $ or 0.74 €) per ton transported to incineration); **Type B**, the most popular (implemented in 19 prefectures), is a special levy on contractors involved in the final disposal of waste, i.e., the quantity transported to the landfill (it is similar to the landfill tax in the EU) and the quantity is 1000 yen (10 $ or 7.4 €) per tonne; **Type C** (implemented in 6 prefectures) is a special tax on intermediate disposal contractors with incinerators and final disposal contractors (also the transport of the ashes from the incinerator to the landfill are taxed) and the quantity is 1000 yen (10 $ or 7.4 €) per tonne on transporting waste to landfills and 800 yen (8 $ or 5.9 €) per ton on transporting waste to incinerators. According to Sasao (2014), the type of tax generating the highest incentives to reduce the amount of waste is type A, followed by type C and lastly type B. It seems that Japan has no levy on natural resources such as sand or gravel.

According to the OECD (OECD, 2019), in Japan there are **subsidies** for prefectures that implement a waste management plan. Other **incentives** are preferential interest rates for firms from the national development bank according to the firm's environmental rating, which includes waste management practices as a factor.

After the Construction Material Recycling Law was enforced in 2002 that obliged the contractor to sort out recyclable waste from demolition wastes, **EPR** principles were introduced to construction materials reinforcing the shared burden among citizens, businesses, municipalities and the national government (OECD, 2019). The Proper Processing on Construction By-products of 2002 specifies the responsibilities of related stakeholders in the process of construction, demolition and recycling, including ordering parties, contractors, demolition and recycling operators (Ma et al., 2021).

Japan started the movement of **GPP** back to the late 1980s with the Eco Mark Program and in 2007 enacted the Green Contract Law that pushes for the procurement of raw materials, parts, and services that reduce environmental loads and allows easy waste separation and recycling. It includes public construction works such as Government Office Buildings (Ministry of the Environment, 2016). The Construction Material Recycling Law enforced in 2002 encourages public works to buy recycled or reusable CDW to facilitate the market development of recycling or reuse.

Based on Japan's global leadership for the 3R's (reduce, reuse and recycle) and the premise of creating a sound material-cycle society, there has been a relatively long history of **indicators and material flow accounts** (Tanikawa et al., 2021)**,** supported by a noticeable development of **information systems,** to inform environmental policies and foster the development of circularity in the economy.

For buildings beyond a certain minimum size, **selective dismantling** is required to recover specific materials such as concrete, asphalt, and wood. This is enforced through a registration of the entity undertaking the demolition. However, since the budget for demolition is typically small, a permit from local government is not necessary, and thus the system is not very effective (CIB, 2000).

Japan established a quantitative target for **public awareness** in its First Fundamental Plan for Establishing a Sound Material Cycle Society: 90% of the people responding the survey should be

[36] Average exchange rate USD - EUR equals 0.7382

aware of, and trying to put into practice, waste reduction and recycling and the purchase of environmentally friendly products (OECD, 2019).

3.2.3. USA

The backbone of the **waste policy framework** in the USA, focused on resource conservation and pollution prevention, relies on two main legal texts: the Enactment of the Resource Conservation and Recovery Act (RCRA, 1976, significantly amended in 1984) that governs the disposal of solid waste and hazardous waste, and the Pollution Prevention Act (1990, amended in 2002) aiming at reducing or eliminating waste by modifying production processes, implementing conservation techniques, and reusing materials. Those are complemented by other programs such as the Resource Conservation Challenge aimed at preventing pollution and promote reuse and recycling, and the Strategic plan of the U.S. Environmental Protection Agency (USEPA) (Sakai et al., 2011). State environmental and/or health departments have jurisdiction over solid waste management policy, and thus differences appear in how each state classifies and manages CDW (USEPA, 2017).

In the USA, the RCRA creates the framework to **define solid wastes** and the exclusions of that definition. The USEPA developed detailed regulations based on that and maintained most of the definitions and exclusions. The Code of Federal Regulations (CFR) 261.2 section e) states the **conditions to stop considering a material as solid waste after recycling**: either used as ingredient in an industrial process; or used as effective substitute for a commercial product; or returned (as a substitute for feedstock material) to the original process without being reclaimed or land disposed. However, each state establishes its own waste directives and might provide different definitions of CDW exempting certain materials (e.g., California exempts uncontaminated concrete, bricks, ceramics, and crushed glass, and Ohio exempts non-hazardous CDW including concrete, bricks, blocks, tiles, stones, used as fill). Exempted materials have fewer management constrains and may be entirely excluded from solid waste public policy. Furthermore, they are typically deemed as inert or clean fill, and to maintain the exempt status, they cannot be commingled with other mixed CDW (USEPA, 2017).

Although there is no state-wide ban of CDW from landfills, some municipalities and counties incorporated their own bans, such as Seattle and King County in Washington, Orange County in North Carolina, and many jurisdictions in California (USEPA, 2017). According to the Northeast Recycling Council (2017), out of the 49 States and the District of Columbia covered in a study, 13 (28%) of them have some form of C&D material **disposal ban** or recycling requirement. For example, Massachusetts banned disposal and transfer for major CDW materials in 2006 including asphalt, bricks and concrete, metal, and wood. In 2015, Vermont implemented a ban on architectural waste including drywall, scrap metal, asphalt, etc. when coming from buildings fulfilling certain criteria of size and location. In California, some counties banned landfilling of CDW, although there is no ban at state level (USEPA, 2017).

At federal level, in the Executive Order 13693 “Planning for Federal Sustainability in the Next Decade”, the government sets a goal of advanced waste prevention by diverting 50 % of non-hazardous CDW from landfills) (U.S. Government, 2015). Many states set **recycling rate goals** for solid waste including CDW. For example, California and Florida set a goal of 75% recycling solid waste by 2020. Delaware sets a goal of 72% recycling for all solid waste including CDW by 2015 (USEPA, 2017).

USA has **no national landfill tax or fee**. However, states and **local governments can choose** to collect fees and taxes on the collection or disposal of solid waste. According to Jenkins & Maguire (2009), taxes are levied by 29 of the states (i.e., 60%) and the average tax was $2.21 per tonne. For example, in the state of New Jersey, a sanitary landfill tax of $0.5 per tonne or $0.15 per cubic yard is imposed to the owner or operator of the landfill on all solid waste accepted for disposal[37]. North Carolina imposes a solid waste landfill tax on MSW and CDW at the rate of 2$ per tonne imposed on the owners or operators of the landfills / transfer stations[38]. In Minnesota, CDW is taxed at 0.6 $ per cubic yard or $2 per tonne[39]. The national average tipping fee at MSW landfills in 2013 was $50 per tonne, being the weighted average tipping fee charged for CDW landfills $31 per tonne (USEPA, 2017).

There is no national **resource tax**, but there are examples of some states that allow counties to impose (and collect) production taxes on the removal of aggregate material from a pit, quarry or deposit. For example, in Minnesota, according to the Statutes 298.75, counties can impose a tax on the extraction of aggregate material including sand, gravel, crushed rock, limestone, and granite among others[40] and they have values, for example in Goodhoe County, of around 0.215 $ per cubic yard or 0.15 $ per tonne[41].

The California Green Building Standards Code (CALGreen) is the first-in-the-nation mandatory **green building standards code** and sets minimum recovery requirements for building and demolition projects. In line with that, several municipalities in California (but also in other states) have also established a form of **deposit-refund system** in which firms pay a deposit when applying for a construction or demolition permit and receive a refund upon demonstration to have exceeded a certain recovery rate threshold of waste or debris, usually ranging between 60% and 75%.

Concerning **GPP**, the above-mentioned Executive Order 13693 promotes sustainable acquisition and procurement of products and services by federal agencies and includes the objective of, when feasible, ensure by 2030 that all new construction of federal buildings greater than 5 000 square feet achieve waste net-zero. The USEPA has provided recommendations of specifications, standards and ecolabels to be used in federal purchasing (USEPA, 2017). Instruments like WasteSpec promotes on-site inspection and assessment of waste management at most building sites (Villoria Sáez & Osmani, 2019).

3.3.Novel policy – aid to sustainable design instruments

This measure is in line with category #9 of economic instruments put forward in Annex IVa of the WFD: “Use of fiscal measures or other means to promote the uptake of products and materials that are prepared for re-use or recycled”. Aid to sustainable design would consist in any measure targeted at the design stage, in the earliest possible stages of project formulation, to favour sustainable solutions (reduce, refurbish, repurpose, etc.) over more conventional unsustainable solutions (demolish and rebuild).

Aid to sustainable design is mostly targeted at architectural and design studios. Typical embodiments of this instrument could include:

- architectural prizes with criteria set on resource efficiency and material throughput.
- award criteria in public works based on refurbishing/repurposing criteria; and

[37] https://www.nj.gov/treasury/taxation/landfill.shtml
[38] https://www.ncdor.gov/taxes-forms/other-taxes-and-fees/solid-waste-disposal-tax
[39] https://www.revenue.state.mn.us/solid-waste-management-tax-information
[40] https://www.revenue.state.mn.us/aggregate-materials-tax
[41] https://www.co.goodhue.mn.us/DocumentCenter/View/103/Aggregate-Tax-Removal-Ordinance

- subsidies based on designed lower CDW generation compared to a baseline calculated on typical construction or refurbishment projects.

Solutions targeted at the design stage (architects) incur low relative costs compared to the overall costs of construction projects (material and building costs, real estate, etc.). The potential leverage effect is therefore large. However, the measures need to be accompanied by approval from the project client as well as follow-through from the builders and demolishers in terms of sustainable building practices to materialise in the form of resource throughput. Roadblocks include the development of sound methodologies and baseline to demonstrate the sustainable characteristics of design projects and the benefits compared to Business-as-Usual.

3.4.EU research and development programs focused on CDW

Research and development are key processes for creating and promoting the technologies used for CDW recycling. The cornerstone at EU level is the actual EU framework programme for research and innovation i.e., the 9th Framework programme named "Horizon Europe" that runs from 2021 to 2027. Previous framework programmes include the 7th named "FP7" that run from 2007 to 2013, and the 8th named "Horizon 2020" that run from 2014 to 2020. Annex 3

Table **A2**) presents a list of projects focused on reuse, preparing for reuse and recycling of CDW obtained through CORDIS42.

Furthermore, the European Commission and the European Economic and Social Committee launched the European Circular Economy Stakeholder Platform in 2017 to accelerate the transition to a circular economy across Europe by fostering dialogue, sharing knowledge and exchanging good practices[43]. There are many examples of good practices for promoting SRM in the framework of CDW. For example, the city of Helsinki leads a project on the reuse of excavated soil in construction projects across the city[44]. Thanks to the improved coordination of excavations in Helsinki, 17 100 tonnes of CO_2 and 74 million € had been saved by the end of 2019.

3.5.Summary: Review of current and best practices

Section 3 provided a comprehensive review of the most relevant policy measures for CDW that are implemented within the EU. Section 3 asks **"What policy measures exist and to what extent are they applied in the EU already?"**.

The review of regulatory instruments, economic instruments, and others herein shows that the EU has implemented many policies to manage CDW sustainably. The overall maturity of CDW management frameworks at the EU and MS level is high. In addition, the EU and many MSs have launched novel ideas and research and development that aims to improve CDW management. MSs such as Netherlands, Denmark, and France are currently using and testing advanced best practices such as novel extended producer responsibility schemes and digital passports.

The EU's CDW regulatory frameworks are on par with the UK, Japan, and USA, although there are differences in the policy mix.

Despite the overarching frameworks, MSs still maintain a variety of regulatory, economic and other instruments which presents opportunities for harmonisation of policies that "work" across the EU to strengthen the single market trade of secondary materials and products from CDW collection and treatment.

[42] https://cordis.europa.eu/en
[43] https://circulareconomy.europa.eu/platform/en/good-practices
[44] https://circulareconomy.europa.eu/platform/en/good-practices/city-helsinki-supporting-reuse-excavated-soil-construction-projects

4. Synthesizing and assessing policy options for CDW

There are three main purposes of this chapter, taken in steps. Each step has its own objective and analytical method as described in summary below (with more detail in each respective step's section).

Step 1: Section 4.1 is primarily a scoping and synthesising exercise defining the universe of CDW policies. The analysis is based on the literature review presented in Section 3 (actual policies as implemented in the EU and beyond) and the JRC review of CDW relevant policies based on theoretical concepts and models as discussed in the scientific and industry literature. The results characterise **43 policy measures** whilst asking and answering critical questions about the buildings and CDW policy ecosystem for each policy measure as follows:

- "What policy measures could be applied?"
- "What are these policies' aims?"
- "What stakeholders/actors are affected and how?"
- "What building lifecycle stages are affected?"

Section 4.1 offers likely and feasible direct and indirect impacts of each of the 43 policy measures on the targeted stakeholder/actors at each stage of the building lifecycle.

Step 2: Section 4.2's purpose is to winnow the universe of possible CDW policies presented in Section 4.1 to a shortlist of priority policy measures. The shortlist of **22 priority policy measures** is developed using the Analytical Hierarchy Process method discussed in Section 4.2 and Annex 4.

Step 3: The policy analyses presented as Factsheets in Section 4.3 benefit from previous techno-economic and lifecycle analyses. The analyses combine the literature on economic, social, and environmental data with bespoke quantitative modelling and qualitative assessments. Many Factsheets are guided by stakeholder information collected specifically for this study. The Factsheets of the quantitative and qualitative analysis of each of the selected policy measures include the authors recommendations on their applicability to the EU-level regulatory framework.

4.1.Universe of potential CDW policy measures

The CDW policy measures compilation shown in Table 10 serves several purposes. First, it **identifies 43 enabling policy measures** that have been selected from the literature that reviews good and best practices of CDW management.

Table 10 also **frames the policy measures by the degree in which they influence actors' behaviours towards the general policy objectives** at different stages along the CDW cycle, i.e., from the perspective of product development, use, and waste generation, recovery, reuse and recycling. Selected actors along the different stages are highlighted. Note that the selection of actors that appear in the table are indicative and may not include all possible actors. The perspective of the current policy analysis is focused on the products and eventual waste fractions to be managed and aligns with but is different than the building life cycle phases perspective, which is focused on the building as a whole - a sum of its products. For reference, the five building life cycle phases are defined in Foster (2020) as follows and are noted in Table 10:

1. design: transformation is planned, designed and financed;
2. building materials sourcing: raw materials are extracted and sourced for project;
3. build: construction, rehabilitation, adaptation;
4. use & operate: the space continuously meets the needs of residents/users; and
5. repurpose & demolition: end of current use, used materials are extracted and disposed.

The behaviours and decisions of the diverse participants and stakeholders involved in the building life cycle phases impact circularity, including local and regional planning officials, residents, and conservation experts (Foster, 2020). Table 10 highlights the actors whose waste-relevant behavioural change is targeted for each potential policy measure, as well as the possible direct or indirect impact on all of them.

Table 10. Synthesis table of actual (demonstrated at MS or EU levels) and potential CDW policy measures.

Legend: The colour-coded legend describes the likely direct and indirect impacts of each of the 43 policy measures on the targeted stakeholder/actors.

Direct compliance impact	Indirect impact	Direct positive impact	Target stakeholder / actor in red squared box

How to read the table: This table summarises the universe of policy instruments and intervention types in its left 3 columns. The policy measures are divided per instrument types presented in Figure 2 explained above ("hard" legally binding rules, soft rules, and Education and information). Each policy measure is described along its row using the framework presented in the first 3 rows. (orange and green) as follows. The stakeholders (1st and header row) are allocated to the main CE lifecycle stages (2nd row). The aims for behavioural changes corresponding to the stakeholders and lifecycle stages are presented in the 3rd row. Based on this framework, the expected outcomes of each policy measure's impact on the stakeholders/actors are presented based on the JRC review of the literature and evidence. Consumers are highlighted in grey as they are not the focus of this analysis.

An example: The table explains that a landfill ban on CDW is a "hard legally binding measure" that has a direct compliance impact for: Constructors and builders; Deconstruction and demolition firms; and Waste management firms. A landfill ban is expected to reduce building waste and open opportunities for the repurpose of unused materials, whilst supporting selective demolition and waste separation to supply secondary material markets and increase reuse / recycling levels. It is noted that a landfill ban increase complexity in construction and demolition, which implies an increase in costs. This table is a synthesis of potential CDW policy measures in the literature and expected outcomes of these, without a selection or ranking of policy measures. The outcome of the JRC analyses leading to a selection of policy measures is presented in the following Section 4.2.

Table 10. Summary of instruments categorised by intervention types and impacts / expected behavioural change on stakeholders

Stakeholders + Main project lifecycle phase			**Developers, investors and building owners; project clients (private and public)** Design, use & operate	**Designers, architects** Design	**Construction and builders** Build	**Producers of construction products** Building materials sourcing	**Consumers (Building users)** Use & operate	**Deconstruction and demolition firms** Repurpose & demolition	**Waste management firms / authorities, landfill operators, recyclers + PROs** Repurpose & demolition	**All**
Targeted behavi-oural changes	***Instrument subtype (Header rows)***	***Measure***	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
'Hard', legally binding rules	Ban	**Landfill ban on CDW**			Increase in construction complexity			Increase in demolition complexity	Supply of sorted waste	
	Ban	**Landfill ban on inert waste**			Increase in construction complexity			Increase in demolition complexity	Supply of sorted waste	
	Product regulation	**CPR revision**								
	Product regulation	**Eurocodes / CPR / WFD update**								Transposition of rules
	Product regulation	**Minimum recycled content levels**	Product price increase			Product design restrictions			Increased demand for recycled material	

	Instrument subtype (Heder rows)	*Measure*	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
Hard', legally binding rules	Targets	**MS-level targets on preparing for reuse and recycling**								Enforcement of targets, implementing legislation
	Waste regulation	**Definition backfilling (WFD)**						Recovery performance (%) will drop	Recovery performance (%) will drop	Recovery performance (%) will drop
	Building regulation	**Minimum recycled content**	Potential material price increase	Recycled material sourcing	Supply of recycled material				Increased demand for recycled material	
	Building regulation	**Design for recycling**	Potential building price increase	Design constraints	Construction constraints			Improved ease of disassembly / recycling	Increase in available separated materials	
	Building regulation	**LCA for buildings**	Potential building price increase	Develop new skills						
	Building regulation	**Minimum recovery requirement (+ optional ADF)**						Increase in time, labour and other costs for demolition		

	Instrument subtype (Heder rows)	***Measure***	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
Hard', legally binding rules	Building regulation	**Mandatory pre-demolition audits**						Increase in time, labour and other costs for demolition	Increased feedstock for recycled material	
	Building regulation	**Mandatory selective demolition**						Increase in time, labour and other costs for demolition	Increased feedstock for recycled material	
	Targets (building)	**Recycled content targets**	Potential material price increase	Recycled material sourcing	Supply of recycled material				Increased demand for recycled material	
	Targets (building)	**Targets on use of materials (natural, bio-based…)**	Potential material price increase	Design constraints	Supply of recycled material	Demand creation for some products			Increased demand for recycled material	
	Disincentives	**Restrict hard-to-recycle materials**	Restricted product choice	Restricted product choice	Restricted product choice	Limitation of product offering		Improved ease of disassembly / recycling	Increased recyclability	
	Ban	**Ban products / techniques**	Restricted product choice	Restricted product choice	Restricted product choice	Limitation of product offering		Improved ease of disassembly / recycling	Increased recyclability	

	Instrument subtype (Heder rows)	***Measure***	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
Soft rules	GPP criteria	**GPP criteria**								Additional burden in tendering
	Investment criteria	**DNSH criteria**	Easier investment choice							
	Standards and certifications	**EoW criteria**				EoW criteria for construction products		EoW compliance / certification	EoW compliance / certification	
	Standards and certifications	**Standards and certifications for recycled materials**	Harmonised product characteristics	Harmonised product characteristics	Harmonised product characteristics	Increase legal certainty and harmonisation				
	Product guidelines	**Safe and sustainable by design**	Voluntary harmonised framework							
	Building passport	**Building Information Management / digital logbook**	Product / building price increase	Increase of project complexity						
	Product passport	**Digital passport (e.g., label/code) for building components**	Product / building price increase			Increase of product complexity		Facilitate demolition /renovation		

	Instrument subtype (Heder rows)	***Measure***	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
Education and information	Market information / labelling **info label on resource efficiency, recyclability, or recycled content**	**Product ecolabel / info**	Product price increase			Increase of product complexity				
	Awareness raising campaign	**Info campaigns separate collection**						Access to information	Can be run by Government or PROs	
	Awareness raising campaign	**Info campaigns use of recyclates**						Access to information	Can be run by Government or PROs	
	Awareness raising campaign	**Info campaign on pre-demolition audits and deconstruction**						Access to information	Can be run by Government or PROs	
	Training	**Training on pre-demolition audits and deconstruction**						Additional costs if mandatory		
	Guidance	**EU guidance to MS on monitoring and enforcement**								Harmonised rules

	Instrument subtype (Header rows)	***Measure***	*Reduce demand for materials*	*Design for deconstruction*	*Reduce building waste*	*Increase use of recycled material*	*Demand for more circular / sustainable products and buildings*	*Selective demolition*	*Increase reuse / recycling levels*	*Monitor rule enforcement*
			Require high quantity of reused / recycled materials	*Increase demand for reused / recycled materials*	*Repurpose unused materials*	*Reduce demand for new products*		*Separate discarding*	*Create SRM markets*	*Increase sustainability in materials used*
						Design for recycling				
Economic instruments	EPR	**EPR scheme on CPs**	CP price increase		EPR fee carryover	EPR fee collection			EPR operating subsidy	
	EPR	**EPR scheme on CP - eco-modulation**				EPR fee reduction				
	EPR	**DRS open-loop / bonus-malus**	Fee payment						Fee collection	
	PAYT	**PAYT**	Fee payment						Fee collection	Fee revenue
	PAYT	**Landfill tax**	Tax payment					Tax invoicing	Tax collection	Tax revenue
	PAYT	**Modulated discarding fee**	Fee payment					Fee invoicing	Fee collection	
	Tax	**Tax on primary resource use**	Potential material and product cost increase			Material cost increase				
	GPP	**GPP bonus malus**								Admin burden
	Subsidies/grants/tax credits	**Aid to sustainable design**				Market access				Subsidy cost
	Subsidies/grants/tax credits	**Aid to recycled content use**	Price reduction		Price reduction	Market access			Market outlet for recycled flows	Subsidy cost
	Subsidies/grants/tax credits	**Aid to preparing for reuse / recycling**			Reuse / recycling support	Reuse / recycling support			Reuse / recycling support	Subsidy cost
	Market facilitation	**Subsidise or operate marketplaces**							Market outlet for circular flows	Subsidy cost

Source: Own elaboration.

4.2.Methods of assessment of policy measures

The purpose of this chapter is to explain the method of selection used by the authors to rank the policy measures using six criteria. The authors defined the criteria, provided an explanation of the relevance of each criteria, and assigned weightings to the different criteria using the Analytical Hierarchy Process (AHP) developed by Thomas Saaty (Thomas Saaty, 2013). More information on the AHP decision-making method and the detailed results of the current AHP analysis are discussed in Annex 4.

Table 11 provides a consolidated summary of the AHP decision-making process. The first 2 columns on the left list the 6 criteria and explain why each criterion is relevant for prioritization. The scoring rules are defined as high, average, and low with a corresponding number of points. Society benefits from improving the management of CDW such that more recovered CDW is prepared for reuse (keeping materials in use, longer) and better performing recycling (feeding secondary material markets to replace primary materials). Scoring rules are a key feature of AHP. The scoring definitions allow for transparent and verifiability of the process to winnow the 43 original policies down to 22 priority policies that are then assessed. In addition, a weighting factor (the last column on the right of the table) was attributed to each ranking criteria to differentiate their relative importance in the overall JRC prioritisation of potential CDW policies.

For example, potential impact is defined as the potential environmental benefit (an estimate of the amount of CDW diverted from landfilling) resulting from its implementation. A policy scored as high impact (2 points) has the potential to divert hundreds of kilo tonnes of CDW from landfilling/incineration. Potential impact is the most important factor in prioritisation as it has the highest weight (46.4%) of all criteria.

The second weighting (25.4%) is based on the EU principle of subsidiarity, meaning that action at the EU level is necessary and is expected to be more effective than actions at the national or local level. The policy must also be feasible to implement in all MS.

Table 11. Ranking criteria, scoring rule and weights used for the AHP prioritization of policy measures.

Criteria	Explanation of relevance to prioritization	Scoring rules			Weight according to the AHP
		High = 2	Average = 1	Low = 0	
Potential impact	The potential environmental benefit (an estimate of the amount of CDW diverted from landfilling) resulting from the implementation of the policy measure.	High potential impact in the range of million tonnes	Average impact in the range of hundreds of kilo tonnes	Low potential impact in the range of kilo tonnes	46.4 %
EU action	Subsidiarity, feasibility and relevance of acting at EU level	The action at EU level is feasible and preferable, and / or the action gains relevance at EU level	The action at EU level is possible, and / or the action's relevance is average	It is difficult to articulate the action at EU level, and / or the action loses relevance at EU level	25.4 %

Criteria	Explanation of relevance to prioritization	Scoring rules			Weight according to the AHP
		High = 2	Average = 1	Low = 0	
Implementa-tion	Ease of implementation and enforcement, as well as the administrative cost incurred and the potential unintended consequences.	Low difficulty in the implementation and / or low costs and / or low unintended consequences	Average difficulty in the implementation and / or average costs and / or average unintended consequences	High difficulty in the implementation and / or high costs and / or high unintended consequences	12.3 %
Targeted intervention	According to Table 9, the policy measure is directly incentivising the intended behavioural change.	It directly incentivises the intended behavioural change	It somehow incentivises the intended behavioural change	It does not incentivise the intended behavioural change	9 %
Track record	Evidence of having worked at MS level.	Clear evidence that it has worked at MS level	Certain evidence that it has worked at MS level	No / low evidence that it has worked at MS level	3.6 %
Waste policy	The policy measure is developed through waste policy (e.g., under the WFD) or as a cross-cutting one.	-	Waste policy	Cross-cutting policy	3.3 %

Source: Own elaboration.

Following Thomas Saaty (2013), the overall score of each policy measure is calculated using the weighted sum of the individual scores obtained by each policy measure in each ranking criterion. The ranking is produced by sorting the results from the largest to the smallest value. A summary of the results of this prioritization process is shown in (more detailed results with individual scores are shown in Annex 5 – Table A3).

Table 12a includes the policies included for additional analyses. A Factsheet presenting the results of each of the analyses is provided in Section 4.3. The policies included will be analysed in detail. Similar instrument subtypes are grouped (e.g., instrument subtypes EPR, PAYT). Table 12a reflects the order of prioritisation; although not strictly, as some measures have been bundled together for analysis.

The measures not analysed further in the current report (shown in Table 12b) are not necessarily to be discarded for all follow-on work of the Commission or JRC. They may still be relevant in future analyses for national/regional/local levels or may be revisited when technical or market conditions change. In addition, several of these policies are already being analysed in different and parallel contexts (see Section 4.5).

Table 12. Policy measures included and excluded in the detailed analysis. 12a includes the 22 Priority Policies analysis for which Factsheets are presented in Section 4.3. 12b includes the 21 Policies without further analysis in the current report.

12a) 22 Priority Policies analysis for which Factsheets are presented in Section 4.3				
Instrument subtype	Measures			
EPR	EPR scheme on CPs	EPR scheme on CPs + eco-modulation	DRS open-loop / bonus-malus	
Building regulation	Mandatory pre-demolition audits	Mandatory selective demolition	Design for recycling	
PAYT	Modulated discarding fee	PAYT	Landfill tax	Landfill ban on CDW or Landfill ban on only inert fraction
Standards and certifications	EoW criteria	Standards and certifications for recycled materials		
Subsidies/grants/tax credits	Aid to preparing for reuse / recycling	Aid to sustainable design	Tax on primary resource use	
GPP criteria	GPP criteria			
Product regulation	Recycled content targets			
Targets	MS-level targets on preparing for reuse and recycling			
Market facilitation	Subsidise or operate marketplaces			
Building / Product passport	Building Information Management / digital logbook	Digital passport (e.g. label/code) for building components		

Source: Own elaboration.

12b) 21 Policies without further analysis in the current report				
Instrument subtype	Measures			
Investment criteria	DNSH criteria			
Product guidelines	Safe and sustainable by design			
Product regulation	CPR revision	Eurocodes / CPR / WFD update	Minimum recycled content levels	Restrict hard-to-recycle materials
Building regulation	LCA for buildings	Recycled content targets for buildings	Minimum recycled content in building projects	Targets on use of materials (natural, bio-based...)
GPP	GPP bonus-malus			
Building regulation	Minimum recovery requirement (+ optional recoverable fee)	Ban products / techniques		
Awareness raising campaign	Info campaign on pre-demolition audits and deconstruction	Training on pre-demolition audits and deconstruction	Info campaigns separate collection	Info campaigns use of recyclates
Market information / labelling	Product ecolabel / info label on resource efficiency, recyclability, or recycled content			
Waste regulation	Definition backfilling (WFD)			
Guidance	EU guidance to MS on monitoring and enforcement			
Subsidies/grants/tax credits	Aid to recycled content use			

Source: Own elaboration.

4.3.Factsheets: Results of assessment of 22 priority policy measures

The next step following the ranking of policy measures with AHP is to summarise the qualitative and quantitative empirical evidence. The factsheets reference existing data from credible sources (e.g., Eurostat, Commission MS, EEA, and JRC), and new data collected for the current study (stakeholder input),

A factsheet is presented for each of the 22 priority policy measures listed in the green-shaded columns of table 12a above. The policies are grouped by 10 instrument subtypes. Some Factsheets analyse a group of policies together by subtype, i.e., EPR. The additional 22 policies in Table 12b are not investigated further and do not have Factsheets.

Please note that the policy analyses herein are not intended to replace the life cycle analysis and cost-benefit analysis typically carried out in impact assessments. Each analysis draws heavily on the lifecycle analysis and techno-economic analysis in the first study of this series, and the wealth of scientific studies cited in the preceding chapters. **The analyses rely on economic, social, and environmental quantitative modelling of impacts as well as on a qualitative assessment**. Each factsheet is organised as follows:

- **Description of selected policy measure;**
- **Costs** – Collected cost **information** from stakeholders and literature;
- **Qualitative assessment (Pros and Cons)**;
- **Results of quantitative modelling of impacts, where applicable** – Where suitable data is available for the policy measure:
    I. A scenario(s) for the measure with objective(s) is (are) defined.
    II. The scenario(s) are modelled with life cycle assessment (LCA) and life cycle costing (LCC). For some policy measures other types of quantitative analyses inform the recommendations.
    III. The results are shown graphically where possible. In several cases, full environmental and economic modelling is not recommended because the cause-effect relation (or data on effectiveness) is weak or because there is no ex-post evaluation of the practice available. If so, this is noted.
- **Recommendations and next steps based on the qualitative and quantitative analyses** – The authors summarise the results to make recommendations for each of the 22 priority policy measures. Attention to the indicated implementation level (i.e., regulatory ambition) and next research steps are suggested for further studies / investigations.

4.3.1. Factsheet #1: EPR schemes

EPR (and DRS) are defined and recognised in the WFD (Annex IVa) as examples of instruments / measures that provide incentives for the application of the waste hierarchy. EPR has been already implemented within the EU for different sectors such as packaging, batteries, cars, and WEEE, and there is evidence that EPRs have contributed to reducing waste disposal and increasing recycling (OECD, 2016a). However, the implementation of an EPR for CDW is challenging, due to the multiplicity of materials, the lifespan, the complexity of the value chain, the wide variety in company types and sizes, etc.

However, an EPR is being set up in France, and considered in other MSs. The analysis herein conducted is therefore based on the (up to now) unique EPR for CDW existing in the EU which is the one implemented in France. In the French EPR, producers (and retailers, for imported products) of building products and materials (BPM) join one of the "eco-organisations" (corresponding to Producer Responsibility Organisations or PROs) approved by the public authorities, to which they transfer their obligation of organising the management of waste from their end-of-life products by **paying** in return **a financial contribution** (funded by eco-contributions on products, see below). At the other end of the life cycle, it is established that the BPM waste discarding will be done free of charge when it is collected separately by individual fraction (as opposed to mixed CDW), so that the traceability of this waste is ensured.

BPM producers add an eco-contribution to the sale price of their products to offset the logistical costs of free discarding, also covering some of the collection and processing costs of the sorted fractions. It is important to note that in the EPR scheme for CDW, BPMs are *not* paying for the waste coming directly from their actual products (since they will remain in the building for decades) but for the proportional quantity of wastes generated annually according to the quantity of their products put on the market: this corresponds to the concept of an "open-loop" EPR. The scheme is still being set up, but the distribution of cost burdens is calculated and set to be revised every year in agreement between the various subsectors to ensure that there is a balance between the amounts of products put on the market for a certain fraction (e.g., bricks, wood, plastics) and the costs linked to the amounts of waste of the corresponding materials collected at end-of-life.

Within EPR schemes, different approaches appear possible (Laubinger et al., 2021) for setting the EPR fees (contributions) and are briefly explained herein.

Basic "eco-contributions" (the term for EPR fees in the French EPR) are set following criteria based on type of material and / or product and are loose proxy for EoL costs. For instance, one of the French PROs sets around 200 different categories with fees ranging from 0.20 € to 7.46 € per tonne, loosely reflecting the complexity of dealing with the material at end-of-life.

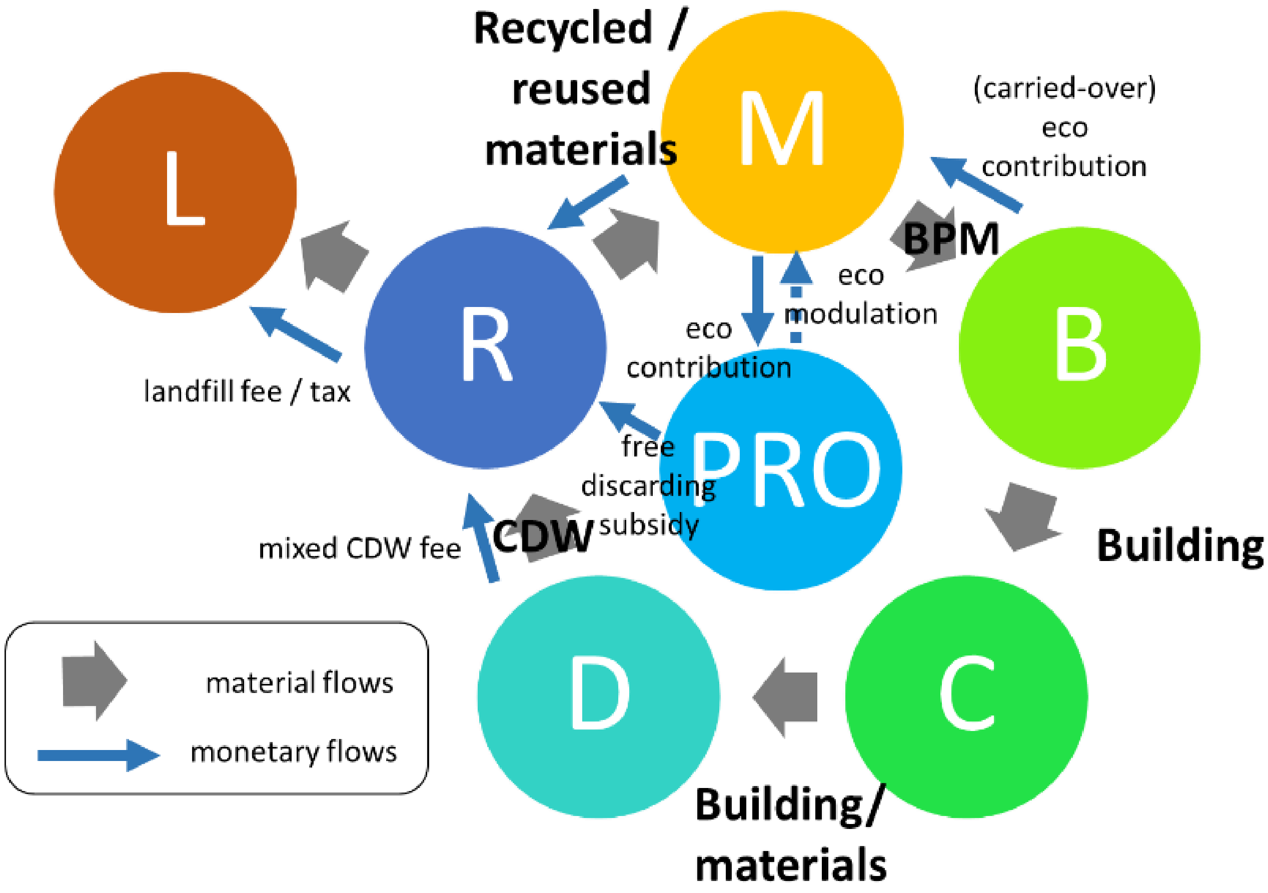
Advanced "eco-modulations" add complexity to the system and use additional criteria to set the fees by capturing some of the environmental impacts or other characteristics that are considered (environmentally) desirable or undesirable in the products. These criteria include: overall material efficiency; recycled material content; renewable material content; reparability; reusability; recyclability, etc. Thus, an advanced eco-modulation will favour BPMs aligned with the environmental criteria and policy objectives, which will pay lower eco-contributions. Besides, advanced eco-modulations can provide more targeted incentives for eco-design (criteria may relate to eco-design aspects other than weight). Eco-modulation is therefore implemented as a **bonus-malus**, i.e., an adjustment of basic EPR fees introducing specific incentives (i.e., bonuses) and disincentives (i.e., maluses) based on eco-modulation criteria, or even based on measurable operation cost differences of EoL products. Note that at the PRO level, bonuses translate into reduced revenues (the bonus is for the BPM that will pay lower eco-contributions), and maluses translate into additional revenues. The PRO is tasked with ensuring overall financial equilibrium, adjusting to market evolutions.

Distinction between EPR and DRS: Depending on how an incentive scheme is administered, it could be considered closer to an "EPR" or closer to a "DRS. For instance, with **a DRS a user claims a deposit paid on a new article at purchase upon returning it as separated waste.** The deposits are returned to the purchasers, therefore there is no surplus to finance other waste collection and disposal. **With an EPR, the end-of-life processing is financed by fees charged on categories of product sales (eco-modulation), not tied to individual articles.** In this case, there is no need to track each article at sale and at return when financing waste collection and disposal, thus overcoming a commonly cited barrier to applying a DRS to CDW. An EPR incentive scheme funded by current producers with a broader scope could pay for free collection and disposal of materials that never had a deposit, as opposed to a discarding charge for mixed CDW.

Costs

Figure 7 below illustrates the material and monetary flows present in an EPR model. **NB** the monetary flows are only represented insofar as they are affected by the scheme.

Figure 7. Funding model of the EPR.



Source: Own elaboration.

Note – M: Manufacturer of construction product; B: builders; BPM: Building Product Material; C: project client; D: Demolition company; R: Waste manager and recycler; L: Landfill. PRO: Product Responsibility Organisation.

Example of the French EPR:

Macro level: According to ADEME (the French environment and energy management agency), the cost of CDW management without EPR is estimated as 2 215 M€ in 2021 for a total quantity of 41 000 kt of CDW as shown in Table 13 (ADEME, 2021). ADEME makes a projection of the CDW management cost without the EPR in 2028 of 2 655 M€ (considering a 20% increase due to increases in collection and valorisation taxes, etc.). And based on a projection for 2028 with EPR the cost would be 2 730 M€. It seems that the administrative and operating costs for running the EPR equals 3% of the cost of collection, transport and treatment of the waste without the EPR. Based on these estimations and following the same logic, we calculate the cost of the EPR per ton of waste (excluding the hazardous waste).

Table 13. CDW quantities and management costs estimated in France in 2021.

	Inert	Non-Hazardous	Hazardous	Total	Unit
Total cost (collection, transport, treatment)	478.5	893.2	842.5	2 214.2	M€
Quantity	30 000	9 700	1 300	41 000	kt

Source: (ADEME, 2021).

Thus, excluding the hazardous waste, the total cost of managing the waste would be 1 371.7 M€ for 39 700 kt of CDW. Since the EPR is 3% (i.e., 41.2 M€), the (additional) cost in €/t of the EPR for the non-hazardous and inert waste would be around 1 €/t.

When advanced eco-modulation is implemented, complexity is added to the EPR system and therefore there is an expected increase in administrative load of all stakeholders associated with additional cost, both initially to establish the modulation system and on an ongoing basis (i.e., additional reporting, monitoring and enforcing). These costs have not been yet reported but according to Laubinger et al. (2021), BPMs and PROs perceive that the benefits of a more advanced fee modulation system do not justify the costs incurred by the added complexity of implementing and complying with it.

Micro level: herein, the price impact on selected material streams is analysed. The scheme has initially been set up with 4 different PROs, covering different but partially overlapping fractions (Ecominero for inert wastes, Ecomaison/Ecomobilier for fixtures and furniture, Valdelia for stone/wood/metal and Valobat covering all streams). Each PRO proposes its own fee scheme for the covered construction products and materials. Table 14 presents example EPR fees as well as illustrative baseline material prices to illustrate relative price impacts.

Table 14. EPR fees and baseline material prices in the French EPR.

Construction material	Subtype	Type	EPR fee (ex tax) - Valobat	unit	EPR fee - ecominero	Typical price	Typical price increase
Concrete, ready-to-use mix	Undefined	inert (mineral)	**1.78**	€/m3	1.68	195	**0.91%**
Concrete, ready-to-use mix	R0 (<5% recycled content)	inert (mineral)	**1.72**	€/m3	1.6	195	**0.88%**
Concrete, ready-to-use mix	R1 (5-10% recycled content)	inert (mineral)	**1.38**	€/m3	1.26	195	**0.71%**

Cement		inert (mineral)	**5.70**	€/tonne	5.70 to 1.40 (recyc content)	225	**0.6-2.5%**
Concrete block	Undefined	inert (mineral)	**0.69**	€/tonne	0.66	1000	**0.07%**
Concrete block	R0 (<5% recycled content)	inert (mineral)	**0.66**	€/tonne	0.63	1000	**0.07%**
Concrete block	R1 (5-10% recycled content)	inert (mineral)	**0.53**	€/tonne	0.5	1000	**0.05%**
Concrete block	R2 (10-15% recycled content)	inert (mineral)	**0.35**	€/tonne	0.33	1000	**0.04%**
Aggregates		inert (mineral)	**0.25**	€/tonne	0.22 to 0.20	95	**0.26%**
Bricks		inert (mineral)	**1.88**	€/tonne	0.75-0.36	360	**0.52%**
Bathroom sink		inert (mineral)	**0.06**	€/unit	0.09-0.015 (7.46/tonne)	40	**0.15%**
Paint		non-inert	**77.19**	€/tonne	not covered	490	**15.8%**

Source: Own elaboration.

As illustrated in Table 14, most of the price increases for inert materials are relatively minor (sub-few percent) especially in a context of fluctuating raw material prices; however, some fractions would undergo noticeable increases, e.g., for paints (solvents and fluids).

Qualitative assessment (Pros and Cons)

Pros - A positive factor for introducing EPRs is that they are well understood and are widely used in Europe and globally. The concept of an EPR is clear, pricing in externalities. Concerning advanced eco-modulation, the principal benefit is that BPMs are provided with additional incentives to invest in eco-design, leading to societal benefit such as lower costs of EPR implementation in the long term and lower environmental impacts of products beyond EoL costs.

Cons - The main disadvantage of EPRs is complexity. Building a well-functioning EPR for any type of waste is a complex task. Introducing an EPR requires coordinating the many actors and stakeholders involved to ensure fairness: producers, distributors, retailers, resellers, customers/end users, reusers, waste collection operators on behalf of governments, waste treatment operators, and secondary materials market participants. Each of these have different incentives or disincentives for participating. Besides, following the example in France, the establishment of an EPR relies on the obligation of the PROs to develop a territorial network of collection points (every 10 or 20 km) that, depending on the MSs, might be much more demanding in terms of costs (or even not possible) depending on the starting point in terms of infrastructure development.

Quantitative modelling of impacts

Given the lack of effectiveness data for modelling, a consequence of the fact that the EPR has been running for very few years, no LCA or LCC were conducted. Instead, the authors calculated the increase in recycling that, assuming the cost of the EPR equal to 1 €/t of CDW calculated above, will be needed to overcome that cost. Using the baseline scenario for 2030 as defined in Cristóbal

García et al. (2024 - Table 14), the estimated amount of 'additional recycling' needed to compensate (because of revenues) for the additional costs introduced by the EPR using the following Equation 1.

Equation 1. Estimated amount of 'additional recycling' needed to compensate for the additional costs introduced by the EPR.

$$\sum_i ELCC\_REC_i * Q_i * REC_i + (COST_{EPR} * \sum_i Q_i) = \sum_i Q_i * ELCC\_REC_i * (REC_i + \Delta REC_i)$$

Where *i* represents all CDW fractions (except for excavated soils and dredging spoils since the EPR does not apply to those fractions), $ELCC\_REC_i$ is the cost of recycling fraction *i* (in €/t), Q_i is the total quantity of waste generated (in t), and REC_i is the share of waste *i* managed through recycling (in %), $COST_{EPR}$ is the individual cost of 1 €/t reported for the EPR, and ΔREC_i is the increase in recycling (in %).

This calculation applies environmental life cycle costing (ELCC). The result shows that an increase of 7.8% (4.5% if including externalities in the equation, i.e., if we apply the fELCC in place of ELCC) in the recycling of CDW (excluding the CDW fractions of excavated soils and dredging spoils) would be enough to justify the establishment of an EPR scheme. The underlying condition is that a market for the separated materials exists.

Further research is needed to identify and report the additional costs for advanced eco-modulation systems to assess the cost-efficiency of such a system.

Recommendation and next steps

Data so far collected and analysed would support the **consideration of an EU-level mandate**. Our preliminary findings suggest that an EPR scheme might be beneficial at MS level given the low costs estimated at macro level, as well as the generally relative minor price impact on products in the market (within the existing one in France), and the reasonable quantity of recycling increase that would be sufficient to compensate this cost. The European Commission could support **guidance** (according to Article 8-5 of the WFD) on the rationale for granular EPR fees and modulation criteria in the building sector (if this sector is / or will be included) as done for other sectors (i.e., packaging, electronics, and batteries). According to the information gathered, it is recommended to start with a basic eco-contribution and then evolve into an advanced system. Advanced eco-modulation seems to be a desirable approach within an EPR if policy objectives are clear and properly selected. **Further monitoring** of the development of the French EPR is needed to strengthen the evidence base.

As a next step, further research is needed to investigate the benefits and impacts on **SMEs** and construction and demolition markets, to be analysed and evaluated with stakeholders. Also, it is suggested to investigate the minimum harmonisation needed to avoid cross-border effects between MS with different EPR schemes.

4.3.2. Factsheet #2: Pre-demolition audits

Pre-demolition audits are not mandatory legally at EU level (except for asbestos), but they are already mandatory in several MSs, as well as promoted by standards such as BREEAM certification for the built environment[45] and the new EU Protocol on Construction and Demolition Waste Management following from the 2018 guidance. Also, the European Demolition Association offers

[45] https://breeam.com/standards

"Guidelines for the waste audits before demolition and renovation works of buildings".[46] Although, pre-demolition audits are not mandatory they are well understood by industry stakeholders.

The intention of the pre-demolition audit is to estimate quantities of material in the building and thus facilitate a managing of the project following the waste hierarchy (including reuse – e.g., leaving the structure in place for reuse, ultimately leading to waste prevention). The process consists in i) identifying different materials present, ii) measuring their quantity; iii) calculating the labour and machinery needed to deconstruct the building; iv) analysing options to valorise them and evaluating costs of collection, transport and disposal; v) evaluating the whole budget of the project; vi) documenting everything in a technical memorandum. A pre-demolition audit can determine for which parts it is worthy to do selective demolition and for which not (e.g., poor quality or condition of window frames) and gives direct info to the demolition contractor and team.

Costs

According to the European Commission (2016b), it is difficult to estimate the cost of the audit process itself, but it is considered to be below 5% of the whole demolition and treatment process activities. Based on stakeholders' feedback (demolishers and recyclers), the authors made further estimates of the cost of pre-demolition audits per tonne of waste generated. The cost depends on the project complexity (and not on the area of the demolition, even if there is a positive correlation between both). The range given by stakeholders is between € 3 000 and 5 000 spanning for demolitions of up to € 300 000 of total cost. Assuming a cost of demolition in the range[47] of 39 to 78 €/m^2, this means that the area (total surface of building) of a demolition that costs € 300 000 is in the range of 3 850 - 7 700 m^2. Assuming that the generation of CDW of that demolition ranges between 664 and 1 637 kg/m^2 (Dodd et al., 2021), a demolition project of € 300 000 would generate between 2 550 and 12 600 t of CDW. Thus, the cost of the pre-demolition audit is estimated in the range of 0.24 €/t - 1.96 €/t of CDW.

Qualitative assessment (Pros and Cons)

Pros – It supports planning of demolition and waste management, giving companies and contractors useful information incentivising the reduction of waste generation and landfilling. Besides, they create awareness of the environmental benefit at building level. Auditing costs seem generally negligible relative to the whole project's construction and demolition costs. The concept is well understood and in use for many years in the industry.

Cons – For small demolition projects, they can be an economic and administrative burden.

Quantitative modelling of impacts

The influence of waste audits on the economy cannot be directly assessed, and several doubts have been raised about its economic benefits (especially when the contractor performs an additional inspection after the official audit made by the owner or engineering company) (European Commission, 2016b). Given the lack of effectiveness data for modelling, no LCA or LCC was conducted. Instead, the authors calculated the increase in recycling that, assuming the cost of the pre-demolition audit to be in the range of 0.24 €/t and 1.96 €/t of CDW, will be needed to overcome that cost. Against a baseline scenario for 2030 as defined in Cristóbal García et al. (Table 14 in Cristóbal García et al. 2024), the quantified the increases in the recycling percentages of CDW

[46] Guidelines for the waste audits before demolition and renovation works of buildings - EDA
[47] Reported as 4-8 $/ft^2 in https://proest.com/construction/tips/interior-demolition-cost/

streams needed to compensate (because of revenues) for the additional auditing costs using the following Equation 2.

Equation 2. Increases in the recycling percentages of CDW streams needed to compensate for the additional auditing costs.

$$\sum_i ELCC\_REC_i * Q_i * REC_i + (COST_{PDA} * \sum_i Q_i) = \sum_i Q_i * ELCC\_REC_i * (REC_i + \Delta REC_i)$$

Where *i* represents all CDW fractions (except for excavated soils and dredging spoils since the EPR does not apply to those fractions), $ELCC\_REC_i$ is the cost of recycling fraction *i* (in €/t), Q_i is the total quantity of waste *I* generated (in t), and REC_i is the share of waste *i* managed through recycling (in %), $COST_{PDA}$ is the individual cost reported for the pre-demolition audits (in €/t), and ΔREC_i is the increase in recycling (in %).

According to the range of pre-demolition audit cost mentioned above, the result shows that an increase in the range of 4.3% - 35% (3.2% - 26% if externalities are included in the equation, i.e., using fELCC in place of ELCC) in the recycling of CDW is enough to compensate for the additional cost of the pre-demolition audits. The underlying condition is that a market for the separated materials exists.

Recommendation and next steps

The analysed data supports **considering the development of an EU-level mandate**. The authors find that a pre-demolition audit can be useful given the low costs estimated according to stakeholders' data (acknowledging uncertainty factor of 10 on the costs). This is reinforced by the fact that they are already mandatory in some MSs. The European Commission **already provided guidance** in 2018 for waste audits before demolition and renovation works in buildings (European Commission, 2018b), which has been recently updated in 2024 (Oberender et al., 2024).

As a next step, if this measure is considered for future policy, more research and updated data collection to support the specific policy formulation would be needed, in particular to determine whether a minimum threshold for mandatory application could be necessary (e.g., based on project size).

4.3.3. Factsheet #3: Selective demolition

Selective demolition, also referred to in this document and in the literature as "deconstruction" or "construction in reverse", consists in a sequence of demolition activities that allows to separate the waste at the place of generation, thereby increasing the capture rate and the quality of waste (Iodice et al., 2021). It is usually suggested as a possible practice with great potential in the construction sector, when compared to the traditional demolition (i.e., without specific regards to sorting and recycling CDW), yet rarely applied. This technique is referenced in the EU Guidelines for waste audits (European Commission, 2018b). Furthermore, the WFD 2018/851 promotes selective demolition in the EU MSs (article 11.1, par. 3 also lists a tentative number of fractions that could be separated: "... at least for wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic and plaster...”), and the EU Taxonomy (European Commission, 2023c) includes selective demolition as one of the criteria for a construction activity to be considered environmentally sustainable.

According to the CityLoops project (Lauritzen, 2022), the selective demolition, as part of the demolition process, should be based on the pre-demolition audit as planning element before the CDW management phase. Combined with pre-demolition audits, it allows to obtain pure flows of homogeneous material from the demolition of a structure. Mixed waste decreases and consequently also its disposal at landfills. The CityLoops project (Lauritzen, 2022) distinguishes six processes in the selective demolition : i) preparatory works, ii) establishment of the work site, iii) selective demolition in six stages (i.e., disconnection of supply and drain lines, removal of loose items, materials and other objects, removal of hazardous substances, cleansing and decontaminating, sorting of not-bearing structures, ceiling, flooring, doors, windows, etc., demolition of bearing structures, and break-up foundation and basement decks), iv) clearing of site, v) finishing, vi) quality control.

Costs

Selective demolition is a labour-intensive and time-consuming activity, and the total cost, including labour, equipment, transport and final disposal is difficult to determine in general terms and very uncertain. According to Coelho & Brito (2010), the total labour costs in selective demolition could be up to 6 times that of traditional demolition; similarly for the time needed to complete the work, acknowledging that traditional demolition is more dependent on disposal costs (above 76%), while the selective demolition cost structure is more levelled (22% cost in labour, 20% in equipment operation, 27% in transport and 28% in material discarding). Based on Coelho & Brito (2010) conservative estimates, Iodice et al. (2021) calculated labour costs of 1.2 €/t for traditional demolition and 6.2 €/t for selective demolition. Accordingly, selective demolition consumes more electricity and diesel, 1.6 kWh/t and 2.8 MJ/t, respectively, comparing to traditional demolition, 0.1 kWh/t and 1.8 MJ/t, respectively. However, more recent studies than Coelho & Brito (2010), such as Yu et al. (2021), report much lower costs, suggesting that the cost of selective demolition is only 20 to 25% higher than traditional demolition. According to a stakeholder of this study, the cost mark-up of selective demolition relative to traditional is around 10%, which seem aligned to the more recent literature on the field. This implies that costs would not really be a barrier for its implementation, being the main constraint the commitment and the adequate instruction of the workers.

Additionally, the extra cost of selective demolition itself compared to traditional demolition should be compensated by saving costs of CDW management (less disposal) and extra income from the sale of recycled materials (Lauritzen, 2022), though the profitability is conditional on local circumstances and possibly on other possible policy measures in place (e.g., landfill taxes). With respect to a thorough discussion of the potential environmental benefits of selective demolition relative to conventional, the reader is referred to the comprehensive review study of Pristerà et al. (2024).

Qualitative assessment (Pros and Cons)

Pros – Reduces waste quantity disposed in landfills. It promotes higher quality of material streams directed to recycling. Besides, it enables the preservation of a building's historical and architectural components when possible.

Cons – Implementing such practices requires enhancing competence and creating know-how amongst the companies involved in the demolition. Might require synergies with other policy instruments to be effective, such as landfill taxes, pre-demolition audits, and quality standards (to ensure secondary material match the grade required for subsequent applications).

Quantitative modelling of impacts

There are no studies based on real experiments that give the effectiveness and costs of selective demolition practices for all the CDW materials. Thus, given the lack of data for modelling, no LCA or LCC were conducted. Note that the scenario analysed for preparation for reuse and recycling targets already implies the use of the selective demolition as a prerequisite for recycling and preparation for reuse of the different materials, but it is impossible to isolate the effects of the selective demolition alone.

However, there are some case studies that assessed the effectiveness for certain materials. Christensen et al. (2022) reported the reuse rate in % achieved with selective demolition for some materials in three projects in Denmark, including bricks (68%), wooden beams (99%), wooden floorboards (43%) and tiles (87%). Andersen et al. (2022) reported that the selective demolition for a façade steel cladding led to 82% preparing for reuse and 17% recycling of steel, compared to 95% recycling of steel with the traditional demolition. Cristóbal García et al. (2024) gives an overview of the possible waste management routes (and the possible enablers for increased preparing for reuse) for all CDW materials when selective demolition is in place.

Recommendation and next steps

The collected and analysed data supports **considering the development of an EU-level mandate**. The authors find that selective demolition is an essential pre-requisite to foster reuse and high-quality recycling of the individual fractions of CDW. Costs are negligible relative to the total life cycle costs of construction and demolition and have low impact on the waste management cost according to recent estimates (10-25% cost mark-up compared to conventional demolition; see above). Besides, benefits of increased CDW recycling and less disposal outweigh costs, under the condition that a market for the separated materials exists. This is reinforced by the fact that it is mandatory in some MSs (e.g., Spain – Art. 30.3 of the Spanish Waste Law 7/2022). The European Commission **already provided guidance** in 2018 for waste audits before demolition and renovation works of buildings (European Commission, 2018b) that has been recently updated in 2024 (Oberender et al., 2024).

Similar as for the pre-demolition audit, as the next step, if this measure is considered for future policy, research and updated data collection to support the specific legal proposal would be needed, in particular to determine whether a minimum threshold for mandatory application might be necessary (e.g., based on project size).

4.3.4. Factsheet #4: Pay-As-You-Throw (PAYT) – Overarching instrument

This section reviews the PAYT as an overarching instrument that encompasses different subtypes of economic instruments providing a price signal on waste, i.e., fees and charges incurred to cover the costs of waste management (discarding fees).

4.3.4a.-Factsheet #4a: Landfill taxes and fees on inert waste to landfill

This section assesses landfill taxes and fees for disposal of inert waste in a landfill. A landfill tax / fee is defined here as it is defined in section 3.1.2.1 (Table 3 and Table 4), that includes municipal or national tax, as well as gate fee, disposal fee, or tipping fee for placing inert waste in a landfill as treatment and final disposal of the waste. Landfill tax / fees are considered fundamental to waste management in the EU and globally today. Nearly all MS (i.e., 25 out of 27), have introduced or increased taxes on landfilling to encourage waste reduction, recycling, and recovery. It is notable that the MS with the lowest rates of CDW landfilling all have landfill taxes in place.

The goal of landfill taxes is to discourage landfilling and make recycling more competitive. Recent modelling results using average EU landfill tax concur (see Box 3). The summary of the literature indicates that results are mixed. In some cases, "too high" landfill taxes and fees may dissuade recycling and perversely incentivise illegal dumping. However, high fees can have a positive impact too, the OECD's international study, including non-EU countries, showed that, "countries with high landfill taxes tend to have low landfill rates" (OECD, 2019). Conversely, "too low" landfill taxes / fees are ineffective in reducing wastes.

Box 3. Analysis of the effectiveness of landfill taxes discouraging landfilling (Cristóbal García et al., 2024)

"The Environmental Life Cycle Costing results (which include already internalised environmental taxes but not monetised externalities) indicate that **landfilling, when including an average EU landfill tax, is the worst economic option for half of the waste material fractions considered. For the other half, the cost of landfilling is simply cheaper**. More advanced recycling pathways for concrete, ceramic and tiles, and bricks (to cement and aggregates) are (with data currently available) clearly more expensive than landfilling, mainly due to the processing costs, although the cost increase due to selective demolition is also relevant. However, even simpler recycling processes producing only recycled aggregates appear to have comparable costs to landfilling overall and are thus in close competition with landfilling economically."

The importance of enforcement is shown by the continued evidence of illegal landfill actions and / or bad application of directives and regulations in the EU. The EU infringements database lists 19 cases of bad application of directives and regulations concerning landfills (e.g., illegal landfills) in the last 5 years[48]. This means that despite the existence of landfill tax / fees in nearly all MS, poor management of landfills and illegal landfills still occur. A discussion of what factors determine open / illegal dumping and the related literature on the unintended consequences of waste charges is discussed in sections 2.1.3.2 and 3.1.2.1

In summary, the available data does not support a strong conclusion that landfill taxes are the sole levers for reducing waste to landfill whilst incentivising recycling. Landfill tax is a foundation that works in concert with other good practice regulatory and economic measures, in particular enforcement and aid to reuse / recycling are co-measures.

Costs

There is no harmonised level of landfill tax / fee in the EU currently. The average landfill tax / fee in the EU is 19 €/t for inert waste (the largest portion of CDW). This figure is taken from Cristóbal García et al. (2024) and Caro et al. (2024) where it is derived based on the available data. In addition, many MS (see section 3) have differentiated taxes for inert wastes, mixed CDW, and hazardous / contaminated CDW. Different fees incentivise better waste separation. It is not clear if one "optimal" tax is possible because of the macroeconomic differences between MS. Economic theory suggests that the optimal tax would be high enough to implement the producer pays principle to pay for the cost of environmental protection provided by proper disposal in a landfill. At the same time, the tax must not be too high as to perversely incentivise illegal dumping in areas where illegal dumping is possible.

Qualitative assessment (Pros and Cons)

Pros – Landfill tax / fees are designed to reduce CDW by incentivising better design and management towards waste reduction and recycling rather than landfill, which has environmental benefits. With landfill taxes, disposal in landfills is the least economic option compared to recycling for some CDW material fractions although not all of them. Landfill taxes can encourage waste sorting by charging more for unsorted waste or simply not accepting it (see landfill ban section below). The polluter pay principle is implemented, while paying for the municipal costs of waste management.

Cons – Implementing and enforcing landfill taxes can be administratively complex and require significant resources, imposing a significant administrative burden on municipalities. As discussed, it

[48] Infringements (europa.eu) Downloaded October 7, 2024

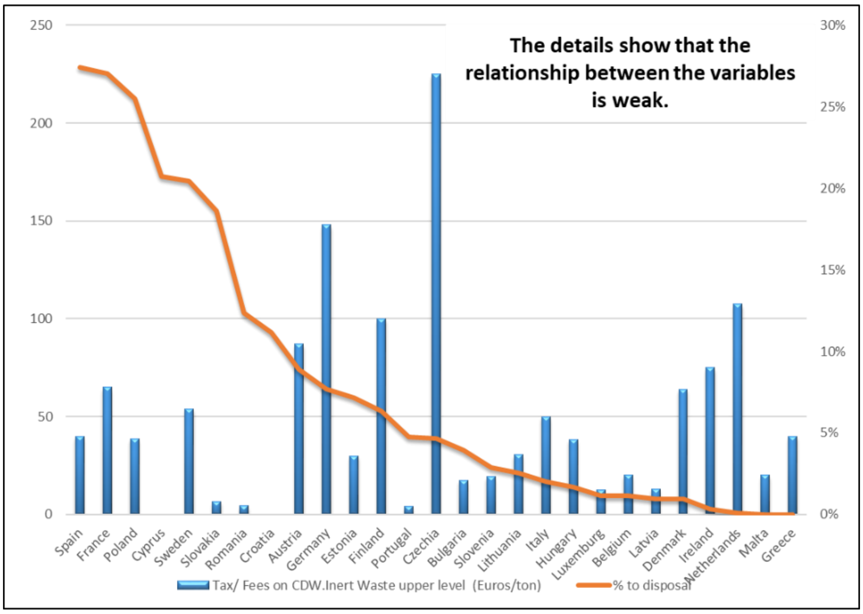
is not clear what landfill tax rate would be "just right" to achieve the WFD goals, therefore, unintended consequences are possible.

Quantitative modelling of impacts

No LCA or LCC was specifically conducted as the causal relationship between tax and recycling rates could not be clearly demonstrated. As for the relation between tax and recycling rates, a straightforward correlation and comparison method was employed for the landfill taxes and fees established in each MS for inert waste (excluding soils) from multiple sources between 2017 and 2022 (Table 3), with the latest available (year 2020) Eurostat data for the "disposal" rate of mineral waste for each MS. The statistical correlation between the two variables is not strong for the high range or the low range of taxes and fees. As is shown in Figure 8, a general trend exists in the EU indicating that MS with higher fees have a lower percentage of waste to landfill disposal. However, there are many MS exceptions and outliers, particularly in the middle range as shown in Figure 8. Estonia and Portugal have much lower landfill taxes/fees matched with lower percentages of waste to landfill disposal than Austria and Germany. In summary, the trend of higher taxes driving lower rates of landfill disposal (and presumably higher recycling rates) is not consistent for all MS.

There are many possible reasons for today's lack of strong correlation as shown by the current analysis, including the long use of MS landfill taxes in several countries that coincides with the Landfill Directive, WFD, and the development of national Waste Management Plans in the last decade. One interpretation is that the existence of fees is only one of many indicators of a strong waste management system that disincentives landfilling CDW. The results are consistent with the literature, which presents mixed conclusions on the effectiveness of landfill fees in isolation.

Figure 8. Graphic comparison of the correlation between landfill taxes and fees with CDW landfill rates for each MS.



Source: Own elaboration.

Recommendation and next steps

As discussed, most MSs have landfill fees currently and the data does not indicate a strong independent causal relationship between landfill fees and the landfilling rate today. Because of its wide prevalence and proven effect, the authors **consider landfill fees a generic good practice and a necessary background condition.** It is important to monitor unintended effects such as illegal disposal if the landfill disposal fee is too high. The data and analyses **suggest further**

assessment of possible harmonisation of **landfill taxes and fees for CDW inert wastes**. The authors note that the EU CDW Management Protocol 2024, also suggests that "public authorities implement integrated waste management strategies with economic instruments such as landfill taxes." (Oberender et al., 2024).

4.3.4b.-Factsheet #4b: Landfill ban on CDW

It is acknowledged that landfill bans are one of the most effective practices for increasing CDW recovery rates (European Commission, 2017). To be effective, landfill bans need to be fully enforced across the whole European territory; they are often used in combination with or as an alternative to landfill taxes (EEA, 2023a). Landfill bans are dissuasive regulations therefore rely on strict enforcement measures and viable alternatives.

Costs

The costs and benefits of landfill bans are measured with the LCC analysis shown below, where environmental life cycle costing is applied (ELCC). ELCC considers internal costs, including already internalised environmental costs such as landfill and incineration taxes, but does not include other externalities (i.e. external cost associated with environmental emissions in general like GHGs). Similarly, although the clean-up costs of illegal disposal are generally societal costs paid by local governments, these costs are not included in the analysis due to lack of data. Administrative costs to monitor and enforce compliance with a landfill ban at the MS level would need to be detailed in future.

Quantitative modelling of impacts

We propose a simplified model to analyse the efficiency of a landfill ban which assumes a redirection only to legal end-of-life options once the landfilling option has been banned. Illegal disposal is not modelled for lack of data. The model sets a landfill ban scenario (LAN-BAN) against a baseline scenario (BASE) for 2030 representing the status quo of CDW management in the EU27 as defined in Cristóbal García et al. (2024 - Table 14) and against another scenario representing, for the purpose of comparison, a maximum potential for reuse and recycling (MAX-REU). For the LAN-BAN scenario, the share of each waste fraction sent to landfilling is set to zero and redistributed between recycling, backfilling and incineration (but not illegal disposal) according to the 'next-cheaper treatment' criteria. This selects technologies based on the least-cost hierarchy that favours conventional demolition processes and technologies with high Technology Readiness Levels (as reported in Cristóbal García et al. (2024 - Table 8)).

On this basis, as shown in Table 15, the landfilling quotas of steel, aluminium, glass, glass wool and stone wool (STE, ALU, GLA, GLW and STW) are redistributed to recycling, those of concrete, ceramic and tiles, bricks, mixed CDW, excavated soil and dredging spoils (CON, C&T, BRK, MIX, ESR and DDS) to backfilling, and those of wood, Polyvinyl Chloride, and Expanded Polystyrene (WOD, PVC and EPS) to incineration. Note that the recycling technologies selected are the most conventional ones, i.e., for the mineral fraction (including the mixed CDW) we only assume production of recycled aggregates (no recovery of cement). Year 2030 is indicative of the analysis, though this has no impact on the results except for the type of energy mix in use in EU27. Notice also that the underlying condition in the assessment is that a market for the separated materials exists (thus recycled materials are absorbed by the market and replace corresponding primary materials).

The MAX-REU scenario assumes that all the material that can be potentially reused (per each CDW fraction) is prepared for reuse, while the share potentially recyclable is subject to advanced recycling technologies[49]. The underlying assumptions are based on a literature review and stakeholder consultations reported in Cristóbal García et al. (2024 - Table 14) and can be viewed as benchmark representing an upper bound.

The life cycle model (LCA and LCC) and underlying datasets used to assess the impacts and costs of the CDW management scenarios are detailed in Caro et al. (2024). The quantities of CDW managed in 2030 are maintained as in 2020 (i.e., 848 Mt accounting for 319 Mt of infrastructure and building CDW, assuming infrastructure composition is equal to building, 450 Mt of excavated soil, excluding 6 Mt polluted not assessed, and 79 Mt of dredging spoils). The only change made to the life cycle model of Caro et al. (2024) is the share of material sent to the different management options in LAN-BAN and the EU energy mix applied (we update the model of Caro et al. (2024) using the projections of the Global Energy and Climate Outlook for EU27 in 2030; (Keramidas et al., 2023)).

Table 15. Shares of CDW sent to preparing for reuse, recycling, recovery (backfilling), incineration and landfill in the baseline scenario (BASE), landfill ban scenario (LAN-BAN), and in the scenario representing a maximum of reuse and recycling (REC-REU).

	BASE					**LAN-BAN**					**MAX-REU**				
Fraction	REU	REC	RBB	INC	LAN	REU	REC	RBB	INC	LAN	REU	REC	RBB	INC	LAN
CON	0	79	10	0	11	0	79	21	0	0	13	87	0	0	0
WOD	0	30	0	64	6	0	30	0	70	0	25	19	0	56	0
STE	10	84	0	0	6	10	90	0	0	0	29	70	0	0	1
ALU	10	84	0	0	6	10	90	0	0	0	50	49	0	0	1
PVC	0	30	0	12	58	0	30	0	70	0	0	90	0	10	0
EPS	0	10	0	66	24	0	10	0	90	0	0	27	0	73	0
GYP	0	10	0	0	90	0	100	0	0	0	0	95	0	0	5
C&T	0	79	10	0	11	0	79	21	0	0	10	90	0	0	0
GLW	0	2	0	0	98	0	100	0	0	0	0	100	0	0	0
STW	0	2	0	0	98	0	100	0	0	0	0	100	0	0	0
BRK	0	79	10	0	11	0	79	21	0	0	59	41	0	0	0
GLA	0	6	24	0	70	0	76	24	0	0	20	80	0	0	0

[49] The term refers to recycling technologies that are not fully commercially ready today but that allow better material recovery and environmental performance. An example is recovering cement fines from concrete together with aggregates (in place of aggregates only). More details may be found in Cristóbal García et al. (2024).

	BASE					LAN-BAN					MAX-REU				
MIX	0	79	10	0	11	0	79	21	0	0	10	90	0	0	0
ESR	0	35	40	0	25	0	35	65	0	0	100	0	0	0	0
DDS	0	8	4	0	88	0	8	92	0	0	100	0	0	0	0

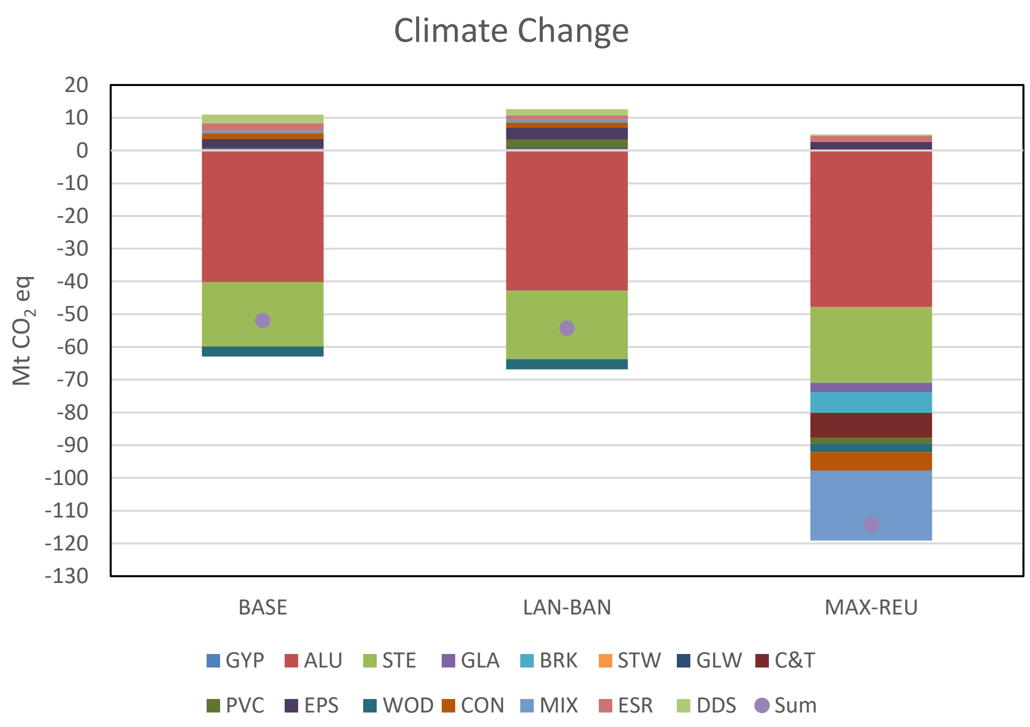
Source: Own elaboration.

Note - BASE: baseline scenario; REC-REU: scenario for the targets; MAX REU: scenario of a maximum potential for reuse and recycling; REU: share sent to preparing for reuse; REC: share sent to recycling; RBB: share sent to recovery backfilling; INC: share sent to incineration; LF: share sent to landfill; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood.

For the climate change impact category (see Figure 9), achieving the proposed targets (LAN-BAN scenario) leads to a total net saving of 54 Mt CO_2 eq., i.e., an extra saving of 2.3 Mt of CO_2 eq. relative to the baseline scenario (BASE).

For the costs (see Figure 10), the achievement of the proposed target (LAN-BAN) leads to total net savings of 2 353 M€, i.e., an extra saving of 12 381 M€ compared to the baseline scenario (BASE) mainly due to the contribution of additional revenues from the recycled material substituting primary material of excavated soils and dredging spoils. Note that the extra savings compared to the baseline scenario (BASE) would be just 2 267 M€ when excluding excavated soils and dredging spoils, for which cost savings are very uncertain. The cost savings achieved in a scenario of maximum reuse and recycling (MAX-REU) would equal 9 518 M€, €, i.e. an extra saving of 19 546 M€ compared to the baseline scenario (BASE).

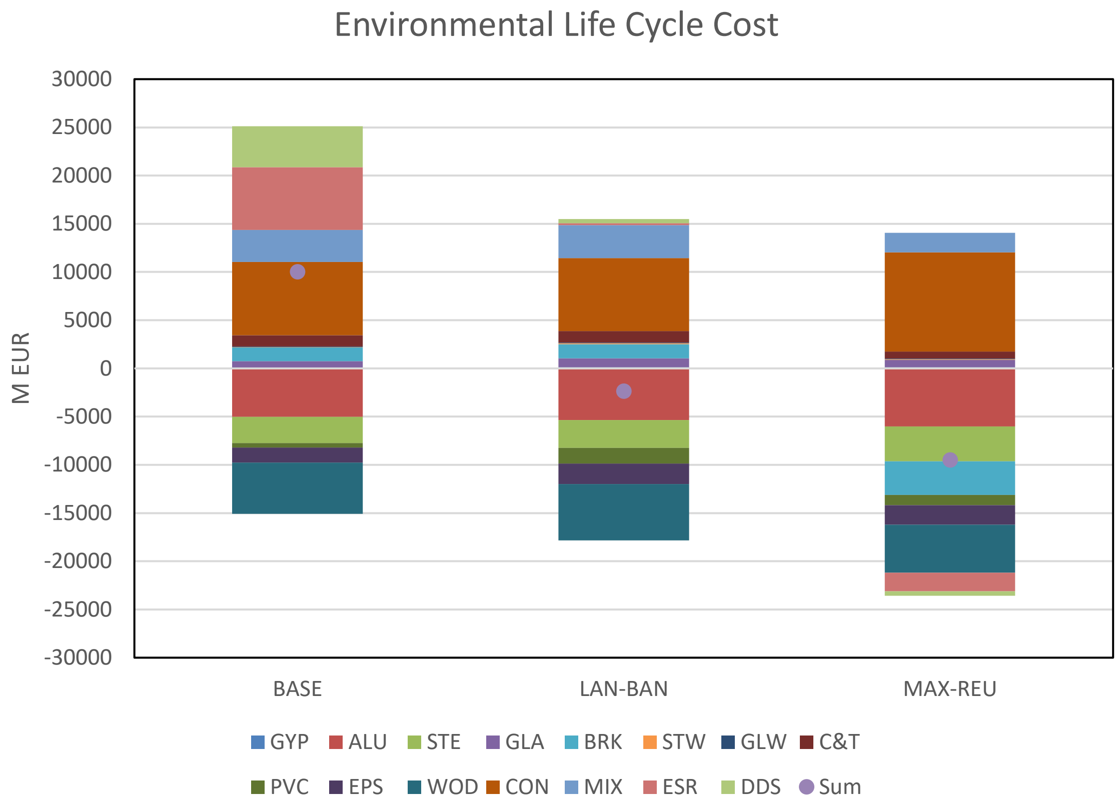
Figure 9. LCA results for the climate change impact category for the baseline scenario (BASE), landfill ban scenario (LAN-BAN) and the scenario representing a maximum of reuse and recycling (MAX-REU).



Source: Own elaboration.

Note - BASE: baseline scenario; LAN-BAN: scenario for the landfill ban; MAX REU: scenario of a maximum potential for reuse and recycling; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood; SUM: sum of all CDW fractions' impacts related to each scenario.

Figure 10. Environmental life cycle costs (internal costs including already internalised environmental costs such as incineration and landfill taxes, but without other externalities) for the baseline scenario (BASE), the landfill ban scenario (LAN-BAN), and the scenario representing a maximum of reuse and recycling (MAX-REU).



Source: Own elaboration.

Note - BASE: baseline scenario; LAN-BAN: scenario for the landfill ban; MAX REU: scenario of a maximum potential for reuse and recycling; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood; SUM: sum of all CDW fractions' impacts related to each scenario.

Recommendation and next steps

Based on the previous experiences with other waste categories such as MSW (European Commission, 2023b), the authors consider that setting an EU level ban on landfilling CDW could be an efficient policy measure, but at the same time it needs other policy measures to be considered along with it. In the current state of national legislation and established CDW practice, there is a risk that blanket landfill bans might trigger unintended consequences, such as an increase in illegal dumping; however, a medium-term objective should be to eliminate the need for CDW landfilling, based on complementary policy instruments. Therefore, an intermediate measure could include a ban on direct landfilling of separated CDW fractions (as is the case for municipal waste), or of untreated CDW directly from waste generators, as opposed to waste which has already had an opportunity to be processed by waste treatment operators. **The recommendation is to review whether a harmonised EU landfill ban for all CDW fractions is workable, considering that other CDW reduction policies and enforcement measures are needed.**

As a next step, if this measure is considered, benefits, costs, and impacts on **SMEs** and construction and demolition markets would need to be analysed in detail and evaluated with stakeholders.

4.3.4c. -Factsheet #4c: "Advance Discarding Fee", a refundable fee paid in advance of CDW generation to ensure legal waste treatment

As discussed in 3.1.2.1.3, in Spain municipalities may implement a fee whereby CDW generators pay a deposit to the municipal permitting authority for proper waste treatment of their projects' CDW as a condition of the building permit. **The deposit is refunded when the builder provides proof that the estimated amount of CDW of the permitted building project has been collected and treated legally in accordance with local rules. The deposit is thus a refundable fee paid in advance (a bond or financial guarantee) to ensure legal waste treatment.** This study refers to this type of fee as an 'Advance Discarding Fee'. In Spain it is referred to as a Deposit Refund System (DRS), although it does not function as a product DRS.

The Spanish framework is written in national law (Royal Decree 105/2008) and is implemented in several municipalities and regions. The national law sets the CDW management responsibilities of waste generators and handlers including waste reduction and separation. It states that **autonomous communities may tie building permits to a refundable deposit** to act as a bond or financial guarantee of legal disposal. Three municipalities / regions in Spain reported using their own **deposit systems for legal waste treatment as a permit condition**. These were Barcelona, Catalonia, and Seville. It is likely that more municipalities in Spain use similar refundable deposit frameworks.

The estimated amount of CDW that a building owner generates is evaluated during the demolition or renovation permitting process. A deposit for waste handling and treatment (for example, landfilling and recycling) is charged based on the amount of expected CDW. Seville's CDW deposit-refund system legislation was approved in November 2003 and implemented in early 2006 Solís-Guzmán et al. (2009). This method is used to determine the square meters of area to be demolished or refurbished and then it **estimates the waste to be generated based on the characteristics of the building, an analysis of similar projects' waste generation, packaging involved in the construction, and the size of the building / unit**. The implementation in Seville was studied during the first two years, but not after.[50]

The structure of the refundable deposit system is similar across the regions (Basque, Catalonia, Andalucía), but the handling of the refund works differently. In general, the deposit is paid at the outset of the permit by the owner or firm handling the work. When the waste is generated and brought to recycling and proper disposal, **a certificate is issued by the authorised waste management facility which allows the owner to reclaim the deposit.** Anecdotal evidence indicates that the deposit is treated differently in the different municipalities / regions.[51] In some cases, the deposit is perceived as a waste management fee and owners routinely choose not to seek reimbursement, or the administrative burden for reclaiming the fee is deemed too high. In other cases, the refund of the deposit is customary. Although inspectors may review the practices onsite to ensure waste separation and recycling, the number of inspections is low.

[50] Email communications between authors and Solís-Guzmán.

[51] Personal communications between Gillian Foster and construction experts at the INDICATE Spain research project meeting on Friday, May 17, 2024, at the Escuela Técnica Superior de Arquitectura de la Universidad de Sevilla, Spain

The authors conclude that the Spanish framework can be considered a hybrid PAYT-DRS system on estimated CDW. As a refundable fee paid in advance to ensure legal waste treatment, the Spanish framework discourages CDW landfilling (and therefore, arguably, increases in waste separation and recycling).

Costs

The deposit in the Spanish national law is 12 €/m^3 for the mixed CDW and 6 €/m^3 for excavated soil. It is applied to the waste produced while constructing and while demolishing. It is not a deposit on the materials that will stay in the building for 60-100 years. The volumes are calculated ex-ante with a model. Table 16 shows some examples of the amounts deposited based on the type of project and the constructed area.

Table 16. Examples of the amount of the deposit for selected building elements.

		Foundation Structures		Steel Framework for the Foundation	
Number of floors	Constructed area (m^2)	New construction	Demolition	New construction	Demolition
1	100	560 € (5 €/m^2)	-	-	-
2	120	480 € (4 €/m^2)	-	-	-
4	1 600	6 000 € (4 €/m^2)	-	-	-
4+B	1 600	16 000 € (10 €/m^2)	20 000 € (12 €/m^2)	15 500 € (10 €/m^2)	22 000 € (13 €/m^2)
5	2 000	7 000 € (3.5 €/m^2)	-	9 400 € (5 €/m^2)	27 400 € (14 €/m^2)
5+B	2 000	17 400 € (9 €/m^2)	27 000 € (12 €/m^2)	17 000 € (9 €/m^2)	26 500 € (13 €/m^2)
7+B	2 000	17 600 € (9 €/m^2)	38 000 € (13 €/m^2)	-	-

B: basement.

Source: (Ramírez de Arellano Agudo & Solís-Guzmán, 2006).

Table 16 (from Ramírez de Arellano Agudo & Solís-Guzmán 2006) reports the expected deposit relevant to building elements such as the foundation footings and steel framework for the foundation. They estimated that the cost of the deposit, in new construction, moves in the range of 500-18 000 € (4-10 €/m^2) and in demolition between 1 000 - 40 000 € (12-14 €/m^2). From the study of Solís-Guzmán et al. (2009), it can be estimated that the cost of waste management is around 3 €/m2, given that the cost for earth is 1.5 €/t and for mixed CDW 12.50 €/m3. The cost of construction is approximately 600 €/m2, so the cost of CDW management represents 0.5% of the cost of construction and 0.1% of the sale price. These results are on par with the **"approximate 0.5% increase in the project execution costs**" proposed by Solís-Guzmán et al. (2009).

Qualitative assessment (Pros and Cons)

Pros – The deposit system (as applied in Spain (Catalonia, Basque, and Andalucia regions) has positive effects; although, the authors were not able to identify long term empirical evidence to measure these effects. First, they encourage project owners to estimate the amount of waste that will be generated by their projects and how the waste will be managed "throughout the project's duration" in a Waste Management Report (European Commission, 2017) at the design phase before receiving the permit and starting. This pre-demolition assessment of waste allows the builder to make choices regarding the recovery, reuse, and recycling options. Second, the deposit / refund process promotes that wastes are directed towards correct handling because the refund is made only when the waste is received at the depot. This provides a strong incentive that the waste is not illegally dumped. Third, if the deposit is perceived as a fee and not reclaimed, then its purpose follows a polluter pays principle for CDW and offsets the municipality's costs.

Cons – The point of the deposit is to provide an economic incentive for collection and legal treatment. The mechanism works for CDW because of the benefits described above, however, if the deposit is never recovered and seen as a waste management fee, it does not work as a DRS. Furthermore, there is no direct incentive to reduce waste quantities based on cost, because the developer would get the deposit back. Gálvez-Martos et al. (2018) offers this critique of the Spanish model, “it is oriented to avoid illegal dumping, i.e., it does not increase the performance of the system but avoids a particular local problem of CDW management”. Finally, it has not been possible to establish statistically an increase in recycling or reuse or a decrease in illegal disposal of CDW directly related to the advance disposal fee system from the available examples at this time. As of 2015, in a study for the Commission, Deloitte et al found that "data on illegal dumping does not exist; stakeholders indicated that while levels of illegal waste disposal has diminished (per general knowledge/observations), it is still a challenging aspect to control and quantify” (European Commission, 2017 - Country factsheets).

Quantitative modelling of impacts

The various approaches to the deposit implementation mean it is difficult to gauge the effectiveness of the actions. For example, it is not clear the number of tons that are diverted to recycling. Given the lack of data for modelling, no LCA or LCC were conducted.

Recommendation and next steps

We suggest **conducting further research**. The collected data so far is insufficient to support the development of an EU-level legislative proposal. However, the authors find that the legal framework of the Spanish deposit is an interesting case relevant for MS, regions, and municipalities to consider. Perhaps, by creating pilot programs that clearly define the parameters of the instrument for CDW, (costs, estimation methodology, administrative burden, differentiation between materials, enforcement rules, etc.) can provide workable models.

4.3.4d. -Factsheet #4d: Pay-As-You-Throw (PAYT)

This measure can cover different embodiments of PAYT whereby the remittal of waste (CDW, in this case) to a waste management facility or waste disposal site is subject to the payment of a fee proportional to the volume (weight) delivered. It is also a generalisation of landfill taxes examined above.

For all practical purposes, from the perspective of a waste generator, an undifferentiated discarding fee (or crudely differentiated e.g., inert vs non-inert) will act as a landfill tax. Therefore, this factsheet focuses on modulated discarding fees. Note that when the waste is not destined for disposal (landfilling or incineration) but rather for recovery or recycling, this study calls the scheme ‘a discarding fee’ rather than a ‘disposal fee’. Once delivered to a waste management operator it can still be subject to further treatment such as sorting and posterior recycling or recovery.

Costs

Different strategies can be employed for the pricing of discarding fees. In the case of undifferentiated fees, those are set at least to cover headline disposal costs.

Differentiated fees are more difficult to balance, as there may be some cross-subsidisation from the fees collected on the unsorted fraction towards the sorted fractions. Even further, the cross-subsidisation may be from product EPR to discarding fee (cf. the case of the EPR scheme in France where the EPR scheme cross-subsidises free discarding of sorted fractions).

In addition, the evaluation of overall costs to the whole system should consider the clean-up costs of illegal disposal, which may or may not be borne by the same economic actor (e.g., local government).

Qualitative assessment (Pros and Cons)

Pros - Modulated discarding fees offer a less crude approach than landfill bans and landfill taxes by sending differentiated price signals. This mechanism is considered best practice in waste management and has fewer drawbacks than e.g., landfill taxes. In addition, offering free take-back (or paid take-back) greatly reduces the incentives for illegal disposal. These incentives remain for mixed waste fractions if they are subject to a fee.

A further refinement could be a **combination of deposit (advance payment) with modulated discarding fee**:

- o charging in advance for disposal dissuades illegal disposal.
- o differentiating mixed and separate disposal incentivises selective demolition and separation.

In practice this can be enacted with a deposit which could be reclaimed only partially, for the separated fractions, while mixed waste disposal could not be considered eligible for refund.

Cons – It is relatively complex to manage in administrative terms.

Recommendation and next steps

Based on the analysis of the previous instruments (landfill taxes / bans) and the experience of PAYT with household waste, the authors recommend to **further investigate the development of differentiated discarding fees**, potentially coupled with an **advance fee or deposit**. Considering the varied situation currently in place across Member States, it can be envisaged to **design appropriate PAYT schemes** based on existing economic instruments (e.g., landfill taxes) to streamline price signals and extend their policy objectives towards increased separation and higher material efficiency while dissuading illegal disposal.

As a baseline, the key features of PAYT schemes should include: differentiated fees for sorted and mixed waste; low fees incurred at the point of discarding; advance charging on product consumption or waste generation.

Since existing instruments such as landfill taxes are already in place in most EU countries, PAYT could be deployed in the short- to medium-term (e.g., 2030). Two analyses could be conducted for future impact assessments. One study to seek reliable data on illegal dumping including clean-up costs and a study on the impacts of PAYT on SMEs and housing affordability.

4.3.5. Factsheet #5: Preparing for reuse and recycling targets

The potential impacts of preparing for reuse and recycling targets are assessed (scenario named REC-REU) for all the different materials composing CDW against a baseline (scenario named BASE), representing the status quo of CDW management in the EU27 as defined in Cristóbal García et al. (2024 - Table 14), and also against an additional scenario representing, for comparison, a maximum potential for reuse and recycling (scenario named MAX-REU). This study includes the LCA of these options. More information drawing on Cristóbal García et al. (2024) is presented in Annex 6.

Costs

Apart from the direct economic impacts (benefits and costs) generated by achieving these targets (measured through LCC analysis below), there will be cost impacts incurred by the implementation of the EU targets at the level of MS, related to enforcement and monitoring of compliance, as well as at the business level that should comply with them. The former would be negligible since the system is already set to administer a recovery target for CDW. For the latter, the establishment of new targets for all CDW fractions will affect a great number of businesses that will have to implement administrative procedures to comply with the administrative obligations included in the legal rules such as measuring, reporting, and registering the waste generation and treatment data.

Quantitative modelling of impacts

We assess the potential impacts of possible preparing for reuse and recycling targets (REC-REU) for all the different materials composing CDW (shown in Table 17) against a baseline (BASE), representing the status quo of CDW management in the EU27 as defined in Cristóbal García et al. (2024 - Table 14), and against an additional scenario representing, for comparison, a maximum potential for reuse and recycling (MAX-REU). The scenario REC-REU conservatively assumes that the recycling technologies for the mineral fraction (including the mixed CDW) produce aggregates (no recovery of the fines for use in cement production). The authors choose year 2030 as the indicative year of the analysis, though this has no impact on the results except for the type of energy mix in use in EU27. The MAX-REU scenario assumes that all the material that can be potentially reused (per each CDW fraction) is prepared for reuse, while the share potentially recyclable is subject to the most advanced recycling technologies[52]. The underlying assumptions are based on a literature review and stakeholder consultations reported in Cristóbal García et al. (2024 - Table 14) and can be viewed as benchmark representing an upper bound. Notice that the underlying condition in the assessment is that a market for the separated materials exists (thus recycled materials are absorbed by the market and replace corresponding primary materials).

The proposed targets are inspired and in line with similar targets proposed by the EU Taxonomy and the upcoming *Do No Significant Harm* Technical Guidance that, even if voluntary, show the ambition and engagement with the circular economy expected at EU level in the coming years. Whenever possible, recycling is prioritized over recovery (i.e., backfilling and incineration) and landfilling. Similarly, preparing for reuse is prioritized over recycling whenever feasible. This means that at least 95% of the mineral fractions (including mixed CDW that is mostly mineral) and 70% of the non-mineral fractions are separately collected and sent to preparing for reuse or recycling. The only fractions not respecting this general rule are wood and EPS because of limitations related to contaminants present in the construction products, following feedback from stakeholders and literature. It must be acknowledged that the ambition of this scenario is very high and the difficulty of increasing treatment capacity in such a short period of time.

The life cycle model (LCA and LCC) and underlying datasets used to assess the impacts and costs of the CDW management scenarios are detailed in Caro et al. (2024). The quantities of CDW managed in 2030 are maintained as in 2020 (i.e., 848 Mt accounting for 319 Mt of infrastructure and building CDW, assuming infrastructure composition is equal to building, 450 Mt of excavated soil, excluding 6 Mt polluted not assessed, and 79 Mt of dredging spoils). The only change applied to the life cycle model of Caro et al. (2024) is the rate of material sent to reuse and recycling in REC-REU and the EU energy mix applied. We update the model of Caro et al. (2024) using the projections of the Global Energy and Climate Outlook for EU27 in 2030 (Keramidas et al., 2023). Note that the scenario REC-REU assumes that selective demolition is in place.

Table 17. Shares of CDW sent to preparing for reuse, recycling, recovery (backfilling), incineration and landfill in the baseline scenario (BASE), preparing for reuse and recycling targets scenario (REC-REU), and in the scenario representing a maximum of reuse and recycling (MAX-REU).

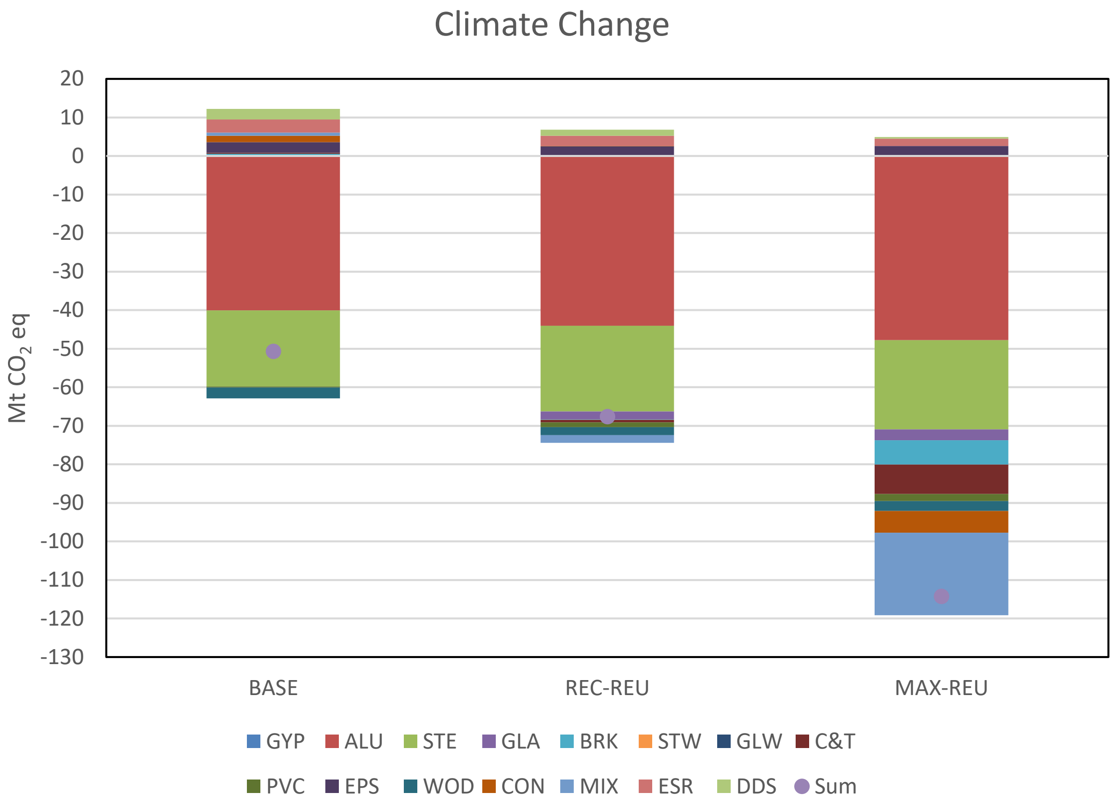
[52] The term refers to recycling technologies that are not fully commercially ready today but that allow better material recovery and environmental performance. An example is recovering cement from concrete. More details may be found in Cristóbal García et al. (2024).

	BASE					REC-REU					MAX-REU				
Fraction	REU	REC	RBB	INC	LAN	REU	REC	RBB	INC	LAN	REU	REC	RBB	INC	LAN
CON	0	79	10	0	11	10	90	0	0	0	13	87	0	0	0
WOD	0	30	0	64	6	20	40	0	40	0	25	19	0	56	0
STE	10	84	0	0	6	20	80	0	0	0	29	70	0	0	1
ALU	10	84	0	0	6	20	80	0	0	0	50	49	0	0	1
PVC	0	30	0	12	58	0	70	0	12	18	0	90	0	10	0
EPS	0	10	0	66	24	0	20	0	66	14	0	27	0	73	0
GYP	0	10	0	0	90	0	70	0	0	30	0	95	0	0	5
C&T	0	79	10	0	11	10	90	0	0	0	10	90	0	0	0
GLW	0	2	0	0	98	0	70	0	0	30	0	100	0	0	0
STW	0	2	0	0	98	0	70	0	0	30	0	100	0	0	0
BRK	0	79	10	0	11	10	90	0	0	0	59	41	0	0	0
GLA	0	6	24	0	70	10	60	0	0	30	20	80	0	0	0
MIX	0	79	10	0	11	0	95	0	0	5	10	90	0	0	0
ESR	0	35	40	0	25	20	80	0	0	0	100	0	0	0	0
DDS	0	8	4	0	88	20	80	0	0	0	100	0	0	0	0

Source: Own elaboration.

Note - BASE: baseline scenario; REC-REU: scenario for the targets; MAX REU: scenario of a maximum potential for reuse and recycling; REU: share sent to preparing for reuse; REC: share sent to recycling; RBB: share sent to recovery backfilling; INC: share sent to incineration; LAN: share sent to landfill; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood.

Figure 11. LCA results for the climate change impact category for the baseline scenario (BASE), reuse and recycling targets scenario (REC-REU), and the scenario representing a maximum of reuse and recycling (MAX-REU).



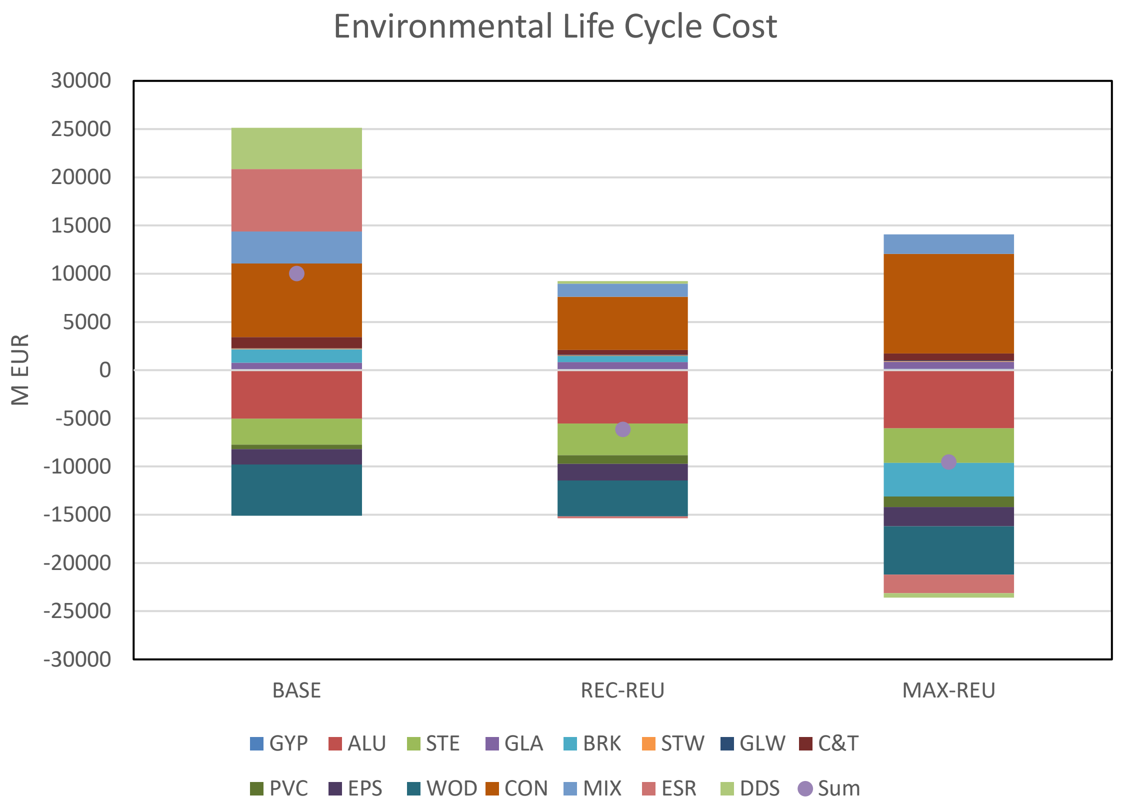
Source: Own elaboration.

Note - BASE: baseline scenario; REC-REU: scenario for the targets; MAX REU: scenario of a maximum potential for reuse and recycling; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood; SUM: sum of all CDW fractions' impacts related to each scenario.

Results show the climate change impacts and life cycle costs (Figure 11 and Figure 12, respectively). For climate change, the achievement of the proposed targets would lead to a total net GHG savings of 68 Mt CO_2 eq. (REC-REU) against 51 Mt CO_2 eq. in the baseline (BASE), i.e. additional 17 Mt of CO_2 eq. savings. It is noted that achieving a maximum of recycling or preparing for reuse (MAX-REU) would increase the GHG savings up to 64 Mt CO_2 eq. relative to baseline.

For the costs (see Figure 12), the achievement of the proposed targets would lead to total net cost savings of 6 139 M€. This means additional 16 167 M€ savings relative to the baseline mainly due to the contribution of excavated soils and dredging spoils (avoided costs of their disposal). Achieving a maximum of recycling or preparing for reuse would increase the cost savings to up to 19 546 M€ relative to the baseline. However, when excluding soils and dredging spoils (for which costs are very uncertain) from the cost assessment significantly lower cost savings for the scenario REC-REU (i.e., 5 446 M€) occur. Thus, indicating that revenues from recovery may be compensated by increased cost of processing for building materials (other than soil). The results suggest that recycling pathways and technologies likely need financial support to be competitive, e.g., starting with mandating selective demolition (to provide quality material) and following with other financial incentives.

Figure 12. Environmental life cycle costs (internal costs including already internalised environmental costs such as landfill and incineration taxes, but without other externalities) for the baseline scenario (BASE), the reuse and recycling targets scenario (REC-REU), and the scenario representing a maximum of reuse and recycling (MAX-REU).



Source: Own elaboration.

Note - BASE: baseline scenario; REC-REU: scenario for the targets; MAX REU: scenario of a maximum potential for reuse and recycling; CON: concrete; ALU: aluminium; BRK: bricks; C&T: ceramic and tiles; DDS: dredging spoils; EPS: expanded polystyrene; ESR: excavated soil; GLA: glass; GLW: glass wool; GYP: gypsum; MIX: Mixed CDW; PVC: poly vinyl chloride; STE: steel; STW: stone wool; WOD: wood; SUM: sum of all CDW fractions' impacts related to each scenario.

Recommendation and next steps

Based on previous experience with other waste categories, the **authors consider setting overarching EU level targets** as a potentially efficient policy measure, but such targets would need other supporting measures to be fully effective. As a next step, if targets are ultimately considered, it is recommended to build upon the target values proposed in this and the previous JRC study (Cristobal Garcia et al., 2024) and these targets could be below the maximum potential and realistically in line with other voluntary instruments like the Taxonomy or GPP. Investigations of the technical and economic feasibility of those target values acknowledging that additional policy and enforcement measures are needed to support the achievement of targets need additional information.

4.3.6. Factsheet #6: Digital passports for buildings

This section focuses on digital passports for buildings, apartments, or houses. These have several different titles in Europe, including building pass / passports and digital building logbooks or building renovation passports. In practice, all building digital passports catalogue the main materials and equipment contained in the building. A "materials passport" goes further as it is designed to "evaluate the recycling potential and environmental impact of materials embedded in buildings" specifically for deconstruction and materials recovery (Honic et al., 2021). The building digital passports are "leaner." They provide information to the owner, which is transferred upon sale to a new owner and to the next construction firm renovating or deconstructing the building.

This report does not focus on digital passports for construction products that are components of the building renovation such as concrete, because this topic is currently being handled in the proposed revision of the Construction Products Regulation (as adopted on 30 March 2022) and its linked regulation the Ecodesign for Sustainable Products Regulation (ESPR), which entered into force on 18 July 2024. The strategy is described in the ESPR as shown in Box 4.

Box 4. Excerpt of Regulation (EU) 2024/1781 (European Union, 2024b) establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repealing Directive 2009/125/EC.

"While construction products, including cement, are to be covered under a Regulation of the European Parliament and of the Council laying down harmonised conditions for the marketing of construction products (the 'construction products Regulation'), they remain under the scope of this Regulation. To avoid a lack of product requirements urgently needed to reach our climate and environmental objectives, in the absence of adequate performance requirements and information requirements for such products under the construction products Regulation, the Commission should adopt delegated acts setting ecodesign requirements for cement not earlier than 31 December 2028 and not later than 1 January 2030."

As discussed in section 3.1.6, the prevalence of digital building passports, in the form of building renovation passports, is set to expand due to the new requirements in the Energy Performance of Buildings Directive (EPBD) (European Union, 2024a). The EPBD creates a voluntary passport focused on the energy efficiency aspect of building renovation in all MSs in 2026. This is an increase from 15 MSs that already required some form of passport before the EPBD entered into force in May 2024 to all MSs. The new directive indicates that digital building passports are now widely accepted and proposes some uniformity. Annex VIII requires that the passports include, "general information on available options for improving construction products' circularity and for reducing their whole life cycle GHG emissions, as well as wider benefits related to health and comfort, indoor environmental quality and the improved adaptive capacity of the building to climate change". Also, the EPBR requires national building renovation plans to include a mandatory reference to policies on the "prevention and high-quality treatment of CDW in accordance with Directive 2008/98/EC, in particular as regards the waste hierarchy, and the objectives of the circular economy". In summary, the important foundation for CDW digital building passports has already been set. Therefore, current questions are about the impacts of further improvements about the CDW aspects of the planned building renovation plans in future amendments.

Costs

A stand-alone policy program for CDW digital building renovation plans is not necessary, given the current already developed regulatory context. For information purposes only, the impact assessment for building renovation plans estimated the set-up costs for the building renovation plans at 250 000 € to 600 000 € per MS and an additional 90 000 € for communications (e.g., "media plan, designing and printing brochures, short introduction movie, buying space in printed media and social media"). Direct training costs are not included as commercial actors are foreseen (Volt et al., 2020).

Assuming that sufficient staff within the Commission already are working to implement the building renovation plans, the **cost to emphasize the CDW aspects of the plans** as already described in the EPBD Directive is deemed to be **negligible**. What is required is directed action and coordination within the Commission to raise the CDW relevance of building renovation permits at the MS level in guidance and assistance.

Qualitative assessment (Pros and Cons)

Pros – First, building renovation plans are optional for building owners; however, they are effective policy tools. An assessment of optional building renovation plans concluded that they would have "an effect on renovation rate (number of energy renovations), renovation depth (magnitude of the renovations), the timing of the works (people with a BRP tend to renovate earlier than they previously planned) and the quality of the works (fewer mistakes and unwise renovation decisions)" (Volt et al., 2020). Therefore, building renovation passports are an effective vehicle for increasing renovation, which increases the overall amount of CDW generated. Fortunately, the building renovation plans also create an opportunity for better, more circular management of these CDW.

Second, there is an existing political commitment and stakeholder support for building renovation plans for energy efficiency in all MS. The current momentum and rapid rollout of the optional building renovation plans over the next two years means that new knowledge and data on what works for CDW can be collected from real examples.

Third, the 2024 report "Putting Science into Standards" (PSIS) summarises the stakeholder consultation and workshop held in 2023 on circularity in construction and two stakeholder surveys (Jenet et al., 2024). It discusses both digital product passports and digital building passports. The authors find that there are legal and technical aspects of both that "need more standardisation to ensure traceability and transparency". Certainly, the EPBD create more standardisation; however additional information sharing and standardisation across MS focused on CDW and CE is possible. In particular, the training of building renovation passport providers can include CDW reduction, reuse, and recycling options. Further, the building renovation passports can integrate, where necessary, recent EU guidelines relevant to CDW such as the EU Taxonomy and Do No Significant Harm Technical Guidance[53,54].

Cons – The rapid deployment of the optional building renovation plans may mean that it is already too late to achieve a significant integration of CDW. Alternatively, CDW could be built into future versions.

Quantitative modelling of impacts

Building renovation passports improve the design phase of renovations including waste management. As renovations increase the generation of CDW, it is important to create opportunities for waste prevention. It is less clear to what extent the specific activity of developing a building renovation passport, augmented with an emphasis on CDW minimisation, would be effective in reducing CDW. The scientific literature holds that decision making, planning and better design of buildings, renovations, and demolitions can reduce the amount of CDW (Quiñones et al., 2021).

Data for the specific activity of using building renovation plans to also decrease CDW is not available; therefore, this option was not modelled with LCA or LCC.

Recommendation and next steps

The Commission might consider writing **a guidance document** on how to incorporate CDW management in building renovation plan templates and training for the MS (it could exploit expertise of staff already working on CDW and energy efficiency). The guidance should include recommendations on measurement and reporting.

Each MS will report on the energy efficiency renovations that could provide data and information on the levels of CDW generated due to rehabilitation of different types of buildings and other factors

[53] https://commission.europa.eu/document/download/993e026c-4118-46ed-b7ff-5224c19aa254_en?filename=2021_02_18_epc_do_not_significant_harm_-technical_guidance_by_the_commission.pdf#:~:text=In%20the%20context%20of%20the

[54] ESMA30-379-2281 'Do No Significant Harm' definitions and criteria across the EU Sustainable Finance framework (europa.eu)

relevant to better estimating types and volumes of CDW generation. Also, the authors suggest stressing **data collection in EU funded research** (Horizon, etc.).

4.3.7. Factsheet #7: Financial aid to preparing for reuse / recycling

Financial aid to preparing for reuse and recycling can take many forms including tax incentives, grants, or subsidies for individual commercial activities and companies. It is in line with the examples of economic instruments to provide incentives for the application of the waste hierarchy as described in Annex IVa of the WFD. It states, "Use of fiscal measures or other means to promote the uptake of products and materials that are prepared for re-use or recycled".

The current assessment of state aid to preparing for reuse and recycling reflects the EU multi-level governance in line with real examples. First, the MS may provide **fiscal incentives** in the form of tax reductions and tax incentives to individual companies. Second, the EU and MS may provide **research grants** and other subsidies that promote preparing for reuse and recycling technologies. Third, the EU and MS may **sponsor programs** that address **training and skills** for circularity that directly or indirectly reduce CDW.

For the purposes of this analysis, the focus is on possible tax reductions and incentives to companies operating CDW processing plants which produce secondary products and materials. This means new construction, rehabilitation, and demolition projects that generate CDW need recycling options for CDW fractions, either onsite or offsite. CDW processing plants offer an indispensable service to scaling up the percentage of recycling of CDW fractions. Therefore, the present analysis focuses on CDW plants rather than the many other relevant types of commercial activities that are also contributing to preparing for reuse or recycling. For example, subsidies for firms involved in recycling activities in France under the Anti-waste Law[55]. Or the incentives in the German Raw Materials Strategy for recycling "construction raw materials" (Schmid, 2021).

The costs of building and operating a CDW processing plant can vary widely, depending on factors such as the type and quality of the waste, the level of automation, and the local market conditions. These plants typically work by using a combination of mechanical and manual sorting to separate the different components of the CDW, such as concrete, brick, and metal. Quality control matters (perhaps certification or labelling): the final aggregates are inspected and tested to ensure they meet the required quality standards for certain products where certification is desired by the manufacturer.

Whether receiving mixed or sorted CDW, recycling plants commonly share high start-up costs and all the economic / financial considerations on the supply and product demand side that can make the business of CDW recycling precarious. In short, the estimated social and environmental costs are partly external to the actual price of CDW management, making market competition more difficult for recycled products in many locations. Adding to the complexity of recycling CDW, waste sorting can be done offsite, onsite or a combination of both to balance the speed of project delivery, costs of waste management, and space available onsite.[56] Further, the market prices may not be economically feasible for operators due to the energy costs for transporting and processing / recycling CDW into useful products. In summary, CDW processing plants are complex commercial enterprises, with market factors on the supply and demand side that might justify some form of financial aid, given their pivotal role for an overall more circular CDW management.

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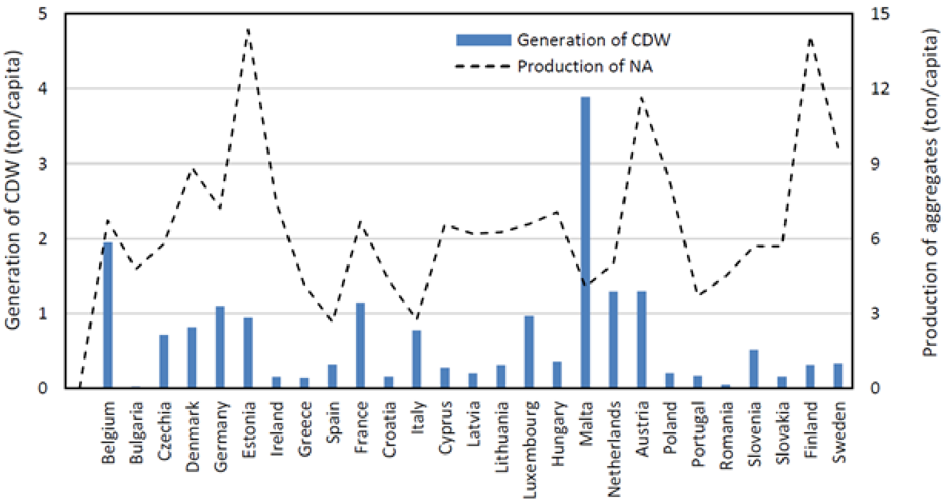
[55] https://www.ecologie.gouv.fr/sites/default/files/documents/en_DP%20PJL.pdf
[56] https://www.cmaanet.org/sites/default/files/resource/Construction%20Waste%20Recycling.pdf

The Geography of CDW Supply and Demand in the EU Plays a Role

The market demand for products substituted by recycled or refurbished CDW and supply of CDW in the EU is geographically uneven. Figure 13 shows the generation of CDW per capita in the EU27 for 2018 compared to natural aggregate production (note that natural aggregates are generally extracted from larger rock formations through an open excavation and the extracted rock is typically reduced to usable sizes by mechanical crushing). Both statistics are indicative of construction sector activity (Pacheco et al., 2023). The chart can be interpreted in different ways. One perspective is that areas of higher construction activity are good target markets for increased CDW recycling that could meet some of their demand for natural aggregates.

Figure 13. CDW generation compared to natural aggregate production for the EU27 in 2018.



Source: The original graphic appears as Figure 2 in Pacheco et al. (2023). NA stands for 'Natural Aggregates'

There are three main conclusions drawn from the above analysis:

- The costs of CDW recycling are significant and financial aid can help alleviate these costs when environmental benefits can be achieved. The modelled costs (average in EU27, across all CDW fractions) for a recycling scenario are described in Cristobal-Garcia et al., 2024 or Annex 6 – Tables A4 to A11. These costs are estimated between 40-65 €/tonne according to whether business-as-usual or more advanced recycling technologies are employed.
- There are a variety of economic and non-economic incentives that are currently in place to encourage commercial reuse and recycling of CDW.
- The market is local and regional and diverse, requiring local policy solutions.

Costs

Oliveira Neto et al. (2017) provides detailed estimates of the cost for initiating and operating a range of CDW recycling plants and platforms. They harmonised several sources to develop their estimates, which range between 7.5-13.9 M€ for start-up costs depending on the technologies and capacities of the plants. The authors estimate annual operating costs in the range of 0.88 to 3.1 M€. They found that "the share of labour costs in the total operating costs is approximately 45%". Their analysis confirms that start-up costs are not negligible and that an increase in the number of or capacity of CDW recycling plants generates jobs.

The assessment of preparing for reuse and recycling targets (see Section 0) shows that increasing preparing for reuse and recycling results in total net cost savings when compared to current practice (baseline), and considering both environmental and full life cycle cost. This means that environmental and other benefits outweigh costs in general. However, the underlying assumption of these results is that a market for secondary products exists, i.e., that the supply of recycled material is absorbed by the market to displace corresponding primary material. It is thus necessary to verify that a market exists.

As discussed above, financial aid can be designed as subsidies, grants, tax credits or other forms. Each of these designs have different rates of effectiveness based on the local situation. Therefore, the authors have not made a specific financial aid proposal herein. However, previous analysis of costs of recycling technologies in Cristobal-Garcia et al., (2024) suggest two conclusions.

First, the cost difference between landfilling and recycling would even without intervention lead to recycling for some fractions. For example, from Table 18 at today's average costs in the EU, the business-as-usual (BAU) recycling technologies can be the least cost or comparable option **when an average landfill tax/fee (19 €/t) is applied**. This landfill tax rate is the average in the 25 MSs that have landfill taxes. Consequently, concrete which is 60% of CDW costs ca. 25.4 €/t to recycle versus a more expensive ca. 26.8 €/t to landfill. Therefore, under these conditions market mechanisms will lead towards recycling with BAU technologies.

However, for most fractions, under the same conditions, the cost of landfilling (with or without taxes) is the least cost option. For example, the biggest cost gap is between advanced recycling of concrete including cement fines (>46 €/tonne, when also fines are recovered to produce cement) and landfilling. In conclusion, the much higher cost of advanced recycling of concrete is unlikely to emerge without a regulatory support.

In summary, the overall lifecycle recycling cost per tonne of CDW across a representative share of all fractions is about 40 – 65 €/t, or 6 - 19 €/t above landfilling with tax. This means that if ambitious targets for recycling are adopted, for some fractions recycling will most likely not be economically feasible in the short term and will require financial aid (or other regulatory support) for the start-up costs of recycling plants and platforms, as well as for the additional operational costs of recycling per tonne treated.

Table 18. Estimated life cycle cost (i.e. internal costs including landfill and incineration taxes, but without other externalities) of managing CDW via recycling or landfilling. This is reported with and without an average EU landfill tax/fee (in brackets without). The data are taken from previous work of the JRC, thoroughly reported in Caro et al. (2024) and Cristobal Garcia et al. (2024).

CDW fraction	Share in CDW %	EU Average lifecycle cost of BAU Landfill* €/t CDW	EU Average lifecycle cost of BAU Recycling Technology €/t CDW	EU Average lifecycle cost of Advanced Recycling Technology €/t CDW
BRK	7.0	3.1 (1.8)	5.0	5.3
CON	60	27 (15)	25	46
GYP	0.6	0.27 (0.2)	0.5	0.5
WOD	3.1	1.4 (0.8)	-1.3	-1.3
EPS	0.8	0.34 (0.2)	-5.2	-5.2
C&T	5.9	3.1 (1.9)	4.0	4.9
PVC	0.8	0.34 (0.2)	-3.3	-3.3
STW	0.3	0.15 (0.1)	0.2	0.2

GLW	0.3	0.15 (0.1)	0.2	0.2
GLA	4.3	1.9 (1.1)	3.1	3.1
MIX	17	8.7 (5.5)	11	14
Sum	100	46 (27)	40	65

Source: Own elaboration.

*19 €/t landfill tax applied to all the CDW fractions (average across EU27 without considering STE, ALU, ESR and DDS; see Cristóbal García et al. (2024). The cost without tax is reported in brackets for comparison. BRK: bricks; CON: concrete; GYP: gypsum; WOD: wood; EPS: expanded polystyrene; C&T: ceramic and tiles; PVC: poly vinyl chloride; STW: stone wool; GLW: glass wool; GLA: glass; MIX: Mixed CDW.

Qualitative assessment (Pros and Cons)

Pros – Providing financial aid to preparing for reuse and recycling is a step to incentivise activities that result in improved waste management in line with the waste hierarchy. It is likely that financial aid will result in increased recycling rates and reduction in landfilling, therefore environmental benefits. Funding also supports jobs and skill development in the sector. Further, support for innovative technologies can help commercialize new recycling technologies and techniques, driving innovation and improving the efficiency of CDW recycling.

Cons – At the EU level, there is a recognised need for additional CDW recycling capacity. However, as the CDW recycling business model is heavily influenced by local demand (level of construction, rehabilitation, and demolition activity) and transport costs, the decisions about which regions' need is highest and most hampered by market barriers **is better analysed and addressed at the MS or regional level**. Further, the MS and local governments control tax incentives for investment. It would be difficult to create a one-size-fits-all solution at the EU level. Further, aid to recycling plants, for example, could have the unintended consequences of supporting companies that may not be viable in the long term, distorting market prices and potentially harming companies that are not savvy or large enough to access the funding early. It is important to keep in mind that most companies in the construction sector are SMEs that are sensitive to price competition and regulatory burden.

Quantitative modelling of impacts

No specific modelling was carried out on this measure.

Recommendation and next steps

MSs should be **encouraged to assess** their local and regional supply and demand for CDW recycling. For the case of aggregates, JRC has produced a detailed analysis identifying market characteristics by MS linked to actionable policy recommendations. "These measures range from training, research and knowledge transfer to improvement of industrial capacity and promotion of increased market demand. Economic instruments, increased societal awareness and the role of certifications and regulations are also presented." (Pacheco et al., 2024).

As next steps, MSs should **assess the possibility of providing financial aid** to reuse and recycling at the MS and local and regional levels considering budgetary, legal, and administrative constraints. At the EU level, the Commission should consider **continuing to publicise** the need to improve reuse and recycling; **fund research** on new CDW recycling technologies and techniques; and **provide access to relevant training**.

4.3.8. Factsheet #8: Tax on primary resource

This section focuses on environmental taxation (including license fees and royalties) for primary materials that can be substituted with secondary materials (recycled or reused) from CDW. Every

MS has various forms of environmental taxation, including a variety of tax interventions on primary raw materials. Ostensibly, the main goals of taxes on primary materials are twofold. The first goal is to price the cost to society of negative environmental externalities not normally included in the price of the primary production product; for example, increasing the price of natural sand extracted from riverbeds. The second goal rests on the first. By raising the price of the primary product, recycled products (i.e., recycled aggregates) that are generally higher priced due to recovery and treatment costs become more competitive in the marketplace. The tax mechanism addresses the economic market barrier for recycled products due to price differences.

These above goals are not the only motivations that MS have for taxing natural resource production, such as taxes on mining sand and gravel. For example, some MS charge royalties for the fair use of public resources. Public resources are interpreted differently amongst MS. For example, all resources below ground, or on publicly owned land. In addition, MS or municipalities often charge license fees for mines to pay the government's cost for the environmental impact assessments and inspections that mining operations require. Further adding to the diversity amongst MS that impose resource taxes, some MS tax the revenue of the firm engaging in the natural resource extraction, whilst others tax on tonnage extracted. Although motivations may vary, theoretically, taxes on primary products reduce the price gap between these products and their substitutes from recycled materials, which is a market barrier to recycled products' success.

Nonetheless, taxing natural resource extraction focuses only on price mechanisms, with little impact on other significant market barriers. Other significant market barriers that reduce the uptake of recycled CDW are not addressed, such as perception of quality differences, purchaser information (standards), or lack of recycled materials in sufficient quantity and local supply chain availability, and regulatory uncertainty. These factors are important for the development of sustainable markets for all recycled CDW fractions. However, each fraction has significantly different characteristics (Legg et al., 2008) that make a single analysis of tax effects impossible. The case of recycled aggregates informs the current analysis on the utility of a natural resource tax. Recycled aggregate is the largest portion of CDW; therefore, pivotal to the management of all CDW. Aggregates recovered from CDW can substitute natural gravel and stone in several uses including road construction and cement manufacturing. These recycled mineral building materials have a long history of treatment and reuse in the EU. The report from Pacheco et al. (2023) conducted a thorough literature review and analysis of taxes on natural resources in relation to recycled aggregate feasibility. The authors reiterate the finding reported in Tošić et al. (2015) that taxes on natural aggregates contribute to recycled aggregate competitiveness.

Costs

The price comparison between recycled aggregates and other primary materials used in construction can vary depending on the country, supplier, and market conditions. In most cases, recycled aggregates are more expensive than natural aggregates (Pacheco et al., 2023). Any tax increase on primary material extraction (of aggregates and other materials used in construction) would increase production costs and the price of the final products purchased by consumers. However, an EEA ex-post study on the effectiveness of taxes on aggregates (both natural and recycled) concluded that, "**the relative competitiveness of recycled aggregates with respect to virgin materials has not changed significantly after introducing taxes, and as result, consumption patterns have remained unaffected**" (Legg et al., 2008). A case study in the UK in 2016-2017 found that the drop in primary aggregates use per unit of construction output in the UK coincided with the introduction of a levy (Ettlinger, 2017). The study notes that other factors including landfill taxes also contributed to the lower primary aggregates use (Ettlinger, 2017). According to literature, (Luciano et al., 2022; Söderholm, 2011), the empirical analysis shows that the European aggregate taxes have assisted in reducing virgin resource use despite the relatively low own-price responses (elasticity). The authors conclude that taxes on primary materials is one way to boost the competitiveness of recycled materials but needs to be accompanied by policies to increase the supply of the recycled material to correct for its low own-price elasticity (Söderholm, 2011 describes the positive example of Denmark and the negative of UK and Sweden).

Few quantitative studies have investigated the effectiveness of taxes to reduce primary material production. The study from The World Bank (2022) modelled a 30 percent tax imposed on primary metals and plastics production and a 30 percent production subsidy for secondary materials production. The study concluded, "taxing primary materials production can have similar effects as subsidizing secondary production to reduce the use of primary materials". The EEA study (Legg et al., 2008) affirms that the level of the tax is not necessarily linked to the value of the negative environmental impacts, and in addition the tax revenue is not always earmarked for the mitigation of the damages. An OECD study (OECD, 2024a) modelled the effect of taxes on primary materials in Italy, finding "that estimated economic and environmental outcomes of the proposed tax on the extracted construction aggregates appear relatively modest due to the generally low demand elasticity".

The principle of **taxes on primary materials is included in the EU Construction and Demolition Waste Protocol and Guidelines**[57]**,** citing decentralised taxes on sand, gravel and rock in Italy as a best practice case. However, there are caveats regarding the price impact, as noted in the 2024 update of the same guidelines: "Depending on the local situation, taxes on virgin materials may be considered to provide price incentives to use recycled materials. However, they should be used prudently as they could increase the cost of construction without necessarily bringing the desired benefits to the environment or to the economy, especially if they lead to imports/transports of materials from countries or regions where such taxes are lower or not applied." (Oberender et al., 2024).

Qualitative assessment (Pros and Cons)

Pros – Environmental taxes for natural resources are well known part of the business model for construction products from primary materials such as aggregates. Here are some examples:

- As a principal objective, the EU's policy is to shift taxes from labour to environmental pollution (EEA, 2016a). The EEA[58] points out that, "despite the essential role of environmental taxation for the transition to a greener economy" the share of environmental taxes in total revenues from taxes and social contributions in the EU decreased from 6% in 2010 to 5.4% in 2021.
- Due to a lack of targeted taxes and outcomes it is difficult to measure effectiveness (Milios, 2021). Nevertheless, taxes are shown to be effective to reduce the extraction of primary materials in reality (Legg et al., 2008; Söderholm, 2011) and with modelling (The World Bank, 2022), when accompanied by measures to increase the recycled material supply.
- Business's expectations include taxes. For example, Tost & Ammerer (2022) reported a survey of aggregate producers in Spain in which they expect with high consensus that by 2030 taxation related to environmental protection (exploitation taxes, landfill taxes, CO2 emission taxes, restoration guarantees, etc.) will have an increasing impact on extractive activity.
- The EU Construction and Demolition Waste Protocol Guidelines have included natural resource taxes since 2016.

Cons – Taxing natural resource production alone does not address critical market barriers that are not driven (directly) by price. For example, in the case of aggregates used for concrete, the JRC highlights quality and availability in addition to prices, noting that the higher price of recycled

[57] https://single-market-economy.ec.europa.eu/news/eu-construction-and-demolition-waste-protocol-2018-09-18_en

[58] https://www.eea.europa.eu/en/analysis/indicators/share-of-environmental-taxes-in

aggregates causes concrete producers to reject it "for natural aggregates since they find little incentive in adapting their industrial units and production processes to accommodate additional suppliers and materials, especially when considering that the new material (RA) has worse qualities than the natural aggregates typically used" (Pacheco et al., 2023). The literature indicates that non-price factors are significant barriers requiring different policy mechanisms.

Product taxes risk to create unintended negative market and trade effects. An increase in the price of primary construction products could mean a loss of competitiveness in the global market and cross-border markets within the EU. Countries with lower prices due to a lack of natural resource taxes would offer lower prices to consumers in the markets with higher taxes on primary materials. The products that would be substituted by recycled CDW have some degree of protection against negative market and trade effects due to the weight and expense of shipping these products cross border. However, market and trade effects must be considered if considering the introduction of new or increased natural resource taxes. As discussed under the section on costs, taxes on natural resources follow different objectives and it is not easy to link the tax revenue to achieving those objectives.

Quantitative modelling of impacts

No quantitative modelling was carried out for the current assessment.

Recommendation and next steps

The assessment of the current data concludes that taxation of primary materials is a practical and well-understood tool to increase resource efficiency and improve the relative competitiveness of CDW substitutes. However, the literature agrees that taxation is not a solution on its own and must be combined with other economic and non-economic incentives for replacing primary materials with recycled substitutes. Therefore, in line with the August 2024 Guidelines, MS, local, and regional managers should consider integrated CDW management including taxes – "Taxes (e.g., product levies on aggregates, landfill taxes, incineration taxes)" (Oberender et al., 2024). MS tax methods and definitions are often unique to the MS.

To help authorities to evaluate the utility of taxation at the local level, **the Commission could consider new research** answering the following questions:

- What is the latest data available at the local and MS level to determine empirically if taxes on primary materials such as gravel taxes are effective in opening markets to recycled products and increasing their demand without negative trade effects?
- What are the best tax mechanisms on natural resource use (tonnage, revenue, and source, etc.) to increase the demand of recycled products?
- What are the best ways to design the tax to approximate the cost of negative environmental impacts and to dedicate the tax revenue to mitigating the negative impacts?

Further based on the answers to the above research questions and the information in the current report, the Commission can analyse whether a uniform and harmonised tax is possible and/or preferable over the diverse landscape of different tax rates and taxation strategies MS currently have implemented as discussed herein.

4.3.9. Factsheet #9: Standards and certifications for recycled materials

In the CDW sector, the use of sustainability certifications is a strategy to orient design for reversible building and the use of recycled materials. The use of **building sustainability certifications**, through reward mechanisms, favours the development of circular practices not yet commonly applied and helps all the stakeholders to optimize and lower costs (Giorgi et al., 2022). Sustainability certifications are seen by stakeholders as a lever to trace the materials in input and output and, sometimes, to demonstrate the impact of intervention through LCA.

Recycled material standards establish requirements necessary to assure accuracy and transparency of claims at product level whenever certified by a third-party system. Comparing products should now be easier with the introduction of the ISO 14021 standard that identifies recycled content as part of an Environmental Product Declaration (EPD). The EN 15804 standard is the basis of the Type III (EPD) of construction products through which it is possible to perform LCA of recycled material and compare it with primary one.

Standards and certification guarantee the **quality** of the construction products (such as recycled aggregate; RA), meets recognized criteria and are within audited quality assurance schemes. Certified RA conform to the same specifications as those of traditional Natural Aggregates (NA) and may be sourced from dedicated aggregate producers and mobile waste transformation producers. A performance-based classification system of RA can be easily implemented thanks to the predictable relationship of physical properties of RA, and it can also show high reliability and reproducibility of results and thus facilitate certification of the final product. Effective quality control and certification of RA by suppliers are essential to instigate and sustain high stakeholder confidence in the materials. However, this must be backed by greater governmental intervention in the form of robust legislation and standardization as suggested by Silva et al. (2017).

Costs

The cost of implementing a product certification program varies by order and scheme and implies a certification process with several variables (e.g., external consultants, certification body, internal resources) which make it difficult to perform a detailed cost evaluation. General factors that can affect the cost of a product certification program are:

- Complexity of the product to be certified along its life cycle stages (e.g., procurement of raw materials, production processes, use, transport, end of life of the product).
- Consulting costs: companies can rely on specialized external consultants to guide them through the implementation of product certification and to ensure compliance with the requirements of the reference standard. Consulting costs can also include technological costs (e.g., LCA modelling software for product certification related to environmental impacts) and represent one of the most significant costs in the product certification process.
- Personnel costs of the organization involved in the product certification: it consists of the time taken away from work to follow training courses and to collaborate in the drafting of documentation. It can be quite high and is highly dependent on the presence and involvement of the consultant.
- Costs of the audit and evaluation: in the product certification process, audits and the overall evaluation of the product to be certified are fundamental steps to verify its compliance with the requirements of the reference standard. These costs may vary based on the certification body chosen.
- Administrative costs: Once the certification audit is passed, the certification body issues the product certificate. The costs associated with the issuance of the certificate (but also the preliminary costs for the opening of the practice) may vary according to the certification body.

The above factors must be considered at least annually because of surveillance and renewals aimed at maintaining product certification.

The costs of certifying a building for sustainability are divided in indirect and direct costs. The former includes consulting expenses, consultancy extras (depending on the certification level) and the fixed certification fees of the certifier. The latter include costs directly incurred in the construction of the building. **The expense of certifying a building with BREEAM or LEED ranges between 0.5% and 7% of the total construction cost, for LEED Certified / BREEAM Approved and LEED Platinum / BREEAM Excellent, respectively**[59]. Those upfront costs should be compensated by savings in operating and maintenance cost over the lifetime of the building.

Qualitative assessment (Pros and Cons)

Pros – Voluntary certification can be used as a marketing tool since it allows manufacturers to differentiate their products in competitive markets. Consumers are aware that certified products are more reliable and cost-beneficial than cheaper, uncertified products. Product certification matters because governments (easily the biggest buyer of materials and supplies) have procurement standards that they must enforce. Many governments will not allow companies to tender for contracts if they fail or refuse to certify their products. Furthermore, consumers' willingness-to-pay appears to increase when environmental and social product claims are supported by a third-party certification because labels help increase consumers' confidence about the credibility of product claims (Pretner et al., 2021).

Cons – Costs of verification, time effort, and implementation and maintenance costs hamper the adoption of third-party certification products, especially for SMEs. Cost of adoption is the biggest problem for smaller companies, but also technical considerations such as the lack of external technical support and information, as well as the lack of internal human resources and competences (Iraldo et al., 2020). Concerning public awareness on the implementation of the product certifications by EU organizations, there is a limited access to the relative databases. Among the different Member States belonging to the European co-operation for Accreditation (EA), only Italy's accreditation body allows detailed access to its database through several filters (among which certificate no., issue date, company name, certification scope, product name, technical standard). As application example, 264 organizations apply the aforementionedUNI/PdR 88:2020 of which 33 include recycled aggregates in their scope (data updated to July 2024). The use of easily accessible advanced IT tools is required to have an effective information dissemination and increase transparency on products with recycled content (e.g., on their origin, composition and conditions of processing and reuse), on their processes and on the criteria of the related certifications (Shooshtarian et al., 2024).

Quantitative modelling of impacts

Given the lack of effectiveness data for modelling, no LCA or LCC were conducted.

Recommendation and next steps

Along with associations in the construction sector, policymakers could initiate **promotional activities** through the media to increase the awareness of European citizens on the potential benefits and objectives of recycled product certifications, thus influencing their attitudes and lifestyles in general (including through regular training activities among industry stakeholders and certification bodies, as suggested by Bao & Lu (2020)), potentially creating a purchase application of products with certified recycled content (reducing certification costs) and creating a virtuous system of information dissemination on certified products and their environmental characteristics (Ghisellini et al., 2022).

Moreover, the authors find that recycled product certifications (i.e., environmental labels) could be incentivized by the introduction of **mandatory GPP requirements** along with the implementation

[59] https://blog.zeroconsulting.com/en/how-much-does-it-cost-to-certify-a-building-with-breeam-and-leed

of rating criteria as part of new voluntary certifications (e.g., for the sustainable use of green building resources) to support European policies in the building sector (Arnesano et al., 2019).

4.3.10. Factsheet #10: Minimum recycled content

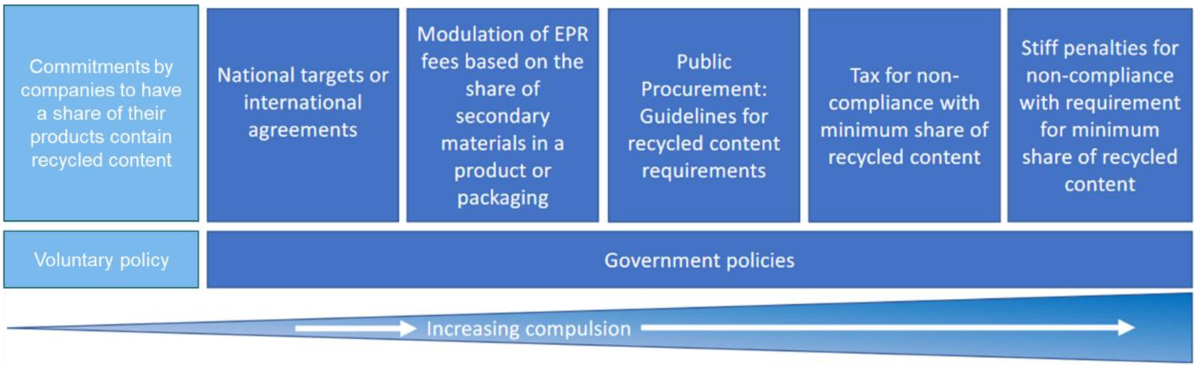
Governments across the OECD are making use of a wide range of policies to ensure that a certain fraction of the materials from which a given product is made stems from recycled materials - a so-called minimum share of recycled content. These policies vary by the degree to which the policy compels producers (Figure 14): voluntary **commitments** by companies to increase the share of post-consumer recycled content in their products or packaging; **targets** announced by national governments or set by international agreement do not by themselves compel compliance by producers; modulation of **EPR** fees based on the share of recycled content in a product as a policy that can provide economic incentives to increase the share of recycled content in products or packaging; guidelines for recycled content requirements on **public procurement**; varying degrees of severity of the **taxes / financial penalty** set by government regulations for non-compliance of products or packaging (Brown & Börkey, 2024).

Concerning **voluntary targets**, it is unclear if companies have sufficient motivation to achieve commitments to use recycled content in products in the absence of more compelling government policy. Environmentally friendly actions by companies are typically motivated by demand for sustainable products, lower costs of production (e.g., waste reduction or lower costs of inputs of secondary material), and the aim to deter or lessen public perception of a need for policy interventions (Lyon & Maxwell, 2016). If market conditions are unfavourable, either due to insufficient quality of supply or high relative prices (compared with primary materials) there is potentially an economic incentive to forego or delay the company commitments. To overcome some of these issues, the EU has adopted sustainability **reporting standards** on, among other circular aspects, the percentage of recycled content for products (including construction and buildings) for companies to help inform the public on their sustainability performance[60].

Among the practical examples for stimulating the transition to a circular and sustainable building sector assessed by the Interreg project Sustainable and Circular Construction[61] and related to the **government polices** mentioned above, the one which requests minimum recycled content as mandatory requirement in the building sector is the **public procurement**. Although several MSs in the EU have developed GPP criteria for the building and construction sector, Italy is the only MS to have made them mandatory. Indeed, in 2017 Italy has become the first European country to introduce mandatory Green Public Procurement Minimum Environmental Criteria (MEC) for public buildings (D.M. 24/12/2015 and update with D.M. 11/10/2017) for all public construction contracts, both in new construction and renovation of existing buildings, pursuant to the new Procurement Code (D.lgs. 50/2016). These GPP criteria include several important measures from a circular economy perspective among which the **minimum and certified recycled content** (minimum recycled content of 30% according to the D.M. 203/2003) **in all major construction materials and products**.

[60] https://finance.ec.europa.eu/news/commission-adopts-european-sustainability-reporting-standards-2023-07-31_en
[61] https://www.interregeurope.eu/sites/default/files/2024-03/Policy%20brief%20on%20Sustainable%20construction.pdf

Figure 14. Recycled content policies vary by key actor and level of obligation.



Source: Adapted from OECD (2024b)

In a future perspective, the recent **Ecodesign for Sustainable Products Regulation (ESPR)** (European Union, 2024b) is part of a package of measures that are central to achieving the objectives of the 2020 Circular Economy Action Plan. They will contribute to helping the EU reach its environmental and climate goals, doubling its circularity rate of material use, and to achieving its energy efficiency targets by 2030. The ESPR is a framework legislation, meaning concrete product rules will be decided progressively over time, on a product-by-product basis, or horizontally, based on groups of products with similar characteristics. This means that within the first half of the 2025 the first ESPR Working Plan will be adopted and published. According to the ESPR, the minimum recycled content is among the elements that fall under:

- **Sustainable product design**: The recycled content is among the eco-design requirements (ESPR's Article 5) and among the product parameters used (either individually or in combination with each other) to improve product aspects (ESPR's Annex I). In general, for products for which there is no specific EU legislation setting mandatory environmental sustainability requirements, the ESPR will provide the legal framework under which EU rules are to be established. Specifically for construction products, to date they fall within the scope of the ESPR. According with the future ESPR Working Plan, construction products, including cement, will have to be regulated by a regulation of the European Parliament and of the Council setting harmonised conditions for the marketing of construction products (the 'Construction Products Regulation'), e.g. for cement no later than 1 January 2030.
- **Demand for sustainable products**: Public procurement procedures (in accordance with Directives 2014/24/EU and 2014/25/EU) account for 14% of the European Union's GDP. Green public procurement requirements should be minimum requirements, which means that contracting authorities and contracting entities are able to define additional and stricter requirements (e.g., the Commission could set mandatory minimum technical specifications requiring products to comply with the best possible performance standards). For example, it would be mandatory for contracting authorities and contracting entities to establish that the products' recycled content would be no less than 20 % (European Union, 2024b).

Qualitative assessment (pros and cons)

Pros: Recycled content is acknowledged to be a pull mechanism for creating a market for secondary material from waste. In this sense, it could be envisaged as a complementary measure to reach the targets on recycling and circularity in the sector.

Cons: There are however some negative aspects to be considered, which stem from the early feedback from attempting to introduce this instrument in other sectors and product markets:

- volume-based instrument (as opposed to price-based instrument): recycled content obligations represent a heavy-handed market manipulation directly affecting supply and demand for given markets which would normally operate under complex dynamics. There is a high risk of giving rise to supply bottlenecks, generating price volatility.
- market adequacy: depending on the material considered, it is likely that there will be a mismatch between the quality and quantity of outgoing and ingoing flows (as in the CDW case, possibly produced hundreds of years apart).
- disregard of waste hierarchy: mandating recycled content prioritises recycling as the preferred outcome for CDW. However, recycling is not among the highest tiers of the waste hierarchy. There is a risk that mandating a minimum volume for the demand of specific recycled materials might crowd out other, more circular options such as prevention, reuse, refurbishment, etc.

While some studies also point to possible design constraints due to recycled content obligations (Abedin Khan et al., 2024), this is expected only when recycled content-based products do not meet given product specifications (e.g., the stability and durability of pavement mainly depend upon the strength of its granular aggregates; in case of use of recycled aggregates, their physical and mechanical properties are highly variable and depend on the composition of recycled wastes, recycling techniques, and aggregate sizes). The authors conclude that future regulatory conditions - when the recycled product to be placed on the EU market is required to meet given technical specifications (thus it is functionally equivalent to the virgin counterpart) will influence future market conditions.

Quantitative modelling of impacts

This study does not perform any quantitative modelling of impacts. This should be part of future assessments.

Recommendation and next steps

While recycled content requirements are acknowledged to be pull-levers helping to create a market for secondary material, targets should be defined carefully. Available research (e.g., ongoing JRC projects but also published literature) shows that the construction sector is characterised by a great imbalance between what is fed into the sector / market each year and what is generated as waste. This ratio is, e.g., currently around 10:1 for concrete. Therefore, **further research is recommended** to ensure that recycled content targets and their consequential **market effects be carefully investigated** to **match demand with supply and to avoid leakages from other sectors** due to market-mediated effects. For example, to avoid that plastic or wood waste destined to packaging applications is absorbed by the construction material market, where quality standards (e.g., accepted impurity levels) are typically lower.

4.3.11. Factsheet #11: Subsidies for operating own marketplaces

A CDW marketplace is a physical location or an online platform that connects buyers and sellers of reusable and recyclable materials from construction and demolition projects. By providing a platform for the exchange of reusable and recyclable materials, a CDW marketplace can help reduce waste sent to landfills and increase the reuse and recycling of materials.

Numerous MS examples make clear that providing a depot or network for CDW collection and redistribution to citizens increases reuse (Nordic Council of Ministers, 2014). The difficult part in analysing this question is estimating the cost of a depot either specifically for CDW or the additional cost of expanding an existing depot to include CDW. The costs depend on the amount and types of materials collected and stored (indicating space needed), the cost of staff needed to maintain the facility (which depends upon location, and roles of staff) and whether the role of the staff include assessing/rating the materials and transportation costs (is the depot receiving only or is truck transport to collect the materials included). Online networks connecting buyers and sellers face similar diverse activities and related costs, including material storage, assessment, webmaster, photographing materials for posting online, answering questions online, customer facing staff, etc. These and other factors make estimating the costs of the marketplace activity a difficult task.

Exchanges with stakeholders suggest that the demand for CDW depots and networks for reuse is rising. There are two stakeholders who expressed a need for additional possibilities to access reuse, recycling and proper disposal routes. These are households carrying out renovations and dismantlers, and those carrying out pre-demolition activities. Many municipalities cater to households by allowing private waste handlers to pick up wastes from households and others provide the service themselves or provide depots. An issue that is discussed in the literature and by stakeholders is the timing of dismantling / selective demolition in the construction schedule. Unless depots or networks are readily available, developers/builders do not want to invest the project time to essentially store materials onsite whilst potential buyers or donation recipients are found[62]. The builders are not retailers or marketers and do not always have the means to connect to buyers. The two gaps described here are the supply chain from "waste" collection to reuse and the supply chain from suppliers to purchasers/users.

Accompanying the supply chain gaps are information market barriers. For example, waste generators may not know which wastes can be reused, such as furniture, fittings, and appliances, and which materials cannot. Here, more information and communication on regulations for reuse possibilities in local markets is needed. Also, EoW rules clarifying when recovered materials can be sold as products are helpful. Another information barrier is the quality of materials. In this case, EoW criteria, certifications, and independent refurbishment and cleaning can be helpful to inform purchaser/users. Finally, purchaser/users miss information about where to find reusable products. Here, the information and communication to connect buyers with sellers can come through business networks and online platforms.

Costs

Cost information on marketplaces needs to be estimated at the MS level. There are three reasons. First, not all MS have marketplaces now, so significant local knowledge is needed to estimate costs. Second, "costs of collection are of a more short-term nature and less capital intensive. The main items are likely to be contracts with contractors that typically have a lifetime of no more than five years."[63] Third, the need for marketplaces is based on forecasting waste management supply and demand for reuse, which is local[64].

The costs of subsidising marketplaces or municipalities operating their own marketplaces could be covered or defrayed by EPR fees if an EPR system is in place. The PRO could collect the fees and pay for the collection and redistribution services or run their own marketplaces. Therefore, EPR is a policy measure that could be coordinated with the financial aid to subsidise or run marketplaces.

Qualitative assessment (Pros and Cons)

Pros – Buyers and sellers can more easily access reclaimed materials such as lumber, roofing materials, doors, windows, and other building components. The market reduces purchases' time and effort. The authenticity, origin, quality and condition are known and can be advertised. Prices are negotiated, so new market information is available leading towards consolidated secondary material markets. Some materials will be available at a lower cost than new materials, while sellers can recover value from materials that would otherwise be discarded.

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[62] On-site vs. Off-site Sorting: Which Construction Waste Recycling Method Is Best? Keith Osmun https://www.cmaanet.org/sites/default/files/resource/Construction%20Waste%20Recycling.pdf

[63] Guidance document to support Member States to develop Waste Management Plans https://circabc.europa.eu/ui/group/636f928d-2669-41d3-83db-093e90ca93a2/library/dad8f274-4e94-487f-848b-b71c25d30e80/details?download=true%3Fdownload%3Dtrue

[64] Ibid.

Cons – A new depot, network, or online marketplace may have high upfront costs. There is limited public and commercial awareness and education about reuse, so the new project will take time to show a significant diversion of wastes from landfilling. It is possible that materials brought to the depot could be contaminated with hazardous substances. Consumer behaviour to proactively use the marketplace for buying and selling will need to be developed over time.

Quantitative modelling of impacts

No quantitative modelling was carried out for the current assessment.

Recommendation and next steps

Given that marketplaces for secondary material are successful waste prevention actions, **MS should consider financial aid for marketplaces** in its suite of economic and non-economic policy measures. To determine its necessity, **MS should review the need to support CDW marketplaces** as part of their waste management plans and waste prevention plans mandated by the WFD. The key information needed to provide funding for marketplaces is the costs of collection and management of the marketplace, the future supply and demand for CDW reuse, useful distance of depots from consumers or pickup services. Due to the local circumstances upon which effective marketplaces depend, an **EU-wide mandate does not seem advisable**.

However, one specific type of action which could be taken and recommendable **at EU level** could be **fostering competition and the single market for CDW marketplaces and trading platforms**. For instance, make it easier for online marketplaces which are today mostly national, to operate across the EU.

4.4. Policy measures investigated in parallel (other JRC/Commission studies)

To reiterate, several policies that were not assessed in detail in the current work because they are under scrutiny in parallel studies carried out by the Commission for different regulatory contexts. Three of the most important policies for CDW, EoW, GPP, and design for recycling are summarised below.

4.4.1. End-of-Waste criteria

The detailed assessment of EoW criteria for CDW is being addressed in specific projects and dedicated studies within the European Commission and the JRC. DG GROW commissioned a study to assess the prioritisation for the introduction of possible future European EoW criteria for a list of ten pre-selected CDW and by-product streams (Reetsch et al., 2024). The study identified four CDW streams with high potential for possible future European EoW criteria, based on 15 ranking parameters, namely aggregates, concrete, fired clay bricks and gypsum. Furthermore, streams with average potential are asphalt, inert insulation, plastic foam insulation, rigid plastic and wood. In the same line, recently, the JRC has started a study to support the Commission (DG GROW) in collecting data on CDW to serve as a basis to develop future EoW criteria on the mineral fraction of CDW (used for aggregates).

4.4.2. GPP criteria

The detailed assessment of GPP criteria is being addressed in specific projects and dedicated reports within the European Commission and the JRC. The JRC is leading the criteria development process based on an annual GPP work plan which is coordinated with the EU Ecolabel work plan. There is an ongoing project to revise the EU GPP criteria (published in 2016) for office building design, construction and management. The revision process shall include the consideration of expanding the scope to other types of buildings purchased and/or maintained by public authorities, in particular schools and social housing (Ranea Palma et al., 2024). The GPP criteria aim to be clear and ambitious environmental criteria, based on a life-cycle approach and scientific evidence.

4.4.3. Design for recycling

The detailed assessment of design for recycling criteria of specific materials (e.g., plastics) is being addressed in specific projects and dedicated reports within the European Commission and the JRC. Thus, Watkins et al. (2020) identified a list of priority plastic products and product groups in the construction sector including PVC (window profiles, roller shutters, doors), HDPE pipes and EPS insulation, and highlighted that design for recycling has the potential to improve recyclate quality, and therefore to promote the uptake and hence the supply of recyclates in the future.

4.5. Summary: Synthesizing and assessing priority policy measures

This section paints a comprehensive tableau of the universe of identified 43 policy measures that improve CDW management and treatment. Six criteria that define successful policies are applied to rank the policies. The ranking resulted in 22 priority policies. 11 Factsheets assess environmental, social, and economic impacts of the priority policies.

5. Conclusions, key messages, and policy recommendations

The purpose of this section is to summarise the targeted actions at MS and local levels and the recommendations for action at the EU level for selected priority policies. While the recovery target for CDW can be considered fulfilled at EU level, preparing for reuse and high-quality recycling (along with reducing waste generation) should be further promoted in line with the circular economy paradigm.

Table 19 and Table 20 present an overview of this study's conclusions and recommendations for the policy measures for CDW analysed in Section 4 (including an indication of possible complementary or accompanying measures). Table 19 highlights measures that should be considered for a mandate or other response at EU level. In addition, Table 19 succinctly presents the JRC recommendations on the next steps to be considered in the implementation of the CE policy agenda for improved CDW reduction, reuse, and recycling at the EU level. Table 20 summarises the evidence base for additional policy measures at MS and local levels which are complementary measures.

Based on the evidence, the authors make:

- 8 recommendations for action at the EU level which are summarised in Table 19.
- 10 recommendations for additional measures at MS / local levels as summarised in Table 20.

Returning to the rubric used to characterise the universe of CDW policies introduced in Section 4, the recommendations range from 'hard' (legally binding) rules to 'soft' regulations, education and information, and economic instruments. In addition, research and monitoring the progression of on-the-ground initiatives such as the EPR in France are recommended.

Furthermore, Table 20 summarises measures that were analysed in Section 4 of this study but are recommended for the MS and local levels. These measures were found to be globally beneficial (generally soft measures) but are possibly more relevant to be pursued either (a) at national level, with EU coordination and guidance, or (b) through policy instruments with a different or broader scope, such as product policy. In the same manner as for the table above, herein the JRC recommends policy actions or next steps to implement the CE policy agenda for improved CDW reduction, reuse, and recycling.

Finally, for three policy measures (i.e. **EoW criteria**, **GPP** and **design for recycling**), no formal recommendation is made within this document because these policy measures are within the scope of other ongoing JRC/EC studies. Concerning **aid to sustainable design**, neither detailed analysis nor a formal recommendation have been developed herein because these involve novel policy instruments mostly targeted at architectural and design firms.

In conclusion, this JRC report fulfils its role as a science for policy tool. This study serves as a foundational resource for informing European Commission policy decisions, providing a robust evidence base to underpin future EU regulatory initiatives for CDW. Through rigorous and comprehensive analysis, it yields data-driven recommendations that merit consideration for inclusion in future policy frameworks to be articulated in detailed impact assessment processes that should also involve dedicated stakeholder consultations. This study makes a meaningful contribution to the development of effective and sustainable CDW policies for the EU.

Table 19. Summary of policy measures that may be considered to promote higher circularity for CDW that together represent the best chance for circular CDW management in the future as the EU transitions to a sustainable economy.

Measure	Targeted action at MS / local level	Recommendation for action at EU level	Next steps for policy preparation	Justification synopsis	Complementary or accompanying measures
Extended producer responsibility (EPR) schemes	**Set up national EPR schemes**	1. **Consider a mandate for EPR schemes in each MS** for material categories or groups of materials. 2. **Close monitoring and analysis** of the French EPR scheme for CDW.	- Costs, benefits, and impacts on **SMEs** and construction and demolition markets (e.g. housing affordability) to be analysed and evaluated with stakeholders. - Investigate minimum harmonisation needed to avoid undesired cross-border effects between MS with different EPR schemes.	EPR is recognised in the WFD as an instrument that provides incentives for the application of the waste hierarchy. This instrument has already been implemented within the EU for different sectors including CDW (in France). According to the estimations, the EPR cost would equal 3% of the cost of collection, transport and treatment of the waste without the EPR (i.e. the cost of the EPR for non-hazardous and inert waste is estimated to be around ca. 1 €/t).	- Landfill ban - Mandating pre-demolition audits and selective demolition • Financial aid for preparing for reuse and recycling - Secondary materials marketplaces - Deposit Refund Systems / PAYT as part of EPR schemes.
Pre-demolition audits	**Impose mandatory pre-demolition audits**	**Consider a mandate for pre-demolition audits** for all projects [over a size TBD] based on existing (and potentially updated) guidance.	Promote additional research and updated data collection to support a more detailed assessment (incl., if applicable, an Impact Assessment), to determine **whether a lower threshold for mandatory application is necessary** (e.g. based on project size).	The Commission issued guidance on pre-demolition audits in 2018 and updated it in 2024. Several MSs already mandate pre-demolition audits. The costs are low, estimated to be between 0.2 and 2 €/t of CDW. Benefits of increased CDW recycling due to audits are expected to outweigh costs, **provided a market for secondary materials exists**.	- Landfill ban - EPR - Digital Passport for Buildings - Mandating selective demolition
Selective demolition	1. **Impose mandatory selective demolition** 2. **Adopt complementary measures** such as landfill bans for mixed CDW	**Consider an EU-level mandate for selective demolition** for all projects [over a size TBD] if legally feasible and implementable/verifiable in practice based on further analysis.	Promote additional research and updated data collection to support a more detailed assessment (incl., if applicable, an Impact Assessment), in particular, to determine **whether a lower threshold for mandatory application is**	It is suggested as a possible practice with great potential in the construction sector compared to traditional demolition and is promoted by the WFD. The European Commission has **already provided guidance.**	- Landfill ban - EPR - Digital Passport for Buildings - Mandating pre-demolition audits

Measure	**Targeted action at MS / local level**	**Recommendation for action at EU level**	**Next steps for policy preparation**	**Justification synopsis**	**Complementary or accompanying measures**
			necessary (e.g. project size), if this could be done legally, and consider how to ensure consistent application in practice.	Costs are estimated to be between 10% and 25% higher than traditional demolition. Benefits of increased CDW recycling due to selective demolition are expected to outweigh costs, **provided that a market for secondary materials exists**.	
PAYT	1. **Refine landfill bans** and landfill taxation towards advanced PAYT schemes. 2. **Adopt complementary measures** such as DRS/EPR. 3**. Monitor impacts** and strengthen enforcement especially on CDW generation and illegal dumping	1. **Consider issuing targets and potentially guidelines** on the setup and parameters of PAYT schemes, also considering free take-back for separated CDW, e.g. by 2030. 2. **Consider harmonising landfill bans (i.e. review necessity and conditionality for an EU-level mandate) and landfill taxation of CDW (e.g. if separately collected or untreated) in the EU**, via legal clarification of landfilling, backfilling and recycling definitions. 3. **Fund research and data collection** at EU and MS levels - Funding for data collection on cost-effectiveness and correlation with illegal dumping.	Promote additional research and updated data collection to support a more detailed assessment (incl., if applicable, an Impact Assessment), for: - impacts on **SMEs** (the large majority in the construction sector) and **housing affordability**; - impacts of economic instruments on waste discarding practices and extent of illegal CDW dumping in the EU.	Waste management charges are one realisation of the polluter-pays principle which is recognised in the WFD. Charges should discourage illegal disposal, incentivise separate collection of CDW fractions and incentivise waste prevention and reduction.	- Enforcement, e.g. against illegal dumping - Landfill tax / ban - Advance discarding fee - EPR - Digital Passport for Buildings
Preparing for reuse and recycling targets	**Achieve EU-set targets** for material-specific CDW preparation for reuse and recycling.	**Consider target-setting for material-specific CDW fractions**. These targets could be set, as proposed in this report, below the maximum potential and realistically in line with other voluntary instruments like the Taxonomy or GPP.	Costs, benefits, and impacts on **SMEs**, and construction and demolition markets (e.g. housing affordability) to be analysed and evaluated with stakeholders.	Setting overarching EU-level targets (excluding backfilling and promoting preparing for reuse and high-quality recycling) could be part of a larger policy mix, acknowledging that additional measures are needed to support their achievement.	Landfill ban, EPR, Digital Passport, Mandating pre-demolition audits selective demolition. Financial aid for preparing for reuse and recycling, Secondary materials marketplaces, EoW criteria.

Source: Own elaboration.

Table 20. Summary of the evidence for additional policy measures that are proposed to enhance the MS / local management of CDW towards higher circularity. The policies listed here are predominantly "soft" as the majority are not mandatory (recycled content is a clear exemption to such rule) but influence the ecosystem of CDW stakeholders/actors.

Measure	Targeted action at MS / local level	Recommendation for action at MS / local level in coordination with EU level	Next steps for policy preparation	Justification synopsis	Complementary or accompanying measures
Digital Passport for Buildings	In line with the Energy Performance of Buildings Directive (EPBD), make voluntary digital and paper passport schemes available. To the extent possible, incorporate CDW estimation, prevention, and reduction in the EPBD's "building renovation passports" .	1. Consider **publishing Commission Guidance** on how to incorporate CDW prevention and management into building renovation passports templates at the MS level. And coordinate training for MSs' roll-out of voluntary building renovation passports under the EBRD. 2. **Consider funding research on implementation** - Prioritise funding for data collection and measurement of CDW reduction effectiveness of the building renovation passports.	Internal Commission coordination between DG ENV and DG ENER on the rollout of the building renovation passports. A joint guidance document to be issued by the end of 2026 is recommended.	Building renovation passport schemes for energy efficiency to be implemented in all MS in 2026 with the EPBD. The Commission can leverage existing efforts to reduce CDW.	- Pre-demolition audits - Selective Demolition - Refundable advance discarding fee
Financial aid to preparing for reuse / recycling	MSs should assess their local and regional supply of and demand for CDW recycling to assess funding needs.	1. **Publicise** the need to improve reuse and recycling. 2. **Promote research** on advanced CDW recycling technologies and techniques. 3. **Provide access to relevant training**.	No change.	There is a recognised need for additional CDW recycling capacity. However, the CDW business model is heavily influenced by local demand (level of construction, rehabilitation, and demolition activity) and transport costs. The decisions about which regions have the highest need and are most hampered by market barriers are better analysed at the MS or regional level.	- Reuse and recycling targets - Minimum recycled content - GPP criteria
Tax on primary resources	MS, local, and regional authorities **should consider implementing taxes on primary materials** in line with the August 2024 guidelines, "Taxes (e.g. product levies	**Consider conducting research to inform a Commission view on whether a uniform and harmonised tax is possible and/or preferable** over the diverse landscape of inconsistent tax rates	Based on research outcomes, consider if a uniform and harmonised tax is more beneficial overall.	Tax on primary resources prices the cost to society of negative environmental externalities not normally included in the price of the primary production product.	- Landfill tax - Landfill ban - Aid to sustainable design - Recycled content targets

Measure	Targeted action at MS / local level	Recommendation for action at MS / local level in coordination with EU level	Next steps for policy preparation	Justification synopsis	Complementary or accompanying measures
	on aggregates, landfill taxes, incineration taxes)", considering possible inflationary effects.	and taxation strategies discussed herein.			
Standards and certifications for recycled materials	Promote consumers' and buyers' awareness and confidence towards secondary material quality.	1. **Initiate** promotional activities to raise awareness. 2. **Consider fostering the development of EN standards** on recycled materials quality for use in construction.	Contact relevant standardisation bodies that may work in synergy with European institutions (e.g. JRC), focusing on material characterisation and safety analyses.	Consultation with stakeholders within this and previous studies on CDW has highlighted that low confidence in recycled materials quality also constitutes a barrier for the formation of markets for secondary materials.	- Minimum recycled content - Preparing for reuse and recycling targets - EPR - GPP
Subsidise or operate CDW marketplaces (physical, digital, and networks)	MS should **consider financial aid for marketplaces** (physical or virtual). **Review the need for marketplaces** as part of waste prevention and waste management plans under WFD.	**Due to the local circumstances** upon which effective marketplaces depend, an **EU-wide mandate is not** currently **advisable**. However, **facilitating the operation of marketplaces across all EU** (e.g., via online platforms) could be a low-hanging fruit to smoothen the functioning of the internal market.	Consider facilitating their operations across EU.	Marketplaces successfully avoid waste to landfill by connecting buyers and sellers for reuse. Effectiveness depends on **local factors**.	- EoW criteria - DRS - EPR
Minimum recycled content targets	Set recycled content targets in GPP criteria and products (via the ESPR, CPR), or in EPR schemes through eco-modulation of EPR fees.	Continue current ESPR-, CPR- and GPP-related initiatives.	**Targets should be investigated** thoroughly along with their consequential market effects, to **ensure balancing supply and demand while avoiding unintended market signals**, such as the diversion to construction products of secondary material originally destined (or potentially better utilised) in other markets.	Recycled content targets could provide a demand pull-lever, instrumental to foster a market for secondary materials.	- Standards and certifications for recycled materials - Preparing for reuse and recycling targets - EPR (with eco-modulation for recycled content)

Source: Own elaboration.

References

Abedin Khan, Z., Balunaini, U., Costa, S., & Nguyen, N. H. T. (2024). A review on sustainable use of recycled construction and demolition waste aggregates in pavement base and subbase layers. *Cleaner Materials*, *13*(July), 100266. https://doi.org/10.1016/j.clema.2024.100266

Adams, K. T., Osmani, M., Thorpe, T., & Thornback, J. (2017). Circular economy in construction: Current awareness, challenges and enablers. *Proceedings of Institution of Civil Engineers: Waste and Resource Management*, *170*(1), 15–24. https://doi.org/10.1680/jwarm.16.00011

ADEME. (2019). *Caractérisation de la problématique des déchets sauvages - Compréhension de leur formation, description de leur gestion au niveau national, retours d'expérience*. https://librairie.ademe.fr/dechets-economie-circulaire/2278-caracterisation-de-la-problematique-des-dechets-sauvages.html

ADEME. (2021). *Produits et matériaux de construction du secteur du bâtiment (PMCB)*. https://filieres-rep.ademe.fr/filieres-REP/filiere-PMCB

Advanced Construction Technology Center. (2019). *Case studies of Advanced Construction and Demolition waste (CDW). Recycling initiatives and technologies In Japan* (Issue 37413, pp. 1–94).

Albizzati, P. F., Antonopoulos, I., Caro, D., Cristobal Garcia, J., Egle, L., Gaudillat, P., Manfredi, S., Marschinski, R., Martinez Turegano, D., Pierri, E., Saveyn, H., & Tonini, D. (2023). *Development of an EU harmonized model for separate waste collection and related policy support - Literature review.* (Issue May 2022). https://doi.org/10.2760/158073

Albizzati, P.F., Walker, A., Milios, L., Besler, M., Pinero Mira, P. et al., Environmental and Socio-Economic Impacts of the Circular Economy Transition in the EU Aluminium sector - Identification of Circular Economy levers and assessment of their impact with life cycle-based and macroeconomic models, Publications Office of the European Union, Luxembourg, 2025, https://data.europa.eu/doi/10.2760/5505344, JRC143128.

AMS. (2021). *Green Deal Timber Construction - Houtbouwmythes ontkracht (in Dutch)*. Amsterdam Institute for Advanced Metropolitan Solutions. https://www.ams-institute.org/news/signed-and-sealed-green-deal-timber-construction/

Andersen, R., Ravn, A. S., & Ryberg, M. W. (2022). Environmental benefits of applying selective demolition to buildings: A case study of the reuse of façade steel cladding. *Resources, Conservation and Recycling*, *184*(March), 106430. https://doi.org/10.1016/j.resconrec.2022.106430

Andersson, L. (2004). *Taxing Raw Materials - A qualitative study of the Swedish tax on natural gravel and the Danish tax on raw materials* [Lulea University of Technology]. https://www.diva-portal.org/smash/get/diva2:1019717/FULLTEXT01.pdf

Arnesano, F., Balossino, E., Di Somma, N., & Landini, C. (2019). *Holistic Innovative Solutions for an Efficient Recycling and Recovery of Valuable Raw Materials from Complex Construction and Demolition Waste - D 6 . 2 Report on Strategy and proposal for measures to be undertaken towards Standardization and Certificatio*. https://ec.europa.eu/research/participants/documents/downloadPublic?documentIds=080166e5c11e66bf&appId=PPGMS

Bao, Z., & Lu, W. (2020). Developing efficient circularity for construction and demolition waste management in fast emerging economies: Lessons learned from Shenzhen, China. *Science of the Total Environment*, *724*, 138264. https://doi.org/10.1016/j.scitotenv.2020.138264

Barth, S., & McKinnon, D. L. (2023). *Nordic Network for Circular Construction. Chapter 5 - Circular construction in the Nordic countries*. Nordic Council of Ministers. https://doi.org/http://dx.doi.org/10.6027/nord2023-031

Boddaert, S., Bonomo, P., Eder, G., Mikalsen, R. F., Ishii, H., Kim, J.-T., Ko, Y. J., Kovács, P., Li, T., Olano, X., Parolini, F., Qi, D., Shabunko, V., Slooff, R., Stølen, R., Valencia, D., Villa, S., Yang, R., Wilson, H. R., & Yang, R. (2023). *Fire safety of BIPV : International mapping of accredited and R&D facilities in the context of code and standards* (V. Shabunko & P. Kovács (eds.)). https://iea-pvps.org/

Brown, A., & Börkey, P. (2024). *Plastics recycled content requirements*. https://www.oecd.org/en/publications/plastics-recycled-content-requirements_b311ee60-en.html

Brown, A., Laubinger, F., & Börkey, P. (2023). *New Aspects of EPR: Extending producer responsibility to additional product groups and challenges throughout the product lifecycle. OECD Environment Working Paper No.225* (Issue 225). www.oecdilibrary.org

Caro, D., Lodato, C., Damgaard, A., Cristóbal, J., Foster, G., Flachenecker, F., & Tonini, D. (2024). Environmental and socio-economic effects of construction and demolition waste recycling in the European Union. *Science of the Total Environment*, *908*(October 2023). https://doi.org/10.1016/j.scitotenv.2023.168295

CEWEP. (2021). *Landfill Taxes and Restrictions Overview*. https://www.cewep.eu/landfill-taxes-and-restrictions/

Christensen, T. B., Johansen, M. R., Buchard, M. V., & Glarborg, C. N. (2022). Closing the material loops for construction and demolition waste: The circular economy on the island Bornholm, Denmark. *Resources, Conservation and Recycling Advances*, *15*(June), 200104. https://doi.org/10.1016/j.rcradv.2022.200104

CIB. (2000). Overview of Deconstruction in Selected Countries. In *CIB Report, Task Group 39* (Issue August, pp. 6–13). https://www.iip.kit.edu/downloads/CIBpublication252.pdf

Coelho, A., & Brito, J. (2010). Traditional vs selective demolition – comparative economic analysis applied to Portugal. *Sixteenth International Waste Management and Landfill Symposium Conference: Portugal SB10 - Sustainable Building Affordable to AllAt: Algarve, Portugal*, 699–712. https://doi.org/10.13140/RG.2.1.3509.8642

Cramer, J. (2021). The transition to sustainable concrete in the Netherlands through network governance. *IABSE Congress, Ghent 2021: Structural Engineering for Future Societal Needs*, 21–24. https://doi.org/10.2749/ghent.2021.0021

Cristóbal García, J., Caro, D., Foster, G., Pristerà, G., Gallo, F., & Tonini, D. (2024). *Techno-economic and environmental assessment of construction and demolition waste management in the European Union. Status quo and prospective potential*. Publications Office of the European Union. https://doi.org/10.2760/721895

Cristóbal, J., Pierri, E., Antonopoulos, I., Bruns, H., Foster, G., & Gaudillat, P. (2022). Separate collection of municipal waste: citizens' involvement and behavioural aspects. *Publications Office of the European Union*. https://doi.org/10.2760/665482

Damgaard, A., Lodato, C., Butera, S., Fruergaard Astrup, T., Kamps, M., Corbin, L., Tonini, D., & Astrup, T. F. (2022). *Background data collection and life cycle assessment for construction and demolition (CDW) waste management. May*. https://doi.org/10.2760/772724

Danish Government - Ministry of Environment of Denmark. (2021). Action Plan for Circular Economy - National Plan for Prevention and Management of Waste 2020-2032. In *MiljøMinisteriet*. https://ddrn.dk/wp-content/uploads/2024/01/alle-faktaark-1.pdf

Dodd, N., Donatello, S., & Cordella, M. (2021). Level(s) – A common EU framework of core sustainability indicators for office and residential buildings. *JRC Technical Report*, *January*, 25. https://susproc.jrc.ec.europa.eu/product-bureau/product-groups/412/documents

Donatello, S., Arcipowska, A., Perez, Z., & Ranea, A. (2022). *EU Green Public Procurement (GPP) criteria for the design, construction, renovation, demolition and management of buildings. Draft*

Technical Report (v1.0) (Issue February). https://doi.org/10.2760/XXXXX

Dutch Government – Ministry of Housing Spatial Planning and the Environment. (2004). *ENVIRONMENTAL MANAGEMENT ACT dated 1 May 2004*. https://www.asser.nl/upload/eel-webroot/www/documents/national/netherlands/EMA052004.pdf

Dutch Government - Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. (2016). *A Circular Economy in the Netherlands by 2050* (p. 72). https://circulareconomy.europa.eu/platform/sites/default/files/17037circulaireeconomie_en.pdf

Dutch Government – Ministry of Infrastructure and Water Management. (2017a). *Grondstoffenakkoord (Raw materials agreement)*. https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/documenten/rapporten/2017/01/24/grondstoffenakkoord-intentieovereenkomst-om-te-komen-tot-transitieagenda-s-voor-de-circulaire-economie

Dutch Government - Ministry of Infrastructure and Water Management. (2017b). *National Waste Management Plan*. https://rwsenvironment.eu/subjects/from-waste-resources/national-activities/national-waste/

Dutch Government - Ministry of Infrastructure and Water Management. (2023). *National Circular Economy Programme 2023 - 2030*. file:///C:/Users/crisjor/Downloads/NPCE+Circulaire+Economie+rapport+Engels.pdf

Dutch Government – Ministry of the Interior and Kingdom Relations. (2021). *The Environment Buildings Decree of the Netherlands* (Issue December).

EEA. (2016a). Environmental taxation and EU environmental policies. In *EEA Report No 17/2016* (Issue 17). https://www.eea.europa.eu/publications/environmental-taxation-and-eu-environmental-policies

EEA. (2016b). *Overview of national waste prevention programmes in Europe: Belgium - Flanders* (Issue October). https://doi.org/10.1787/9789264252639-9-en

EEA. (2020). Construction and Demolition Waste : challenges and opportunities in a circular economy. In *Briefing no. 14/2019* (Issue January, p. 8). https://www.eea.europa.eu/publications/construction-and-demolition-waste-challenges/at_download/file

EEA. (2022a). *Early warning assessment related to the 2025 targets for municipal waste and packaging waste - Country profile Cyprus* (Issue June). https://www.eea.europa.eu/publications/many-eu-member-states/early-warning-assessment-related-to

EEA. (2022b). *Investigating Europe's Secondary Raw Material Markets* (Issue 12). Publications Office of the European Union. https://doi.org/10.2800/48962

EEA. (2023a). *Economic instruments and separate collection systems - key strategies to increase recycling*. https://doi.org/10.2800/05314

EEA. (2023b). *Waste prevention country profile: Denmark*. *April*. https://www.eea.europa.eu/en/countries/eea-member-countries/denmark?size=n_10_n&filters%5B0%5D%5Bfield%5D=spatial&filters%5B0%5D%5Btype%5D=any&filters%5B0%5D%5Bvalues%5D%5B0%5D=Denmark&filters%5B1%5D%5Bfield%5D=objectProvides&filters%5B1%5D%5Btype%5D=any&

Ernst & Young, Guidance for separate collection of municipal waste. Report prepared for the European Commission by EY, PlanMiljØ, ACR+, RWA and Öko-Institut, 2020.

Ettlinger, S. (2017). *Aggregates Levy in the United Kingdom* (pp. 1–9). Institute for European Environmental Policy. https://ieep.eu/uploads/articles/attachments/5337d500-9960-473f-8a90-3c59c5c81917/UK Aggregates Levy final.pdf?v=63680923242

Eunomia, & European Environmental Bureau. (2022). *Circular Taxation - A policy approach to reduce resource use and accelerate the transition to a circular economy* (Issue November). https://eeb.org/wp-content/uploads/2022/11/Circular-Taxation-study-EEB-Final-Report.pdf

European Commission. (2011). Commission Decision of 18 November 2011 establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council. In *Official Journal of the European Union* (Vol. 310). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011D0753&from=EN

European Commission. (2016a). *COMMISSION STAFF WORKING DOCUMENT: EU GPP Criteria for Office Building Design, Construction and Management. Brussels, 20.5.2016 SWD(2016) 180 final* (p. 43). http://ec.europa.eu/environment/gpp/pdf/swd_2016_180.pdf

European Commission. (2016b). *Technical and Economic Study with regard to the Development of Specific Tools and/or Guidelines for Assessment of Construction and Demolition Waste Streams prior to Demolition or Renovation of Buildings and Infrastructures. Specific Contract 30-CE-0751644. December*.

European Commission. (2017). *Resource Efficient Use of Mixed Wastes - Improving management of construction and demolition waste. Final Report* (Issue October). https://doi.org/doi:10.2779/99903

European Commission. (2018a). *Development and implementation of initiatives fostering investment and innovation in construction and demolition waste recycling infrastructure*. https://op.europa.eu/en/publication-detail/-/publication/3637d9db-1c3e-11e8-ac73-01aa75ed71a1/language-en/format-PDF/source-116393861

European Commission. (2018b). *Guidelines for the waste audits before demolition and renovation works of buildings*. https://ec.europa.eu/docsroom/documents/31521/

European Commission. (2019). *European Construction Sector Observatory. EU construction sector: in transition towards a circular economy*. *April*, 27.

European Commission. (2020). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - A Renovation Wave for Europe - greening our buildings, creating jobs, improving lives. COM(2020) 662 f. In *Official Journal of the European Union* (p. 26). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0662

European Commission. (2021). *Green Taxation and Other Economic Instruments: Internalising Environmental Costs to Make the Polluter Pay* (Issue September). https://environment.ec.europa.eu/economy-and-finance/ensuring-polluters-pay_en

European Commission. (2023a). *'Better regulation' toolbox - July 2023 edition* (p. 612). https://commission.europa.eu/law/law-making-process/planning-and-proposing-law/better-regulation/better-regulation-guidelines-and-toolbox_en

European Commission. (2023b). *Report from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions identifying Member States at risk of not meeting the 2025 preparing for re-use and recycling target for municip* (Issue COM(2023) 304 final). https://eur-lex.europa.eu/legal-content/en/ALL/?uri=celex%3A31994L0062

European Commission. (2023c). *The Taxonomy Environmental Delegated Act C(2023) 3851 final specifying the technical screening criteria, Annex 2* (pp. 5–24).

European Union. (2011). Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC. In *Official Journal of European Union*. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0305

European Union. (2024a). *Directive (EU) 2024/1275 of the European Parliament and of the Council of 24 April 2024 on the energy performance of buildings* (Vol. 1275, pp. 1–68). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021DC0550&from=EN

European Union. (2024b). *Regulation (EU) 2024/1781 of the European Parliament and of the Council of 13 June 2024 establishing a framework for the setting of ecodesign requirements for sustainable products, amending Directive (EU) 2020/1828 and Regulation (EU) 2023/1542 and repeal* (Issue Junio). Official Journal of the European Union. http://data.europa.eu/eli/reg/2024/1781/oj

Eurostat. (2023a). *Statistics explained. Waste statistics*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics#Total_waste_generation

Eurostat. (2023b). *Waste generation, excluding major mineral waste, EU, 2004-2020 (million tonnes)*. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Waste_generation,_excluding_major_mineral_waste,_EU,_2004-2020_(million_tonnes)_25-05-2023.png

FCRBE Project. (2019). *Review of existing pre-demolition tools , policies , resources for identifying , quantifying and organizing the reclamation of reusable elements. WPT2 / Action 1 / D.1.1*. https://vb.nweurope.eu/projects/project-search/fcrbe-facilitating-the-circulation-of-reclaimed-building-elements-in-northwestern-europe/

FOES. (n.d.). *Lithuania ecotax rates*. https://foes.de/pdf/Lithuania Ecotax Rates.pdf

Foster, G. (2020). Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts. *Resources, Conservation and Recycling*, *152*(October 2019), 104507. https://doi.org/10.1016/j.resconrec.2019.104507

Foster, G., Kreinin, H., & Stagl, S. (2020). The future of circular environmental impact indicators for cultural heritage buildings in Europe. *Environmental Sciences Europe*, *32*(1). https://doi.org/10.1186/s12302-020-00411-9

Gálvez-Martos, J. L., Styles, D., Schoenberger, H., & Zeschmar-Lahl, B. (2018). Construction and demolition waste best management practice in Europe. *Resources, Conservation and Recycling*, *136*(December 2017), 166–178. https://doi.org/10.1016/j.resconrec.2018.04.016

Ghisellini, P., Passaro, R., & Ulgiati, S. (2022). The Role of Product Certification in the Transition towards the Circular Economy for the Construction Sector. *Key Engineering Materials*. https://www.scientific.net/KEM.919.248

Giorgi, S., Lavagna, M., Wang, K., Osmani, M., Liu, G., & Campioli, A. (2022). Drivers and barriers towards circular economy in the building sector: Stakeholder interviews and analysis of five european countries policies and practices. *Journal of Cleaner Production*, *336*(April 2021), 130395. https://doi.org/10.1016/j.jclepro.2022.130395

Gouvernement de la Région de Bruxelles-Capitale. (2016). *Programme régional en économie circulaire 2016-2020*. 1–69. http://document.environnement.brussels/opac_css/elecfile/PROG_160308_PREC_DEF_FR

Han, Y., Zheng, H., Huang, Y., & Li, X. (2022). Considering Consumers' Green Preferences and Government Subsidies in the Decision Making of the Construction and Demolition Waste Recycling Supply Chain: A Stackelberg Game Approach. *Buildings*, *12*(6). https://doi.org/10.3390/buildings12060832

Henrotay, C., Steinlage-Cornet, M., Debakcer, W., Peeters, K., Apelman, L., Quintas, A., & Sharp, J. (2016). *State of the art report on policies and standards*. https://www.bamb2020.eu/wp-content/uploads/2019/02/State-of-the-art-report-on-Policies-and-Standards_V2.pdf

Honic, M., Kovacic, I., Aschenbrenner, P., & Ragossnig, A. (2021). Material Passports for the end-of-life stage of buildings: Challenges and potentials. *Journal of Cleaner Production*, *319*(December 2020), 128702. https://doi.org/10.1016/j.jclepro.2021.128702

ICCT. (2021). *European Vehicle Market Statistics. Poketbook 2021/22*. International Council on clean transportation Europe.

Iodice, S., Garbarino, E., Cerreta, M., & Tonini, D. (2021). Sustainability assessment of Construction and Demolition Waste management applied to an Italian case. *Waste Management*, *128*(2021), 83–98. https://doi.org/10.1016/j.wasman.2021.04.031

Iraldo, F., Griesshammer, R., & Kahlenborn, W. (2020). The future of ecolabels. *International Journal of Life Cycle Assessment*, *25*(5), 833–839. https://doi.org/10.1007/s11367-020-01741-9

Jenet, A., Lamperti Tornaghi, M., Tsionis, G., Sejerse, A., Moseley, P., De La Fuente Nuno, A., Wrobel, M., Hobbs, G., Guldager Jensen, K., Chevauche, C., Levy, M. H., Osset, P., Denton, S., Ottosen, L., Lynch, J., Lewis, M., Fuchs, M., Mian, L., Maurer, P., & Taucer, F. (2024). *Circular technologies in construction. Putting science into standards.* https://doi.org/10.2760/600209

Jenkins, R., & Maguire, K. (2009). *State Hazardous and Solid Waste Taxes: Understanding Their Variability* (Issue Working Paper 09-01). http://www.epa.gov/economics

Jevrić, M., & Ćipranić, I. (2023). Raising public awareness of waste management. *Circular Economy Implementation for Sustainability in the Built Environment*, 139–158. https://doi.org/10.4018/978-1-6684-8238-4.ch006

Johansson, O. (2023). The End-of-Waste for the Transition to Circular Economy: A Legal Review of the European Union Waste Framework Directive. *Environmental Policy and Law*, *53*(2–3), 167–179. https://doi.org/10.3233/EPL-220064

Joint Research Centre. (2011). *Supporting Environmentally Sound Decisions for Construction and Demolition (C&D) Waste Management: Vol. EUR 24918* (S. Manfredi & R. Pant (eds.)). Publications Office of the European Union. https://doi.org/10.2788/54618

Katsumi, T., Gathuka, L. W., Endo, K., Inui, T., Takai, A., & Kamon, M. (2021). Selected Geotechnical and Geoenvironmental Aspects of Landfills in Japan. *Journal of the Indian Institute of Science*, *101*(4), 589–602. https://doi.org/10.1007/s41745-021-00231-7

Keramidas, K., Fosse, F., Diaz, R. A., Dowling, P., Garaffa, R., Oronez, J., Russ, P., Schade, B., Schmitz, A., Soria Ramirez, A., Van Der Vorst, C., & Weitzel, M. (2023). *Global Energy and Climate Outlook 2023*. https://doi.org/10.2760/836798

Laubinger, F., Brown, A., Dubois, M., & Börkey, P. (2021). *Modulated fees for extended producer responsibility schemes (EPR). Environment Working Paper No. 184* (Issue October). OECD. www.oecdilibrary.org

Lauritzen, E. K. (2022). *CityLoops guide for selective demolition. CityLoops WP2 CDW/Soil*. https://cityloops.eu/fileadmin/user_upload/Materials/Tools/CityLoops_guide_for_selective_demolition.pdf

Legg, D., Leveson-Gower, H., Zoboli, R., Herczeg, M., Bahn-Walkowiak, B., Bleischwitz, R., Mazzanti, M., Skovgaard, M., & Dige, G. (2008). *Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries* (Issue 2). EEA.

Liu, Y., Kong, F., & Santibanez Gonzalez, E. D. R. (2017). Dumping, waste management and ecological security: Evidence from England. *Journal of Cleaner Production*, *167*, 1425–1437. https://doi.org/10.1016/j.jclepro.2016.12.097

LNE. (2015). *Mineral Resources in Flanders*. 24. https://www.vlaanderen.be/publicaties/mineral-resources-in-flanders-the-flemish-policy

Luciano, A., Cutaia, L., Altamura, P., & Penalvo, E. (2022). Critical issues hindering a widespread construction and demolition waste (CDW) recycling practice in EU countries and actions to undertake: The stakeholder's perspective. *Sustainable Chemistry and Pharmacy*, *29*(June), 100745. https://doi.org/10.1016/j.scp.2022.100745

Lyon, T. P., & Maxwell, J. W. (2016). Corporate Social Responsibility and the Environment: A Theoretical Perspective. *Reveiw of Environmental Economics and Policy*, *19*(5), 1–23.

Ma, M., Tam, V. W. Y., Le, K. N., Butera, A., Li, W., & Wang, X. (2023). Comparative Analysis on International Construction and Demolition Waste Management Policies and Laws for Policy Makers in China. *Journal of Civil Engineering and Management*, *29*(2), 107–130. https://doi.org/10.3846/jcem.2023.16581

Ma, M., Tam, V. W. Y., Le, K. N., Zhu, Y., & Li, W. (2021). Comparative Analysis of National Policies on Construction and Demolition Waste Management in China and Japan. In G. Ye, H. Yuan, & J. Zuo (Eds.), *Proceedings of the 24th International Symposium on Advancement of Construction Management and Real Estate* (pp. 1363–1376). Springer Nature Singapore Pte Ltd. https://doi.org/10.1007/978-981-15-8892-1_95

Milios, L. (2021). Towards a Circular Economy Taxation Framework: Expectations and Challenges of Implementation. *Circular Economy and Sustainability*, *1*(2), 477–498. https://doi.org/10.1007/s43615-020-00002-z

Ministère de la Transition écologique. (2022). Décret no 2021-1941 du 31 décembre 2021 relatif à la responsabilité élargiedes producteurs pour les produits et les matériaux de construction du secteur du bâtiment. *Journal Officiel de La République Française*. https://www.legifrance.gouv.fr

Ministry of the Environment. (2016). *Introduction to Green Purchasing Legislation in Japan*. *March*, 1–34. https://www.env.go.jp/policy/hozen/green/kokusai_platform/2015report/handbook_eng.pdf

MLIT. (2019). *White paper on land, infrastructure, transport and tourism in Japan* (p. 250).

Monier, V., Mudgal, S., Hestin, M., Trarieux, M., & Mimid, S. (2011). Service contract on management of construction and demolition waste - SR1. In *Final report task 2 - A project under the Framework contrat ENV-G-4/FRA/2008/0112*. https://environment.ec.europa.eu/document/download/22239ead-82d4-42fb-86dc-d202d5f40507_en?filename=2011_CDW_Report_0.pdf

Nordic Council of Ministers. (2014). *Reuse, recycling and recovery of construction and demolition waste in the Nordic countries*. http://www.diva-portal.org/smash/get/diva2:1827748/FULLTEXT01.pdf

Northeast Recycling Council. (2017). *Disposal Bans & Mandatory Recycling in the United States*. https://nerc.org/documents/disposal_bans_mandatory_recycling_united_states.pdf

Nuno Pacheco, J., de Brito, J., Lamperti Tornaghi, M., & European Commission. Joint Research Centre. (2023). *Use of recycled aggregates in concrete: opportunities for upscaling in Europe.* https://doi.org/10.2760/144802

Oberender, A., Astrup, T. F., Witte, S. F., Camboni, M., Chiabrando, F., Hayleck, M., & Akelyte, R. (2024). *EU Construction & Demolition Waste Management Protocol including guidelines for pre-demolition and pre-renovation audits of construction works*. Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/d63d5a8f-64e8-11ef-a8ba-01aa75ed71a1/language-en

OECD. (2004). *Addressing the Economics of Waste - Chapter 7: Efficient targeting of waste policies in the product chain, by Richard C. Porter, OECD (Paris)*. https://doi.org/10.1787/9789264106192-2-en

OECD. (2010). Environmental Performance Reviews: Japan. In *OECD Environmental Performance Reviews*. https://app.dimensions.ai/details/publication/pub.1107172332

OECD. (2012). *Environmental Performance Reviews: Slovenia*. https://www.oecd.org/publications/oecd-environmental-performance-reviews-slovenia-2012-9789264169265-en.htm

OECD. (2014). *Environmental Performance Reviews: Sweden*. https://www.oecd.org/environment/country-reviews/oecd-environmental-performance-reviews-sweden-2014-9789264213715-en.htm

OECD. (2015). *Environmental Performance Reviews: Poland 2015*. https://www.oecd.org/en/publications/2015/04/oecd-environmental-performance-reviews-poland-2015_g1g4eb89.html

OECD. (2016a). Extended Producer Responsibility: Updated Guidance for Efficient Waste Management. In *OECD Publishing Paris*. http://search.ebscohost.com/login.aspx?direct=true%7B&%7Ddb=bth%7B&%7DAN=930867%7B&%7Dsite=ehost-live

OECD. (2016b). *Green public procurement in the Netherlands*. 2–4. https://www.oecd.org/governance/procurement/toolbox/search/green-public-procurement-netherlands.pdf

OECD. (2017). *Environmental Performance Reviews: Estonia*. https://doi.org/10.1016/s1352-0237(00)00200-8

OECD. (2018). *Environmental Performance Reviews: Hungary*. https://www.oecd.org/publications/hungary-2018-9789264298613-en.htm

OECD. (2019). Waste Management and the Circular Economy in Selected OECD Countries: Evidence from Environmental Performance Reviews. In *OECD Publishing*. https://doi.org/https://doi.org/10.1787/9789264309395-en

OECD. (2022). *Environmental Performance Reviews: United kingdom*.

OECD. (2024). *Economic Instruments for the Circular Economy in Italy: Opportunities for reform*.

Oliveira Neto, R., Gastineau, P., Cazacliu, B. G., Le Guen, L., Paranhos, R. S., & Petter, C. O. (2017). An economic analysis of the processing technologies in CDW recycling platforms. *Waste Management*, *60*(2017), 277–289. https://doi.org/10.1016/j.wasman.2016.08.011

Orveillon, G., Pierri, E., Egle, L., Gerbendahl, A., Wessman, P., Garcia, J. E., & Saveyn, H. G. M. (2022). *Scoping possible further EU-wide end-of-waste and by-product criteria.* (Issue March). https://doi.org/10.2760/067213

Pacheco, J., de Brito, J., & Lamperti Tornaghi, M. (2023). *Use of recycled aggregates in concrete - Opportunities for upscaling in Europe*.

Porter, R. C. (2002). *The economics of Waste*. RFF Press.

Potting, J., Hekkert, M., Worrell, E., & Hanemaaijer, A. (2017). Circular Economy: Measuring innovation in the product chain - Policy report. In *PBL Netherlands Environmental Assessment Agency* (Issue January). https://www.pbl.nl/uploads/default/downloads/pbl-2016-circular-economy-measuring-innovation-in-product-chains-2544.pdf

Pretner, G., Darnall, N., Testa, F., & Iraldo, F. (2021). Are consumers willing to pay for circular products? The role of recycled and second-hand attributes, messaging, and third-party certification. *Resources, Conservation and Recycling*, *175*(March), 105888. https://doi.org/10.1016/j.resconrec.2021.105888

Pristerà, G., Tonini, D., Lamperti Tornaghi, M., Caro, D., & Sala, S. (2024a). Taxonomy of design for deconstruction options to enable circular economy in buildings. *Resources, Environment and Sustainability*, *15*(November 2023), 100153. https://doi.org/10.1016/j.resenv.2024.100153

Pristerà, G., Tonini, D., Lamperti Tornaghi, M., Caro, D., & Sala, S. (2024b). Taxonomy of design for deconstruction options to enable circular economy in buildings. *Resources, Environment and Sustainability*, *15*(January), 100153. https://doi.org/10.1016/j.resenv.2024.100153

Quiñones, R., Llatas, C., Montes, M. V., & Cortes, I. (2021). Rehabilitation vs Demolition Methodology to Compare the Waste Generated in Alternative Scenarios of Building Elements in BIM During the Design Stage. In A. Rotaru (Ed.), *Springer Series in Geomechanics and Geoengineering* (CRIT-RE-BU). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-61118-7_22

Ramírez de Arellano Agudo, A., & Solís-Guzmán, J. (2006). Sistema de cuantificación de residuos de construcción en la Mancomunidad de Los Alcores. *Contart 2006*, 1–13.

Ramos, M., & Martinho, G. (2023). An assessment of the illegal dumping of construction and demolition waste. *Cleaner Waste Systems*, *4*(November 2022), 100073. https://doi.org/10.1016/j.clwas.2022.100073

Ramos, M., Martinho, G., & Pina, J. (2023). Strategies to promote construction and demolition waste management in the context of local dynamics. *Waste Management*, *162*(November 2022), 102–112. https://doi.org/10.1016/j.wasman.2023.02.028

Ranea Palma, A., Gonzalez Torres, M., Perez Arribas, Z., & Donatello, S. (2024). *Background report for the revision of EU Green Public Procurement criteria for Buildings*. https://doi.org/10.2760/3484975

RE4 Project. (2017a). *Data collection on CDW - D1.1*. http://www.re4.eu/data-collection-on-cdw

RE4 Project. (2017b). *Use of economic instruments and waste management performances - D8.5*. http://www.re4.eu/documents/deliverables

Reetsch, A., Tessien, J., Schröder, N., van t Zelfde, J., Ooms, J., van Bruggen, R., Lundberg, P., & Zamparutti, T. (2024). *Background Data Collection for Future EU End-of-Waste Criteria of Construction and Demolition Waste – GROW/2022/OP/0015. Deliverable 3 'Final Report on background data and information collected (Task 3).* (Issue July). Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/89a1cfe5-60fd-11ef-a8ba-01aa75ed71a1/language-en/format-PDF/source-342944209

Republic of Cyprus. (2012). *Royalites on mines and quarries*. https://www.moa.gov.cy/moa/mines/minesSrv.nsf/dmllegmining_en/dmllegmining_en?OpenDocument#

République Française. (2020). *General Tax on Polluting Activities*. https://entreprendre.service-public.fr/vosdroits/F23497?lang=en

Sakai, S. ichi, Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M. V., Wejchert, J., Schmid-Unterseh, T., Douvan, A. R., Hathaway, R., Hylander, L. D., Fischer, C., Oh, G. J., Jinhui, L., & Chi, N. K. (2011). International comparative study of 3R and waste management policy developments. *Journal of Material Cycles and Waste Management*, *13*(2), 86–102. https://doi.org/10.1007/s10163-011-0009-x

Sanders, T. (2015). *Permits in the Netherlands: an introduction for foreign Legal Counsel*. akd benelux law firm. https://akd.eu/insights/permits-in-the-netherlands-an-introduction-for-foreign-legal-counsel

Sasao, T. (2014). Does industrial waste taxation contribute to reduction of landfilled waste? Dynamic panel analysis considering industrial waste category in Japan. *Waste Management*, *34*(11), 2239–2250. https://doi.org/10.1016/j.wasman.2014.07.014

Scharff, H. (2014). Landfill reduction experience in The Netherlands. *Waste Management*, *34*(11), 2218–2224. https://doi.org/10.1016/j.wasman.2014.05.019

Schmid, M. (2021). The Revised German Raw Materials Strategy in the Light of Global Political and Market Developments. *Review of Policy Research*, *38*(1), 49–75. https://doi.org/10.1111/ropr.12408

Sharp, J., Bre, G. H., Henrotay, C., Steinlage, M., & Sjögren, C. (2019). *Framework for policies, regulations and standards*. https://www.bamb2020.eu/wp-content/uploads/2019/07/BAMB-Framework-for-Policies-Regulations-and-Standards-web.pdf

Shooshtarian, S., Maqsood, T., Wong, P. S. P., Zaman, A., Caldera, S., & Ryley, T. (2024). Utilisation of certification schemes for recycled products in the Australian building and construction sector. *Business Strategy and the Environment*, *33*(3), 1759–1777. https://doi.org/10.1002/bse.3568

Silva, R. V., de Brito, J., & Dhir, R. K. (2017). Availability and processing of recycled aggregates within the construction and demolition supply chain: A review. *Journal of Cleaner Production*, *143*, 598–614. https://doi.org/10.1016/j.jclepro.2016.12.070

Söderholm, P. (2011). Taxing virgin natural resources: Lessons from aggregates taxation in Europe. *Resources, Conservation and Recycling*, *55*(11), 911–922. https://doi.org/10.1016/j.resconrec.2011.05.011

Solís-Guzmán, J., Marrero, M., Montes-Delgado, M. V., & Ramírez-de-Arellano, A. (2009). A Spanish model for quantification and management of construction waste. *Waste Management*, *29*(9), 2542–2548. https://doi.org/10.1016/j.wasman.2009.05.009

Sönmez, N., & Kalfa, S. M. (2023). Investigation of Construction and Demolition Wastes in the European Union Member States According to their Directives. *Contemporary Journal of Economics and Finance*, *2*(1), 7–26.

Spanish Government – Ministry of the Agriculture Food and Environment. (2015). *Spanish National Framework Waste Management Plan 2016-2022* (pp. 1–182). https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/planes-y-estrategias/Planes-y-Programas.aspx

Spanish Government – Ministry of the Presidency. (2008). *Real Decreto 105/2008, de 1 de Febrero, por el que se Regula la Producción y Gestión de los Residuos de Construcción y Demolición (National Decree 105/2008, February 1, which Regulates the Production and Management of Construction and Demolition Waste).*

Spišáková, M., Mésároš, P., & Mandičák, T. (2021). Construction waste audit in the framework of sustainable waste management in construction projects—case study. *Buildings*, *11*(2), 1–16. https://doi.org/10.3390/buildings11020061

Sumikura, Y., & Katsumi, T. (2022). Material reuse and recycling in construction works in Japan. *Journal of Material Cycles and Waste Management*, *24*(4), 1216–1227. https://doi.org/10.1007/s10163-022-01411-y

Tanikawa, H., Fishman, T., Hashimoto, S., Daigo, I., Oguchi, M., Miatto, A., Takagi, S., Yamashita, N., & Schandl, H. (2021). A framework of indicators for associating material stocks and flows to service provisioning: Application for Japan 1990–2015. *Journal of Cleaner Production*, *285*, 125450. https://doi.org/10.1016/j.jclepro.2020.125450

Taukačs, J., Oksenuka, A., & Vulfa, E. (2018). *Tax Guide: Latvia*. https://www.sorainen.com/UserFiles/File/Publications/tax-Guide-Latvia.2018-08-01..pdf

The World Bank. (2022). *Squaring the Circle - Policies from Europe's Circular Economy Transition*. World Bank Publications. https://www.worldbank.org/en/region/eca/publication/squaring-circle-europe-circular-economy-transition

Thomas Saaty. (2013). Analytic hierarchy process. In *Encyclopedia of operations research and management science.* (pp. 52–64). Springer.

Tošić, N., Marinković, S., Dašić, T., & Stanić, M. (2015). Multicriteria optimization of natural and recycled aggregate concrete for structural use. *Journal of Cleaner Production*, *87*(1), 766–776. https://doi.org/10.1016/j.jclepro.2014.10.070

Tost, M., & Ammerer, G. (2022). *Sustainable Supply of Aggregates in Europe (Final Report 12/2022)*. https://uepg.eu/mediatheque/index/1.html

Transition Agenda Circular Economy. (2018). *Circular Construction Economy*. 1–38. https://hollandcircularhotspot.nl/wp-content/uploads/2019/09/Circular-Construction-

Economy.pdf

U.S. Government. (2015). *Executive Order 13693-Planning for Federal Sustainability in the Next Decade* (Vol. 4, pp. 1–16).

Ukkonen, A., & Sahimaa, O. (2021). Weight-based pay-as-you-throw pricing model: Encouraging sorting in households through waste fees. *Waste Management*, *135*(September), 372–380. https://doi.org/10.1016/j.wasman.2021.09.011

UN. (n.d.). *National Reports on Mining: Bulgaria*. https://sustainabledevelopment.un.org/content/documents/dsd/dsd_aofw_ni/ni_pdfs/NationalReports/bulgaria/MINING.pdf

USEPA. (2017). *The State of the Practice of Construction and Demolition Material Recovery. Final Report* (Issue May).

Villoria Sáez, P., & Osmani, M. (2019). A diagnosis of construction and demolition waste generation and recovery practice in the European Union. *Journal of Cleaner Production*, *241*. https://doi.org/10.1016/j.jclepro.2019.118400

Volt, J., Fabbri, M., & Wouters, P. (2020). *Technical study on the possible introduction of optional building renovation passports: final report.* http://op.europa.eu/en/publication-detail/-/publication/a38ea088-aead-11ea-bb7a-01aa75ed71a1/language-en%0Ahttp://files/1432/language-en.html

Wahlström, M., zu Castell-Rudenhausen, M., Hradil, P., Hauge Smith, K., Oberander, A., Ahlm, M., Gotbring, J., & Hansen, J. B. (2019). *Improving quality of construction and demolition waste - Requirements for pre-demolition audit*.

Walker, A., Albizzati, P. F., Milios, L., Pinero Mira, P., Christis, M., Besler, M., Pedauga, L., & Tonini, D. (2025a). *Environmental and Socio-Economic Impacts of the Circular Economy Transition in the EU Cement and Concrete Sector*. Publications Office of the European Union. https://publications.jrc.ec.europa.eu/repository/handle/JRC143126

Walker, A., Albizzati, P. F., Milios, L., Pinero, P., Besler, M., Pedauga, L. E., Eder, P., & Tonini, D. (2025b). *Capturing the Potential of the Circular Economy Transition in Energy-Intensive Industries*. https://publications.jrc.ec.europa.eu/repository/handle/JRC142938

Watkins, E., Romagnoli, V., Kirhensteine, I., Ruckley, F., Mitsios, A., Pantzar, M., Saveyn, H., & Garbarino, E. (2020). *Support to the Circular Plastics Alliance in establishing a work plan to develop guidelines and standards on design-for- recycling of plastic products* (Issue November). https://doi.org/10.2760/936397

Welsh Government. (2015). *Towards Zero Waste 2010-2050. Progress report* (Issue July). https://www.gov.wales/sites/default/files/publications/2019-05/towards-zero-waste-progress-report-july-2015.pdf

Yu, A. T. W., Wong, I., & Mok, K. S. H. (2021). Effectiveness and barriers of Pre-refurbishment Auditing for refurbishment and renovation waste management. *Environmental Challenges*, *5*(July), 100231. https://doi.org/10.1016/j.envc.2021.100231

List of abbreviations and definitions

ADF	Advance Discarding Fee
BAMB	Buildings as Material Banks
BPM	Building Products and Materials
CAS	Civic Amenities Sites
CDW	Construction and Demolition Waste
CEN	EU Committee for Standardisation
CENELEC	EU Committee for Electrotechnical Standardisation
DRS	Deposit-Refund System
ECI	Environmental Cost Indicator
EEA	European Environment Agency
ELCC	Environmental Life Cycle Costing
EoW	End of Waste
EPA	Environmental Protection Agency
EPR	Extended Producer Responsibility
EPS	Expanded Polystyrene
EWWR	European Week for Waste Reduction
FELCC	Full Environmental Life Cycle Costing
FU	Functional Unit
GHG	Greenhouse Gas
GPP	Green Public Procurement
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MACC	Marginal Abatement Cost Curves
MEC	Minimum Environmental Criteria
MS	Member State
MSs	Member States
MSW	Municipal Solid Waste
OECD	Organisation for Economic Co-operation and Development
PAYT	Pay-As-You-Throw
PRO	Producer Responsibility Organization
PVC	Polyvinylchloride
RA	Recycled Aggregates
SMART	Specific, Measurable, Achievable, Realistic, and Time-bound
SRM	Secondary Raw Material
SWCP	Selective Waste Collection Point
USEPA	U.S. Environmental Protection Agency

WFD	Waste Framework Directive
WMF	Waste Management Fee

Definitions

Unless otherwise specified, the nomenclature applying to waste is used in the sense defined in the Waste Framework Directive and related EU waste legislation. For clarity and convenience, a few terms are additionally defined or specified below:

Backfilling	is defined in Art. 3(17a) as "any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes."
Discarding	refers to the action of a waste producer delivering the waste to further waste management (e.g., transport, sorting, recycling, other recovery, disposal).
Discarding fee	fee applied to the waste producer (waste generator or waste holder) who discards waste. This term is used to distinguish it from the more specific *disposal* fee, meant as a fee applied specifically when the waste is discarded in landfill (or incineration).
Disposal	is used in the sense of WFD (Directive 2008/98/EC, Art. 3(19) and Annex I) but more concretely here generally refers to landfilling and occasionally, incineration.
Material recovery	is defined in Art. 3(15a) of Directive 98/2008/EC as "any recovery operation, other than energy recovery and the reprocessing into materials that are to be used as fuels or other means to generate energy. It includes, inter alia, preparing for re-use, recycling and backfilling".
Preparing for re-use	means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing" (Directive 2008/98/EC, Art. 3(16)).
Recycling	means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It (…) does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations" (Directive 2008/98/EC, Art. 3(17)).
Waste treatment	means recovery and disposal of waste, as per Directive 2008/98/EC, Art. 3(14)
Waste generator	means an original waste producer in the sense of the WFD (Directive 2008/98/EC, Art. 3(5))
Waste management	means the collection, transport, recovery (including sorting) and disposal of waste, as per Directive 2008/98/EC, Art. 3(9)

Waste Management Fee means a fee incurred to cover some or all the costs of waste management.

Regarding the specific terms used or introduced in relation to WMFs, the following diagram illustrates the distinctions between the different kinds of waste management fees (WMFs):

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Annexes

Annex 1. CDW problem analysis (detailed version)

Table A1. Detailed analysis of CDW problem including problem drivers, potential intervention, policy measures and target stakeholders.

	Problem tree				**Solution space**		
	Sub-problem	**Problem driver level 1**	**Problem driver level 2**	**Problem driver level 3**	**Potential intervention**	**Potential policy measure / instrument**	**Target stakeholder**
CDW problem	Insufficiently circular outcomes (CDW treatment too low in waste hierarchy)	CDW value too low (for some streams)	primary materials are cheap	negative externalities not priced in	raw materials price signal (tax/fee)	tax on raw material use / extraction	M
					construction material price signal	tax modulation on primary material content	M
						EPR fee on primary material content	
			secondary materials expensive	materials/buildings not designed for disassembly	mandatory requirements on design for disassembly	building permit conditionality	A
					mandatory requirements on design for recycling	building permit conditionality	
						enforcement measures	
				deconstruction is labour intensive	increase know-how in deconstruction	awareness raising programmes	B/D
						tax breaks on training	B/D
						training programmes (industry / govt run)	B/D/G
					separate collection incentive	differentiated discarding fee (EPR)	D
						differentiated landfill fee	D

					mandatory selective demolition	mandatory pre-demolition audit	D
						ban on mixed CDW disposal / landfill ban	
				lack of info on building composition	mandatory information provision	building passport / BIM / logbook: subsidy / tax break	B
						land registry data expansion	C
						mandatory pre-demolition audit	
				positive externalities not priced in	Secondary raw materials / recycled products incentive	tax break on products containing recycled material	M
						EPR fee eco-modulation on recycled material	M
						EPR fee eco-modulation for reused products	M
			transport costs are prohibitive	distances are too long	development of tight recovery network	public discarding site network	G
						funding of private discarding sites by EPR	R
						Operate CDW marketplace	
						Subsidise CDW marketplace	
		Waste hierarchy not respected	proper disposal not enforced	dumping is economically attractive	enforcement measures	increase penalties/sentences for illegal dumping (environmental crimes)	D/C
					increase attractiveness of proper disposal	separate collection incentive (disposal fees)	D
						monitoring / pre-emptive fee ("DRS") for C/D site	D/C
						EPR cross subsidy to offer separated material collection for free	D/C
			recovery preferred to preparing for reuse and recycle	backfilling is economically atractive	increase attractiveness of recycling and reuse	Establish a better definition of backfilling	
						Exclude backfilling from targets	

			disposal preferred over recovery	landfillling is economically attractive	deter landfilling	Increase landfill tax	
						ban on mixed CDW disposal / landfill ban	
				Targets already set are not respected	Enforce targets	EU guidance to MS to increase monitoring and enforcement	
		Marketplace not structured	Supply side: circular products not widely available	sourcing issues	organise marketplace	Publicly subsidised / operated market exchanges	
				competition with virgin materials / new products	end user price rebalancing	recycled content targets/mandate	M
						recycled content subsidies / tax breaks	
						EPR fee eco-modulation	
				regulatory uncertainty	long term objectives	reuse / recycle targets	G
			Demand side: low consumer demand	lack of awareness	awareness raising	awareness raising programmes	A/B/C
				lack of specific skills to use circular products / materials		tax breaks on training	B
						training programmes (industry / govt run)	B/G
				no incentive for use of circular products	subsidy / market support	EPR fee eco-modulation	M
				circular products uncompetitive	end user price rebalancing	GPP mandate	G
						VAT/other tax break	M
			Marketplaces not established	volumes below critical mass	increase market towards critical mass	Publicly subsidised / operated market exchanges	G / R
				local scale		Publicly available infrastructure (warehouses)	G/R
		Lack of confiden ce in secondar	Presence of hazardous materials	nonselective demolition	mandatory selective demolition	mandatory pre-demolition audit	D
						ban on mixed CDW disposal / landfill ban	D

				hazardous substances in buildings	restriction of hazardous substances in CPs	CPR / Eurocodes update	M
						REACH	
						SSbD	
			Lack of certification / standards	uncertain material quality	increase confidence	EoW criteria	R
						Certification schemes	M
						Product passport	M
		Diversity of CDW materials	Complexity of building value chains		Restrict materials allowed in construction	Reduce range of materials allowed in building code (and certain combinations)	A/B
						Eurocodes / CPR update	A/B
						DRS / EPR fee on certain materials or materials combinations	
		Split incentives along value chain	Durability / longevity dilute responsibility	Impact not affecting producer	create price signal for producer	EPR fee	M
				Impact not visible to end user / client	create price signal for end user	Carryover of EPR	C
	Increasing absolute / relative volumes of CDW	Construction waste volumes	Construction product market structure drives consumption		Foster reuse and longer life (prevention)	DRS	B/C
						open-loop DRS (recover deposit by bringing demolition material)	B/C
			Architects do not design for waste minimization	Non-aligned incentives at design stage	Circularity requirements at design stage	Circularity grading (// energy efficiency)	A
						Building permit conditionality	A/B
						Strengthen EU taxonomy to encourage circular investments	

						GPP criteria	A/C
			Established building practices are resource inefficient		Building regulation driving efficient design	Building permit conditionality	A/B
					Incentivise 3d printing and other material efficient techniques	Eurocodes adaptation / CPR	A/B
		Demolition waste volumes	(Negative) waste cost not acting as disincentive		Internalisation of costs	Increase landfill tax / ban	D
			Refurb not prioritized over demolish + rebuild		Foster reuse and longer life (prevention)	Reuse targets	D
						EU taxonomy	C
		Renovation waste volumes	Renovation wave, energy efficiency		Foster reuse and longer life (prevention)	Reuse targets	D
						EU taxonomy	C
		Systemic trends	Population growth		out of scope	-	
			Urbanisation		out of scope	-	

Source: Own elaboration.

NOTE – stakeholder codes

Actor	**Code**	**shorthand**
Developers, investors and building owners Project clients (private and public)	C	Client
Designers, architects	A	Architect
Constructors and builders	B	Builder
Manufacturers of construction products	M	Manufacturer
(Building users)	U	User
Deconstruction and demolition firms	D	Demolisher
Waste management firms / authorities, landfill operators, recyclers; PROs	R	Recycler
Government, regulators, authorities	G	Government

Annex 2. Detailed summary of how MSs implement resource taxes

In **Belgium**, the Act on Gravel allocated a fixed quota of gravel to the different extractors and introduced a levy on the production of the gravel. The latest important modification of the Act on Gravel (the amendment of the Gravel Flemish Parliament Act of 3 April 2009) makes extraction of gravel possible in certain specific cases and lays the foundation for a project-based approach (LNE, 2015).

In **Bulgaria**, the underground resources are owned exclusively by the state. Mining is regulated by the Law on Underground Resources (LUR) adopted in March 1999. An annual area fee which is charged per square kilometre of occupied area and varies depending on the natural resources group.

Croatia presents since 2009 an extraction charge for sand, gravel crushed stone, limestone and clay. In **Cyprus**, there is a charge on quarrying that also depends on the material.

Czechia extended in 2002 the scope of the existing charge on resources that is done by area, to include aggregate materials. It included an additional charge that is levied on the volume of extracted material, calculated as a proportion of the sale price on the market. Similarly, **Denmark** has tax on raw materials also by area since 1990, where natural gravel and crushed rock is part of the tax base.

In **Estonia**, mining companies pay a tax for the extraction and use of mineral resources belonging to the Estonian state. Taxed minerals include a range of construction materials, such as dolomite, limestone, gravel and sand. These taxes should be based on the estimated value of the resource in the given mine or quarry, essentially amounting to a rent.

In **France**, the general levy on polluting activities (TGAP) is payable by companies whose activity or products are polluting, including resource extraction.

In **Hungary**, the mining tax is applicable to: companies that are subject to mining tax under section 20 Paragraph B of Act XLVIII/1993; whose main activity is quarrying stone or mining gypsum or chalk, mining gravel, sand or clay, manufacturing cement or manufacturing plaster; and whose 2019 net sales reached or exceeded HUF 3 billion, not including affiliates under the act on corporate tax and dividend tax. The government also set price caps above which the extra tax will be levied and when sold at a price higher than the cap, the seller will have to pay a 90% tax on the difference between the sale price and the capped price.

Italy imposes a charge per cubic meter of aggregates extracted. There is no common rate at the national level, and every region has the possibility to apply a different rate with different ways of application at the provincial and municipal level. The effect of the extraction charge has been very limited. The level of tax is too to have had any real effect on demand. Although there are regional variations, the value of these charges at national level can be estimated at 110 million €, which is around 5 % of the estimated turnover of the aggregate industry (RE4 Project, 2017).

In **Latvia**, a natural resources tax is levied on extraction of natural resources and on use of environmentally harmful materials. Under the Natural Resources Tax Law, natural resources tax is imposed on all legal and natural persons whose activities involve pollution or are otherwise harmful to the environment. Different rates apply to different taxable products or taxable events. Relief is available for taxpayers who follow certain approved recycling procedures or keep within agreed quotas.

In **Lithuania**, there is a mineral extraction charge for the management of land, soil and forest resources that cover several materials including sand.

Sweden has a tax on certain raw materials since mid-1990s and the tax on natural gravel has recently increased by about 10%, nearly closing the price gap between gravel and its closest substitute, crushed rock. The tax was successively raised to maintain its incentive function (OECD, 2014)

In other countries such as **Poland**, a mineral extraction fee is in place for copper but does not seem to have a significant incentive effect. An increase of this fee for aggregates extraction could discourage the high use of construction materials, which have been the main area of growth for domestic materials consumption: this could play an important role in promoting greater materials efficiency. In early 2014, the Ministry of Environment was studying options to increase environmental taxes and charges (OECD, 2015). Also, **Slovenia** should consider a tax on the use of primary aggregates as a means for improving the recovery and recycling of construction and demolition waste (OECD, 2012).

Annex 3. Selected EU research focused on CDW

Table A2. List of projects focused on reuse, preparing for reuse and recycling of CDW.

Project Acronym	Project Title	Call	End date	Webpage
ACCORD	Automated Compliance Checks for Construction, Renovation or Demolition Works	HORIZON-CL4-2021-TWIN-TRANSITION-01	31 August 2025	https://accordproject.eu/
BAMB	Buildings as Material Banks: Integrating Materials Passports with Reversible Building Design to Optimise Circular Industrial Value Chains	H2020-WASTE-2014-2015	28 February 2019	https://www.bamb2020.eu/
CINDERELA	New Circular Economy Business Model for More Sustainable Urban Construction	H2020-IND-CE-2016-17	30 November 2022	https://www.cinderela.eu/
CIRC-BOOST	Boosting the uptake of circular integrated solutions in construction value chains	HORIZON-CL6-2022-CIRCBIO-02-two-stage	31 May 2027	https://circboostproject.eu/
CIRCuIT	Circular Construction in Regenerative Cities	H2020-SC5-2018-2019-2020	30 November 2023	https://www.circuit-project.eu/
CityLoops	Closing the loop for urban material flows	H2020-SC5-2018-2019-2020	30 September 2023	https://cityloops.eu/
C2CA	Advanced Technologies for the Production of Cement and Clean Aggregates from construction and demolition waste	FP7-ENV-2010	30 April 2015	https://www.c2ca.tech/
EnCoRe	Environmentally friendly solutions for Concrete with Recycled and natural components	FP7-PEOPLE-2011-IRSES	31 December 2014	-
FutuRaM	Future Availability of Secondary Raw Materials	HORIZON-CL4-2021-RESILIENCE-01	31 May 2026	https://futuram.eu/

HISER	Holistic Innovative Solutions for an Efficient Recycling and Recovery of Valuable Raw Materials from Complex Construction and demolition waste	H2020-WASTE-2014-2015	31 January 2019	https://www.hiserproject.eu/
ICEBERG	Innovative Circular Economy Based solutions demonstrating the Efficient recovery of valuable material Resources from the Generation of representative End-of-Life building materials	H2020-SC5-2018-2019-2020	30 April 2024	https://iceberg-project.eu/
Madaster	Towards a circular economy: Eliminate waste through an open platform that facilitates material passports	H2020-SMEInst-2016-2017	30 April 2019	https://madaster.com/
MOBICCON-PRO	MOBile and Innovative Circularity for CONstruction PROducts	HORIZON-CL4-2022-TWIN-TRANSITION-01	30 November 2027	https://mobiccon-pro.eu/
RECONMATIC	Automated solutions for sustainable and circular construction and demolition waste management	HORIZON-CL4-2021-TWIN-TRANSITION-01	30 June 2026	https://www.reconmatic.eu/
RECOWERS	REusing COnstruction Wood through a common EuRopean Standard	H2020-MSCA-IF-2020 -	31 December 2023	-
ReCreate	Reusing precast concrete for a circular economy	H2020-LOW-CARBON-CIRCULAR-INDUSTRIES-2020	31 March 2025	https://recreate-project.eu/
Reincarnate	Reincarnation of construction products and materials by slowing down and extending cycles	HORIZON-CL4-2021-TWIN-TRANSITION-01	31 May 2026	https://www.reincarnate-project.eu/
RePrintCLAY	Reuse of excavated soil in 3D printing of sustainable earth-based mixtures for low energy buildings	HORIZON-MSCA-2021-PF-01	31 August 2024	-
RE4	REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction	H2020-EEB-2016-2017	29 February 2020	http://www.re4.eu/

TRACK4REUSE	Defining new waste traceability standards for the green Demolition and Construction industry	H2020-EIC-SMEInst-2018-2020	31 October 2022	-
VEEP	Cost-Effective Recycling of CDW in High Added Value Energy Efficient Prefabricated Concrete Components for Massive Retrofitting of our Built Environment	H2020-EEB-2016-2017	31 March 2021	http://www.veep-project.eu/
WOOL2LOOP	Mineral wool waste back to loop with advanced sorting, pre-treatment, and alkali activation	H2020-SC5-2018-2019-2020	30 November 2022	https://www.wool2loop.eu/en/

Source: Own elaboration.

Annex 4. Analytical Hierarchy Process (AHP)

One of most widely used tools for decision-making and prioritization/ranking is the Analytic Hierarchy Process (AHP) proposed by (Thomas Saaty, 2013). Herein, the AHP is used to determine the weights of the different criteria used to prioritize the possible implementation of EU policy instruments / measures.

This method relies on a pairwise comparison of the relative importance of **two criteria** and uses a nine-point scale for the assessment of each pair of criteria, where "1" implies equal importance between two criteria and "9" indicates the absolute importance of one criterion over another.

Intensity of importance	**Definition**
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Absolute importance
2, 4, 6, 8	For compromise between the above values

Source: Own elaboration.

Each of the criteria are defined and scoring rules based on the authors' best professional judgement and review of the available data are applied as shown in the following table.

Criteria	**Explanation of relevance to prioritization**	Scoring rules		
		High = 2	Average = 1	Low = 0
Potential impact	The potential environmental benefit (an estimate of the amount of CDW diverted from landfilling) resulting from the implementation of the policy measure.	High potential impact in the range of million tonnes	Average impact in the range of hundreds of kilo tonnes	Low potential impact in the range of kilo tonnes
EU action	Subsidiarity, feasibility and relevance of acting at EU level	The action at EU level is feasible and preferable, and / or the action gains relevance at EU level	The action at EU level is possible, and / or the action's relevance is average	It is difficult to articulate the action at EU level, and / or the action loses relevance at EU level
Implementation	Ease of implementation and enforcement, as well as the administrative cost incurred and the	Low difficulty in the implementation and / or low costs and / or	Average difficulty in the implementation and / or average costs and / or average unintended consequences	High difficulty in the implementation and / or high costs and / or

	potential unintended consequences.	low unintended consequences		high unintended consequences
Targeted intervention	According to Table 9, the policy measure is directly incentivising the intended behavioural change.	It directly incentivises the intended behavioural change	It somehow incentivises the intended behavioural change	It does not incentivise the intended behavioural change
Track record	Evidence of having worked at MS level.	Clear evidence that it has worked at MS level	Certain evidence that it has worked at MS level	No / low evidence that it has worked at MS level
Waste policy	The policy measure is developed through waste policy (e.g., under the WFD) or as a cross-cutting one.	-	Waste policy	Cross-cutting policy

Source: Own elaboration.

A pairwise comparison matrix CxC is formed, where C is the number of elements to be compared. Note that this can be applied to both qualitative and quantifiable criteria, and it is done by experts in the domain. In this case the elements to be compared are the criteria selected in Table 11 for the prioritization of EU policy instruments / measures in Table 10. Thus, the comparison matrix is the following:

	EU action	**Track record**	**Targeted intervention**	**Potential impact**	**Implementation**	**Waste policy**
EU action	1	5	3	1/3	5	9
Track record	1/5	1	1/3	1/9	1/6	1
Targeted intervention	1/3	3	1	1/6	1	3
Potential impact	3	9	6	1	6	9
Implementation	1/5	6	1	1/6	1	6
Waste policy	1/9	1	1/3	1/9	1/6	1

Source: Own elaboration.

Then, the priority vector (PV) (i.e., the overall weighting for each criterion) is calculated. First, the total as the sum of the values by column is calculated:

	EU action	**Track record**	**Targeted intervention**	**Potential impact**	**Implementation**	**Waste policy**
Total	4.84	25	11.67	1.89	13.33	29

And then, the normalized value is calculated by dividing each value by the total:

	EU action	**Track record**	**Targeted interventio n**	**Potentia l impact**	**Implementatio n**	**Waste policy**
EU action	1/4.84= 0.21	5/25= 0.20	0.26	0.18	0.38	0.31
Track record	(1/5)/4.84 = 0.04	1/25= 0.04	0.03	0.06	0.01	0.03
Targeted intervention	0.07	0.12	0.09	0.09	0.08	0.10
Potential impact	0.62	0.36	0.51	0.53	0.45	0.31
Implementation	0.04	0.24	0.09	0.09	0.08	0.21
Waste policy	0.02	0.04	0.03	0.06	0.01	0.03

Source: Own elaboration.

Finally, the PV is calculated using the arithmetic mean that will be the weighted score suggested for each criterion:

	Weight
EU action	0.254
Track record	0.036
Targeted intervention	0.09
Potential impact	0.464
Implementation	0.123
Waste policy	0.033

The AHP foresees consistency checks to assure that the consistency of the judgements is correct since it is not guaranteed due to the subjective judgements by the experts. This is mainly done through a consistency ratio (CR) computation (consistency index (CI) divided by the random consistency index (RI) that depends on the number of criteria being 1.24 for n=6) with a threshold of 0.1, that once it is exceeded, initial judgments must be revised by the experts:

$$CR = \frac{CI}{RI} = \frac{(\lambda - n)/(n-1)}{1.24}$$

Where λ is the principal Eigen Value and is calculated through first, a matrix multiplication of the pairwise comparison and the PV and then dividing the result matrix by the PV values and calculating the average of these values. In this case the λ equals 6.42 and the CI equals 0.084. Thus, the CR equals 0.067 ≤ 0.1, being the judgement valid.

Annex 5. Detailed results of the prioritization process

Table A3. Criteria score and final total score for the prioritization process.

Policy measure	CRITERIA SCORE						TOTAL SCORE
	EU action	Track record	Targeted intervention	Potential impact	Implementation	Waste policy	
Weighting	0.254	0.036	0.09	0.464	0.123	0.033	
Modulated landfill tax / discarding fee	2	2	2	2	2	1	20
Mandatory selective demolition	2	2	2	2	2	0	19
EPR scheme on CPs	2	2	2	2	1	1	18
EPR scheme on CP - ecomodulation	2	2	2	2	1	1	18
Landfill tax	2	1	1	2	2	1	18
GPP criteria	2	2	2	2	1	0	18
Standards and certifications for recycled materials	2	2	2	2	1	0	18
Landfill ban on CDW	2	1	2	2	1	1	18
Landfill ban on inert waste	2	1	2	2	1	1	18
Design for recycling	2	1	2	2	1	0	18
MS-level targets on preparing for reuse and recycling	2	1	0	2	2	1	18
Subsidise or operate marketplaces	1	1	2	2	2	1	17
Aid to sustainable design	1	0	2	2	2	0	16
DRS open-loop / bonus-malus	1	1	2	2	1	1	16
Aid to preparing for reuse / recycling	1	0	2	2	1	1	15
Tax on primary resource use	1	0	2	2	1	0	15
EoW criteria	2	1	2	1	2	1	15

Mandatory pre-demolition audits	2	1	2	1	2	0	14
Minimum recycled content	1	0	1	2	1	0	14
PAYT	2	2	2	1	1	1	14
Building Information Management / digital logbook	2	1	1	1	2	0	13
Digital passport (e.g. label/code) for building components	2	1	1	1	2	0	13
DNSH criteria	2	0	1	1	2	0	13
Safe and sustainable by design	2	0	1	1	2	0	13
CPR revision	2	1	1	1	1	0	12
Eurocodes / CPR / WFD update	2	1	1	1	1	0	12
LCA for buildings	2	1	1	1	1	0	12
Digital passport (e.g. label/code) for building components	2	1	1	1	1	0	12
GPP bonus malus	1	1	1	1	2	1	11
Recycled content targets	2	0	0	1	1	0	11
Minimum recovery requirement (+ optional recoverable fee)	1	1	2	1	1	0	11
Restrict hard-to-recycle materials	1	1	2	1	1	0	11
Aid to recycled content use	1	0	2	1	1	0	10
Info campaigns separate collection	2	1	2	0	2	1	10
Info campaigns use of recyclates	2	1	2	0	2	1	10
Info campaign on pre-dem audits and deconstruction	2	1	2	0	2	1	10
Training on pre-dem audits and deconstruction	2	0	2	0	2	1	10

Product ecolabel / info label on resource efficiency, recyclability, or recycled content	2	2	1	0	2	0	9
WFD (defn backfilling)	2	0	1	0	2	1	9
EU guidance to MS on monitoring and enforcement	2	1	0	0	2	1	8
Ban products / techniques	0	1	2	1	1	0	8
Targets on use of materials (natural, bio-based…)	2	1	0	0	1	0	7
Minimum recycled content levels	2	0	0	0	1	0	6

Source: Own elaboration.

Annex 6. Background data for the quantitative (Cristobal-Garcia et al., 2024)

Table A4. Carbon footprint per unit material fraction as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	Preparing for reuse BAU	Advanced (BAU) recycling		Landfill BAU	Incineration BAU
	$kgCO_2/t$	$kgCO_2/t$		$kgCO_2/t$	$kgCO_2/t$
BRK	-199	-431.4	(20.1)	14.8	0.0
CON	-69.7	-25.5	(8.9)	14.8	0.0
GYP	0.0	-85.0	(-85.0)	14.8	0.0
WOD	-45	-88.9	(-88.9)	14.8	-568
STE	-2185	-1104.1	(-1104.1)	14.8	0.0
ALU	-9771	-6862.3	(-6862.3)	14.8	0.0
EPS	0.0	-1088.1	(-1088.1)	14.8	1606
C&T	-547	-389.6	(17.9)	17.2	0.0
PVC	0.0	-1058.5	(-1058.5)	14.8	1747
STW	0.0	16.8	(16.8)	14.8	0.0
GLW	0.0	17.1	(17.1)	14.8	0.0
GLA	-1182	-272.4	(23.0)	14.8	0.0
MIX	-547	-389.6	(17.9)	17.2	0.0
ESR	4.3	6.2	(6.2)	12.3	0.0
DDS	4.9	30.1	(30.1)	36.0	0.0

Source: Own elaboration.

Table A5. Environmental life cycle costs per unit material fraction as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	Preparing for reuse BAU €/t	Advanced (BAU) recycling €/t		Landfill BAU €/t	Incineration BAU €/t
BRK	-340.6	75.8	(71.4)	44.2	0.0
CON	-72.3	77.0	(42.3)	44.6	0.0
GYP	0.0	74.4	(74.4)	44.6	0.0
WOD	-145.2	-42.4	(-42.4)	44.6	-882.8
STE	-430.7	-167.6	(-167.6)	44.6	0.0
ALU	-1245.7	-923.7	(-923.7)	44.6	0.0
EPS	0.0	-674.4	(-674.4)	44.6	-955.8
C&T	-340.6	82.6	(68.1)	51.7	0.0
PVC	0.0	-431.4	(-431.4)	44.6	-838.8
STW	0.0	70.9	(70.9)	44.6	0.0
GLW	0.0	70.9	(70.9)	44.6	0.0
GLA	-297.7	72.2	(71.1)	44.2	0.0
MIX	-340.6	82.6	(68.1)	51.7	0.0
ESR	-4.3	0.5	(0.5)	57.1	0.0
DDS	-6.0	5.5	(5.5)	60.6	0.0

Source: Own elaboration.

Table A6. Carbon footprint per weighted material fraction in 1 t CDW as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	CDW share %	Advanced (BAU) recycling $kgCO_2/t$ CDW		Landfill BAU $kgCO_2/t$ CDW
BRK	2.5	-10.6	(0.5)	0.4
CON	21.3	-5.4	(1.9)	3.1
GYP	0.2	-0.2	(-0.2)	0.0
WOD	1.1	-1.0	(-1.0)	0.2
STE	1.8	-19.6	(-19.6)	0.3
ALU	0.7	-45.7	(-45.7)	0.1
EPS	0.3	-2.9	(-2.9)	0.0
C&T	2.1	-8.2	(0.4)	0.4
PVC	0.3	-2.9	(-2.9)	0.0
STW	0.1	0.0	(0.0)	0.0
GLW	0.1	0.0	(0.0)	0.0
GLA	1.5	-4.2	(0.4)	0.2
MIX	5.9	-23.2	(1.1)	1.0
ESR	52.8	3.3	(3.3)	6.5
DDS	9.4	2.8	(2.8)	3.4
Total	**100**	**-117.8**	**(-62.0)**	**15.6**

Source: Own elaboration.

Table A7. Environmental life cycle costs per weighted material fraction in 1 t CDW identified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	**CDW share %**	**Advanced (BAU) recycling €/t CDW**		**Landfill BAU with (without) tax €/t CDW**	
BRK	2.5	1.9	(1.8)	1.1	(0.6)
CON	21.3	16.4	(9.0)	9.5	(5.5)
GYP	0.2	0.2	(0.2)	0.1	(0.1)
WOD	1.1	-0.5	(-0.5)	0.5	(0.3)
STE	1.8	-3.0	(-3.0)	0.8	(0.5)
ALU	0.7	-6.2	(-6.2)	0.3	(0.2)
EPS	0.3	-1.8	(-1.8)	0.1	(0.1)
C&T	2.1	1.7	(1.4)	1.1	(0.7)
PVC	0.3	-1.2	(-1.2)	0.1	(0.1)
STW	0.1	0.1	(0.1)	0.1	(0.0)
GLW	0.1	0.1	(0.1)	0.1	(0.0)
GLA	1.5	1.1	(1.1)	0.7	(0.4)
MIX	5.9	4.9	(4.0)	3.1	(1.9)
ESR	52.8	0.2	(0.2)	30.1	(20.1)
DDS	9.4	0.5	(0.5)	5.7	(3.9)
Total	**100**	**14.5**	**(5.8)**	**53.3**	**(34.3)**

Source: Own elaboration.

Table A8. Carbon footprint per weighted material fraction in 1 t CDW (excluding ESR, DDS) as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	**CDW share %**	**Advanced (BAU) recycling $kgCO_2$/t CDW**		**Landfill BAU $kgCO_2$/t CDW**
BRK	6.5	-28.1	(1.3)	1.0
CON	56.2	-14.4	(5.0)	8.3
GYP	0.6	-0.5	(-0.5)	0.1
WOD	2.9	-2.6	(-2.6)	0.4
STE	4.7	-51.7	(-51.7)	0.7
ALU	1.8	-120.8	(-120.8)	0.3
EPS	0.7	-7.8	(-7.8)	0.1
C&T	5.6	-21.7	(1.0)	1.0
PVC	0.7	-7.6	(-7.6)	0.1
STW	0.3	0.1	(0.1)	0.0
GLW	0.3	0.1	(0.1)	0.0
GLA	4.0	-11.0	(0.9)	0.6
MIX	15.7	-61.2	(2.8)	2.7
Total	**100**	**-327.1**	**(-179.8)**	**15.3**

Source: Own elaboration.

Table A9. Environmental life cycle costs per weighted material fraction in 1 t CDW (excluding ESR, DDS) as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	CDW share	Advanced (BAU) recycling		Landfill BAU with (without) tax	
	%	€/t CDW		€/t CDW	
BRK	6.5	4.9	(4.6)	2.9	(1.6)
CON	56.2	43.3	(23.8)	25.1	(14.4)
GYP	0.6	0.4	(0.4)	0.3	(0.1)
WOD	2.9	-1.2	(-1.2)	1.3	(0.7)
STE	4.7	-7.8	(-7.8)	2.1	(1.2)
ALU	1.8	-16.3	(-16.3)	0.8	(0.5)
EPS	0.7	-4.8	(-4.8)	0.3	(0.2)
C&T	5.6	4.6	(3.8)	2.9	(1.8)
PVC	0.7	-3.1	(-3.1)	0.3	(0.2)
STW	0.3	0.2	(0.2)	0.1	(0.1)
GLW	0.3	0.2	(0.2)	0.1	(0.1)
GLA	4.0	2.9	(2.9)	1.8	(1.0)
MIX	15.7	13.0	(10.7)	8.1	(5.1)
Total	**100**	**36.3**	**(13.4)**	**46.1**	**(27.1)**

Source: Own elaboration.

Table A10. Carbon footprint per weighted material fraction in 1 t CDW (excluding ALU, STE, ESR, DDS) as quantified by Cristobal-Garcia et al., 2024. BAU: Negative values indicate savings. Business-as-Usual.

CDW fraction	CDW share	Advanced (BAU) recycling		Landfill BAU
	%	$kgCO_2$/t CDW		$kgCO_2$/t CDW
BRK	7.0	-30.0	(1.4)	1.0
CON	60.1	-15.3	(5.3)	8.9
GYP	0.6	-0.5	(-0.5)	0.1
WOD	3.1	-2.8	(-2.8)	0.5
EPS	0.8	-8.3	(-8.3)	0.1
C&T	5.9	-23.2	(1.1)	1.0
PVC	0.8	-8.1	(-8.1)	0.1
STW	0.3	0.1	(0.1)	0.1
GLW	0.3	0.1	(0.1)	0.1
GLA	4.3	-11.8	(1.0)	0.6
MIX	16.8	-65.4	(3.0)	2.9
Total	**100**	**-165.2**	**(-7.8)**	**15.3**

Source: Own elaboration.

Table A11. Environmental life cycle costs per weighted material fraction in 1 t CDW (excluding ALU, STE, ESR, DDS) as quantified by Cristobal-Garcia et al., 2024. Negative values indicate savings. BAU: Business-as-Usual.

CDW fraction	CDW share	Advanced (BAU) recycling		Landfill BAU with (without) tax	
	%	€/t CDW		€/t CDW	
BRK	7.0	5.3	(5.0)	3.1	(1.8)
CON	60.1	46.2	(25.4)	26.8	(15.4)
GYP	0.6	0.5	(0.5)	0.3	(0.2)
WOD	3.1	-1.3	(-1.3)	1.4	(0.8)
EPS	0.8	-5.2	(-5.2)	0.3	(0.2)
C&T	5.9	4.9	(4.0)	3.1	(1.9)
PVC	0.8	-3.3	(-3.3)	0.3	(0.2)
STW	0.3	0.2	(0.2)	0.2	(0.1)
GLW	0.3	0.2	(0.2)	0.2	(0.1)
GLA	4.3	3.1	(3.1)	1.9	(1.1)
MIX	16.8	13.9	(11.4)	8.7	(5.5)
Total	**100**	**64.6**	**(40.0)**	**46.2**	**(27.2)**

Source: Own elaboration.

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