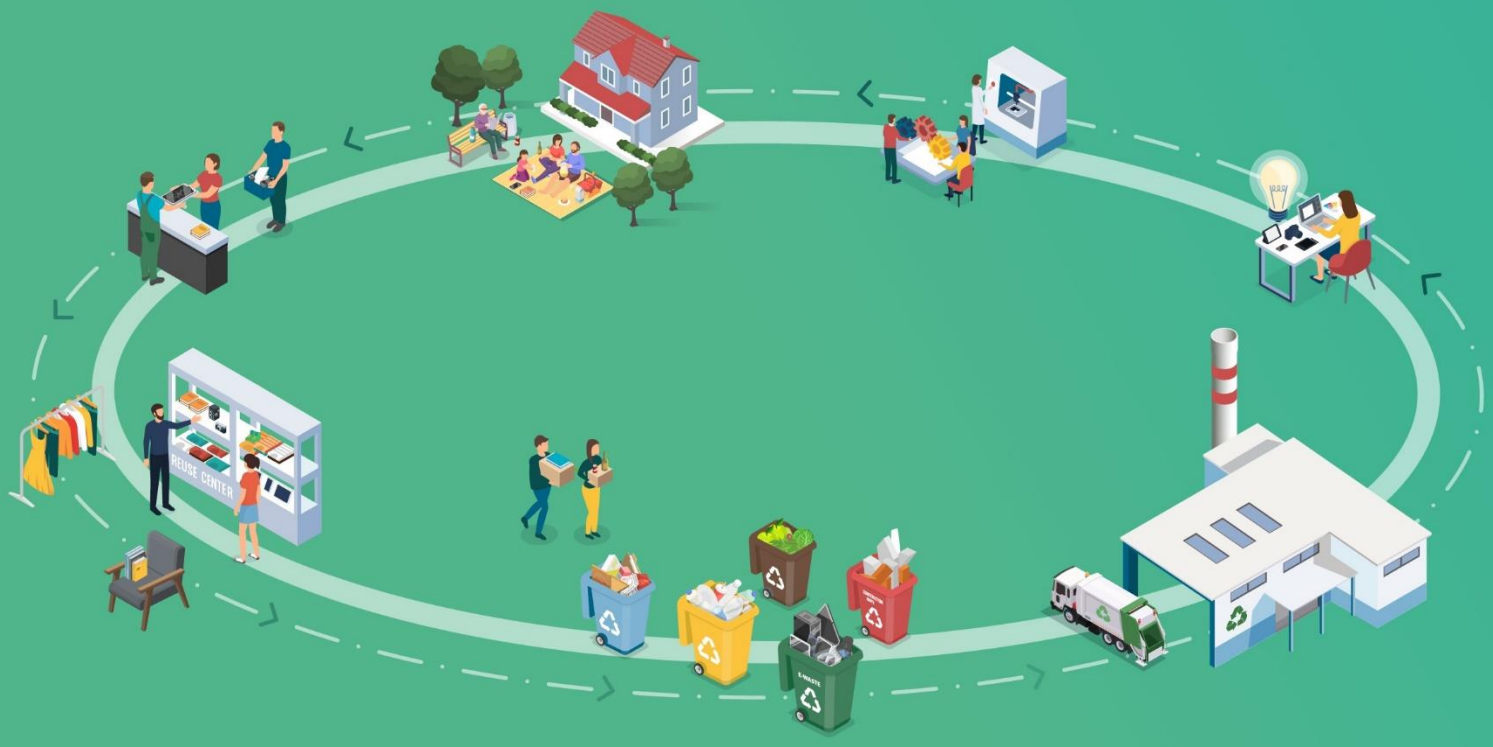
Croatia Circular Economy Approaches in Solid Waste Management (P173141)

ACTIVITY 1.1: Diagnostic analysis for a Circular Economy in Croatia

Task 4&5: International good practices and policy recommendation

(Annex 5)



CIRCULAR ECONOMY APPROACHES IN SOLID WASTE MANAGEMENT

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Abbreviations

%	per cent
AVCP	Assessment and Verification of Constancy of Performance
BIM	Building Information Modeling
BREEAM	Building Research Establishment (BRE) Environmental Assessment Method
CDW	Construction and Demolition Waste
CE	Circular Economy
CLP	Classification, Labeling and Packaging
CPR	Construction Products Regulation
CSR	Corporate Social Responsibility
DfD/A	Design for Disassembly and Adaptability
DMC	Domestic Material Consumption
DoP	Declaration of Performance
DSP_I	Incineration (without energy recovery)
DSP_L	Disposal – landfill
DSP_OTH	Disposal – other
e.g.	for example (exempli gratia)
EC	European Commission
ECI	Environmental Cost Indicator
EN	Eurocodes (https://eurocodes.jrc.ec.europa.eu)
EPA	Environmental Protection Agency
EPD	Environmental Product Declaration
EPR	Extended Producer Responsibility
EU	European Union
EUR	Euro (European Currency)
GDP	Gross Domestic Product
GPP	Green Public Procurement
ISO	International Organization for Standardization
kg	Kilogramme
LEED	Leadership in Energy and Environmental Design
LIBS	Laser-Induced Breakdown Spectroscopy
MFA	Material Flow Accounting
MS	(EU) Member State
MSW	Municipal Solid Waste

N°	Number
NACE	Statistical Classification of Economic Activities in the European Community
NPCB	Notified Product Certification Body
OEF	Organizational Environmental Footprint
OJ	Official Journal (https://eur-lex.europa.eu/oj/direct-access.html)
PCF	Product Carbon Footprints
PEF	Product Environmental Footprints
PEFCR	PEF Category Rules
RCV_B	Recovery - backfilling
RCV_E	Energy Recovery
RCV_R	Recovery - recycling
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals (EU Directive)
SCIP	Substances of Concern in Articles as such or in Complex Objects (Products)
SDS	Safety Data Sheet
SVHC	Substances of Very High Concern
SWMP	Site Waste Management Plan
t	ton (1.000 kg)
UN	United Nations
WB	World Bank

Executive summary

In recent years, the EU has made significant progress in the material recovery of construction and demolition waste and most of the Member States meet the Waste Framework Directive target of 70% material recycling. However, the high recovery rate is due to the use of materials from demolished buildings and other structures mainly in civil engineering projects, for example as a base material in road construction while the building sector hardly uses any secondary materials. Therefore, the higher material recovery rates are a result of low-grade recycling and backfilling which is not in line with the circular economy goals for replacing of virgin raw materials in the production of new construction products with recycled construction and demolition waste. The latest data for Croatia (from 2020) show that the recovery rate is 60% which means that measures must be taken both to prevent the disposal and temporary storage of construction and demolition waste and to increase the use of waste in civil engineering works and production of high-grade products with high recycled content.

As a background description, this report includes a short review of the existing strategies, legislative initiatives and best-practice guidance documents on EU level and in some Member States for increasing recycling of construction and demolition waste and using more recycled waste in construction works, as well as for manufacturing new construction products. This report includes a brief description of the Waste Framework Directive, the Landfill Directive and waste acceptance criteria, Construction Product Regulation, REACH Directive, EU Construction and Demolition Waste Management Protocol as well as several other legal documents and guidelines. The EU legislation is still mainly aimed at ending the harmful effects of waste and material recovery for landfill diversion, while the requirements for construction products still cover only construction qualities and do not include obligations closely related to a circular economy concept such as requiring life cycle assessment, using recyclable waste and manufacturing construction products that are more renewable, durable, non-hazardous, reusable, recyclable, dismountable, etc.

Several Member States are ahead of the EU in the implementation of circular economy actions in the construction sector, which has had a positive impact on the development of the circular economy concept and the improvement of European legislation. The purpose of this report is to describe Pan-European initiatives as well as good practices in individual Member States and to assess areas where Croatia is lagging behind.

In the construction sector, circular economy thinking is applied in all stages of the material and building life cycle to ensure that the building materials and components are kept in a closed loop by not being wasted but recovered and their value is preserved. The purpose of the present study is to identify good practices of circular economy actions during the whole lifecycle of construction products from design to end of life. The good practices were selected in such a way that each takes effect at a different circular economy phase, as follows:

- Material production phase: practical examples of voluntary initiatives and mandatory measures, aimed to ensure that construction products are designed and manufactured so that they remain in circulation for as long as possible and when they reach the end of their useful lives, can be easily reclaimed for the production of new products;
- Design phase: good practices in this phase provide for designing the buildings in a way that constructors use as little material as possible and make the buildings adaptable (suitable for many purposes), modular and detachable;
- Construction phase: measures to implement the circular design as well as recording and exchange of information related to efficient reuse or recycling of construction materials and buildings' components;

- Use phase: best approaches for lifetime extension of existing structures through repair, maintenance, new ways of use;
- End-of-life phase: policy options to make sure that different waste materials are separated and used back into the economy through reuse and recycling, selective demolition and source separation.

Material production phase

Currently, circularity considerations during design and manufacturing of construction products are not legally binding on EU level and in the majority of EU countries, however many factors support the production and marketing of sustainable construction products such as the advances in production techniques, better know-how and the tendency among consumers to buy green products and buildings. There are also economic advantages for example waste management costs associated with green products are lower and they can be sold at higher prices. These enabling conditions as well as the barriers are described in the report but on their own are not enough to provide for greener solutions in the manufacturing of construction products. Various voluntary and mandatory measures taken by the governments and the stakeholders in the construction value chain are described and analyzed.

Voluntary agreements (such as Green Deals in the Netherlands) are usually the first initiative that the Governments and the construction business take, and it includes a voluntary commitment by the manufacturers to produce green materials, while on the other hand the Government commits itself to remove the legal barriers and support the process.

Many producers claim that their products are green and the **Environmental product declaration** (EPD) or **product carbon footprints** (PCF) are the applied voluntary mechanisms to verify and prove such claims. Producers perform a full life cycle assessment of the impact on the environment caused by the product and the result of such assessment is summarized in the so-called Environmental Product Declaration showing whether the product is sustainable and meets the environmental performance criteria. The report provides a description of several EPD programs that exist in the European Union (EU) countries as well as PEF method of the European Commission.

A similar concept is the **material passports,** but instead of measuring the environmental impact, they contain information about the reusability and recyclability of the product. The case studies presented in the report include EPEA Product Circularity Passports in the Netherlands, and the EU-funded research and development project BAMB, on material banks.

Good practices that help builders meet other requirements for circular buildings – renewability and non-hazardousness are also presented. In the Netherlands, the **Bio-based Building Materials Catalogue** provides a clear overview of all building materials currently available on the market and which properties and application possibilities these materials have. Similarly, the **"Bio-based Product" label** applied in France aims to distinguish bio-based materials and promote their use. **BASTA tool** developed in Sweden is a third party system for construction product evaluation and certification that defines construction product requirements about hazardous content and offers the market freely available information about safe material choices.

The voluntary initiatives are further reinforced by obligatory measures in some EU Member States and there is a strong intention for the adoption of mandatory policies on EU level. In its preamble, the European **Construction Product Regulation** calls for making the Environmental product declarations mandatory, however, at this time, environmental performance assessment of construction products is not required since a harmonized system for assessment and verification of other characteristics of construction products is already in place. **Assessment of Environmental Performance of Buildings** is

already mandatory with every application for an environmental permit in the Netherlands. A brief description of the assessment procedure is provided in the report.

Under the REACH Regulation, provision of information on the content of hazardous substances in construction products is mandatory for manufacturers. The Waste Framework Directive extends the communication duties to suppliers of articles containing Candidate List substances which need to submit that information also to the European Chemicals Agency's **SCIP database**. When fully operational, the database will contribute to the substitution of substances of concern in construction products and will allow authorities to monitor the use of substances of concern and support a sustainable choice of construction materials.

Other EU legal documents with the potential for making the environmental performance of construction products more obligatory are the **Eco-design Regulations** that will contain limit values (e.g. minimum recycled content) or prescriptions on how to achieve reusability, recyclability or other properties. Currently, there are Eco-design regulations on energy-using products (such as heaters, ventilation units, lamps), but there are plans to develop regulations on energy-related products such as windows and insulation.

Apart from the legal obligations, a good practice of applying Economic instruments to ensure that recycled materials are competitive with virgin materials is the **tax on raw materials** that has been applied in Denmark since 1990. This is a tax that will artificially increase the price of the virgin materials so that they become more expensive than recycled materials. The materials subject to taxation and the procedure for levying the tax are briefly described in the report.

Some of the listed practices are already applied to a limited extent in Croatia due to market demand, such as certification, incl. material passports, environmental product declarations and environmental performance assessment. For some practices, the basis for their introduction (institutional set-up and implementation procedures) is laid, such as eco-design, "CE" marking (respectively national "C" marking), hazardous waste tracking. For other practices, activities for their introduction have not been carried out, such as differentiation of renewable materials, mandatory environmental performance assessment, database of construction products containing hazardous substances, tax on raw materials.

Design phase

At present, there are not many examples of buildings constructed by applying circular design, and only several demonstration projects exist. Examples of circular design required by the legislation or anyhow encouraged by the public authorities are even rarer. **Building codes** whether European or national currently do not include obligatory requirements for circular design. Of all the studies studied within the project, no example was found of a country that introduced legally-binding circular design. However, there are several voluntary **certification systems** that measure and certify the concept of sustainable development and a voluntary **ISO standard for design for disassembly and adaptability,** which is a precondition for making the circular design obligatory in the future.

Moreover, the economic benefits of the circular design are not visible – buildings designed with intention of circularity have higher financial residual value, but this will be visible in the distant future. Currently, there are several **methodologies for assessment of the future value of the buildings**.

An example of an indirect link between circular design and regulatory requirements is the building permit in the Netherlands. It is required in the application for construction permit that a full environmental performance assessment of the building is performed – for all construction materials used in the building and for the building in general. In the legislation, a **threshold for environmental**

performance is set – and if the total score of the environmental performance is below this limit the building receives a construction permit.

Currently in Croatia, as in most other countries, mandatory instruments for circular design of construction works are not applied with exception of circular design as a part of the certification, which is however limited mainly to large trade or office buildings.

Construction phase

As the circular design is not widely used respectively, the practice shows that it is not applied broadly in the construction phase of the life cycle. Currently, the efforts are focused on recording information about the materials and components used in the building during construction, their location, way of installation and deconstruction, their recyclability and reusability, etc. so that instead of extracting new raw materials from the nature the end-of-life buildings could be used as a storage for materials for construction of new buildings. Examples of good practices for the collection and exchange of such information through **building passports** are presented in the report. The concept of **Building Information Modeling** is also described which facilitates the exchange of information, design for sustainability and certification management. The measure that has significant potential to encourage the introduction of a circular economy in the construction sector is the **Green Public Procurement**, which is why the report examines trends in the development of criteria for GPP and eco-label at European level. The practice in Malta of **lower tax for restoration of old buildings** compared to demolition is described as an example of an economic instrument. The **Directive 2012/27/EU on energy efficiency** and the **Energy Performance of Buildings Directive** are also presented. These introduce obligations and objectives for building renovation.

The practice of using Building Passports and Building Information Modeling is already applied in Croatia as it is part of the certification process, but further measures would be needed to make it more widely used. Environmentally Friendly Labeling Program of Croatia is implemented including a procedure for label awarding and independent verification by a third party, but there is no national construction related to Eco-label criteria. Currently GPP in Croatia is a voluntary mechanism, except for the central state bodies for which is mandatory. Croatian national green public criteria do not include criteria related to the construction sector.

Use phase

The circularity potential during the usage of the buildings could be enhanced through repairing with the purpose of extending the active life of buildings, as well as updating building passports and BIM software. The **Performance-based contract** is an innovative mechanism for ensuring that the maintenance of buildings during their use is optimal by extending the obligations of the GPP contracts to the phase of operation of the buildings. Few examples for application of the performance-based contracts are presented below.

In the construction sector, the **Extended Producer Responsibility** concept is suitable for construction products with short lifetimes, such as carpets, but these may not be appropriate for products that remain in situ over a building's lifetime. Two examples for implementation of the EPR schemes in the Netherlands and in Flanders and one **take-back scheme** established by a manufacturer of construction products are described in the report.

The EPR and the take-back schemes for construction products are not widely applied worldwide but in accordance with the Croatian legislation, producers of construction products are obliged to provide to the buyers and/or users of their product the possibility of returning such used products, free of charge.

Performance-based contracts are a new concept, but it is readily applicable as the Energy Performance Contracts are regularly used in Croatia.

End-of-life phase

In order to return the waste back into the economy, it has to be ensured that recycled waste is at least of equal quality to the products made from virgin materials. Green materials made from recycled waste are often given credits in voluntary environmental rating systems, but some countries have obligatory national **end-of-waste criteria** that set out conditions that have to be met so that the material will no longer be classified as a waste, thus becoming a product. Few examples of national end-of-waste criteria are described.

During this phase, in addition to the policies for ensuring the quality of recycled waste, measures are needed to provide for a sufficient quantity of recycled materials. The report examines good practices for the introduction of material **recovery targets** beyond EU requirements and **mandatory selective deconstruction, pre-demolition auditing**, **deconstruction reporting** and **binding construction permits with recycling targets**.

The economic instruments aiming to boost the market supply of waste for recycling are also described, including **landfill tax** and measures for boosting the market demand for recycled waste such as **minimum content of recycled materials** in GPP and voluntary agreements.

Most of the above practices are already in place in Croatia or are in varying degrees of implementation, with the exception of the landfill tax (which is currently under consideration) and obligations to increase recycled content in construction products and construction works (not required).

Disaster waste management practices and policies

Due to the waste management problems caused by the recent earthquake in Croatia, the report includes a special chapter on disaster waste management. It presents practices and policies on the management of CDW deriving from the collapsing of buildings and infrastructure following earthquakes, in the light of a more circular economy, and especially downstream measures (recycling) and upstream measures (prevention of disaster waste). In order to assess the recyclability of disaster waste, that chapter describes the main factors affecting the feasibility of recycling disaster waste, on-site and off-site separation and the best approaches to improve recycling effectiveness. The focus is not only on recycling but also on waste prevention and land reclamation after disasters. Practical disaster waste management approaches applied during certain type of disasters are provided in the description of several case studies. Different regulatory, economic, waste management, waste prevention and planning policy options in the circular economy context are presented in the report. A description of the Croatian Government response for managing the disaster waste in the aftermath of the Petrinja earthquake in 2020 is also provided.

In order to formulate recommendations for Croatia, first an overview of the construction and CDW sectors is provided, including data on waste generation and management and current policies. Based on this assessment and the good practices identified in the previous Tasks, short and mid to long term recommendations and strategies are proposed to increase the recycling rate together with feasible recycling options for different construction and demolition waste materials.

Overall recommendations

In the short term, it is recommended that mandatory separation is applied to hazardous waste soil, stones and asphalt for which readily available realization in road construction is available. Plaster and mortar should be separated from the mineral waste mix consisting of concrete, bricks, and tiles by

applying simple technologies of crushing and sieving of demolition waste in order to be used in low-grade recycling options mainly in road construction. The main recommended instruments to achieve these initial objectives are obligatory separation of mixed mineral fraction, enforcement of hazardous waste related requirements, landfill restrictions (tax and bans), stricter requirements for backfilling, adoption of national end-of-waste criteria, voluntary agreements for minimum recycled content, and enforcement of the take-back obligations.

In the midterm, selective deconstruction and source separation should be made obligatory for most of the construction and demolition waste fractions, especially for concrete, bricks and tiles that will be utilized for reuse or as high-grade recycled materials used in new construction products. Thus, measures for increasing the supply of high-quality construction and demolition waste materials should be introduced, including mandatory site waste management plan, tax on raw materials and reduced criteria for the use of waste in specific construction applications (definition of quality classes following the example of Austria). In order to increase demand for recycled waste, a national database of EPD has to be created proving environmental claims (following the example of Belgium) and GPP criteria shall become mandatory requiring building passports, BIM, Eco-labels and minimum recycled content.

All possible measures to impose separation and recycling should already be implemented during the short and midterm, and for the long term only additional measures to create a market for recycled products shall remain. The main long term measures would be in the form of requiring Environmental Performance Assessment in “CE” marking and "C" marking (e.g. through Environmental Product Declarations), mandatory assessment of Environmental Performance in construction permitting, design for disassembly and adaptability to be required by the building code and implementation of Performance based contracts in Green Public Procurement (GPP).

For the implementation of the recommended measures, it is proposed to enhance the already established inter-ministerial governance framework by involving important role players in the decision-making in order to promote collaboration in introducing a Circular Economy approach.

Introduction

Stock-taking of international good practices and proposing policy options in the construction sector is part of a broader initiative undertaken by the Government of Croatia and supported by the World Bank for promoting circular economy approaches upon the adoption of the **EU Circular Economy Package**. The purpose of the present report is to gather relevant information/examples on international good practices and draft policy recommendations and strategies in introducing a Circular Economy approach along the value chain in the construction sector.

In this regard, the methodology for selecting good practices is based more on the criteria of completeness of the list of good practices, rather than on the details of their implementation. In other words, the purpose of this selection is to present the range of possibilities for transition to a circular economy in the construction sector rather than to describe the specific way of implementing the relevant practices in Croatia, which is a task that can be performed in the next stage, when the national circular economy action plan will be developed. However, the description of the practices is sufficiently detailed to assess the applicability of the relevant practice in the Croatian context and whether it would be appropriate to introduce it in the short, medium, or long term. The report analyzes both practices that have been shown to make a significant contribution to increasing waste prevention or material recovery rates, as well as circular economy actions (such as mandatory product eco-design or circular building design in building codes) that would have a noteworthy potential for termination of material

and energy leaks in the construction sector. Not only legally-binding measures were considered, but also voluntary initiatives. The feedback from the stakeholder consultation on CDW, which has taken place as part of the project in November 2021, has also been integrated into the formulation of the measures including e.g. market demand for environmentally friendly construction products, buildings and construction works, Corporate Social Responsibility policy, technical progress, raised awareness and economic benefits of sustainable products. For each stage of the life cycle, several good practices have been selected that meet these criteria.

Initially, a general overview of the state of play was performed including a description of policy context, legislation and strategies in the EU and the Member States and outlining the trends in construction and demolition waste generation and treatment. Furthermore, multiple international case studies for implementing voluntary and mandatory measures were analyzed at a different circular economy phase of the built environment as presented in the table below:

Table. Voluntary initiatives and mandatory policies with given examples of good practices. The economic instruments are marked in bold.

Table 1: Voluntary initiatives and mandatory policies with given examples of good practices.

Voluntary measures	Economic instruments	Mandatory measures
Production phase		
- Voluntary agreements	- Tax on raw materials	- CE marking and Construction Products Regulation
- Material passports		- Mandatory assessment of Environmental Performance
- Catalogues of renewable materials		- Tracking and phasing out of hazardous content in construction products
- Environmental product declarations / Product environmental footprints		- Eco-design of construction products
- Databases/ Catalogues of non-hazardous materials		
Design phase		
- Methodology for assessment of future value of the buildings		- Design for disassembly and adaptability in the building code
- Best practice demonstration projects		- Environmental Performance of Buildings
- Voluntary agreements		
- Certification systems		
- Level(s) – aligning all certification schemes in EU		

- Standard for Design for Disassembly and adaptability		
Construction phase		
- Building passports	- Lower tax for restoration of old buildings	- Green Public Procurement criteria
- Building Information Modeling		- Legal obligations for retrofit and renovation on EU level
- Eco-labels relevant to construction sector		
Use phase		
- update Building passports		- Take-back schemes established by bigger manufacturers
- update Building Information Modeling		- Extended Producer Responsibility
		- Performance based contracts
End-of-life phase		
	- Landfill restrictions (taxes)	- Recovery targets
		- Mandatory selective deconstruction and pre-demolition auditing and deconstruction reporting
		- Landfill restrictions (bans)
		- Enforcement measure
		- End-of waste - legislation and standards regarding recycled materials
		- Measures to increase recycled content in construction products

All of the analyzed instruments were compared with the current situation in Croatia and certain possibilities for their implementation in the Croatian context were explored.

Following a review of the available good practices, draft policy recommendations and strategies in introducing a Circular Economy approach to the construction sector were proposed in order to increase the recycling rate of the different materials used in the sector, including possible use in various construction works in short and mid to long term. Finally, the governance framework was assessed and it was proposed to involve important players in the decision-making process to promote collaboration in the introduction of the Circular Economy approach.

1. State of play of CDW in the EU and the Member States

Construction and demolition waste (CDW) results from on-site construction, refurbishment and demolition activities of buildings and infrastructures (Figure 1). Concerning CDW management, subchapter 1.1 introduces the policy context and legislation on a European level and presents those circular economy strategies (Austria, Ireland, Luxembourg, and Malta); in subchapter 2.1.2), and sub chapter 2.2 presents EU-27 Member state and Croatian data on CDW generation and treatment.

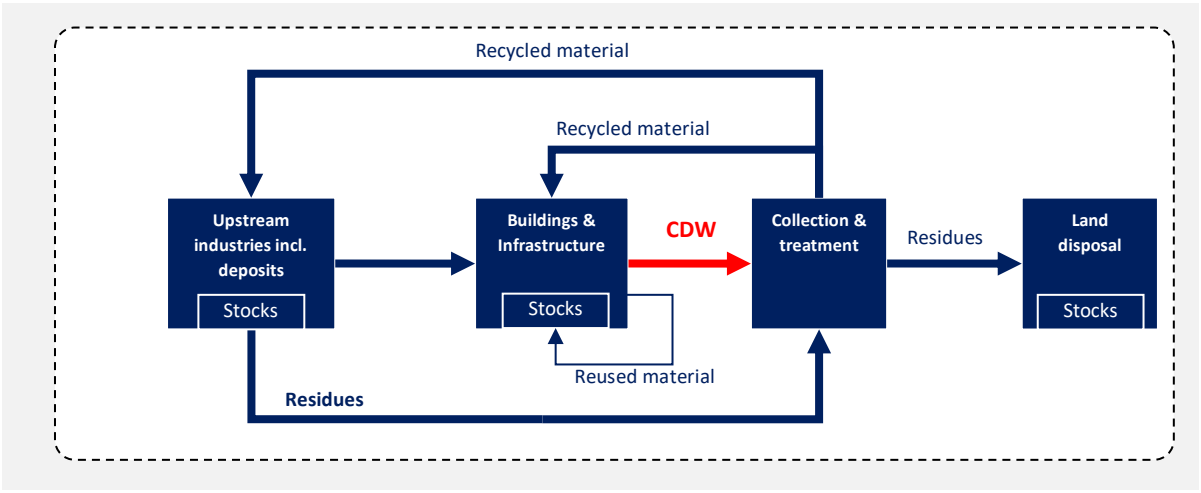

Figure 1: Material flow system for the construction sector, including upstream industries (e.g. mining & quarrying, manufacturing), the use phase (buildings & infrastructure) and the waste management phase (collection & treatment of wastes and land disposal).

1.1 Policy context, legislation and strategies

1.1.1 EU level

The European Union has a broad policy and legislation landscape to boost the circular economy. This chapter highlights the European policies and legislations of key relevance for the management of construction and demolition waste management. It covers EU legislation, the Circular Economy Action Plan and its' strategy for sustainable built environment, including best practice guidance in the sector.

The following **EU legislations** are cornerstones that affect national CDW policy setting, legislation and management:

- Waste Framework Directive (2008/98/EC): The Directive "lays down measures to protect the environment and human health by preventing or reducing the generation of waste, the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use". It requires EU Member States to reduce waste generation at construction and demolition processes, under consideration of best available technologies (Art. 9), 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" (Art. 11), and to achieve a target

for the preparation for re-use, recycling and other material recovery, including backfilling, to a minimum of 70% by weight by 2020 (Art. 11, 2b).

- Directive on the landfill of waste (1999/31/EC, OJ L 182 16.7.1999, p. 1): The directive aims to achieve a reduction of waste disposal in landfills, especially for residues that are suitable for recycling or other recovery options, and to set operational and technical requirements on the waste and landfills in order to prevent or reduce potential negative effects on human and environmental health.
- Council Decision on criteria and procedures for the acceptance of waste at landfills (2003/33/EC): The Council Decision amends the Landfill Directive and provides a framework including the procedure for the acceptance of waste at landfills, waste acceptance criteria, and sampling and testing methods. It directly affects CDW disposal, for instance, by defining criteria for waste without testing needs, leaching limit values for waste and total content of organic parameters. Next, the Council Decision requires EU Member States to dispose of gypsum "only in landfills for non-hazardous waste in cells where no biodegradable waste is accepted". In 2015, Jimenez Rivero, Guzman Baez und Garcia-Navarro found evidence on mono-cell landfill operations in Belgium, France and the United Kingdom.
- Regulation on shipment of waste (1013/2006/EC): This regulation "establishes procedures and control regimes for the shipment of waste, depending on the origin, destination and route of the shipment, the type of waste shipped and the type of treatment to be applied to the waste at its destination". It is noted that Eurostat publishes the data of transboundary shipments in terms of "total waste" and "hazardous waste" without disaggregation by NACE Rev. 2 activity and waste code. Therefore, data on the transboundary shipment of wastes from the construction sector are not publicly available.
- Construction Products Regulation (305/2011/EU): The Construction Products Regulation (CPR) replaces Construction Products Directive (89/106/EEC) and defines conditions for construction products put on market. The regulation clarifies the attachment of the CE labeling, defines rules for the declaration of performance (DoP) as a requirement for CE labeling, defines the roles of all stakeholders and provides a framework for harmonized technical specifications. It is noted that DoPs require information on hazardous substances in construction products (305/2011/EU, p. 25). Initially, the list of hazardous substances in limited to those defined by REACH (1907/2006/EU). The range of substances could be completed by further investigations to ensure a high protection level for the health and safety of workers that handle construction products and users of construction products, including "with regard to recycling and/or reuse requirements of parts or materials".
- REACH Directive (1907/2006/EU): REACH stands for Registration, Evaluation, Authorization and Restriction of Chemicals. Companies have to register their substances and the European Chemical Agency (ECHA) evaluates whether the risks for human and environmental health can be managed (ECHA, 2021). One practical implication is that manufactures have to report substances of very high concern (SVHC) in construction products during CE marking.
- Regulation concerning the making available on the market and use of biocidal products (528/2012/EC): In the construction sector, biocides are mainly used to protect materials against animal pests, fungi and other microorganisms. The directive lays down requirements for the authorization and market placement of biocidal active substances and biocidal products.

The **Circular Economy Action Plan** includes a "**strategy for sustainable built environment**" (*Circular economy action plan,* 2020) containing the following key elements: a) increasing sustainability performance of construction products through revision of the Construction Product Regulation,

including the possible introduction of recycled content requirements, b) promoting measures to improve the durability and adaptability of built assets, and developing digital logbooks for buildings, c) using Level(s) to integrate life cycle assessment in public procurement and the EU sustainable finance framework, d) considering a revision of material recovery targets set in EU legislation for construction and demolition waste and its material-specific fractions, and e) promoting initiatives to reduce soil sealing, rehabilitate abandoned or contaminated brownfields and increase the safe, sustainable and circular use of excavated soils.

In the context of the first EU Circular Economy Package, the EC launched the following **best-practice guidance documents**:

- EU Construction and Demolition Waste Management Protocol (EC, 2016): The protocol aims to improve CDW management processes and the trust in the quality recycling materials by means of improved waste identification, source separation and collection, improved waste logistics, improved waste processing, quality management and appropriate policy and framework conditions.
- Guidelines for waste audits before demolition and renovation works of buildings (EC, 2018):. The guidelines are voluntary, but 10 EU Member States already set mandatory requirements for pre-demolition audits in 2016, including Austria, Belgium – Flanders, the Czech Republic, Finland, France, Hungary, Luxemburg, the Netherlands, Romania and Sweden (Basuyau, 2016). As a supporting instrument, the NWE Interreg project Circulation of Reclaimed Building Elements (FCRBE) developed a „reclamation audit“, which is in essence a guideline to assess the reuse potential of construction products before demolition (Smeyers und Mertens, 2021).

1.1.2 EU national strategies focusing on CDW

The EC launched the 2nd Circular Economy Action Plan in 2020 aiming to move towards a circular economy in Europe. On EU-27 MS level and with respect to Table 1, 19 countries presented complementary strategies and/or actions plans (Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Luxembourg, Malta, Netherlands, Poland, Portugal, Spain, Sweden), 5 countries initiated a strategy/action plan (Austria, Croatia, Lithuania, Slovakia, Slovenia) and 3 countries have not been initiated or published in 3 countries (Bulgaria, Hungary, Romania). The construction and CDW sector, respectively, is directly addressed in 8 countries to various extend (Austria, Denmark, Finland, France, Greece, Ireland, Luxembourg, the Netherlands). **The countries with the most comprehensive and concrete measures for the construction sector are Austria (7 measures), Ireland (> 8 measures), Luxembourg (18 measures) and Malta (15 measures**).

Table 2: Circular economy strategies and action plans and their relevance for the construction sector. Notes: “n.i.” = not identified.

EU MS	Comment
Austria	A draft circular economy strategy was launched in December 2021 (BMK, 2021) and is open for public comments until end of January 2022. Among other sectors, the strategy also includes the constrution sector and suggests seven actions grouped into sustainable procurement of buildings and constructions, lifetime extension of buildings and the production of high quality secondar raw materials from CDW.
Belgium	The Belgian action plan for circular economy includes 21 cross-cutting actions (e.g. definition of recycling criteria) without specifiying tangible actions for the construction sector (Marghem, 2016).
Bulgaria	n.i.
Croatia	A roadmap for circular eocnomy in the construction sector is currently under development.

Cyprus	The Cyprus Cyprus Action Plan for the transition to a circular economy 2021-2027 has a budget of €90 million (Cyprus Circular Economy Network, 2021, Pileidou, 2021). It includes four pillars (Cultural change for a circular economy; Providing incentives for investments in a circular economy; Development of circular economy infrastructures; Municipal Waste Management) and a set of measures. The measures do not address the construction sector directly, but potentially have an effect on CDW management. For instance, as study will be conducted to identify wates that can be declassfied.
Czech	The national strategy „Circular Czech Republic 2040“ is under development and underpinned by OECD report „Towards a national strategic framework for the circular economy in the Czech Republic“ (OECD, 2021). The OECD report provides guidenace to develop and implement the strategy, but does not recommend direct actions for the construction sector.
Denmark	The Danish strategy for circular economy (Danish Government, 2018) includes 15 iniatives, of which most are cross-cutting and only 1 (selective demolition) is directly adressing CDW.
Estonia	The national strategy and action plan for the circular economy is under development and announced for release by end of 2021 (Ringmajandus, 14. Dezember 2021). The official release needs to be awaited before identifying potential effects on the construction sector.
Finland	The government resulution on the strategic programme for circular economy includes one direct measure for the construction sector (Ministry of Economic Affairs and Employment of Finland, 2021). In detail, Finland „will set a goal for extending the useful life of buildings and utilising demolition materials“. Next, the Finish roadmap to a circular economy 2016-2025 (SITRA, 2016) a set of widly defined measures that could potentially affect the construction sector. For instance, to promote the use of secondary materials and the use of surplus spoil.
France	The roadmap for a better circulartiy covers 50 individual measures (Republic of France, 2018). It includes three meaures to strengthen the sorting, reuse and recovery of CDW. First, a feasibility study for the establishment of an extended producer responsibility scheme for building waste. Second, to review the regulatory procedure for pre-demolition audits and suggest effective improvments. Third, the developmenet of technical guidelines for the performance of reused materials.
Germany	The circular economy initiative published a roadmap for Germany (Circular Economy Initiative, 2021). It provides a framwork for the transition to more circularity, but does not include tangible measures for the CDW sector.
Greece	The national ciruclar econmy strategy (Ministry of Environment & Energy, 2018) includes 34 measure, of which two are directly addressing the construction sector. First, the adjustment of an framework for construction projects. Second, the consideration of lifecycle costs during the procurment of construction projects.
Hungary	n.i.
Ireland	Irland launched an waste action plan for circular economy 2020-2050 (Government of Ireland, 2020). It includes 17 distinctive actions areas and one of it is CDW. The CDW area covers 9 tangible measures, which are presented subsequent to this table.
Italy	Italy developed a stratetic framwork for circular economy (Ministry for the Environment, Land and Sea und Ministry of Economic Development, 2017). It draws a landscape for the transition towards more ciruclarity, but does not include tangible measures for the CDW sector.
Latvia	Lativa developed a plan for the transition towards circular economy 2020-2027 (LIKUMI.LV, 22. Dezember 2021). It includes 30 measures, but no tangible measures for the construction sector.

Lithuania	A roadmap for Lithuania's industrial transition to a Circular Economy is currenlty under development (Harding, 2021).
Luxembourg	The circular economy strategy prioritizes the construction sector (Le Gouvernment du Grand-Duche de Luxembourg, 2021). It defines 18 methods and tools (measures) for the construction sector, for instance, the integration of circular criteria in public procurement.
Malta	Malta launched a construction and demolition waste strategy for public consultation (ERA, 2020). The strategy includes 15 distinctive measures, which are presented subsequent to this table.
Netherlands	The government-wide programme for a ciruclar economy by 2050 prioritzes the construction sector (Government of the Netherlands, 2016). It includes voluntary sector agreements, pilot projects for CO_2 reduction and reuse of materials, an implementation agenda for innovation in the construction sector, the use of lifecycle approached in public procurement, and the reduction of material consumption.
Poland	The roadmap towards the Transition to the Circular Economy included 41 actions (Polish Government, 2019), of which some potenially effect the construction sector. For instance, a study will be conducted to identify the potential and legislative changes for the use of combustion residues.
Portugal	The action plan for circular economy 2017-2020 (Republic of Portugal, 2017) suggests a sectoral agenda for construction sector as a starting point for discussion between stakeholders to establish actions.
Romania	Romania developed a ciruclar economy strategy 2020-2030 (Institute for Research in Circular Economy and Environment "Ernest Lupan", 2021), but the final strategy could not be idenfied during this project.
Slovakia	In Novemeber 2020, Slovakia annouced to develop a roadmap for the transition to a circular economy (CEENERGYNEWS, 2020).
Slovenia	The government conducted a study to propose a uniform document on the potentials and opportunities for the transition to a circular economy in Slovenia (Košir et al., 2018). The proposal identified four areas (food system, manufacturing industry, mobility, forest based value chains) and does not include tangible measures for the constuction sector.
Spain	The strategy for circular economy 2030 prioritizes the construction sector (Government of Spain, 2020), but it does not includes tangible measures. However, the reduction target of 30% reduction of domestic material consumption might trigger measure in the construction sector.
Sweden	Sweden launched a ciruclar economy strategy for the transition (Government Offices of Sweden, 2020). The selection of priority waste streams incldues CDW. Tangible measures are not includes, but it is noted that the government will develop actions plans with specific policy instruments and measures.

Croatia is currently missing strategies and action plans to move towards a circular economy. **Croatia is planning to develop a five-year Circular Economy Action Plan on CDW** in order to introduce higher level of circularity in the construction sector. The aforementioned strategies (c.f. Table 1) could inspire the upcoming activities in Croatia. Against this background, those of **Austria, Ireland, Malta and Luxembourg** are compiled as followed. It is noted that the strategies in Ireland and Luxembourg are in the implementation phase and those in Austria and the Netherlands have been published for public commenting.

1) **Ireland launched a waste action plan for a circular economy** in the 2020-2025 period with CDW as priority stream and tailored actions regarding recovery targets, market creation, by-products,

end-of-waste, waste management plans, waste enforcement, permit exemptions, and waste tracking and data reporting (Government of Ireland, 2020).

- **Reuse and recovery targets for plastic** from the CDW sector will be developed.
- To **create a market** for recycled materials, incentives will be put in place including examining a possible levy on the use of virgin aggregates or building thresholds into Green Public Procurement (GPP) and expanding GPP criteria.
- In alignment with the Waste Framework Directive (2008/98/EC, Article 5) on by-product definition, the Environmental Protection Agency (EPA) developed a guidance document for soil and stone **by-products** (EPA, 2019). The utilization of soil and stones is a case-by-case decision based on authority notification. In the context of the action plan, Ireland will take actions to improve the by-product process to provide more certainty and more timely responses.
- **End-of-waste** refers to a status where materials cease to be waste. It takes the material out of the waste regulatory system and allows the creation of new products. In 2020, the EPA drafted end-of-waste guidance documents (EPA, 2020a, EPA, 2020b). The current action plan aims to "streamline the end-of-waste application and decision-making process" on one hand, and to "obtain end-of-waste status for a number of priority waste streams, particularly in the CDW sector" on the other. Single-case decisions were undertaken in the past, for example, for the use of recycled aggregates from crushed demolition concrete (EPA, 2019). The action plan will seek national end-of-waste decisions for specific CDW streams.
- In the context of the action plan, the EPA published guidelines to prepare **resource and waste management plans** for CDW projects (EPA, 2021).
- Effective **enforcement of waste legislation** aims to the cessation of illegal waste activities. The action plan includes measures to expand the role for local authorities to address priority waste enforcement challenges, announces an unauthorized sites action plan and an anti-dumping toolkit, and foresees a fixed penalty notice for breaches of waste law.
- The Waste Framework Directive (2008/98/EC, Article 24) allows EU Member States to issue **permit exemptions** for the disposal of non-hazardous waste at the place of production or the recovery of waste. According to the action plan, several other EU Member States utilized the Article 24 option to "manage the treatment of certain waste streams, particularly in relation to construction and demolition". The action plans include a review of Article 24 exemptions in other EU Member States, the identification of waste activities that might be considered under the exemption approach to encourage greater repair, reuse of recycling of CDW material, and the development of legislative changes necessary for such exemptions.
- **Waste tracking and data reporting** is a measure across all waste streams. The action plan includes eight key measures, whereas one "requires large-scale construction projects to provide local authorities with data on waste management and movements to increase the visibility and traceability of their wastes".
- **Additional** actions in the CDW sector include the examination of methods to encourage source segregation of waste materials on-site, the standardization of waste dockets, and the support of training to roll out the implementation of best practices across the sector.

2) **Luxembourg launched a circular economy strategy in 2021** (Le Gouvernment du Grand-Duche de Luxembourg, 2021) aiming to accelerate the transition path towards more circularity. Among other sectors, the strategy prioritizes the construction sector with the measures in **Error! Reference source not found.**.

Table 3: Measures for the construction sector in Luxembourg. Table taken from Le Gouvernment du Grand-Duche de Luxembourg (2021).

	CATEGORY 1	CATEGORY 2	CATEGORY 3
LEVEL RESOURCE TRIANGLE	REGULATIONS & STANDARDS	FINANCIAL ASPECTS	KNOWLEDGE CREATION & MANAGEMENT
(1) CREATE VALUE	- Integrate circular criteria in public procurement for construction (such as PaaS business models) - Develop the material passport approach for better traceability of materials and products; evaluate the usability of the PCDS for describing the circularity of construction materials - Integrate circular criteria in spatial planning instruments (PAG/PAP) and construction regulation (e.g. 'réglements sur les bâtisses'), for better use of resources and space	- Introduce the Total Cost of Ownership as a decision support tool for circular solutions - Integrate circular construction in the subsidy scheme for municipalities of the 'Pacte Climat' 2.0 - Promote PRIMeHouse subsidies (and LENOZ certification[28]) including circular criteria (healthy materials, deconstruction)	- Set up a database of circular construction materials and products (including health aspects) - Integrate circularity in guidelines for sustainable construction, as well as for spatial and urban planning - Promote the use of the BIM methodology to manage information across the construction value chain - Align training for the sector and ensure its provision
(2) MAINTAIN VALUE	- Expand the concept of Extended Producer Responsibility (EPR) to the Construction Sector - Develop a regulatory framework for the reuse of materials, components and products in the construction sector, including water, in buildings	- Explore incentives (such as support schemes, subsidies or taxation) for the reuse of stock (materials, components and products) and encouraging circular flows in cascades (e.g. reuse of treated greywater)	- Set up a marketplace (physical and digital) for deconstruction materials (including interior elements), focus on cascaded use for wood (see also 'bio-materials') - Extend the guideline for deconstruction to reusable (non/waste) products and components
(3) RECOVER VALUE	- Develop a regulatory framework for the reintroduction of recovered and recycled materials, components and products in the construction market	- Explore incentives adapted to the reuse of recovered and recycled materials, components and products in the construction sector	- Set up a marketplace (physical and digital) for recycled deconstruction materials (including interior elements)

3) **Malta launched a construction and demolition waste strategy** for public consultation in 2020 (ERA, 2020). The strategy aims to identify management options for CDWs by considering sectoral issues, potential future measures, and options to shift waste volumes from backfilling to re-use and recycling. The strategy proposes 15 measures including the following:

- Establish standards for the construction industry;
- Promote innovation through Research and Development;
- Introduce a new regulatory framework directed at the management of CDW;
- Allow for Mandatory Training; Further develop National Occupational Standards;
- Encourage Home Restoration Projects; Set Price Differentiation for Planning Applications;
- Improve Waste Classification and Source Separation; Establish mandatory record keeping on development sites;
- Recognize the need for Resource Recovery and Storage Depots;
- Explore ways of introducing the Polluter Pays Principle;
- Extraction of Resources at Development Sites;
- Promote markets for secondary raw materials;
- Set Re-use and Recycling Targets for any Development;
- Enforce Recovery through Restoration of Void Spaces (carry out an exercise to identify quarries, Launch Schemes for quarry restoration);
- Discourage Landfilling of CDW;
- Assess the Characteristics of the Offshore Spoil Ground;
- Explore the viability for land reclamation.

4) **Austria launched a circular economy strategy** for public consultation in December 2021 (BMK, 2021). Among other sectors and waste streams, the strategy prioritizes the construction sector and CDW flows as followed:

- Sustainable procurement of buildings and constructions:
  - Mandatory consideration of procurement criteria as defined in the Sustainable Action Plan for Sustainable Public Procurement;
  - Measures to use the procurement criteria also in the private sector.
- Extension of building lifetimes:

- Introduction of a license requirement for building demolitions and additional approval/disapproval criteria for authorities;
- Mandatory multifunctional usage concepts for service buildings during the construction approval process;
- Periodization of resource efficient and circular building design in public funding schemes.

- Production and use of high-quality secondary raw materials:
  - Establishment of a legal framework for re-use of building components during the revision of EU building product legislation;
  - Close material loops, especially for gypsum, asphalt, soil, through actions in the waste policy areas (landfill bans) and introduction of material specific minimum targets for recyclables in products.

1.2 CDW data in the EU

This subsection presents data regarding CDW generation and treatment, including recovery rates.

1.2.1 Waste generation

According to the European Waste Framework Directive (WFD), construction and demolition waste (CDW) means "waste generated by construction and demolition activities" (2008/98/EC). More specifically, the **European waste list in chapter 17 defines CDW** as follows (2000/532/EC, OJ L 226 6.9.2000, p. 3): a) Concrete, bricks, tiles and ceramics, b) Wood, glass and plastic, c) Bituminous mixtures, coal tar and tarred products, d) Metals (including their alloys), e) Soil (including excavated soil from contaminated sites), stones and dredging spoil, f) Insulation materials and asbestos-containing construction materials, g) Gypsum-based construction material, and h) Other construction and demolition wastes.

Eurostat collects the data on the generation and treatment of waste from the Member States based on the regulation on waste statistics (2150/2002/EC), amended by Commission Regulation (EU) N° 849/2010. The database "Waste generation and treatment (env_wasgt)" covers the data in tons and tons per capita for the years 2010 to 2018 (Eurostat, 2021). This chapter presents 2018 data for CDW, unless otherwise mentioned, for the waste "soil", "dredging spoil" and "mineral waste from CDW"[1] from all NACE activities plus households on the one hand, and metal (ferrous, non-ferrous, mixed), wood, glass and plastic wastes from NACE Rev. 2 activity F (Construction).

In 2018, about 878 Mio tons of CDW was generated in the EU-27, of which 97% (849 Mio tons) mineral wastes (soil, dredging spoils, mineral waste from construction and demolition waste) and 3% (29 Mio tons) are non-mineral wastes (metal, wood, glass and plastic wastes). The countries with the largest volumes are France (242 Mio tons), Germany (227 Mio tons) and the Netherlands (101 Mio tons). **Croatia reported 1.2 Mio tons of waste, which represents about 0.14% of the EU-27 quantities by mass. Regarding the 1.2 Mio tons, Croatia reported 88% (1.08 Mio tons) of mineral wastes and 12% (0.15 Mio tons) non-mineral wastes.**

[1] The „construction and mineral wastes (12.1)" includes "Concrete, bricks and gypsum waste (12.11)", "Waste hydrocarbonised road-surfacing material (12.12)" and "Mixed construction wastes (12.13).

Table 4: Composition of construction and demolition waste in tons, 2018. Data taken from Eurostat: Generation of waste by category, including a) non-hazardous and hazardous wastes, b) Soils, mineral waste from CDW, dredging spoils from All NACE activities plus households. Metal waste, wood wastes, glass wastes, plastic wastes from NACE Rev. 2 activity F (Construction).

CDW [tons]	EU-27	Croatia	Ratio
Soils	468'598'386	582'492	0.12%
Mineral waste from construction and demolition	303'172'466	490'355	0.16%
Dredging spoils	76'873'001	10'439	0.01%
Mineral wastes	**848'643'853**	**1'083'286**	**0.13%**
Metal wastes	18'868'913	145'831	0.77%
Wood wastes	8'699'145	2'655	0.03%
Plastic wastes	923'539	684	0.07%
Glass wastes	803'917	3'768	0.47%
Non-Mineral wastes	**29'295'514**	**152'938**	**0.52%**
Total	**877'939'367**	**1'236'224**	**0.14%**

On a per capita basis, the EU-27 average of CDW volumes is 1’968 kg/cap countries. The countries with the largest CDW volumes are Luxembourg (12.748 kg/cap), 5’890 kg/cap and Finland (4’285 kg/cap). **Croatia reported about 300 kg/cap of CDW was reported**. So, the per capita CDW generation in Croatia is 85% less compared to EU-27 per capita generation by mass.

Table 5: Composition of construction and demolition waste in kg per capita, 2018. Data taken from Eurostat: Generation of waste by category, including a) non-hazardous and hazardous wastes, b) Soils, mineral waste from CDW, dredging spoils from All NACE activities plus households. Metal waste, wood wastes, glass wastes, plastic wastes from NACE Rev. 2 activity F (Construction).

Wastes [kg/cap]	EU-27	Croatia	Ratio
Soils	1'050	142	14%
Mineral waste from construction and demolition	679.4	119.4	18%
Dredging spoils	172.3	2.5	1%
Mineral wastes	**1'901.9**	**263.9**	**14%**
Metal wastes	42.3	35.5	84%
Wood wastes	19.5	0.6	3%
Plastic wastes	2.1	0.2	8%
Glass wastes	1.8	0.9	51%
Non-Mineral wastes	**65.6**	**37.3**	**57%**
Total	**1'967.5**	**301.1**	**15%**

In regards to the **hazardousness of construction waste**, the EU-27 produced 46 kg/cap hazardous waste, which is 2% of the total CDW (non-hazardous and hazardous). The countries with the largest volumes of hazardous waste on a per capita basis are Luxembourg (454 kg/cap), Denmark (251 kg/cap) and the Netherlands (134 kg/cap). Croatia reported 5 kg/cap of hazardous waste, which is 1% of total CDW.

Table 6: CDW generation per non-hazardous and hazardous classification, 2018. Number rounded. Data taken from Eurostat: Generation of waste by category, including a) non-hazardous and hazardous wastes, b) Soils, mineral waste from CDW, dredging spoils from All NACE activities plus households. Metal waste, wood wastes, glass wastes, plastic wastes from NACE Rev. 2 activity F (Construction).

Wastes [kg/cap]	EU-27	Croatia	Ratio
Non-hazardous	1'922	297	15%
Hazardous	46	5	10%
Total	**1'968**	**301**	15%

1.2.2 Waste treatment

Eurostat provides waste treatment data for "major mineral wastes", including the following waste categories: a) Mineral waste from construction and demolition (EWC-Stat 12.1), b) Other mineral wastes (EWC-Stat 12.2, 12.3, 12.5)[2], c) Soils (EWC-Stat 12.6), and d) Dredging spoils (EWC-Stat 12.7). **Eurostat does not provide waste treatment data by NACE Rev. 2 activity**, which prevents the analysis of treatment data for metal, wood, glass and plastic waste from NACE Rev. 2 activity F (Construction).

The Directive 2008/98/EC defines the treatment operations and for this report, the treatment operations have been grouped into recycling, backfilling, incineration and disposal (**Error! Reference s ource not found.**).

Table 7: Waste treatment operations.

Treatment operations as defined in this report	Treatment operation according to Directive 2008/98/EC
Recycling	Recovery – recycling (RCV_R)
Backfilling	Recovery – backfilling (RCV_B)
Incineration (with and without energy recovery)	Energy recovery (RCV_E): Operation R1; Incineration (without energy recovery) (DSP_I): D10
Disposal (at landfill or others)	Landfill/disposal (D1-D7, D12)(DSP_L_OTH): Operations D1-D7, D12; (DSP_D + DSP_OTH)

The analysis of the Eurostat data on **major mineral waste treatment shows 3'200 kg/cap for EU-27 average. The countries with largest per capita volumes of major mineral waste treatment are Finland (20'500 kg/cap), Bulgaria (12'900 kg/cap), and Luxembourg (11'400 kg/cap). Croatia reported 170 kg/cap**. In Croatia, the largest share of major mineral wastes is soil (88 kg/cap), followed my mineral waste from CDW (75 kg/cap). With respect to **mineral waste from CDW**, Croatia recycles 70% (EU-27: 79%) and disposes 22% (EU-27: 12%).

[2] It is noted that „other mineral wastes" cover waste from all economic activities and are therefore not limited to the construction sector (NACE-Rev.-2-Codes, Division F).

Table 8: Treatment of major mineral waste in kg per capita.

	Dredging spoils	Mineral waste from construction and demolition	Other mineral wastes	Soils	Total
Croatia	**0**	**75**	**7**	**88**	**170**
Disposal	0	17	5	31	53
Recovery – recycling	0	52	2	33	87
Recovery – backfilling	0	6	0	24	30
Incineration	0	0	0	0	0
EU - 27 countries (from 2020)	**168**	**584**	**1'463**	**1'018**	**3'233**
Disposal	157	69	1244	286	1756
Recovery – recycling	8	464	134	373	979
Recovery – backfilling	3	49	84	359	495
Incineration	0	2	1	0	3

1.2.3 Recovery rates

The Directive 2011/753/EU defines the **calculation of the recovery target.** The calculation uses the data from the following non-hazardous wastes:

- Metallic waste (ferrous, non-ferrous, and mixed), glass waste, plastic and wood from the economic activity "construction" (construction of buildings, civil engineering, and specialized construction activities) as defined by NACE-Rev.-2-Codes, Division F (Eurostat, 2008); and
- Mineral CDW including concrete, bricks and gypsum, hydrocarbonised road-surfacing material, and mixed construction waste from all economic activities.

To this day, **Eurostat does not publish recovery rates of CDW in alignment with** Directive 2011/753/EU. However, Eurostat published data on the treatment of major mineral wastes for the year 2018, which enables the calculation of recovery rates under consideration of the following aspects:

- The major mineral wastes include four distinctive wastes (see chapter 1.2.2), of which only the "Mineral waste from construction and demolition" from all NACE Rev. 2 activity used for calculation the recovery rates;
- The recovery operations consider the recovery of materials by recycling and backfilling respectively. It is noted that the calculation of the material recovery rates excludes energy recovery during incineration;
- Deloitte (2017) analyzed the data quality of reported CDW quantities in 2012. They found that 18 EU Member States reported good and modest data quality (Austria, Belgium, Croatia, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Italy, Lithuania, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Slovenia, and Spain) and 9 reported poor data quality (Bulgaria, Ireland, Greece, Cyprus, Latvia, Malta, Romania, Finland, and Sweden). Based on these findings, only the first 18 EU Member States are taken into consideration for presenting the data in this chapter.

The calculation of the **recovery rates** (excluding energy recovery) shows that the EU-18 recovers 90% of mineral waste from CDW by recycling and backfilling operations and 83% by recycling operation (Figure 2). **Croatia recovers 78% and 70% respectively.**

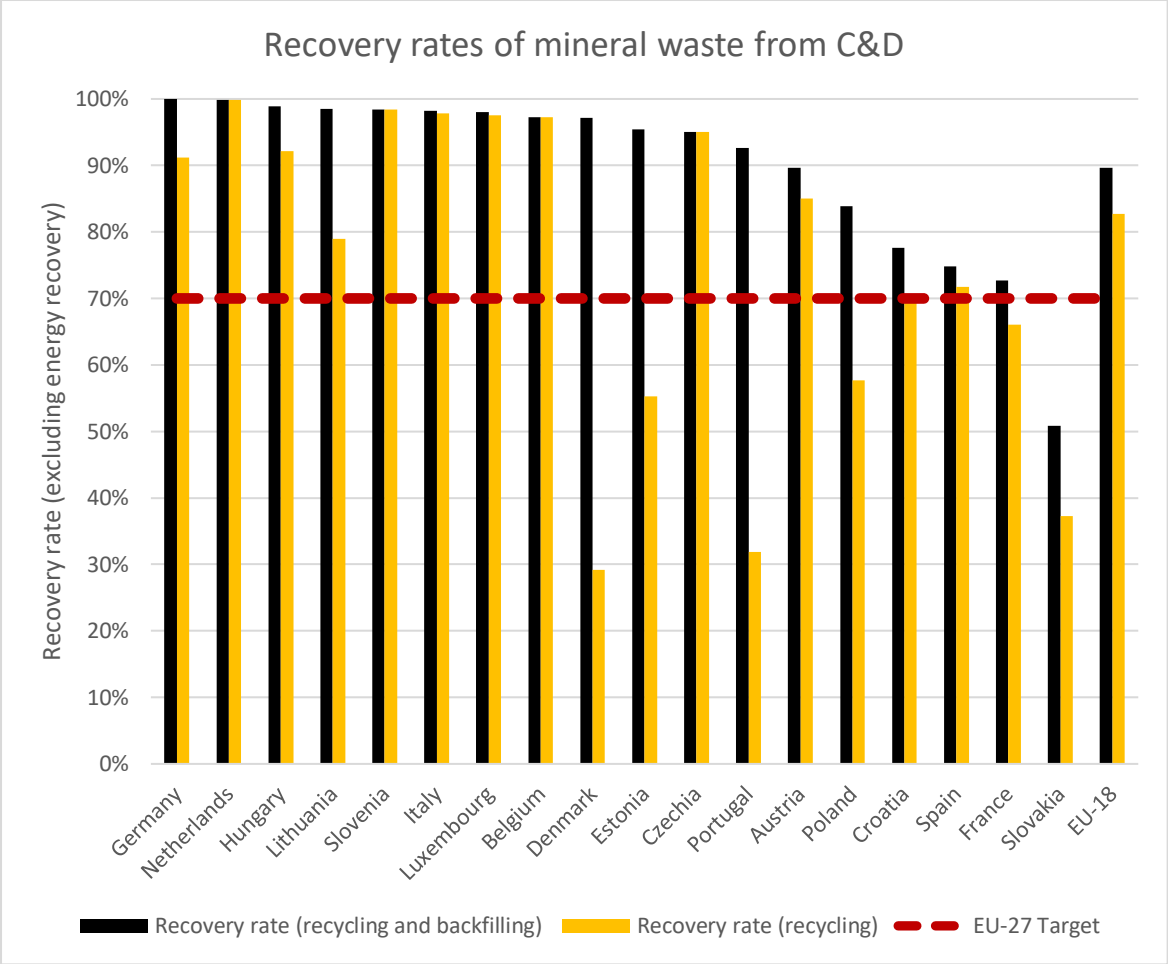

Figure 2: Recovery of materials from mineral waste from construction and demolition for the year 2018. Source: Eurostat.

As indicated above, Eurostat has not published data on recovery rates according to Directive 2011/753/EU until now. But the Croatian administration estimated the recovery rates for 2019 and 2020 according to Directive 2011/753/EU as follows:

- In 2019 the recovery rate for CDW is 67% (Kufrin, 2020). The report notes that data quality should be improved because the reporting system does not capture entire CDW flows in Croatia;
- In 2020, the recovery rate for CDW is 60% (Republic of Croatia, 2021). The decrease compared to the previous year is explained by additional waste from the Zagreb earthquake, reduced amount of construction waste in storage, and better quality waste reporting.

In May 2021, the European Commission published a guidance document for the reporting on material recovery of CDW (European Commission, 2021). The guidance document was published after the calculation of the recovery rates for 2019 and 2020. Potentially, the guidance document affects the reporting of the recovery rates from Croatia to Eurostat. Regardless of any changes, the Croatian administration stated that the recovery rate of 60% in 2020 fails to meet the European recovery target of 70% (Republic of Croatia, 2021).

2. Construction materials of the future/Buildings of the future – international good practices

The main goals of the circular economy in the construction sector are to keep materials in the economy for as long as possible through efficient and intelligent use and preservation of the value of the materials by optimizing their reuse or recycling. In practice, these goals are achieved by introducing legal, technical and economic measures for improving circularity at different stages of the value chain. All measures are inter-linked in the value chain and the benefits cannot be attributed to only one specific stage. This chapter describes the applicable measures to ensure that buildings are designed to be easily adaptable, dismountable and almost non-destructive, as well as for providing construction materials that are durable, renewable, non-hazardous, reusable/recyclable and contain high recycled content which would lead to a maximum recovery of the materials in a closed cycle and almost no material would be wasted.

The following chapters explore different voluntary and mandatory instruments in the construction sector, with relevance to:

- Production of sustainable construction materials (3.1);
- Circular design of buildings and construction works (3.2);
- Sustainable construction and renovation of buildings (3.3);
- Sustainable use and maintenance of buildings (3.4).

In each of these topics, barriers and opportunities are evidenced, and instruments are presented with reference to EU existing practices and case studies.

Finally, comparison and benchmarking against the Croatian situation has been performed, with emphasis on assessing the preliminary applicability of each presented instrument. This is particularly helpful to identify the instruments that can be considered for the development of further strategies or approaches to CDW in Croatia.

2.1 Production of sustainable construction materials

2.1.1 Concept

The first step in the transition to a circular economy in the construction sector begins with the design and manufacture of materials and components that will be used in the buildings. Building materials must meet the following requirements in order to ensure that their useful life is the longest possible and to facilitate their return to the economic cycle when they become obsolete:

- To be highly durable;
- To be renewable;
- To be produced without harmful impact to the environment;
- To have a high recycled content;
- To be non-hazardous.

This chapter presents good practices to ensure the production of sustainable construction material. The table below provides an overview of the measures:

Table 9: Voluntary and mandatory measures for the production of sustainable construction materials.

Voluntary measures	Mandatory measures
– Voluntary agreements (green Deals)	– CE marking and Construction Products Regulation
– Material passports	– Mandatory assessment of Environmental Performance
– Catalogues of renewable materials	– Tracking and phasing out of hazardous content in construction products
– Environmental product declarations/ Product environmental footprints	– Tax on raw materials
– Databases/Catalogues of non-hazardous materials	– Eco-design of construction products

2.1.2 Barriers and enabling conditions

Some of the mechanisms for sustainable construction products listed above are already implemented, driven by market demand and voluntary actions. But to make an economy truly circular, it is necessary to take additional measures by focusing on the whole lifecycle of construction products in a manner that preserves resources and closes the loop of resources and materials.

The demand for sustainable building products is increasing due to the **technical progress** in the production of quality materials from recycled waste and renewable resources, new construction approaches and **know-how,** as well as **raised awareness** among key players in the building value chain.

In recent years, advanced technologies for the production of construction materials (e.g. cement and clean aggregates) from construction and demolition waste have been developed. These include for instance green thermal treatment for concentrating and purifying cement or paste and laser-induced breakdown spectroscopy (LIBS) tools for verifying the quality of input materials for the concrete facilities[3]. Such technologies enable the production of high-quality aggregates from construction and demolition waste, and establish trust with the users that recycled materials are of good quality. This, in turn, can lead to an increase in the market demand for products made from recycled waste.

The integration of life-cycle assessment in the design and manufacture of construction products has given impetus to the expansion of knowledge about the necessary measures to make the products more durable, repairable, replaceable, non-hazardous, reusable, recyclable and containing higher renewable and recycled content. The results of a number of EU-funded projects also contribute in this direction. The findings from the life cycle analysis of different products are available in national and international databases such as the Dutch databases of the NMD Foundation[4], and in some cases publicly available, which facilitates the acquisition and dissemination of know-how in the production of new construction products or redesign of existing ones.

With the spread of the idea for the circular economy, the **demand for sustainable use of materials** is increasing, especially in the business market and larger civil engineering works. Many construction and infrastructure companies want to deal with building materials more efficiently and sustainably based on their Corporate Social Responsibility (CSR) policy. Companies also want to distinguish themselves from others on the market using (more) sustainable materials.

There are also **economic and financial benefits** from sustainable products in construction works. Products that are designed and manufactured for increased durability can generate financial savings

[3] Advanced technologies mentioned in EIONET Report - ETC/WMGE 2020/1 "Construction and Demolition Waste: challenges and opportunities in a circular economy".

[4] https://milieudatabase.nl/database/?_x_tr_sl=nl&_x_tr_tl=en&_x_tr_hl=bg&_x_tr_pto=op

associated with reduced difficulties in the deconstruction of buildings, lower waste management costs, and higher residual value (value after full depreciation) of construction components and buildings in general. Using secondary materials instead of virgin materials often requires less energy when considering energy associated with extraction.

To boost the ongoing trends towards better circularity, stemming from technical progress, raised awareness and economic benefits, government initiatives would be needed. Such initiatives could be in the form of initiation of voluntary agreements, encouraging claims for better circularity of products (respectively adoption of standards for measuring environmental impact throughout the life cycle of products to prove the claims), or mandatory requirements. The experience of the Netherlands shows that it is appropriate to start by encouraging voluntary measures but the real impetus to better circularity is achieved when mandatory measures are adopted, which become more stringent over time.

2.1.3 Implementation and good practices

In the following some examples should be given.

2.1.3.1 Voluntary initiatives

The building buyers and users have a crucial role for the uptake of circular economy principles in the construction sector, since they set targets for sustainability. Voluntary schemes for sustainable buildings, such as EU Level(s), BREEAM and LEED, as well as voluntary agreements between public authorities and construction service providers will probably influence the uptake of new approaches and designs, with effects on both construction waste generation and management. For successful implementation of circular economy concepts in the construction sector, however, relying on voluntary initiatives would not be enough and both voluntary support from all stakeholders in the value chain as well as intervention and incentives by the Governments would be needed.

2.1.3.1.1 Voluntary agreements

With this interactive working method, the government wants to give space to innovative, sustainable initiatives from the business and the society in general. It does this by identifying and removing bottlenecks in legislation and regulations, creating new markets, providing good information and ensuring optimal partnerships in the respective value chain. The usual approach and content of a voluntary agreement in the Netherlands are explained below.

Laws and regulations. In the voluntary agreements, the barriers for green innovations or sustainable action are identified and tackled. The legal actions to remove barriers can be categorized under four topics: 1. licensing procedures; 2. adapting rules; 3. providing scope of the necessary changes in the legislation; and 4. providing information on processes and procedures.

Support for the market of green products. New products and services compete with existing ones. In the initial phases, they may need additional support such as new norms, standards and labels, etc. This is addressed in voluntary agreements by trying out new “arrangements/services”, developing market tools focused on demonstrating “added value” such as certification, and strengthening the role of public authorities as “leading customers”.

Innovations are key to greening the economy and under voluntary agreements, entrepreneurs develop dozens of innovative business cases, products, revenue models and services and apply them together with early adopters. This generally does not involve traditional technical innovations, but mainly initiating activities together with other parties, often from other domains or sectors. This enables new revenue models to be generated.

Networking. Forming partnerships to try out new products and services is one of the main focuses of the voluntary agreements. As an independent party, the government can bring organizations together and, where necessary, help initiate projects and processes with new guidelines, quality standards, etc.

Clear mutual agreements enable participants to work on concrete results, whereby each involved party has its own responsibility. In this way, companies can benefit by developing their sustainable ideas to grow towards better competitive positions and greater export opportunities.

The most important principle of the approach is to ensure a spin-off – that successful agreements inspire others in the society to follow broadly and that the driving force behind this change will be society itself.

The example of Green Deals in the Netherlands, also relevant for CDW, is presented below.

Case Study 1: Green Deals in the Netherlands for the construction and demolition sector

Green Deals in the Netherlands[5]

The conclusion of voluntary agreements in the Netherlands, the so-called Green Deal approach started in 2011. Clear mutual agreements between the Government from one site and stakeholders concerned on the other enable participants to work on concrete results, whereby each party involved has its own responsibility. With this working method, the Government aims to give space to innovative, sustainable initiatives from society by removing bottlenecks in legislation and regulations, creating new markets, providing good information and ensuring optimal partnerships. At the beginning of 2019, 227 Green Deals were concluded with more than 1'300 parties. Currently, there are around 46 Green Deals related to the construction sector. The most relevant ones are briefly described further below.

- **Green Deal Sustainability of the concrete chain**

Nearly twenty parties in the Dutch construction industry collaborate in the **Green Deal Sustainability of the concrete chain**. They are working on far-reaching sustainability of the entire concrete chain from production to application and reuse. What is special about the Concrete Green Deal is that it includes all links in the Dutch concrete chain and concerns concrete products and structures. The aim is to arrive at a widely supported and independent definition of sustainable concrete and to apply it throughout the entire Dutch value chain. Important themes are energy use and emissions in soil, water and air, but also extraction and consumption/reuse of raw materials and the impact of business and production on biodiversity and ecosystems. Aspects as design, logistics, and transport are also considered. Working groups in the four theme areas of energy, raw materials, emissions and biodiversity/ecosystem are developing substantive objectives for 2020 and 2050. The participating companies commit themselves to these objectives.

- Corporate Social Responsibility strategy concrete chain – all companies in the Green Deal commit to actively including CSR in their business operations. Concrete objectives have been agreed by the partners to build sustainably to at least 20% of the Dutch (concrete) construction market by 2020, according to the widely supported definition to be developed further (100% target by 2050);

[5] https://www.greendeals.nl/green-deals

- Platform Sustainability Concrete Chain – consists of (frontrunner) companies from all links in the concrete chain that commit themselves to ensure that the goals set in the program will be achieved and companies and organizations will continue to work actively;
- WIKI: An online wiki about sustainability and concrete accessible to everyone, that consists of a database with an independent evaluation of the solutions (how sustainable is it) based on LCA information, land use, nature value (etc.), and social criteria.

Green Deal Green Building Materials

The Green Deal Green Building Materials was signed between public sector representatives (the Ministry of Economic Affairs, the Ministry of Infrastructure and the Environment); District of Tomorrow B.V. (a supplementary education course for extra qualification in sustainable construction materials); and Green Building Materials V.O.F. (an innovative company specialized in selling sustainable (mainly bio-based) and healthy construction materials).

The signatories of the Green Deal aim to significantly increase the share of green building materials in the construction sector by 2020 through the development and use of green building materials and green building techniques and increasing the sales market for these building materials and techniques. Their main commitments and actions are as follows:

- District of Tomorrow B.V. and Green Building Materials V.O.F. to realize a building (Maxergy) that consists of 100% bio-based and sustainably produced building materials and is energy neutral;
- District of Tomorrow B.V. to build a 'bio-based garden' where, within a time frame of 50 years, the materials used can regrow;
- Green Building Materials V.O.F. to set up a 'Green Building' practice group of suppliers and processors of green building materials and techniques as well as a demonstration center;
- District of Tomorrow B.V. and Green Building Materials V.O.F. to set up a network in which knowledge and experiences with green building materials and techniques are evaluated and made available;
- District of Tomorrow B.V. and Green Building Materials V.O.F. to set up a market-supported assessment method for green (building) materials with a view to possible standardization;
- The national government is making every effort to promote the **standardization** of green building materials and techniques;
- The national government is introducing the subject of green building materials in vocational education, colleges and universities.

A website has been set up to realize the vision: www.groenebouwmaterialen.nl. In addition, a lot of knowledge was shared within this Green Deal about neighborhoods and realized projects.

2.1.3.1.2 Material passports

Materials can be efficiently reused or recycled after demolition if construction works have a material passport. This passport provides an insight into the quality and quantity of the processed materials and building parts. It lists the materials used in a product or construction under the aspect of their recyclability. The aim is to conserve resources in architecture and expand the market for recycled or recyclable materials. The existing alternative tools (such as EPD, Bills of Materials, Materials Safety Data Sheets, Technical Data Sheets) only partially meet those needs, because they focus more on measuring and reducing negative environmental impacts rather than increasing positive value creation. Regarding passports, it is important to know whether maintenance has taken place and

whether parts were replaced, as this potentially changes the materials and products that are available at the time of recovery, and their value for recovery.

There are a variety of initiatives, some of which focus on describing construction products while other on building elements and entire buildings. Examples are EPEA[6], which runs Cradle to Cradle Certified™ products program[7], MADASTER, which is an online platform for building materials and elements, as well as other such as Antea[8], NLGreen[9]. The case studies presented in detail below include Product Circularity Passports in the Netherlands, and the EU-funded research and development project BAMB, on material banks.

Case Study 2: EPEA (the Netherlands) - Product Circularity Passports

EPEA (the Netherlands) – Product Circularity Passports[10]

EPEA's Product Circularity Passports are a Cradle to Cradle® tool to accelerate the implementation of the circular economy. By closing the information gaps, product Circularity Passports provide transparency and pave the way for actual Recycling or even Upcycling. Its aim is to provide continuous exchange of information throughout the life cycle, in particular on product composition, disassembly steps and recycling potential.

- Manufacturing phase (information provided by product manufacturer);
- Material health;
- Reuse potential;
- Positive impacts;
- Use and reuse instructions;
- Connections;
- Locations;
- Use phase (information provided by product user, installer, maintenance, owner);
- Assembly, cleaning, maintenance;
- Defined use period;
- Take-back and reuse options;
- Disassembly phase (information provided by the responsible entity for the deconstruction);
- Ownership models;
- Take-back services;
- Composition;
- Disassembly instructions;
- Connections;
- Locations;
- Design phase (information provided by manufacturer, or its suppliers);
- Defined materials;
- Content origin and situation;

[6] https://epea.com/nl/en/services/buildings
[7] https://epea.com/fileadmin/user_upload/2.0_Leistungen/C2C_Certified_Certification_Abstract_EPEA.pdf
[8] https://anteagroup.nl
[9] https://nlgreen.com
[10] https://epea.com/en/services

- Take-back services.

Case Study 3: the Research and Innovation BAMB (Building as Material Banks)

BAMB Project[11]

The BAMB (Buildings As Material Banks) project started in September 2015 as an innovation action within the EU-funded Horizon 2020 program, focusing on Materials Passports and Reversible Building Design – supported by new business models, policy propositions and management and decision-making models. The electronic Materials Passports developed in BAMB aim to be a one-stop shop for material information. The passports are sets of data describing defined characteristics of materials in products that give them value for recovery and reuse. Within the project more than 300 Materials Passports for various products, components or materials have been developed together with a software solution. The software will facilitate the appropriate accessibility of information for different stakeholders at specific stages in the process.

2.1.3.1.3 Renewable materials

Renewable materials are bio-based materials or local materials that require little energy to produce. Examples of renewable construction materials are fiber cement, rammed earth, bio-asphalt, wood, bio-based polyurethane foam, etc. Good practices for encouraging the use of renewable materials are already in place in several EU countries. The use of technically efficient bio-based raw materials produced with respect for the environment is one of them, and can significantly contribute to limiting the environmental impacts of buildings. In addition, if the products are local, which is common when resorting to bio-based construction materials channels – local cultivation and production channels, the environmental impacts of the transport of goods are further limited.

The examples presented below include a bio-based building material catalogue in the Netherlands, that links demand and offer bio-based material for construction; and a French “bio-label” for construction products, that builds on the current EU standards.

Case Study 4: The Netherlands - Bio-based Building Materials Catalogue

The Netherlands – Bio-based Building Materials Catalogue

Bio-based building materials are gaining ground at the expense of conventional materials, which cause substantial carbon dioxide emissions. In order to encourage the building industry in the Netherland, a **Bio-based Building Materials Catalogue** was compiled by Wageningen Food & Bio-based Research on assignment from the Dutch Ministry of Economic Affairs and Climate. The first version of the catalogue dates back to 2012. Since then, the market for bio-based building materials has developed rapidly and its regular updating has become necessary.

This catalogue provides a clear overview of all building materials currently available on the market, including examples of practical applications. It contains an overview of all bio-based materials which are available for the Dutch building industry, including contact data of suppliers and other parties, such as architects and builders who use the materials. The main objective of the catalogue is to show all parties in the chain, from building owners and manufacturers to builders and architects, which

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

materials are already available and which properties and application possibilities these materials have.

Moreover, in order to be considered renewable, the material has to be obtained from a sustainable source. For example, renewable wood is the wood that comes from a sustainably managed forest. In sustainably managed forests there is no illegal logging and no more wood is harvested than it grows back. As a result, wood always remains available as a raw material. In the Netherlands, the following quality labels guarantee that the forest has been sustainably managed: FSC-labels of Forest Stewardship Council and PEFC Netherlands association.

There is a growing demand, also thanks to the industry's ambition to achieve the goals of the Paris Climate Agreement in the Netherlands. Some builders and architects are already having their specific focus on the bio-based market. However, the market cannot solve the issues itself and more stringent regulatory frameworks are needed.

Case Study 5: France - "bio-based product" label

France – "bio-based product" label[12]

Faced with the challenges of ecological and energy transition, the building sector in France is currently undergoing rapid change: sustainable building is becoming a priority for the public and private sectors.

The European terminology standard NF-EN16575 defines a bio-based product as being "wholly or partially derived from bioresources". Consequently, a product that incorporates only 1% of bio-based material is considered, according to this definition, to be bio-based.

The "Bio-based Product" label was therefore created to distinguish bio-based materials incorporating a significant portion of biomass, by certifying their content as bio-based raw material. A minimum threshold for integrating bio-based material is set per product family, according to the existing market offer (for example, it is set at 70% for insulation, and 25% for plant-based concrete).

The label has the following benefits for the building sector:

- Reinforce the market with a label attesting to the renewable nature of the products;
- Bring visibility and transparency on the bio-based quantities incorporated in the products, and their capacity to store carbon;
- Promote bio-based construction materials.

2.1.3.1.4 Measuring environmental performance of materials through Life Cycle Assessment

An assessment of each construction product using internationally recognized environmental performance criteria is needed to verify whether a construction product meets the above listed and other environmental performance requirements. Product-specific environmental and life cycle-related information has to be compiled by the manufacturers of the construction product and sent to

[12] http://produitbiosource.eu/le-label/pourquoi

independent evaluators for assessment. This LCA-based information may be in the form of environmental product declarations (EPD), **product carbon footprints** (PCF), or product environmental footprints (PEF), based on reliable and verifiable information. All of these use LCA to quantify and report one or more environmental impact categories (such as toxicity, land use, biodiversity and **resource usage**) and may also provide additional information. Currently, the assessment is not mandatory but there are tools available that help choose materials with the least environmental impact in the respective building application. Many EPD programs exist in the EU countries. These might differ from each other concerning calculation rules and guidelines (so-called **Product Category Rules** or PCR) scope, system boundaries and impacts addressed (e.g. multi-impact vs. carbon footprint only). This leads to the existence of many environmental claims on the sustainability of construction materials. Several standards and guidance documents have been published to reconcile the differences, and respectively to confirm the legitimacy of product environmental claims. These include: ISO14025, ISO14067, EN15643–1, the Product Environmental Footprint Guide) and the European standard on EPD—EN15804. Each of these standards and guidance documents requires some form of Product Category Rules in order to publish a claim, but unfortunately, these requirements still lack details which result in a sporadic and uncoordinated process of PCR development.

A comparison between PEF and EPD shows differences, e.g., LCIA impact categories and recycling methodology.

Environmental product declarations

An EPD is a standardized document informing about a product's potential environmental and human health impact. It is normally provided by the product manufacturer and must be verified by an independent expert. An EPD is a short version of an LCA report. It is simpler to read, and therefore easier to use in communication than an LCA report. However, a proper LCA study including a full LCA report must be performed before an EPD can be created.

The basis of an EPD is the standard ISO14025[13] where EPDs are called Type III environmental declarations (Type I and II are not based on LCA and in the case of Type II not even externally verified). So far worldwide, more than 28 EPD programs referring to ISO14025 exist, providing over 2256 PCR documents and more than 3 600 EPDs. On a European level, EN ISO14025, EN15804 and other guidelines are applied. EPD must be produced according to a specific set of Product Category Rules (PCR) which provide calculation rules and guidelines to ensure that all Environmental Product Declarations under the same category report the same type of information. In an international collaboration called Ecoplatform[14], EPD program operators from many countries join forces to ensure that construction EPDs are comparable between countries. An EPD can be created for a company-specific product or an average product of members of a branch organization.

EN15804 (A1+A2) standard for LCAs in the construction sector provides 19 **environmental impact categories** and **additional parameters and indicators** that the manufacturers have to report on for the use of resources, waste types, and output flows of materials & energy. Additional indicators describe:

- Resources used:

  - Primary renewable energy (materials);
  - Primary renewable energy (energy);
  - Primary renewable energy (total);
  - Primary non-renewable energy (materials);

[13] https://www.ecomatters.nl/services/lca-epd/epd
[14] https://www.eco-platform.org/home.html

- Primary non-renewable energy (energy);
- Primary non-renewable energy (total);
- Use of secondary material;
- Use of fresh water;
- Use of renewable secondary fuels;
- Use of non-renewable secondary fuels.

- Waste type:

  - Hazardous waste disposed;
  - Non-hazardous waste disposed;
  - Radioactive waste disposed.

- Output flows:

  - Components for re-use;
  - Materials for recycling;
  - Materials for energy recovery;
  - Energy production.

In many cases, it makes sense to translate them into one aggregated metric, that makes the data comparable. One popular metric for this is the **Environmental Cost Indicator (ECI)**[15] expressed in Euro that unites relevant environmental impacts into a single score of environmental costs, representing the environmental **shadow price** of a product (or project).

EPDs are often required in green public procurement (GPP), tenders by private companies, and building assessment schemes such as LEED, BREEAM and GreenStar. EPDs cannot be expected to have a significant impact on the efficient use of construction materials. According to most certification schemes, they are another criterion for selecting construction materials by measuring product's environmental footprint increasingly taking into account all attributes (called a multi-attribute approach) across all of the phases of a product's life. An EPD option would be just ONE of several Material and Resource Compliance Pathways. The certification schemes still include other rewarding criteria based on single attributes (like bio-based content, recycled content, or regionally produced materials). EPDs would simply improving the materials selection options by providing additional compliance choices to builders but t is not a claim of environmental superiority for a specific product. EPDs do not favor one product over another as they are by their nature product and material neutral, since every company that wants to prepare an EPD has to use the same standards and rules for collecting and reporting information.

Despite the international collaboration, several countries (e.g. The Netherlands) have some EPD requirements additional to the EN15804 standard. These can be the addition of indicators such as toxicity, slightly different certification procedures, and different lists of certified reviewers.

The following case studies present the examples of Austria, Belgium, Netherlands and Germany in applying EPD.

[15] https://ecochain.com/knowledge/environmental-cost-indicator-eci

Case Study 6: EPD in Austria[16]

EPD in Austria

Based on **EN15804 and ISO14025**, in July 2013, the Austrian Bau-EPD GmbH (Bau EPD Ltd.) was founded by the Austrian Sustainable Building Platform (ASBP), which has been formed by the two leading Austrian associations for sustainable building, the Austrian Sustainable Building Council (ÖGNB) and the Austrian Green Building Council (ÖGNI). Due to the first upcoming EPDs, **specific PCR documents for the product category** were developed and verified. In May 2014, the first Austrian EPD was published. In October 2014, the six Austrian EPDs published by then were **authorized to place the ECO Platform emblem** on their covers, i.e. the Austrian EPD program fulfilled all requirements of the ECO Platform and is now part of the European EPD harmonization progress as an "established member" of the ECO Platform. EPDs of the Austrian EPD program are entered into the **Austrian construction-book database** and the German oekobau.dat. In addition to EN15804, national specific rules in the form of the National appendix of EN15804 have been developed.

Case Study 7: EPD in Belgium[17]

EPD in Belgium

There is no private EPD program operator in Belgium. Instead, the Federal Public Administration of Health and Environment has prepared a legislative document (Royal Decree) that lays down the rules for the uptake of specific EPDs in a federal database. If a manufacturer decides to put an environmental claim on his product, he is obliged to make an EPD publicly available in the national database from 2015 onwards. The Royal Decree refers to the EN15804 yet includes an article which ensures that since 2017 also modules A4, C and D become mandatory, as well as the whole set of environmental indicators of the EC PEF method in order to have a robust set of indicators.

[16] Passer, Alexander & Lasvaux, Sébastien & Allacker, Karen & Lathauwer, Dieter & Spirinckx, Carolin & Wittstock, Bastian & Kellenberger, Daniel & Gschösser, Florian & Wall, Johannes & Wallbaum, Holger. (2015). Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries. The International Journal of Life Cycle Assessment. 20. 1199-1212. 10.1007/s11367-015-0926-3.

[17] Passer, Alexander & Lasvaux, Sébastien & Allacker, Karen & Lathauwer, Dieter & Spirinckx, Carolin & Wittstock, Bastian & Kellenberger, Daniel & Gschösser, Florian & Wall, Johannes & Wallbaum, Holger. (2015). Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries. The International Journal of Life Cycle Assessment. 20. 1199-1212. 10.1007/s11367-015-0926-3.

Case Study 8: EPD in Germany[18]

EPD in Germany

In Germany, the first EPD was published in 2005, representing unlaminated rockwool of Deutsche Rockwool Mineralwoll GmbH & Co. OHG. The initial and most relevant EPD program operator is the "Institut Bauen und Umwelt e.V."—IBU, a non-profit NGO with more than 200 construction product manufacturers as members. IBU is the German member of the European ECO PlatformFootnote5 and adopted EN15804 into IBU's program rules in 2011. IBU as an independent organization is headed by an elected board, and the EPD program operation is executed by the IBU office. IBU's expert panel ("Sachverständigenrat", SVR) assures compliance with EN15804, resolves any methodological or rule-defining issues and appoints independent verifiers who review EPDs and associated background reports in compliance with a defined set of criteria. IBU's PCR part A covers a set of rules that is common to all EPDs across all product categories. IBU's PCR part B documents are specific to individual product categories. In Germany, EPDs are recognized as feasible communication format by the two major building certification systems, DGNB ("Deutsche Gesellschaft für Nachhaltiges Bauen e.V."/German Sustainable Building Council) and BNB ("Bewertungssystem des Bundes für Nachhaltiges Bauen"/Federal assessment scheme for sustainable construction). EPDs are collected into the German "Ökobau.dat" public database for building product LCA data that is operated by a subsidiary administration of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection.

Case Study 9: EPD in the Netherlands[19]

EPD in the Netherlands

In The Netherlands, the environmental performance is calculated according to the procedures described in a so-called Determination Method (method for determining environmental performance), which is based on the European standard EN15804, and is calculated using a Life Cycle Analysis. The Dutch method for determining the environmental performance was developed as a reaction to the proliferation of methods for measuring the environmental performance of products. There were several independent initiatives within the Netherlands to calculate the environmental performance of construction works. However, the results of these calculations were diverse and lacked the possibility for fair and consistent benchmarking. A step-by-step harmonization of several independent initiatives, started by the Dutch Ministry of the Interior and Kingdom Relations, resulted in a Dutch data structure for calculating and declaring the environmental performance of construction works. The Dutch method for determining the environmental performance of construction works consists of harmonized **national rules** for the

[18] Passer, Alexander & Lasvaux, Sébastien & Allacker, Karen & Lathauwer, Dieter & Spirinckx, Carolin & Wittstock, Bastian & Kellenberger, Daniel & Gschösser, Florian & Wall, Johannes & Wallbaum, Holger. (2015). Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries. The International Journal of Life Cycle Assessment. 20. 1199-1212. 10.1007/s11367-015-0926-3.

[19] Passer, Alexander & Lasvaux, Sébastien & Allacker, Karen & Lathauwer, Dieter & Spirinckx, Carolin & Wittstock, Bastian & Kellenberger, Daniel & Gschösser, Florian & Wall, Johannes & Wallbaum, Holger. (2015). Environmental product declarations entering the building sector: critical reflections based on 5 to 10 years experience in different European countries. The International Journal of Life Cycle Assessment. 20. 1199-1212. 10.1007/s11367-015-0926-3.

calculation of the environmental impacts of construction works, combined with rules for the **environmental performance declarations** of construction products. The intention of the method is not to prescribe certain materials and construction products, but rather to **let users design and create construction works with a minimum environmental impact**. In this regard, the environmental performance is defined by including the complete life cycle: **cradle to gate** based on EN15804; and **gate to grave** based on EN15978. The sum of product EPDs equals the environmental performance of a building element. (**Cradle to Gate** + reuse/recycling). The sum of product and element EPDs plus scenarios (distribution, installation, maintenance, use, end-of-life) equals the environmental performance of construction works (**Cradle to Grave**).

A LCA is performed by a specialized LCA company. The results (the environmental impacts per category) and underlying report of this LCA are first verified by an independent third party, after which the data will be submitted to The Dutch Environmental Database ("de Nationale Milieudatabase"). For calculating the environmental impact of buildings, the Dutch method for determining the environmental performance of buildings and construction works and data from a uniform database should be used. The national Environmental Database contains the environmental performance of many construction products for several different impact categories, like emissions, resource use, ozone depletion, etc. that companies can easily refer to.

Description of the product environmental footprints (PEF) method and PEF category rules (PEFCRs)

Due to the need for harmonization of LCA studies and LCA-based environmental claims for all kinds of products, the European Commission developed additional to the EN15804 method, the so-called **product environmental footprints** (PEF) method, for the calculation of the environmental footprint of products. A similar method is applied for the calculation of the environmental footprint of organizations (OEF).

The PEF method supports a **multi-criteria assessment of the environmental performance of a product (i.e. a good or service) throughout its life cycle**[20]. It accommodates a broad suite of relevant environmental performance indicators in order to decrease the probability of burden shifting. The EC PEF method also includes guidelines on how to develop **PEF category rules** (PEFCRs) —comparable to the PCRs—for specific product groups. Whereas the EC PEF is a general method that is also valid for construction products and buildings, specific PEF category rules for construction products have not been developed yet. Currently, the Flemish Institute for Technological Research (VITO), KU Leuven and TU Graz carry out a PEF4Buildings project[21] commissioned by the European Commission in order to test the applicability of the PEF method Guide (Commission Recommendation 179/2013 on The use of common methods to measure and communicate the life cycle environmental performance of products and organizations). The assessment and the overview will contribute to the development of a final approach to develop benchmarks and classes of performance for different typologies of buildings. In 2019, a substantial revision of the standard EN15804 has been accepted by CEN and now it is more aligned with European Commission's PEF.

[20] COMMISSION RECOMMENDATION of April 9, 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organizations (2013/179/EU).

[21] https://www.energyville.be/onderzoek/pef4buildings-application-product-environmental-footprint-pef-method-newly-built-office

2.1.3.1.5 Transparency on chemicals of concern in construction products

Distinguishing construction products containing hazardous substances from products that meet the safety criteria for human health and the environment will guide the choice towards safer construction products and buildings. Currently, at the European Union level, mandatory measures for reporting, disclosing and tracking the content of hazardous substances in more complex objects such as articles and products are not applied. However, in some Member States, there are targeted measures for voluntary registration of products that meet criteria requirements concerning substances with hazardous properties and the provision of information to value chain stakeholders and the general public. The example presented below to enhance the transparency on chemicals in the construction sector was applied in Sweden.

Case Study 10: Managing and communicating hazardous contents in the construction sector in Sweden (BASTA)

BASTA - instrument to manage the content of and communicating on hazardous substances in construction products in Sweden[22]

BASTA tool is a third-party system of construction product evaluation and certification that defines construction product requirements concerning hazardous content, collects information from the suppliers of these products, conduct testing on a routine or random basis and communicate compliance with the requirements in the form of inclusion of the product in a database. Here, no direct communication takes place between the suppliers and users of materials, but the system takes over the information flow and focuses it on the recipient of the article.

BASTA online AB is a non-profit company and is jointly owned by Swedish Environmental Research Institute and the Swedish Construction Federation. Major players in the construction industry support BASTA, as do authorities such as the Swedish Chemicals Agency and the Swedish Transport Administration.

The purpose of the BASTA system is to use a clear and transparent methodology to guide the building and construction industry towards a systematic and sustainable way of phasing out substances with hazardous properties. The database is a self-declaration system for suppliers and manufacturers of the construction industry. The databases' search function is open and freely available for any user. The database is "positive" and shows all articles that pass the criteria defined by BASTA. Associated suppliers pay an annual fee to register their products. The system comprises three types of registers:

- BASTA-products meeting stringent criteria on substance content;
- BETA-products, meeting the basic criteria, i.e., concentration thresholds for SVHC and some heavy metals; and
- Risk-Evaluated products, which do not meet the BASTA criteria but are difficult to replace (non-compliant substances fulfilling essential functions).

The BASTA systems Properties Criteria is based on European chemicals legislation REACH and CLP, which ensures that a comparable and relevant requirement level is met. The Properties criteria in the BASTA system include both chemical products and articles. BASTA uses independent audits of their affiliated companies to ensure the quality of the data. It offers the market freely available information about safe material choices.

[22] https://www.bastaonline.se/about-basta/about-basta/?lang=en

2.1.3.2 Mandatory measures

On EU level, the life cycle environmental performance of construction materials is assessed following the above described voluntary approaches (EPD and PEF). However, gradually more mandatory requirements are increasingly being imposed both at the European level and in some Member States.

2.1.3.2.1 Environmental performance assessment at EU level - Construction Products Regulation

The aim of Regulation (EU) N° 305/2011 (the Construction Products Regulation – CPR) is to remove technical barriers to trade in the field of construction products in order to enhance their free movement in the internal market. It sets out methods and criteria for assessing and expressing the performance of construction products, and the conditions for the use of CE marking. The products put on the EU market should meet the requirements for their performance related to the relevant **essential characteristics of construction products** for which there are provisions on the Union market. EU countries, on the other hand, are responsible for **specific requirements of construction products** relevant to the **basic requirements for construction works** (set out in Annex I) such as fire safety, mechanical resistance and stability, environmental, energy and other requirements. For assessing performance concerning the essential characteristics of construction products, testing, calculation and other means are defined within harmonized standards and European Assessment Documents[23]. When a construction product is covered by a harmonized standard or conforms to a European Technical Assessment which has been issued for it, the manufacturer shall draw up a **declaration of performance** when such a product is placed on the market. Each construction product with CE marking must be accompanied by a Declaration of Performance (DoP). To ensure that the DoP is accurate and reliable, the performance of the construction product should be assessed and the production should be controlled in accordance with the harmonized system of "**Assessment and Verification of Constancy of Performance**". AVCP defines how to assess products and control the constancy of the assessment results. This system safeguards the reliability and accuracy of the Declaration of Performance. The AVCP systems define the tasks for manufacturers and notified bodies. Five different systems are in place for construction products in the Construction Products Regulation. They range from large-scale third-party involvement to self-declaration and monitoring by the manufacturer. The European Commission establishes which systems are applicable for:

- A construction product;
- A family of construction products;
- An essential characteristic.

The harmonized technical specifications (harmonized European + European Assessment Documents) include the technical details for the implementation of the AVCP system. The five different AVCP systems are titled System 1+, System 1, System 2+, System 3 and System 4. Different systems have different requirements regarding the role of the manufacturer, and the notified product certification body, as expressed in the table below. In the table below if the responsibility of the respective task is on manufacturers it is indicated by “M” and when NPCB is responsible it is indicated by “NPCB”.

[23] EUROPA - European Commission - Growth - Regulatory policy - NANDO

Table 10: Different Systems and distribution of tasks between Notified Product Certification Body (NPCB) and Manufacturers (M). The Notified Product Certification Body shall issue the certificate of consistency of performance of the product.

Tasks to be carried out	System 1+	System 1	System 2+	System 3	System 4
Factory production control	**M**	**M**	**M**	**M**	**M**
Further testing of samples taken at the factory in accordance with the prescribed test plan				-	-
Determination of the product-type on the basis of type testing (including sampling), type calculation, tabulated values or descriptive documentation of the product	NPCB	NPCB		**NPCB**	**M**
Initial inspection of the manufacturing plant and of factory production control			NPCB	-	-
Continuous surveillance, assessment and evaluation of factory production control				-	-
Audit-testing of samples taken before placing the product on the market		-		-	-

As mentioned above, Member States are responsible for basic requirements for construction works but wherever possible, uniform European methods should be laid down for establishing compliance with the basic requirements set out in Annex I. CEN/TC 350 committee is currently working on harmonization issues at the EU level. The European CPR mentions EPDs as possible means to assess the sustainable use of natural resources and the impacts of construction works on the environment. However, the CPR does not explicitly refer to EN15804, and the EPD reference is made in the introduction of the CPR, not in the articles. How Basic Requirements have to be dealt with is not yet clear and is currently under discussion.

The lack of a mandatory EPD in the Construction Products Regulation shows that this instrument alone cannot be relied on to ensure the production of sustainable construction products when introducing a system for assessment of environmental performance. The problem should be addressed on both levels, on product manufacturing level and on building level. The subsidiarity principle reflects two competence fields, the European market for construction products is regulated according to Regulation 305/2011 (Construction Products Regulation – CPR) while construction works are regulated at National level by Member States. However, the environmental performance of construction products only makes sense in the context of the building or the construction works. Therefore, substantial results will be achieved only if environmental performance of buildings is addressed by the Member state and some of them have already established legal frameworks and regulations on this topic.

2.1.3.2.2 EU-country level: Mandatory assessment of Environmental Performance of Buildings in the Netherlands

The Environmental Performance of Buildings (EPB) is mandatory with every application for an environmental permit in the Netherlands[24]. The EPB indicates the environmental impact of the materials used in a building. It is the sum of product and element EPDs plus scenarios (distribution, installation, maintenance, use, end-of-life). Therefore, the environmental performance of building materials will become an increasingly important factor in the overall environmental impact of buildings. To determine the environmental impact of a single material, an LCA is performed.

It is not necessary to perform an LCA of the same product/material over and over again. In the Netherlands, the characteristics of materials from the LCAs are collected in the National Environmental Database. This database is managed by the Construction Quality Foundation. Producers or suppliers must ensure that a product is included in the database.

Environmental performance assessment is obligatory for new office buildings (larger than 100 m²) **and new-build homes.** It is an important measure for the sustainability of a building. The lower the EPB, the more sustainable the use of materials is. As of January 1, 2018, a maximum limit value of 1.0 applies to the environmental performance of buildings. On July 1, 2021, the environmental performance for new homes (not for offices) has been tightened from 1.0 to 0.8. The aim is to gradually tighten the requirement and halve it by 2030 at the latest.

2.1.3.2.3 Tracking and eventually phasing out hazardous content in construction products

While assessment of environmental performance is not regulated in the CPR, the provision of information on the **content of hazardous substances** in construction products is mandatory for manufacturers. Identifying and tracking hazardous materials throughout the value chain is of great importance, as the potential presence of hazardous materials in construction products leads to concerns about the quality, environmental risk, upcycling potential and a lack of confidence or trust in the construction products.

Article 6(5) of the CPR requires **safety data sheets** (SDS) or information on hazardous substances (i.e., SVHCs) contained in construction products to be provided with the declaration of performance.

- For construction products that are substances or mixtures that meet the criteria for classification as hazardous it is obligatory under the Regulation (EC) N° 1907/2006 (REACH) to deliver a safety data sheet (SDS) according to REACH, Art. 31. For these construction products, a harmonized format exists already in form of the SDS.
- For construction products which are articles the communication duties of REACH, Art. 33 apply. This means that the recipient of the article shall be provided with sufficient information to allow safe use of the article including, as a minimum, the name of the substances of very high concern (SVHC). For this communication duty (as well as for mixtures containing SVHC in cases where an SDS is not obligatory - REACH, Art. 31(3b/4)) no harmonized format exists under REACH, but some national authorities such as the German Environment Agency recommend a data entry template as a harmonized communication format in order to provide the

[24] https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/nieuwbouw/milieuprestatie-gebouwen

construction sector with a common format to deliver this information with the declaration of performance as long as no precise guidance is available from the European Commission.

Article 9 (1)(i) of the Waste Framework Directive 2008/98/EC extends the REACH Article 33 duties of suppliers of articles to communicate, under certain conditions, information about the presence of Candidate List substances in their articles down the supply chain and to consumers (upon request), by requiring them to submit that information also to the European Chemicals Agency (ECHA). ECHA has to establish and maintain a database with information on substances of concern in articles, as such or in complex objects (products), named the "**SCIP database**". The information is submitted by companies supplying articles containing SVHCs on the Candidate List placed on the EU market. The SCIP database will ensure that this information is available throughout the whole lifecycle of articles and materials, including at the waste stage. The three main objectives of the SCIP database to support the circular economy are the following:

- Decrease the generation of waste containing hazardous substances by supporting the substitution of substances of concern in articles placed on the EU market;
- Make information available to further improve waste treatment operations;
- Allow authorities to monitor the use of substances of concern in articles and initiate appropriate actions over the whole lifecycle of articles, including at their waste stage.

The increased transparency on chemicals of concern is to help consumers make more informed decisions and improve waste companies' recycling processes.

The information submitted to the SCIP database is public and therefore readily available to waste operators to bridge the current gap in the information flow. ECHA will publish the received information on its website. The quality of the data remains the responsibility of each duty holder.

Despite its importance, currently, the SCIP database is not used to its full potential. The obligations for communication of information to SCIP database (as well as the provisions of the Waste Framework Directive as a whole) have to be transposed into the national law of each EU Member State, the enforcement of which is the responsibility of these Member States. In Germany for example, at present, there is only an informal obligation to report to the ECHA under Section 16f of the Chemicals Act, which does not include the obligation to actually use the SCIP database. . A wide coalition of European industry organizations raised concerns regarding the SCIP:

- Short period to submit the information (2 months instead of 12 moths as initially planned);
- Requirement to submit complex and large amounts of manufacturers' compliance data which is challenging, burdensome and time-consuming;
- Regulatory obligations were introduced without impact assessments and consultations.

2.1.3.2.4 Fiscal instruments to ensure that recycled materials are competitive with virgin materials

Production processes using waste as input material can only be efficient if production costs are lower than the costs of using primary materials, and market absorption can be ensured. **A tax on raw materials** is an effective policy measure that can have a strong impact on these market conditions.

Levies on virgin materials are implemented in some Member States, such as taxation of mining activities in Italy, aggregates Levy in the UK, aggregate tax in France, mineral resource extraction tax in Estonia, and tax on extraction and import of raw material in Denmark. The case study of Denmark is presented in detail in the box below.

Examples of other policy measures are the encouragement of green public procurement, taxes for landfilling, end-of-waste criteria and extended product responsibility (EPR), which are discussed in the next chapters as they are more relevant to the extension of the life cycle.

Case study 11: Denmark - tax on raw materials that are extracted or imported

Denmark – tax on raw materials that are extracted or imported[25]

Starting from January 1, 1990, a tax on raw materials was introduced. Prior to 1 January 1990, the then Minerals Act and the Continental Shelf Act proscribed fees for recovered or imported raw materials. The current rules on tax on raw materials are set out in Statutory Order N° 503 of April 20, 2020. Companies that extract or import less than 200 m^3 of raw materials annually do not have to register or pay tax. The purpose of the tax is to encourage the reduction of raw material consumption. Together with the waste tax, **the raw material tax promotes the recycling of construction and demolition waste**. According to the definition raw materials is a common term for the types of soil and rocks that are extracted from the land and the sea. The most common raw materials that are within the scope of Statutory Order N° 503 are sand, gravel, stone, granite, lime, chalk, clay and sphagnum.

From the entry into force of the Act on January 1, 1990 and until March 31, 2020, the tax rate amounted to DKK 5 per m^3 of the raw material. The tax has been increased from DKK 5 to DKK 5.27 from April 1, 2020. The tax will be further increased to DKK 5.56 from January 1, 2023.

Importers have the option of paying tax on the documented amount of raw materials used to produce the finished product cement, with supplier and manufacturer declarations or analysis from an accredited institute. Similarly, Danish cement producers must provide documentation of the amount of raw materials used to produce cement. If the importer or manufacturer is unable to provide documentation the taxable quantity of raw materials is converted to m^3 according to the conversion factors specified in 2 of the Statutory Order N° 503.

Taxable raw materials are materials that have either not been processed or have only been subjected to single processing. Single processing entails sorting, crushing, air drying, or other simple processing. After the treatment, the raw material still appears as a raw material. It is only at the time when the raw material is included in the advanced process that the taxable quantity must be calculated and thus the tax settled: any waste or waste in the form of water content from the time of extraction to the time of supply must therefore not be included in the taxable quantity.

The registered companies must calculate the taxable amount for each quarterly tax period. The companies must state and pay the amount no later than the 15th of the first month after the end of the quarter.

According to a study[26] from 2011, the combined aggregate and waste taxes in Denmark have produced a greater demand for recycled substitutes: in 1985 only 12% of construction and demolition waste was recycled, compared with 94% in 2004.

Case study 122: Italy - Decentralized taxes on sand, gravel and rock

[25] https://www.skat.dk/skat.aspx?oID=1921384&chk=217592

[26] Söderholm, P. (2011) Taxing virgin natural resources: Lessons from aggregates taxation in Europe. Resources, Conservation and Recycling. 55: 911-922

Italy – Decentralized taxes on sand, gravel and rock[27]

The application of taxes on sand, gravel and rocks has been decentralized in Italy and has been in place since the early 1990s. There is no common national tax rate and each region applies different rates at provincial and municipal level per cubic meter of sand, gravel and rock. Taxes are levied by municipalities, and the law obliges them to spend them on "compensatory investments" in mining areas. The aggregate charge is part of a comprehensive planning, permitting and regulatory system related to extraction activities.

The main purpose of extraction taxes in Italy is not to reduce the extracted amounts or to encourage recycling. Instead, their aim is to help cover the costs of extraction activities by financing land conservation investments. In 2008, the EEA conducted an analysis of the effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries[28]. The results of the analysis show that the effect of the extraction tax in Italy is limited. The tax rate is generally too low (around 0.41-0.57 EUR/m^3) to have a real effect on demand.

2.1.3.2.5 Eco-design of Construction Products

Eco-design of Construction Products on a European level is driven by several Directives and Regulations.

Eco-design of Energy Related Products Directive (2009/125/EC)[29] provides a framework that allows setting minimum environmental performance requirements for dozens of product groups. Its main focus is on energy performance in use, whether that is the energy the product uses or the impact the product has on energy use where it is installed. The Directive covers:

- Energy-using products: products that use, generate, transfer or measure energy including consumer goods such as boilers, computers, TVs, washing machines, light bulbs and industrial products such as transformers, industrial fans, industrial furnaces;
- Energy-related products: products that do not necessarily use energy, but have an impact on energy such as windows, insulation material or bathroom devices (e.g. shower heads, taps).

The directive's additional scope ensures the free movement of the concerned products within the internal European market by establishing harmonized rules for verifying whether the products meet EU safety, health, and environmental protection requirements, conformity assessment, issuing the EU declaration of conformity and affixing the CE marking. Manufacturers are responsible to ensure that these rules for affixing the CE marking to a product are observed. These six steps have to be followed:

- Identify the harmonized standards;
- Verify product-specific requirements;
- Identify whether an independent conformity assessment (by a notified body) is necessary. The need for involving a notified body is determined in the specific implementing measures adopted under the Directive 2009/125/EC. To find the notified bodies appointed by the Member States to carry out conformity assessment, the manufacturer should consult the NANDO database – the New Approach Notified and Designated Organizations;

[27] Guidelines for the waste audits before demolition and renovation works of buildings- EU Construction and Demolition Waste Management, May 2018

[28] EEA, Effectiveness of environmental taxes and charges for managing sand, gravel and rock extraction in selected EU countries, N° 2/2008, https://www.eea.europa.eu/publications/eea_report_2008_2

[29] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02009L0125-20121204&from=EN

- Test the product and check its conformity. The conformity assessment procedures the manufacturer can choose from are specified by the implementing measures. In principle, the implementing measures leave the manufacturer the choice between internal design control and a harmonized standard management system;
- Draw up and keep available the required technical documentation;
- Affix the CE marking and draw up the EU Declaration of Conformity.

Implementing measures are mandatory requirements in the form of regulations, which come into force without further implementation into national laws. The European Commission selects product groups in the so-called working plan, mandates preparatory studies to compile specific data for each product group that serves as background information for the development of appropriate minimum requirements. Based on the preparatory studies, the European Commission develops requirements for the environmental performance of the selected products or product groups. The Directive prioritizes self-regulations by manufacturers as an alternative to Regulations. So far, implementing measures mainly on energy-using products have been published, but currently, there are no eco-design implementing regulations on windows, insulation material, or other products that do not use energy but have an impact on energy consumption. The mandatory product requirements in the regulations specific requirements (which set limit values, such as minimum lifetime or minimum quantities of recycled material), or generic requirements, which do not set limit values but may require, for example, that a product is “energy efficient” or “recyclable”.

2.1.4 Comparison of the case studies with the current situation in Croatia and assessment of possible implementation

The presented measures for the Production of Sustainable Materials and their applicability in the Croatian context are explored in detail in the tables below, indicating both voluntary and mandatory measures respectively.

Table 11: Applicability of measures for the Production of Sustainable Construction Materials in Croatia. Voluntary measures.

Voluntary agreements (green Deals)	Voluntary agreements are not currently applied in Croatia. This is usually one of the first tools to accelerate recycling in the construction sector, as it is voluntary and is used to initially determine the degree of readiness to apply binding measures. It involves the private sector that makes voluntary commitments to apply green design and the government which takes the engagement to remove the barriers and support the business. This measure can be used at an early stage in the introduction of the concept of a circular economy in the construction sector. Effectiveness of voluntary instruments is discussed in sub-section 3.1.3.1.
Material passports	Material passports are part of specific measures that projects can take to improve circularity, and this instrument is taken into account in project assessment and awarded by the certification schemes. Therefore, all certified construction projects have to apply this instrument. For example, the projects Eurocenter, Point Shopping Center, Zagrebtower, DOC Zagreb are certified under one of the BREEAM schemes and should have recorded product details for future reference using material passports. Creating own tool with sets of data describing defined characteristics of materials in products and recording

	of the information throughout the value chain is not necessary in Croatia, whereas there are already existing tools available for international use.
Catalogues of renewable materials	A catalog of renewable construction products in Croatia has not been developed and it is not possible to assess whether designers use internationally available catalogs such as Dutch Bio-based Building Materials Catalogue. However, the creation of a Croatian catalog makes sense because it would include materials available on the Croatian market and their applicability for construction purposes according to local conditions, and it would contain contacts of local suppliers. The creation of such a catalog is not easy because it requires the participation of scientific institutes to evaluate the properties of materials and their potential use for various construction applications in Croatia.
Environmental product declarations/ Product environmental footprints	EPDs are often required in green public procurement, tenders by private companies, and in building assessment schemes such as LEED, BREEAM and GreenStar. The establishment of the EPD program operator in Croatia will require the development and verification of Croatian-specific PCR documents for product category were as well as national-specific rules in the form of a National appendix to EN15804. The introduction of a national system makes sense if a large number of products are produced in Croatia, especially those that are innovative or specific and need a life-cycle performance assessment. There are no obstacles for a Croatian product to be evaluated according to one of the existing international EPD systems. Belgium has a more feasible approach where if a manufacturer decides to put an environmental claim on his product, it is obliged to make an EPD publically available in the national database.
Databases/ Catalogues of non-hazardous materials	Information systems or catalogs to distinguish products containing dangerous substances from non-dangerous products are not applied in Croatia. The creation of a national database similar to the Swedish BASTA requires the construction business to show corporate responsibility in the form of allocating financial resources for the creation and maintenance of an information system, including independent audits to verify the claims of manufacturers. In any case, manufacturers of construction products will have to report to the European tracking/phasing out hazardous content system (SCIP). Accordingly, measures should be taken by the Croatian Government to ensure the use of SCIP.

CE marking and Construction Products Regulation	Construction Products Act[30] is in force in Croatia since 2013. The Act and the secondary legislation lay down rules for the marketing of construction products in accordance with the EU Construction Products Regulation including the required procedures for assessing the performance of construction products which enable manufacturers to draw up a declaration of performance on the basis of harmonized standards or alternative procedures not covered by harmonized standards (European assessment documents and European technical assessments), appointment of notified

[30] https://www.zakon.hr/z/226/Zakon-o-gra%C4%91evnim-proizvodima

	bodies as well as control systems for Assessment and Verification of Constancy of Performance. Croatian legislation also regulates (Chapter III of the Act) the non-harmonized area of construction products where national rules apply and environmental requirements may be set out. The rules in the non-harmonized area are similar to those in the harmonized one, but with some modifications. Instead of harmonized technical specifications, Croatian technical specifications apply. The body for approval is analogous to the notified body, and the designated body (Croatian Technical Assessment Body) adopts the Croatian assessment document. The systems for assessing and checking the constancy of properties are identical, and declarations of properties of construction products are given identically. While construction products are "CE" marked in the harmonized area, in the non-harmonized area in Croatia "C" mark is affixed. In addition to the Act and secondary legislation several technical regulations are in force: • Technical regulation for masonry constructions; • Technical regulation for chimneys in buildings; • Technical regulation for wooden structures; • Technical regulation for lightning protection systems on buildings; • Technical regulation on rational use of energy and thermal protection in buildings; • Technical regulation for steel structures; • Technical regulation for composite steel structures and concrete; • Technical regulation for concrete structures; • Technical regulation for low voltage electrical installations; • Technical regulation for aluminum structures. Technical regulations contain both harmonized and non-harmonized standards for construction products. A list of non-harmonized standards referred to by technical regulations can be found on the Ministry's website. However, currently these standards do not contain means to assess the sustainable use of natural resources and the impacts of construction works on the environment. Although all necessary product evaluation procedures have been put in place in Croatia and the necessary bodies have been appointed to do so, an assessment of the environmental performance of products is not carried out according to both harmonized and non-harmonized standards. This tool is applicable at a later stage - Environmental performance assessment of the products would make sense when a common European approach is introduced or if the environmental performance of buildings becomes mandatory, for example, if it is linked to the issuance of a building permit (following the example of the Netherlands).
Mandatory assessment of	In Croatia, a mandatory assessment of the environmental performance of both products and buildings as a whole is not required. The application of such a tool would require the development of a methodology for assessing the

Environmental Performance	environmental impact of different types of products, the application of the methodology to a significant number of products, and the storage of assessment results in a national database, which should be maintained and updated. In addition, in order to achieve a significant result from the implementation of this instrument, it is necessary to make the assessment of environmental performance mandatory. To this end, following the example of the Netherlands, environmental performance limit values should be introduced in the legislation and the issuance of a building permit should be linked to these limit values. Such a step is realistic in the medium or more likely in the long run.
Tracking and phasing out of hazardous content in construction products	EU Regulation (EC) N° 1907/2006 (REACH) applies directly into Croatian legislation and it is further implemented through the *Law on the implementation of Regulation (EC) N° Regulation (EC) N° 1907/2006 of the European Parliament and of the EC Council on the Registration, Evaluation, Authorization and Restriction of Chemicals*. It establishes the competent authority and the tasks of the competent authority for the implementation of Regulation (EC) N° Regulation (EC) N° 1907/2006. Inspection supervision over the implementation of Regulation is performed by sanitary inspectors of the State Inspectorate. There is a penalty for suppliers of products that fail to provide a recipient of the product with sufficient information to allow safe use of the article including, as a minimum, the name of the substances of very high concern (SVHC). However, for this communication duty, no harmonized format exists (except SDS). The extension of this duty through Article 9(1)(i) of the Waste Framework Directive to submit that information also to the European Chemicals Agency (to "**SCIP database**") is regulated by the Waste Management Act (84/2021). Reporting of information on substances of concern in articles, as such or in complex objects (products) throughout the supply chain is of high importance as it will increase the transparency on chemicals of concern and help consumers make more informed decisions and improve waste companies' recycling processes. Therefore, this should be of high priority and needs to be implemented in the short term, despite adopting a reporting format and ensuring that producers report to the SCIP database.
Tax on raw materials	Tax on raw materials with the purpose of increasing the costs of primary raw materials is not applied in Croatia. The introduction of such economic instrument would require determining the most appropriate tax rate and the method for levying the tax and defining the taxable materials. The introduction of such an instrument in Croatia will not involve significant administrative costs and efforts, as existing tax authorities may be used. At the same time, the introduction of the tax must be accompanied by measures to ensure the supply of large quantities of recyclable waste, otherwise, without a viable possibility for the extracting industry to replace virgin materials with recycled waste, it could become a revenue-generating activity for the national budget. This instrument can be applied in short to middle term depending on the implementation of the measures for selective deconstruction and separation of CDW at source.

Eco-design of construction products	European legislation introducing the principles of eco-design has been transposed into Croatian legislation. The necessary institutional set-up has been established and responsibilities for control and conformity assessment procedures including testing of the products and checking their conformity have been allocated. According to the *Ordinance on determining the requirements for eco-design of energy-related products* the Ministry responsible for the economy shall take all appropriate measures to ensure that products covered by implementing measures may be placed on the market and/or put into service only if they comply with these measures and bear the "CE" mark. The competent inspection body, in accordance with the competencies arising from the special regulations relating to their work, shall supervise the market. Currently only the requirements for the environmental performance of products or product groups specified in the EU implementing Regulations apply. The approach on eco-design is that the implementing acts are Commission regulations, which are directly applicable in the Member States and there is no need for Croatia to adopt its own rules. However, one of the measures that can be taken by the Government on a national level is to provide for active involvement of stakeholders concerned in the drafting of the implementing regulations and close coordination with the construction industry, environmental and consumer associations by organizing events for assessing the proposals tabled by the European Commission. Institutions and organizations responsible for materials research and testing should take part in this process. The results have to be fed back into the process at a European level with arguments in favor of solutions that are technology-neutral and environmentally and economically sound.

2.2 Circular design of buildings and construction works

2.2.1 Concept

In the design phase, there are many opportunities for sustainable use of materials. Circular design has several angles:

1. **Less-material and light design** – when designing a building it often appears possible to use less material without compromising specific functional requirements of the building such as bearing capacity.
2. **Adaptive/flexible design,** aimed at longer service life - ensures that buildings can be made suitable for a different function or are suitable for the same users for a longer period (e.g., a school that gets a residential function after 10 years)
3. **Modular and demountable designs**, aimed at reusing materials in the next use cycle - if readily recyclable/reusable building materials are attached to other materials during construction, they cannot be easily separated during demolition, therefore a demountable design is required to make building parts or materials suitable for high-value reuse/recycling
4. **Optimizing the choice of materials and design with the least environmental impact**, focused on the reuse of materials from previous construction projects, use of renewable materials, or other types of materials with the least environmental impact.

The design focus depends on the type of project. For example, for a temporary building, demountable construction is very important and a long lifespan is less important.

Good practices to ensure the practical application of the concept are discussed below.

Table 12: Good practices to enhance the circular design of buildings. Potential mandatory and voluntary measures.

Voluntary measures	Mandatory measures
– **Methodology for assessment of future value of the buildings**	– Design for disassembly and adaptability in the building code
– **Best practice demonstration projects**	– Environmental Performance of Buildings
– **Voluntary agreements**	–
– **Certification systems**	–
– **Level(s) – aligning all certification schemes in EU**	–
– **Standard for Design for Disassembly and adaptability**	–

2.2.2 Barriers and enabling conditions

Barriers to the more frequent application of circular design are more related to **economic concerns** due to the higher investment costs of construction works rather than for purely technical reasons. There is a general opinion that circular design requires higher investment. Although some additional costs may indeed arise, such as costs for higher quality materials for future reuse, the circular design can significantly reduce overall life-cycle costs because[31]:

- Dismantling simplifies the maintenance and adaptation processes that buildings usually have to face during their entire life cycle;
- Reduces the operating costs of buildings that require frequent maintenance and replacement, such as shops, schools, nursing homes and offices;
- Stricter quality requirements for construction components, easier disassembly and increased reusability, contribute to stronger market demand, higher financial residual values and lower end-of-life disposal taxes.

In practice, however, these **financial savings are difficult to evaluate**, as they will arise in the future and are highly dependent on the specific construction project. Currently, the demand for buildings is driven by short-term investment benefits.

The market demand for buildings that implement circular design could be further encouraged through:

- Voluntary initiatives (due to financial savings or Corporate Social Responsibility policy of large companies) or mandatory measures (due to legal requirements);
- Improved know-how (development of guidelines, assessment instruments and new construction techniques) to encourage the use of quality materials, reversible connection techniques, proper assembly sequences, accessibility, etc. in construction methods as well as to overcome the perception that circular design entail high financial costs and the reluctance of designers/clients to use second-hand materials;
- Information availability - standardization of qualitative data/information over the entire product/building value chain in order to make all information needed for deconstruction available at all times;
- Certification and quality assurance for reclaimed products and recycled materials.

[31] EIONET Report - ETC/WMGE 2020/1 "Construction and Demolition Waste: challenges and opportunities in a circular economy"

2.2.3 Implementation and good practices

2.2.3.1 Voluntary initiatives

2.2.3.1.1 Demonstration projects for circular buildings

Many organizations and research institutes have developed pilot projects to gain experience and demonstrate the principles of design for circularity. Examples are given to illustrate how the circular design can be realized and what are the main expected benefits, including sustainable wooden buildings in Amsterdam, a temporary courthouse in the Netherlands that can be dismantled and reused after five years, and a hotel with prefab rooms.

Case Study 13: Wooden high-rise construction – HAUT residential tower in Amsterdam

Wooden high-rise construction – HAUT residential tower in Amsterdam[32]

The residential building HAUT tower is advertised as the first residential building to receive the highest attainable sustainability label, to become the new standard in healthy building and luxury living and to serve as an icon and an enrichment for Amsterdam.

HAUT is made of wood which is a centuries-old building material and at the same time the innovation in sustainable construction. With a height of 73 meters and 21 floors, HAUT will be the tallest wooden residential building in the Netherlands. Wood framing limits the mass of structures. Wood has even more qualities it is breathable, feels warm and therefore provides unprecedented living comfort.

In addition to a wooden high-rise construction, HAUT will have energy-generating facades, triple glazing and it will also be realized in such a way that the materials used are reusable as much as possible.

The construction of HAUT is expected to be completed at the end of 2021.

Case Study 14: Temporary courthouse in the Netherlands

Temporary courthouse[33]

The Central Government Real Estate Agency (the Netherlands) had a temporary building constructed that will be dismantled and reused after five years. Temporary courthouse Amsterdam has won the Amsterdam Architecture Prize 2017. The building has been designed to be adaptable and will soon allow for different uses by different residents in different locations. The removal and reuse of the materials are contractually agreed within the contract. Other important criteria were the prevention of waste and the maximizing of the building's residual value. On every scale, including the structure as a whole, designers consequently looked for reduction, reuse, and recycling possibilities.

Case Study 15: Hotel with prefab rooms in Amsterdam

[32] https://hautamsterdam.nl/nl/?_x_tr_sl=nl&_x_tr_tl=en&_x_tr_hl=en
[33] https://archello.com/project/temporary-courthouse-amsterdam

Hotel with prefab rooms[34]

Hotel Jakarta in Amsterdam is an example of a modular and demountable design which makes building parts or materials suitable for high-value reuse. It is made up of separate ready-to-use rooms. The hotel rooms with concrete floors and wooden walls and roofs are assembled in the factory. Standard profiles are easier to reuse in another construction project. The 200 rooms are stacked on top of each other like Lego bricks on the site. The prefab rooms can be given a second life in a subsequent construction project.

Case Study 166: Construction works in the preparation of the Olympics games in London

Construction works in the preparation of the Olympics games in London [35]

The Olympic Delivery Authority (ODA) pledged to hold the greenest Games of modern times and sustainability was built into all the activities, from the procurement to the operation of the Games. The ODA set a number of CDW targets during the demolition, design and construction phases of the London 2012 Olympic Park, including:

- 90% re-used or recycled demolition waste by weight;
- 90% re-used or recycled construction waste by weight;
- 20% of materials to be from a re-used or recycled source by weight;
- 25% recycled aggregate by weight.

2.2.3.1.2 Methodology for assessment of future value of the buildings

Building requirements change over time and this leads to poor efficiency or high adaptation costs incurred to the user and all kinds of environmental issues when adapting the building. With this in mind, business organizations together with the national government of the Netherlands[36] have started a public-private project for determining the future value of buildings from the perspective of adaptive capacity, financial return and sustainability. The project aims to prepare a description of how the assessment of the future value of buildings should be approached, in terms of adaptive capacity, financial return and sustainability. The objective is to obtain a complete and complete set of indicators, which has support and is recognized in practice.

The determination method provides a description for owners and/or investors in real estate to set requirements for and make an assessment of the future value of new or existing buildings from the perspective of the adaptive capacity.

[34] https://www.ursem.nl/en/projects/hotel-jakarta

[35] Bio by Deloitte, 2017, Resource Efficient Use of Mixed Wastes Improving management of construction and demolition waste

[36] https://www.joostdevree.nl/bouwkunde2/jpgo/open_bouwen_21a_gebouwen_met_toekomstwaarde_2014_www_adaptiefvermogen_nl.pdf

Based on questions and points of interest, the method guides the user step by step through the crucial questions that must be answered in order to determine the future value from the perspective of adaptive capacity of a building. To this end, requirements are first formulated in the field of the adaptive capacity, after which building characteristics from a design process or an existing object are tested on the basis of those requirements. In addition, a financial and sustainability test is performed. This financial and sustainability assessment is based on existing instruments; no new method has been developed for these two points. There is, however, a new method for adaptive capacity, in which knowledge and insights from a variety of existing literature and previous instruments have been combined and supplemented.

2.2.3.1.3 Voluntary agreements

Different voluntary agreements, such as Green Deals, are adopted in the EU Member States. These include, for instance, the **Green Deal Sustainable Civil Engineering** in the Netherlands, which is presented in detail below.

Case Study 17: Green Deal Sustainable Civil Engineering (the Netherlands)

Green Deal Sustainable Civil Engineering (the Netherlands)

On June 10, 2013, the Green Deal Sustainable Civil Engineering[37] was signed by 21 parties in Utrecht. Later, other parties, including provinces, joined. The **'Sustainable Civil Engineering partnership'** now consists of central government and public clients, contractors and knowledge institutions, all working in the rail & ground, road and hydraulic engineering sectors. The parties together form a broad representation of the civil engineering sector in the Netherlands.

In the Green Deal, the parties have made agreements about raising sustainability in projects in the rail, civil engineering, road and hydraulic engineering sectors. The parties in this partnership support the government's ambitions to purchase sustainably. In addition, they want a better connection with functional tendering with solution-free criteria and more ambition in sustainability in civil engineering in general. The working method developed with the title 'Sustainable Civil Engineering Approach' has shown that quality, sustainability, effectiveness and room for creativity can go hand in hand.

The Sustainable 'Sustainable Civil Engineering Approach' turned out to be a success and developed into a 2.0 version. The transition lines envisage that by 2020 the Sustainable Civil Engineering Approach will be applied in all relevant civil engineering projects, in planning, construction and tendering as well as in management and maintenance. That is why the Green Deal parties have expressed their ambitions in four practical transition lines:

1. From cost to value, sustainability is seen as an added value, a yield instead of a cost item. Sustainability can lead to savings, but also adds value (value creation) through innovative sustainable solutions. The aim is to make the sustainable added value visible within civil engineering projects.
2. From reactive to proactive. Sustainability must be 'business-as-usual' which requires understanding each other's interests and needs, division of responsibilities between stakeholders and actively sharing experiences and successes. The parties draw up a joint communication plan.

[37] https://www.duurzaamgww.nl

3. From unique to uniform. Parties made a commitment to embed sustainability in all their business processes. Parties are accelerating the implementation of the Sustainable Civil Engineering Approach in their programs, projects and business processes.
4. From alone to together. Collaboration within the civil engineering sector is necessary to make sustainability an integral part of all civil engineering projects.

On the other hand, the Central government made commitments and engaged in actions to:

- make every effort to remove any obstacles in legislation and regulations for the Approach
- ensure that the civil engineering projects are carried out in accordance with the Sustainable Civil Engineering Approach increases annually (to 100% in 2020).
- incorporate the experiences from this Green Deal in the elaboration of the Socially Responsible Procurement Program and the Cabinet-wide Circular Program

The ambition to make sustainability „*business as usual*" within the sector within four years, unfortunately, turned out to be too ambitious. The Sustainable Civil Engineering Green Deal officially expired at the end of 2020 but, the Sustainable Civil Engineering Approach continues. According to the Manifest 2030, the goal remains the same "In 2024, sustainability will be an integral part of all rail and civil engineering works projects". A qualitative and quantitative analysis of the Green Deal 2.0 draws the following recommendations to make sure the goal is achieved:

- More municipalities have to make active use of the Sustainable Civil Engineering Approach;
- Sustainability objectives must become more concrete so that they can be translated into clear project objectives;
- Participation should be less non-committal and concrete program goals should be set;
- Sustainable GWW Approach should be done more often and should be deployed earlier – already in the early planning phase;
- Continuing the trend to include more and more durability with sufficient weight weighing in tenders.

2.2.3.1.4 Certification systems

The certification systems are quantitative standards to measure the concept of sustainable development. By defining a set of criteria and a rating system to score them, these systems assess construction projects. However, these certificates are different from building codes of practice. The codes show the minimum requirements for development and construction, whereas certificates rate buildings and projects according to quality and predefined criteria, and they can show the maximum.

The following items can be pointed out in the definition of certification systems:

- **Define criteria and indicators**: This is the main element in these systems. Criterion: states the main specifications and details of the determined objectives (i.e. objectives and aspects of sustainable urban development);
- **Indicator**: Quantitative and measurable description of the criteria. Each criterion might be evaluated by a number of indicators [2];
- **Rating system**: Shows the specific boundaries of classification. Also, the evaluation method (quantitative or qualitative) for indicators measurement, the criteria importance factor, and the minimum level of requirement must be carefully identified in this part. Finally, the result of the evaluation must be shown simply and specifically;
- **Certification process**: Decides the necessary measures and the steps to award the certificate. Assessment and rating usually take place in a number of building (or a city quarter) life cycle phases (e.g., design and planning, construction, etc.). It has to be taken into account that the assessment process and what is observed in each phase must be explained in detail.

There are several certification systems that offer sustainability assessment most prominent of which are BREEAM (1990 UK)[38], HQE (1996 France)[39], LEED (1998 USA)[40], CASBEE (2001 Japan)[41], Green Star (2002 Australia), DGNB (2009 Germany)[42]. Each system has its own characteristics depending on its rating system, certification process, and criteria and therefore there are advantages, disadvantages, and unique features of each of them.

All systems use a mix of Economical, Sociocultural, Technical and Environmental criteria when rating a building project but the definition and the weights of criteria are different. In comparison at the level of sustainability aspects, it can be established that the DGNB is the single one that covers all three dimensions of sustainability equally - economical, ecological and social qualities. On the other hand, both the LEED and BREEAM systems place their main focus on the ecological dimension of sustainability. Energy efficiency makes up the largest portion of the overall assessment here. The use of renewable energy, the reduction in water consumption and the use of sustainable construction materials are also considered important criteria.

With BREEAM, the economic quality experiences relatively little consideration (only life cycle cost calculation and value retention criterion due to the resistance to wear). Economic aspects are not taken into consideration for the LEED. All three systems are relatively similar in terms of the socio-cultural aspects.

The DGNB does in principle build upon the other systems, yet it considers all aspects of sustainability and for this reason, it is characterized as an assessment method of the second generation.

2.2.3.1.5 Level(s) – aligning all certification schemes in EU

Level(s)[43] is a European framework to help assessment and monitoring of the environmental performance of buildings. It is a free, open-source tool enabling building projects to assess, report on and improve their sustainability performance from design until end of life. Level(s) complements existing assessment or certification schemes in the European Union. It provides a common reference point at the EU level and aims at aligning assessment and certification schemes. Since 2019, the EU-funded LIFE Level(s) project has been supporting the alignment of assessment and certification schemes and public procurement criteria with Level(s). One of the project's key initiatives has been the development of a mapping tool (to compare schemes against the Level(s) framework) and reporting template (that summarizes the results of a Level(s) assessment in a single document) to help assessment and certification schemes align their work with Level(s). The European Commission is also developing Level(s) eLearning material and a calculation and assessment tool, both of which will enable users to collect and structure data to help report against the Level(s) indicators in a consistent manner.

A project team decides which objectives to focus on, which indicators to work with and finally, at what level. Level(s) can be applied at each stage of a building´s life cycle:

> **Level 1** – Conceptual design: Early stage qualitative assessments and reporting on the concepts that the chosen indicators will cover. It provides a simple structure that can be presented to clients to prioritize attention on sustainability aspects.

[38] https://www.breeam.com
[39] http://www.hqegbc.org
[40] https://www.usgbc.org/leed
[41] https://www.ibec.or.jp/CASBEE/english
[42] https://www.dgnb.de/de/index.php
[43] https://ec.europa.eu/environment/levels_en

Level 2 – Detailed design and construction: Quantitative assessment of the designed performance. Allowing comparison between different design options and monitoring construction according to standardized units and methods.

Level 3 – As-built and in-use: Monitoring and surveying of activity both on the construction site and of the completed building, and its first occupants. Level 3 helps the entire team understand actual building performance and identify lessons learned from the design to inform and improve future projects.

2.2.3.1.6 Standard for Design for Disassembly and adaptability (DfD/A)

The standard *ISO20887 (2020) - Sustainability in buildings and civil engineering works — **Design for disassembly and adaptability*** is intended to provide a framework of the DfD/A principles and the key issues that should be considered by the different actors, particularly designers involved in the project. The standard deals with environmental, social, economic, technical and functional aspects of sustainability. It provides an overview of the design for disassembly and adaptability (DfD/A) principles and potential strategies for integrating these principles into the design process.
It does not contain testing methods or compliance criteria, but several examples are provided.
The standard gives an example of how specific elements or components/assemblies can be assessed for each DfD/A principle. The example deals with building mechanical systems, which include ducting, diffusers, pipes, flexible tubing, and connectors but a similar DfD/A evaluation process can be applied to other elements.
It also describes the development of different end-of-life approaches for materials, products, components and systems on the construction works or construction product level. This is important because to model the full life cycle of building products it is necessary to develop probable end-of-life scenarios for the construction works. The development of end-of-life scenarios for construction works should take into account the decisions made during the design and construction stages of the life cycle.
The standard provides guidance on measuring performance related to DfD/A objectives including setting objectives, targets and performance monitoring. This document does not set specific levels of performance for the disassembly or adaptability of constructed works, however, it does include requirements that are mandatory for the implementation.
ISO20887 (2020) standard is one of the ISO documents dealing with sustainability in construction works as shown below.

Standards covering general principles:

- ISO15392, Sustainability in buildings and civil engineering works — General principles – environmental, social and economic aspects;
- ISO/TS12720, Sustainability in buildings and civil engineering works — Guidelines on the application of the general principles in ISO15392 – environmental, social and economic aspects;
- ISO/TR21932, Sustainability in buildings and civil engineering works — A review of terminology – environmental, social and economic aspects.

Standards related to buildings (Parts 1) and Civil Engineering Works (Parts 2):

- ISO21929-1, Sustainability in building construction — Sustainability indicators — Part 1: Framework for the development of indicators and a core set of indicators for buildings – environmental, social and economic aspects;

- ISO/TS21929-2, Sustainability in building construction — Sustainability indicators — Part 2: Framework for the development of indicators for civil engineering works – environmental, social and economic aspects;
- ISO21931-1, Sustainability in building construction — Framework for methods of assessment of the environmental performance of construction works — Part 1: Buildings – environmental, social and economic aspects;
- ISO21931-2, Sustainability in buildings and civil engineering works — Framework for methods of assessment of the environmental, social and economic performance of construction works as a basis for sustainability assessment — Part 2: Civil engineering works – environmental, social and economic aspects;
- *ISO20887 (2020) - Sustainability in buildings and civil engineering works — Design for disassembly and adaptability – environmental, social, economic, technical and functional aspects;*
- ISO21678, Sustainability in buildings and civil engineering works — Indicators and benchmarks — Principles, requirements and guidelines – environmental, social and economic aspects;
- ISO16745-1, Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 1: Calculation, reporting and communication – environmental aspects only;
- ISO16745-2, Sustainability in buildings and civil engineering works — Carbon metric of an existing building during use stage — Part 2: Verification – environmental aspects only.

Standards related to products:

- ISO21930, Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services – environmental aspects only;
- ISO22057, Enabling use of Environmental Product Declarations (EPD) at construction works level using building information modeling (BIM) – environmental aspects only.

Circular design standards are voluntary but in many cases, they are referred to in legal documents for example in Annex 1 of EU Taxonomy Regulation (EU) 2020/852 which describes the technical screening criteria for determining the conditions under which an economic activity (in this case Construction of new buildings - section 7 of the Annex) qualifies as contributing substantially to climate change mitigation and for determining whether that economic activity causes no significant harm to any of the other environmental objectives.

2.2.3.2 Mandatory measures

2.2.3.2.1 Design for disassembly and adaptability principles in the building code

The stringency of the building legislation is a way of ensuring compliance among the practitioners in the construction industry. This is because building construction works require planning approval and the authorization must be given within the legislative framework of building regulations.

However, currently**, there are no requirements for the use of DfD principles in the building code in any country**. In the past, from 2008 until 2015 so-called Code for Sustainable Homes was temporarily mandatory in the UK for residential building construction.

Case Study 18: The Code for Sustainable Homes – UK

The Code for Sustainable Homes – UK

In 2006 the Labour government announced the 'Code for Sustainable Homes'. It was launched in 2006 to help reduce UK carbon emissions and create more sustainable homes. In 2008, the code became **temporarily mandatory**. Sellers were required to issue buyers of newly constructed homes a sustainability certificate (either a Code for Sustainable Homes certificate or a nil-rated certificate). However, in 2010 the requirement for a sustainability certificate was suspended. Until March 2015, the code could be mandatory in England, Wales, and Northern Ireland if it was a requirement of a local authority's local plan, or where affordable housing was funded by the Homes and Community Agency. In 2015 the government published a plan titled 'Fixing the foundations: creating a more prosperous nation', aimed at increasing the productivity of the UK. Within this plan, the deliverability of much-needed new housing took a forefront, and the delivery of zero carbon homes was stalled. Among others the following reasons were given:

- On an annual basis, new homes only account for 1% of the total housing stock, therefore the proposed measures would take a long time to have a significant impact on carbon emission levels;
- Concerns over the impact the new measures will have on the delivery rate of new homes.

Many of its requirements were incorporated into a national framework centered on the Building Regulations. The Code is still operational but is now generally voluntary.

The Code requires assessment of the performance of new dwellings both during design and once construction is complete. It measures sustainability against nine categories. Performance targets are set for each area, and these targets are more demanding than those required by the building regulations. Credits are awarded depending on the performance of the dwelling in each area, and weightings are then applied to adjust their relative values. In addition, mandatory minimum performance standards are set for seven specific areas.

- Environmental impact of materials;
- Management of surface water run-off from;
- Storage of non-recyclable and recyclable waste;
- Emission rate;
- Indoor water use;
- Fabric energy efficiency;
- Lifetime homes.

A certificate is then issued which illustrates the overall rating achieved by the dwelling by a row of 1 to 6 stars.

Although the use of the 'Code for Sustainable Homes' is no longer compulsory in England, it provided the construction industry with a sense of environmental responsibility towards building more sustainable homes and effective waste management.

One of the most important factors for the success of a policy measure is its predictability and perseverance. Frequent policy changes lead to uncertainty in business models. Simplification of regulations is justified, but replacement instruments must lead to at least the same result. While the energy efficiency of buildings and Carbon Index ratings are addressed in the new Building Regulations, the environmental requirements for construction products are not enshrined in the new regulations. UK's Regulation 7: Materials and workmanship reflects European Construction

Product Regulation regarding the CE marking but all previous references to the environmental impact of building work have been deleted.

2.2.3.2.2 Environmental Performance of Buildings

In order to prioritize reversibility, resource recovery and recycling alongside energy efficiency some countries require life cycle assessment of construction works. In particular, the environmental performance of buildings during their one or multiple lifecycles needs to be assessed in order to ensure that legislation and regulations promote circularity. This practice is already applied in some countries, including the Netherlands, where environmental performance is measured through two main indicators - the **Environmental Performance Calculation** for Buildings (EPC) and the **Environmental Cost Indicator** (ECI). They are aimed at steering towards sustainable use of materials in the design process.

Case Study 19: Measuring Environmental Performance of Buildings in the Netherlands

Measuring Environmental Performance of Buildings (the Netherlands)[44]

As explained in section 2.1.3.1.4 the results from the measuring of the environmental performance of materials used for the construction of buildings are later used for measuring the Environmental Performance of the building.

With the data stored in the Dutch Environmental Database, the environmental performance of a building or an infrastructure project can be calculated, using special Calculation Tools. These tools are a commercial software, developed by companies, that are verified and licensed by the Dutch Environmental Database to be used for this purpose. Examples of tools used to calculate the environmental impact of the choice of materials in different design variants are GPR Building and DuboCalc. The lower the EPC or ECI, the more sustainable the use of materials.

When calculating the EPC and ECI, environmental profiles of products and materials are used.

These environmental profiles are drawn up by producers and based on a life cycle analysis (LCA); it is a sum of the environmental impact during the entire lifespan, from the extraction of raw materials to waste processing. The environmental profile consists of various environmental effects, such as depletion of raw materials, climate change, toxicity and acidification. The results of an LCA are sometimes publicly available, but difficult to interpret without a calculation tool.

The environmental performance is calculated by multiplying the results of the LCA (the environmental impacts per category) with weighting factors. These weighting factors are determined on a member state level. Together, this creates an aggregated value for the environmental performance of a construction product. In order to be able to compare the environmental impact of new houses and office buildings, the environmental performance is converted into a comparable unit by dividing the value through the Gross Floor Area (GFA) and the lifespan of the building: the outcome is a single-score indicator of the environmental performance per m^2 per year. The figure below shows a simplified representation of the relationship between the results of the LCA and the Single-score indicator.

[44] https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/gebouwen/wetten-en-regels/nieuwbouw/milieuprestatie-gebouwen

In the Dutch national building legislation, a threshold value for the Single-score indicator of <=0,8 is applicable for new houses and office buildings. In public or private procurement stricter requirements are used: for example the threshold value is 0,6. In the case of infrastructure projects, the client, usually a government agency, could lower the total required score as a policy goal, which is often based on a reference project.

2.2.4 Comparison of the case studies with the current situation in Croatia and assessment of possible implementation

In this paragraph, the presented measures for the Circular Design of Buildings and their applicability in the Croatia context are explored in detail in the tables below, including both voluntary and mandatory measures.

Table 13: Circular design of buildings in Croatia-Voluntary measures.

Methodology for assessment of future value of the buildings	**Currently, in Croatia, as in most other countries, the higher residual value of buildings designed using the circular design principle is not taken into account (for example, when setting the interest rate on mortgages or in public-private partnership contracts Build-Operate-Transfer). Development of Croatian methodology or adaptation of the existing one into the Croatian conditions is a measure that can be implemented in the short term.**
Certification systems	**Certification is limited mainly to large trade or office buildings** due to the implementation of corporate responsibility programs of big corporations or because of the trend for advertising of commercial buildings as "green". But the opportunities for an increase due to market demand are already exploited. Further development in the number of certified construction projects could be achieved if certification becomes part of GPP or environmental performance assessment of buildings becomes legally binding. Realistically this could happen in the middle to long term.
Standard for Design for disassembly and adaptability	The standard ISO20887 (2020) for Design for disassembly and adaptability and the other sustainability-related ISO standards are not adopted by the national standardization. Voluntary implementation of the existing international standards is connected to the certification of construction projects and is currently limited in scope. Further extension in the use of standards could be expected if their application is required by GPP or the legislation (for example in Annex 1 of EU Taxonomy Regulation (EU) 2020/852). Therefore, implementation of this measure depends on the strategy and timeline for a gradual introduction of circular design of buildings – starting with the construction projects funded with public funds, voluntary commitments of the green construction business and gradually making circular design obligatory for all projects.

Table 14: Circular design of buildings in Croatia- mandatory measures.

Design for disassembly and adaptability in the building code	The introduction of obligations to implement circular design in building codes is still not applied even in advanced countries. This measure is feasible in the long run.

Environmental performance of buildings	As mentioned in Croatia, the assessment of the environmental performance of buildings is not mandatory and can realistically be applied in the medium or long term.

2.3 Sustainable construction and renovation of buildings

2.3.1 Concept

Circular approaches in the building sector could be strengthened during the construction stage by applying construction techniques that promote:

- Durability of buildings and the resilience of the materials;
- Maintenance and repairs to different parts of the buildings and building products and systems;
- Reversibility for various parts of the building that will facilitate adaptability of the buildings;
- Preference to use recycled, recyclable, reusable and/or reused products.

Good practices to ensure the practical application of the concept are discussed below.

Table 15: Good practices to enhance the sustainable construction and renovation of buildings. Potential mandatory and voluntary measures.

Voluntary measures	Mandatory measures
– Building passports	– GPP criteria
– Building Information Modeling	– Lower tax for restoration of old buildings
– Eco-labels relevant to construction sector	– Legal obligations for retrofitting and renovation on EU level

2.3.2 Barriers and enabling conditions

Through the application of sustainable building practices, there are opportunities to retain or even increase the value of materials, products and components including the buildings as a whole over time. Circular building design and material recovery contribute to eradicating construction and demolition waste and downcycling.

The major barriers to recirculating materials and products during construction are due to the fact that the information relevant for circularity is not centralized, there are no standardizing methods of data collection, and there is a lack of practical implementation of certification instruments and warranties, especially to guarantee supply of quality recycled materials. The lack of legal and economic instruments is the reason for the low supply and demand of recycled materials.

2.3.3 Implementation and good practices

2.3.3.1 Voluntary initiatives

2.3.3.1.1 Building passports

Materials can be efficiently reused or recycled after demolition if a structure has a building passport. This passport provides insight into the quality and quantity of the materials and components used in the building. There are various initiatives that focus on this, including MADASTER - a digital online platform for registering buildings – that allows the adoption and utilization of circular passports; and the **Green Deal Circular Buildings in the Netherlands, already presented in previous chapters, which also applies the concept of circular passports.**

Case Study 20: MADASTER - digital platform for registering of buildings,

MADASTER - digital platform for registering of buildings, including the materials and products that were used in their construction[45]

An example of such an initiative is Madaster which is an online platform for building materials and elements; by labeling materials you can find and reuse them. Madaster is an independent platform offering free access to individuals as well as companies, governments and research organizations. Unlike other platforms that focus on building materials and products, Madaster circular passports take into account the entire construction perspective. Their material passports give an idea of the materials used in the building, their quantities, information on the quality of the materials, their location and their monetary and circular value. The Madaster platform is designed as a public online library. This facilitates the registration, organization, storage and exchange of data while taking into account aspects of confidentiality, security and continuity. Madaster automatically generates secure, web-based passports for registered buildings and construction objects.

The platform helps to organize, store and exchange data. By subscribing to the platform, the user (depending on its private or public status and its function) can have access to different tools and services including generation of material passports (from a BIM model) describing materials in each layer of the building and how easy it is to retrieve it, estimation of how much they will be worth, access to a library of building-specific information on materials, components and products.

The platform also proposes a Circularity Indicator, based on the Ellen MacArthur Foundation Material Circularity Indicator, which scores a building between 0 to 100%. Besides an overall indication on the building level, Madaster also indicates the level of circularity for each layer or each phase of the building: construction, use and end of life.

Case Study 21: Green Deal Circular Buildings – the Netherlands

Green Deal Circular Buildings – the Netherlands

In the Green Deal Circular Buildings, the participants tried to apply the principles of the circular economy to buildings. The participants contributed to the identification of important circular principles in buildings. This involved looking at various building characteristics, such as the use of materials and opportunities for life extension. In addition, an attempt has been made to make these building characteristics measurable and record them at building level. In this way, a **circular passport** has been developed that describes the circularity of buildings.

The Green Deal was realized in several phases. Within these phases, the participants took the first important steps to make existing and new buildings in the Netherlands more circular. Knowledge and experience in the field of circular buildings are made available through the participants and pilot projects.

During the first phase of the Green Deal, indicators were established that determine the circularity of a building. This not only concerns the products and materials used, but also the way in which

[45] https://madaster.com

management and maintenance are arranged, how renovations are handled and how flexible/adaptive the building is to the future. These indicators are laid down in the circular passport.

After the realization of the passport, the so-called **circular journey** started. The circular journey is an addition to the circular passport and describes the entire process of how to achieve a circular building. The journey can be consulted in every phase of the circular process and provides insight into the various processes and steps that must be followed. It offers tools for the realization of a circular building.

The result of Green Deal Circular Buildings is a digital platform where a circular journey can be taken including the various steps to achieve a circular building.

2.3.3.1.2 Building Information Modeling (BIM)

Building information modeling is a software solution aimed at representing in 3D digital format of physical and functional characteristics of a building or other type of construction work. The information in the model could be extracted, exchanged or networked to support decision-making related to a built asset. The concept has been developed since the 1970s but was uniformed through the standards developed in the United Kingdom from 2007 onwards that have formed the basis of international standard ISO19650, launched in January 2019. Building information modeling extends beyond drawing construction works in 3D format by incorporating construction project information about time, costs, asset management, spatial relationships, etc., as well as matters that are more important for the circular economy such as quantities and properties of building components and sustainability issues.

BIM enables a virtual information model to be shared by the designer, the builders, and the owner/operator. It can allow designers to integrate and analyze environmental issues in their design over the life cycle of the building. BIM enhances green building in four main areas: land, water, energy and materials. In regard to materials, BIM tracks material consumption, calculates material requirements, and manages material information uniformly[46].

The three rating systems used to evaluate the environmental performance of buildings that can integrate with BIM are LEED, BREEAM, and Green Star. Integration is performed through "design assistance" and "certification management" modules. The **design assistance module** assists designers with efficient sustainable knowledge that is built into the BIM tool. The **certification management module** is used to manage project information, sustainable documentation and submissions for certification purposes.

Experience has shown that BIM improves the efficiency of design and construction. It supports decision-making by allowing designers to use the information on sustainable materials stored in the database and use design and analytical tools to quantify the environmental impact of systems and materials so that more sustainable buildings are being built. Such data are useful for assessing the life cycle of a building.

2.3.3.1.3 Eco-labels relevant to construction sector

In order to support business-to-consumer environmental initiatives, the European Commission is developing the Ecolabel as an EU tool for assessing/communicating the environmental performance of products and services. The EU Ecolabel is a type I environmental label in accordance with ISO14020

[46] https://www.frontiersin.org/articles/10.3389/fbuil.2021.713976/full

(ISO2000) and is intended to be a voluntary market-based instrument for promoting environmental performance in products and services in a standardized way.

As this is a typical optional "business to consumer" tool, the Ecolabel cannot have a significant impact on the construction and building materials sector, unless its interaction with GPP is clearly defined.

The product and service groups belonging to the construction sector for which eco-label criteria have been developed are as follows:

- Coverings (wooden, hard, and textiles);
- Indoor and outdoor paints and varnishes;
- Tourist accommodation;
- Office buildings;
- Road construction (currently, there are no eco-labels, but there are GPP criteria in place).

Details of the definition of product and criteria assessment and verification are reported in the EU Ecolabel Regulations published in the Official Journal of the European Union.

There are three other groups which are mostly related to domestic systems:

- Heating systems;
- Sanitary tapware;
- Taps and showers;
- Furniture;
- Solar photovoltaics (not finalized).

2.3.3.2 Mandatory measures

2.3.3.2.1 GPP criteria

Green Public Procurement criteria aim to be clear and ambitious environmental criteria, based on a life-cycle approach and a scientific evidence base. The main types of criteria are: selection criteria (what requirements a tenderer must meet to be allowed to bid); technical specifications (what requirements must be met by all bids received); award criteria (additional optional requirements that, if met, will make a bid more competitive) and contract performance clauses (specific measures that are taken to ensure that certain aspects of the winning bid have been met during the construction project or after the project is completed).

Two levels of ambition are foreseen for technical specifications and award criteria: “core level” and “comprehensive level”:

- **Core criteria** are considered those that allow a relatively straightforward application of GPP, keeping administrative costs for a company to a minimum;
- **Comprehensive criteria** continue to focus on environmental performance, but with a higher ambition level and in such a way that might require more thinking by authorities and involve more effort from bidders about how to achieve this higher ambition.

The European Commission has identified the potential of green public procurement (GPP)[47] as an important instrument for promoting environmentally friendly products and services and encouraging eco-innovation which contributes to sustainable development. It is important to ensure that criteria used by Member States are similar to avoid distortion of the single market and a reduction in community competition.

[47] https://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm

GPP development by The European Commission is a voluntary instrument. However, **Member States and public authorities may decide to apply it as mandatory** and determine the extent to which they implement it. Its use may present problems as it may prove difficult to verify the fulfillment of environmental requirements provided by tenderers. To overcome this problem, the EU Ecolabel, other 'Type 1' or 'ISO14024' labels (e.g., the Nordic Swan, The Blue Angel, NF Environment, Milieukeur) and 'single-issue' labels (such as energy efficiency labels) may be used as appropriate instruments to provide the source for identifying environmental criteria and describing them. The criteria can then be directly inserted into tendering documents according to specific guidelines and may be divided into two types, core and comprehensive (see previous section).

GPP criteria for some product groups related to building materials have been developed or under development by the European Commission, such as:

- buildings (ongoing);
- solar photovoltaics (ongoing);
- furniture;
- heating systems:
- paints and varnishes;
- roads;
- sanitary tapware;
- taps and showers.

The revision of EU GPP Criteria is carried out on a periodic basis, prioritizing product groups where criteria may have become outdated, either due to innovation, market changes or new legal, technical or environmental requirements. Examples of criteria for construction products being discontinued by the European Commission are windows, thermal insulation, and wall panels.

2.3.3.2.2 Lower tax for restoration of old buildings

This type of instrument includes economic incentives (lower tax) for the restoration of old buildings instead of demolition. The introduction of economic incentives in the form of lower tax rates for first-time buyers purchasing old property is explored in the case study of Malta

Case Study 22: Incentives to buy, renovate property in conservation areas in Malta

Incentives to buy and renovate property in conservation areas in Malta

In October 2021, three-year incentives have been announced for purchasing and renovating a property, with tax waivers for buyers of residences built over 20 years ago but vacant for at least seven years, as well as for those in UCAs and new ones built in typical Maltese style. The scheme is limited to the first EUR 750,000 of the value of the properties, on which no duty or capital gains tax will be charged. First-time buyers of such properties will also receive a grant of EUR 15,000. Also, people who renovate such properties will get VAT refunded for up to EUR 54,000 on the first EUR 300,000 spent on renovation works. In order to benefit from the schemes and to avoid speculation, such properties cannot be divided - as is the case if split up into a number of apartments.

2.3.3.2.3 Legal obligations for retrofit and renovation on EU level

Directive 2012/27/EU on energy efficiency[48] establishes a common framework of measures for the promotion of energy efficiency to step up Member States' efforts to use energy more efficiently at all stages of the energy chain – from the transformation of energy and its distribution to its final consumption. Measures include the legal obligation to establish energy efficiency obligations schemes or policy measures that will drive energy efficiency improvements in households, industries and transport sectors. Other measures include an exemplary role to be played by the public sector and a right for consumers to know how much energy they consume.

The main requirements that can be achieved via improved heating systems, fitting double-glazed windows or insulating roofs are the following:

- Member States are requested to reduce energy sales to final customers by 1.5% each year;
- The public sector is required to renovate each year 3% of the buildings "owned and occupied" by the central government in each country to meet at least the minimum energy performance requirements that it has set in the application of Article 4 of Directive 2010/31/EU on the energy performance of buildings.

The Energy performance of buildings directive (Directive 2010/31/EU)[49] aims to promote the energy performance of buildings. EU countries must set optimal minimum energy performance requirements. These should be reviewed every 5 years. They must cover the building, its components and the energy used for: space heating (including combined systems with ventilation); space cooling; domestic hot water; ventilation; built-in lighting; other technical building systems.

The European Commission has established a comparative methodology framework to calculate the optimal cost levels for the energy performance requirements.

New buildings must meet the minimum standards. Buildings owned and occupied by public authorities should achieve nearly zero-energy status by December 31, 2018, and other new buildings by December 31, 2020.

When undergoing major **renovation, the existing buildings** must upgrade their energy performance to meet the applicable requirements.

EU countries must operate an energy performance certification system. The certificates:

- Provide information for prospective purchasers or tenants of a building's energy rating;
- Include recommendations for cost-effective improvements;
- Must be referred to in all commercial media advertisements when premises are offered for sale or rent.

Member States are responsible for putting in place a system of regular inspections of heating and air-conditioning systems in buildings by qualified personnel to ensure optimal performance.

EU countries to draw up long-term **renovation strategies** to support the renovation of both residential and non-residential buildings into a highly energy-efficient and decarbonized building stock by 2050. The strategies should set out a roadmap with measures and measurable progress indicators, with a view to the EU's long-term 2050 goal to reduce greenhouse gas emissions by 80-95% compared to 1990. The roadmap must include indicative milestones for 2030, 2040 and 2050, and specify how they

[48] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02012L0027-20210101&from=EN
[49] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:02010L0031-20210101&from=EN

contribute to achieving the EU's energy efficiency targets in accordance with Directive 2012/27/EU on energy efficiency.

In 2020, the Commission adopted a delegated act and an implementing act establishing an optional common EU scheme for rating the smart readiness of buildings.

2.3.4 Comparison of the case studies with the current situation in Croatia and assessment of possible implementation

In this paragraph, the presented measures for Sustainable Construction and Renovation of Buildings and their applicability in the Croatia context are explored in the tables below, including both voluntary and mandatory measures.

Table 16: Sustainable Construction and Renovation of Buildings in Croatia-Voluntary measures.

Building passports	Building passports are taken into account by the certification schemes in their procedures for project assessment and awarding. There are several big construction projects certified in Croatia. Creating a platform for registering buildings, including the materials and products that were used in their construction would help to organize, store and exchange data between different stakeholders in the value chain and will enable assessment of the buildings in terms of circularity (provided that circularity indicators and respective methodology are integrated into the scheme). However, this will require scientific research and financial commitment by the industry and may not be feasible in the short term.
Building Information Modeling	Building Information Modeling software is already used by big design and construction companies. Its wider use can be encouraged by making environmental performance assessment obligatory (or awarding criteria in GPP) as BIM software contains design and analysis tools to quantify the environmental impact of systems and materials and submission of information for certification purposes.
Eco-labels relevant to construction sector	The Environmentally Friendly Labeling Program of Croatia is implemented to promote products and services that have a less negative impact on the environment. The program is part of a national policy on environmental protection and sustainable development. The procedure for awarding the Environmentally Friendly label is based on independent verification by a third party (authorized institutes, accredited laboratories, etc.). The procedure and manner of awarding the Environmentally Friendly label, the content of the benchmark for individual product groups, the description and procedure of benchmark development and the method of revision of the benchmark, conditions for use and revocation of the Environmentally Friendly label are regulated in the Ordinance on the "Environmental Friend" environmental label. The procedure for awarding the Eco-Friendly Label is in line with the procedure for awarding the European Union's environmental label - the EU Ecolabel. There are no national construction-related Eco-label criteria.

	As both national and EU eco-label programs are a typical "business to consumer" tool, which is optional, the Ecolabel could be further encouraged through its interaction with GPP.

Table 17: Sustainable Construction and Renovation of Buildings in Croatia- Mandatory measures.

GPP criteria	Currently, **GPP in Croatia is a voluntary mechanism**, except for central state bodies for which is mandatory. Croatian national green public criteria do not include criteria related to the construction sector.
Lower tax for restoration of old buildings	Currently, **tax relieves are not applied for restoration of old buildings** but this is a viable option in Croatia especially for the tourist areas that need urgent renovation and could be implemented in short term in case a decision for allocation of public funding is taken.
Legal obligations for retrofit and renovation on EU level	The Energy Efficiency Act (OG 127/14, 116/18, 25/20, 32/21, 41/21) prescribes energy renovation of at least 3% of the area of central government buildings per year as a mandatory measure of the National Energy Efficiency Action Plan. The legislative framework prescribing the Energy Performance of Buildings Directive criteria in the Republic of Croatia is: - Construction Act (Official Gazette N°. 153/13, 20/17, 39/19, and 125/19); - Technical Regulation on Rational Use of Energy and Thermal Protection in Buildings (Official Gazette 128/15, 70/18, 73/18, 86/18, 102/20); - Long-term strategy for encouraging investments in the renovation of the national building fund of the Republic of Croatia (Official Gazette N° 28/19); - Plan to increase near-zero energy buildings by 2020 (2014); - Program to encourage the construction of new and renovation of existing buildings to almost zero energy standards (2018). All new buildings for which an application for a location permit or construction permit is submitted as of December 31, 2019, must meet the requirements for Energy Performance of Buildings. Also the new buildings used and owned by the public authorities must have been designed as buildings with almost zero energy, if the application for the issuance of a location or construction permit for which there is no previous location permit was submitted after December 31, 2017. Minimum requirements for the energy performance of new and existing buildings undergoing reconstruction and significant renovations are prescribed by the Technical Regulation on Rational Use of Energy and Thermal Protection in Buildings. Specific requirements for the reconstruction of existing buildings are in force. In case of significant renovation or reconstruction of a building, no

	request is given for a building of almost zero energy, but the Technical Regulation determines the requirements that the building and its parts must meet. Therefore, **there is no obligation to meet nZEB standards for existing buildings** except in the case of additions and/or upgrades that is, the conversion of unheated space into heated space and when the area of that part is greater than or equal to 50 m^2. In that case, the obligation to meet the nZEB standard only needs to be met for that part.

2.4 Sustainable use and maintenance of buildings

2.4.1 Concept

The following key factors are necessary for promoting longer lifetimes of buildings:

- Adapt and renovate buildings to avoid demolition;
- Improve maintenance to extend the lifespan of key (structural) components;
- Design and build upgradable, repairable and adaptable constructions.

Good practices to ensure the practical application of the concept are discussed below.

Table 18: Good practices to enhance the sustainable use and maintenance of buildings. Potential mandatory and voluntary measures.

Voluntary measures	Mandatory measures
– **update Building passports**	– Take-back schemes established by bigger manufacturers
– **update Building Information Modeling**	– EPR
	– Performance based contracts

2.4.2 Barriers and enabling conditions

Barriers and drivers for extension of the service life of constructions are often related to socio-economic factors – the knowledge base in the decision-making process. Examples of typical barriers to the renovation of residential buildings are especially higher structural and comfort standards of new buildings, lack of knowledge and trust in contractors.

For new constructions, designing for longevity is the foundation for long-term durability. Durable materials and robust construction standards lower subsequent maintenance costs and increase the value of a building or structure.

It is possible to extend the lifetime of existing buildings through the use of maintenance, upgrades and rehabilitation. Rehabilitation involves retrofitting outdated buildings to meet current energy efficiency regulations, construction guidelines and/or standards on comfort and usage.

To encourage longevity schemes for lower taxation of maintenance costs and value-increasing investment are applied in several EU Member States. The technical progress allows the use of sensors for continuous performance monitoring and implementing long-term durability rehabilitation with ultra-high performance concrete.

Some of the barriers for the longer use and renovation of existing buildings are the higher structural and comfort standards. Economic obstacles could be the lack of data and methodologies for

determining the residual value of the buildings as well as the time delay in visible benefit of the lifetime extension.

2.4.3 Implementation and good practices

2.4.3.1 Take-back schemes established by bigger manufacturers

For construction products with short lifetimes, such as carpets, there are several successful examples of take-back schemes, including Tarkett's ReStart program or Desso's Take Back Program, but these may not be appropriate for products that remain in situ over a building's lifetime.

Case Study 23: Take Back Program of Desso

Take Back Program of Desso[50]

DESSO is a leading carpet brand acquired by Tarkett in 2015. It has more than 85 years of experience in manufacturing high-end, innovative carpet solutions. Its manufacturing facilities are located in Waalwijk, the Netherlands and Dendermonde, Belgium.

Desso offers clients a Take Back program to ensure that products will be recycled according to the Cradle to Cradle principles. Products are taken back by Desso after their useful life and will be safely recycled into new carpet products, or used in other recycling initiatives. By sourcing positively defined raw materials, introducing new manufacturing methods and collecting used carpets from clients, we are doing everything we can to achieve a closed-loop process (from production to use and back again). Carpets are recycled using our innovative separation technique called Refinity, which separates the yarn and other fibers from the backing thereby producing two main material streams which can be recycled. After an additional purification stage, the yarn (with the required purity) is returned to the yarn manufacturer for the production of new yarn. Some virgin material is needed to compensate for losses and process inefficiency.

For Polyamide 6 yarn, this process takes place at Aquafil, one of Desso's yarn suppliers. Aquafil has developed proprietary technology at its regeneration plant to turn recovered post-consumer polyamide 6 carpet fibers into new polyamide 6 again and again. The polyolefin-based layer of EcoBase backing is 100% safely recyclable in Desso's production process, whereas the bitumen backing (used in most carpet tiles in Europe presently) is reused in the road and roofing industry. All non-recyclable fractions are used as secondary fuel in the cement industry.

2.4.3.2 EPR

For construction products with short lifetimes, such as carpets, there are several successful examples of EPR schemes. However, EPR may not be appropriate for products that remain in a building over its lifetime. The chosen examples present the case study in the Netherlands on EPR schemes for float glass, and a collaboration agreement with producers to boost recycling of CDW in the Netherlands.

[50] http://www.desso.pt/globalaccounts/regus/take-back%E2%84%A2-programme

Case Study 24: EPR scheme for float glass in the Netherlands

EPR scheme for float glass in the Netherlands

The Netherlands is the only country that has an EPR scheme for float glass. It therefore has one of the few fully operational EPR schemes with a PRO for construction materials in Europe. The EPR scheme applies an environmental fee of EUR 0.5/m^2 for new double-glazed windows in order to finance the collection and recycling of end-of-life float glass. Actually, pure float glass shards have a positive value which means that glass recyclers are paying to collect large volumes of selectively sorted end-of-life float glass. Thanks to the positive price of float glass, shards collection and recycling also occur in neighboring countries such as Belgium. Therefore, the main contribution of the Dutch EPR scheme is situated in improved monitoring of the material flow and more intensive collection of small quantities.

Case Study 25: Collaboration agreements with producers in Flanders

Collaboration agreements with producers in Flanders[51]

Flanders has set up **collaboration agreements** with producers in order to recycle construction and demolition (CDW) waste. More specifically, producers of several smaller material streams have initiated pilot projects, set up logistic schemes, or invested in infrastructure to collect post-consumer materials as input for new materials: gypsum, autoclaved aerated concrete, bituminous roofing, PVC and mineral wool.

2.4.3.3 Performance based contracts

The durability of a building can also be promoted for the period for which it is in use. This can be done, for example, through performance-based contracts that encourage optimal use and understanding of buildings. Three good examples of such innovative procurement contracts from different European countries are presented below, including leasing contracts between public authorities and construction companies in Italy to include leasing of the building (instead of ownership) in the contracts; and the examples of France and Finland, promoting energy-performance clause in the tender contracts for the construction of new public buildings.

Case Study 26: Leasing contract between public authority and building company - municipality of Vinovo

Leasing contract between public authority and building company - municipality of Vinovo[52]

In 2008, the Italian municipality of Vinovo needed a new kindergarten and decided to use a specific form of Italian public-private partnership. Typically, this partnership is between a founder and a construction company. This model included that the financing and tendering for the design and construction were to be carried out jointly. In the case of Vinovo, a leasing contract was drafted, according to which the authority would pay leasing fees (capital and interest) for using the building

[51] Exploration of the Role of Extended Producer Responsibility for the circular economy in the Netherlands, June 27, 2016

[52] State of Play for Circular Built Environment in Europe; Author: Ninni Westerholm.

for a set period. At the end of the lease period, the ownership of the building would then pass to the authority. Additionally, there was a design and build contract with a construction company managed by the founder. The strong partnership enabled by this procurement helped to guarantee the quality of the construction.

Case Study 27: Energy performance contract - Alsace, France

Energy performance contract - Alsace, France[53]

In Alsace, France, there is a strong political will to promote sustainable development. Therefore, the authorities wanted to explore new procurement possibilities when planning an energy-efficient renovation for their schools, to reduce the annual energy costs. What they ended up doing was procuring through an energy performance contract. Such contracts are mostly financed through the energy savings achieved. Additionally, the experts involved were committed to being available for a three-year period to ensure that the buildings were used as intended. This included consulting in cases when user patterns changed during this period, thus optimizing the performance of the adapted building.

Case Study 28: Energy performance contract - Finnish city of Jyväskylä

Energy performance contract - Finnish city of Jyväskylä[54]

In 2010, the Finnish city of Jyväskylä started the Jyväskylän Optimi project aimed at increasing innovation and promotion of lifecycle thinking in public procurement. In this case, the procurement was the construction of a school and day-care center, with a focus on energy efficiency and sustainable development. The city tendered for a contractor to design, build and operate the building, thus seeking a contract focused on enhancing efficiency. Additionally, what made this procurement special is that, via the contract, it transferred the risk of exceeding the agreed targets on energy use from the customer to the service provider. At the same time, possible profits were shared 50/50 between the customer and the service provider. This sharing of costs, by contract, encourages both parties involved to ensure that the building is used optimally.

2.4.4 Comparison of the case studies with the current situation in Croatia and assessment of possible implementation

In this paragraph, the presented measures for Sustainable Use and Maintenance of Buildings and their applicability in the Croatia context are explored in the table below, only considering voluntary measures (since mandatory measures were not identified in this category).

[53] State of Play for Circular Built Environment in Europe; Author: Ninni Westerholm.
[54] [54] State of Play for Circular Built Environment in Europe; Author: Ninni Westerholm.

Table 19: Sustainable Use and Maintenance of Buildings in Croatia-Voluntary measures.

Take-back schemes established by bigger manufacturers	In accordance with Article 5 of **Ordinance on construction waste and waste containing asbestos**, the Croatian manufacturer of construction products, which places a products on the market in Croatia, that has the same or similar general intended purpose as prescribed in Annex II of the **Ordinance,** is obliged to provide to the buyer and/or user of the product the possibility of returning such used product, which includes surplus material, and the possibility of taking over the waste generated by such a product. However, more efforts are needed for the practical implementation of such take-back schemes. Bigger producers could be encouraged to set up such schemes if the Government initiates dialogue about their corporate responsibility for environmental protection to test their readiness and commitment for taking the responsibility to organize and finance take-back schemes of postconsumer waste.
EPR	Currently, **EPR for construction products is not widely applied worldwide** and is limited to construction waste types that are readily recyclable and with a positive price. This option would become practically applicable in the middle to long term.
Performance based contracts	This innovative procurement contract is a new approach even for countries with traditions in GPP and sustainable use of buildings, and **is currently not applied in Croatia** (up to the best of the knowledge of the authors). However, after researching the experience of countries that already apply it, this approach could be a viable option for extension of the responsibility into the use phase of the buildings and could be implemented even in middle to long term. Energy Performance Contracts are regularly being used in Croatia.

3. Recycling of CDW/Reduction of quantities of CDW – international good practices

3.1 Concept

The overall aim of the measures at the final stage of the life cycle of constructions is to recover high-quality (pure) material fractions for recycling or reuse.

Good practices to ensure the practical application of the concept are discussed below.

Table 20: Good practices to enhance the recycling of CDW/Reduction of waste generated quantities. Overview of potential mandatory and voluntary measures.

– Recovery targets
– Mandatory selective deconstruction and pre-demolition auditing and deconstruction reporting
– Landfill restrictions
– Enforcement measure
– End-of-waste - legislation and standards regarding recycled materials
– Measures to increase recycled content in construction products

3.2 Barriers and enabling conditions

The economic factors are very important and can either promote or hamper the reclamation of high grade recycled waste. The measures for selective demolition or source separation result in materials with a higher value, for which treatment costs are lower, but on the other hand, these processes are more expensive, labor-intensive and more time-consuming.

In some countries, other common factors affecting the reclamation of recycled materials from construction and demolition waste are legal requirements for mandatory separation, removal of hazardous materials, occupational hazards legislation and safety requirements.

3.3 Implementation and good practices

In the following sub-chapters the best practices are presented.

3.3.1 Recovery targets

Construction and Demolition waste (CDW) is considered a priority area in EU's Circular Economy Action Plan[55] and a recovery target of 70% has already been set and achieved in many Member States. Additionally, countries that have not met the target yet have received a warning and a suggested plan for how to reach it. Few Member States have introduced more ambitious targets, especially Member States which have already achieved high levels of CDW recovery and have exceeded the threshold of 70% of the Waste Framework Directive (WFD) target. The Member States that have set out targets that more ambitious than the 70% target of the WFD (including backfilling) are as follows[56]:

[55] A new Circular Economy Action Plan - For a cleaner and more competitive Europe; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2020) 98 final, 11.3.2020

[56] Resource Efficient Use of Mixed Wastes Improving management of construction and demolition waste, Final report, October 2017

- Germany: 85%
- Estonia: 75%
- The Netherlands: above 90%
- Flanders (Belgium): 85%

However, the recovery rates of the EU Member States cannot be seen as reliable circularity indicators, since extensive amounts of downcycling, such as backfilling, have been included in these figures. As a response to increased amounts of CDW being used for backfilling, the 2018 WFD included the specification that CDW should be used as backfilling only to the extent necessary to achieve the functional and structural requirements. It is hoped that this will lower the rate of low-quality recovery of CDW and encourage countries to adopt better recycling practices.

Setting ambitious goals alone is not a recipe for success unless the recovery targets are defined together with a clear prioritization of treatment options to ensure sustainable management of CDW. The case studies presented below aim at analyzing the preconditions and measures necessary to achieve an ambitious target for the recovery of construction waste. These include Estonia, where recovery targets (include backfilling) were set and which led to significant amounts of construction waste being returned to the economy.

Case Study 29: CDW recovery targets in Estonia

CDW recovery targets in Estonia[57]

Before the adoption of the National Waste Management Plan, Estonia had already achieved high levels of CDW recovery and had exceeded the threshold of 70% of the WFD target. According to the calculations of the Environmental Agency, in 2011 the level of waste recovery was high - 72% and already reaching the recovery target set in the Waste Act by 2020. A large part of construction and demolition waste was utilized in landfills and in road construction, and to a lesser extent CDW was recycled, for example, wood waste was used for the production of heating pellets and glass waste for the production of insulation material.

In 2013, the CDW recovery rate of Estonia was 91%. However, these high recovery rates were reached mostly through backfilling. Estonia is facing a problem with acquiring high quality recycling materials and the production of recycled CDW that can be effectively used back into construction activities. In order to address the existing situation and in an effort to overcome the apparent barriers in improving the quality of recycling and the market of CDW recycled products, the waste management sector in Estonia through its Waste Management Association initiated the creation of a Waste Recycling Cluster, eventually becoming the Waste Recycling Competence Centre). The Centre offers the following activities:

- Training programs;
- Knowledge sharing and international networking: partnerships were established with other cluster networks and recycling associations in the EU;
- Supporting the implementation of research and demonstration projects;
- Trademark of high quality recycled products: the center has also developed its own trademark for certifying the quality of recycled products.

Another important factor for success are the legal requirements for compliance, and their enforcement in the form of monitoring the compliance and penalizing individuals and organizations which do not comply with the requirements, as set out in the legislation. According to the Estonian

[57] NATIONAL WASTE PLAN 2014–2020 (RIIGI JÄÄTMEKAVA 2014–2020)

legislation each construction project must be accompanied by a **construction waste management plan**. The waste management plan is part of the construction project. The waste management plan must refer to the current national and local waste management rules. Construction and demolition companies must submit CDW management plan to local authorities for approval.

Other important policy measures and initiatives are

- Pollution charge (landfill tax) of 29.8 EUR/ton applied to all waste being disposed in landfills and lower gate fees for separately collected CDW than for mixed CDW;
- Services providing recovery and recycling options are well developed because landfilling is an expensive option in Estonia;
- Mineral resource extraction tax;
- Local waste management rules in municipalities.;
- Well-developed Waste Register database (JATS);
- Standards for recycled aggregates as a result of a project crushed concrete as constructions material (recycling of aggregates) developed by the Estonian Waste Management Association financed through the Enterprise Estonia.

3.3.2 Mandatory selective deconstruction and pre-demolition auditing and deconstruction reporting

The waste audits before demolition aim to understand the type and amount of elements and materials that will be deconstructed and/or demolished, and to issue recommendations on their further handling. An assessment of the viable recovery routes for materials can also be given.
The **deconstruction permits** are usually the legal instrument used to make the waste audits obligatory by the following documents to be presented before and after the deconstruction:

- A pre-deconstruction audit and a deconstruction plan;
- Deconstruction report after a building has been demolished to monitor whether the deconstruction has been carried out according to the guidelines and policies.

Public procurement is another instrument to require waste audits. Waste audits should be performed before the call for tenders and should be part of the specifications for tenders.

Usually the waste audit process includes the following steps:

- Desk study - to gather all relevant information from original building documentation and maintenance protocols;
- Field survey includes visual inspection of the building, comparisons of findings with collected documents, taking measurements, preliminary planning of deconstruction techniques and on-site waste handling, sampling and analysis (Chemical, mechanical for better identification of materials);
- Inventory - quantity estimation to provide not only the total amount of waste, but also the total amount of the different types of materials, waste classification and assessment of the feasibility of separation;
- Waste management recommendations for safe removal of hazardous waste materials, re-use or recycling possibilities for certain (high value) materials, legally binding conditions for storage, transport and treatment of certain materials;
- Reporting – preparation of final report summarizing the findings and recommendations using legally-binding templates (if such are required in the country).

The case studies explored here include Green Deal requirements for pre-deconstruction audits in Finland, control process for dismantling activities in Austria, and requirements for source separation in the Nordic countries. They present the different mechanisms for implementation of the deconstruction permits and waste audit processes.

Case Study 30: Green Deal requiring pre-deconstruction audits in Finland

Green Deal requiring pre-deconstruction audits in Finland[58]

One example of a voluntary commitment for pre-deconstruction audits is the Green Deal between the Finnish Association of Property Owners and Construction Clients (RAKLI) and the Ministry of the Environment. RAKLI is the most comprehensive and prominent association of professional property owners, real estate investors, corporate real estate managers and construction clients in Finland, and provides research information to help its clients develop and engage in responsible decision-making. Additionally, RAKLI's members are committed to being at the forefront of responsible construction. RAKLI and the Ministry of the Environment signed a Green Deal in 2020 that aims to boost the recycling of CDW by encouraging actors to undertake pre-deconstruction audits especially when entire buildings are being demolished or in case of extensive renovations.

The Ministry of the Environment and the association acting as parties to the agreement are committed to taking certain measures. The association's responsibilities include encouraging and instructing industry members to join the agreement, communicating the content of the agreement to its members and the real estate and construction industry in general, and sharing information with its members regarding more sustainable demolition, such as demolition marketplaces. In the agreement, the association also promises to promote co-operation between property owners and those implementing repair and demolition projects, to participate in the reporting of information related to demolition materials arising from repair and demolition projects, and to plan various training packages if necessary. The association reports on the results achieved to the Ministry, after which the Ministry makes an assessment of the effectiveness of the results.

In order to achieve the goals, the Ministry will find out what measures can be taken to promote sustainable dismantling. In addition, the Ministry will further develop the recycled material market and demolition auditing guidelines, if necessary, participate in the planning of training units, development of information related to demolition materials and carrying out necessary background studies to achieve the objectives.

Companies, municipalities and other communities can join the Sustainable Decommissioning Green Deal by making a separate commitment. The agreement sets out four mandatory measures, as well as other measures from which at least one of the commitments must be selected. Those mandatory measures are as follows:

- carrying out demolition surveys in all repair and demolition projects;
- reporting the demolition materials generated to the Ministry of the Environment;
- promoting the reuse of demolition materials; and
- promoting recycling in its operations and information on demolition surveys and marketplaces.

[58] Green Deal agreements in Finland (Green Deal –sopimukset Suomessa) Author: Noora Pakanen, ENVIRONMENTAL TECHNOLOGY Bachelor's thesis, November 2020

Case Study 31: Control process for dismantling activities in Austria

Control process for dismantling activities in Austria

The Austrian Recycled Construction Materials Ordinance sets out requirements to be fulfilled during the construction and demolition procedure. Prior to the demolition activities, an audit of on-site conditions and the presence of reusable components, hazardous materials and containments has to be carried out. According to the Ordinance, the audit has to be based on the Austrian Standard ÖNORM B3151 "Dismantling of buildings as a standard method for demolition".

The Austrian Recycled Construction Material Ordinance prescribes the control process for dismantling activities at different stages.

Actions before tendering

An external expert or a professional institute has to carry out a so-called **extensive examination of contaminants and undesired substances** in case that the gross building volume of a demolition object exceeds the value of 3'500 m³. Such examination has to follow standard ÖNORM EN ISO16000-32.

If the gross building volume of a demolition object is less than 3'500 m³ but the expected construction and demolition waste (excluding excavated material) amounts more than 750t, then a so-called **oriented examination of contaminants and undesired substances** has to be carried out by a demolition recovery specialist.

If the gross building volume of the demolition object is less than 3'500 m³ and the occurring construction and demolition waste is less than 750 t, the **possible use or disposal of CDW** has to be determined prior to demolition.

Actions after tendering and before dismantling

In case that the gross building volume exceeds 3,500 m³ or if it is less than this value but the waste amounts more than 750t a **demolition recovery concept**, according to the Austrian Standard ÖNORM B3151, has to be developed on behalf of the builder by a demolition recovery specialist or by an external expert. The identified contaminants and undesired substances in the building have to be removed during this step according to the developed recovery concept. The removal of such contaminants and substances has to be confirmed by the demolition recovery specialist or the external expert. This step called **confirmation of removal** must be documented in writing and has to be enclosed to the demolition documents.

In case the building volume is less than 3'500 m³ and the waste quantities are less than 750t hazardous waste has to be removed before demolishing of the building and collected separately. **Assurance**, that the leftover waste is free of contaminants and undesired substances in arrangement with the waste collecting company or the builder, has to be given. Furthermore, excavated soil, mineral waste, excavated asphalt, wood waste, metal waste, plastic waste and residential waste have to be separately collected. If the separation on-site is not possible, due to technical reasons or disproportionate costs, the separation has to be executed at an authorized treatment plant.

In Austria, backfilling is strictly controlled and permitted as a form of recovery only if the following criteria are fulfilled:

- Substitution of other material for a concrete purpose (structural engineering);
- Quality comparable to that of the substituted product by a quality assurance system;
- Limited use to an extent absolutely necessary for reaching the goal of backfilling.

List of CDW materials that need to be removed from the building before demolition - example of the Austrian standard ÖNORM B3151.

CDW materials representing or containing dangerous substances:

- Loose artificial mineral fiber (if hazardous);
- Components or parts containing mineral oil (such as an oil tank);
- Smoke detectors with radioactive components;
- Industrial smoke stacks (for ex., fireclay boxes, bricks or lining);
- Insulating material made up of components containing Chlorofluorocarbon ((H)CFC) (like sandwich elements);
- Slags (for ex., slags in inserted ceilings);
- Oil-contaminated or otherwise contaminated soils;
- Fire debris or otherwise contaminated debris;
- Isolations containing polychlorinated biphenyl (PCB);
- Electrical properties or equipment with pollutants (for ex., vapor discharge lamps containing mercury, fluorescent tubes, energy-efficient lamps, capacitors containing PCB, other electrical equipment containing PCB, cables containing insulation liquids);
- Cooling liquid and insulations from cooling devices or air-conditioning units containing Chlorofluorocarbon ((H)CFC);
- Materials containing polycyclic aromatic hydrocarbon (PAH) (like tar bitumen, tar board, cork block, slags);
- Components containing or impregnated with salt, oil, tar, phenol (e.g. impregnated wood, cardboard, railway sleepers, masts);
- Material containing asbestos (for ex., asbestos cement, sprayed asbestos, night storage heaters, asbestos flooring);
- Other hazardous materials.

Commencement of demolition

For buildings with volume exceeding 3’500 m³ or buildings with lower volume but for which the waste amounts more than 750t the mechanical dismantling may start after completion of the **confirmation of removal.** The dismantling is carried out according to the **recovery concept** and the legal requirements.

In case the building volume is less than 3’500 m³ and the waste quantities are less than 750t, the mechanical dismantling of the main components may take place after the waste transferee or the builder assures that the leftover waste is free of contaminants and undesired substances.

The documents concerning the demolition process have to be kept on file for a minimum of seven years. Additionally, the documents have to be submitted to the authorities when required.

Case Study 32: Requirements for source separation in Nordic countries

Requirements for source separation in Nordic countries[59]

Pre-demolition auditing and deconstruction reporting are usually closely linked to waste sorting requirements. However, in Denmark there are no obligations for demolition auditing and yet strict requirements for demolition activities and on-site sorting are well implemented.

In Denmark, Finland and Sweden there are legal requirements for sorting different waste fractions either at national or local level. This means that the waste has to be separated at the demolition site, although in all 3 countries there is a possibility of allowing mixed construction waste to be sorted at a special facility.

Legal requirements or recommendations for material-specific separation of CDW in Nordic countries.

	Denmark	Finland	Sweden
Brick/tiles	X	X	X
Concrete	X	X	X
Glass	X		X
Gypsum	X	X	X
Insulation	X		X
Mixed stony fraction		X	
Mixed concrete and asphalt		X	
Paper	X	X	X
Cardboard		X	
Plastics	X	X	X
Polyvinyl chloride (PVC)	X		X
Scrap metal	X	X	X
Stone materials, e.g. granite		X	
Tiles and ceramics	X		X
Wood	X	X	X

3.3.3 Landfill restrictions

Landfill restrictions are essential for developing a successful market for recycled CDW materials. These restrictions can, for example, take the form of punitive measures such as bans and tax-based disincentives like landfill taxes or higher gate fees at landfills. Such actions make the disposal of materials to landfill difficult and undesirable, thereby favoring recycling.

The **landfill tax** has been implemented differently in different MS, with some countries having regional variations or variations for different materials. There are also differences in the way the tax is collected and spent.

High Landfill taxes may encourage illegal landfilling but the link between increasing landfill costs on the illegal management of CDW is not clear. For example, the landfill tax has been in place for several years in the UK and the levels of illegal fly-tipping in England have increased. For Austria and the Netherlands, which have also had a landfill tax in place for several years, the level of illegal CDW management is not a major issue. The Netherlands and Denmark have had landfill tax in place for

[59] EIONET Report - ETC/WMGE 2020/1 "Construction and Demolition Waste: challenges and opportunities in a circular economy".

several years and the tax has increased over time. The tax is thought to have been effective at reducing the levels of landfilling. In contrast in Bulgaria, the implementation has not been effective due to contradictions between national law and local implementation[60].

In addition, some MS have **landfill bans** (or partial bans) in place. For example, the Netherlands has a landfill ban on recyclables and Belgium has bans in Wallonia and Flanders (ban on landfilling of mixed CDW). Denmark has a ban on landfilling of waste suitable for incineration. Czech Republic will ban landfilling of recyclable, reusable and untreated mixed municipal waste after 2023. A landfill ban is in place in Germany since 2005. In Malta there is a ban on landfilling of clean inert CDW and instead, such CDW is diverted to quarries for backfilling.

The details on the restrictions on landfilling are presented in the case studies below.

Case Study 33: The UK landfill tax legislation

The UK

There is landfill tax legislation in the UK, which has recently been devolved to Wales and Scotland. There are two rates – £84.60/ton standard rate and £2.65/ton lower rate. The lower rate is paid on wastes such as rocks or soil. By taxing the non-inert waste at a higher rate, companies are encouraged to separate the fractions. The Landfill Tax has had a positive effect on the amount of waste that has been landfilled since its introduction in 1996.

[60] Bio by Deloitte, 2017, Resource Efficient Use of Mixed Wastes Improving management of construction and demolition waste.

Case Study 34: The Spanish landfill tax legislation

Belgium

Flanders and Wallonia both have landfill taxes. The average landfill tax for inert landfills is of EUR 12.73/ton in Flanders. In Wallonia it is EUR 7.23/ton.

It is forbidden to landfill the mixed fraction of CDW directly and there are bans for materials that are collected together which due to their nature, quantity and homogeneity should be considered for re-use or recycling according to the best available techniques.

Flanders

Landfill taxes are charged dependent upon the waste types. It depends on whether they come from a certified crushing facility and on whether the waste stream is not flammable.

The average landfill operational cost for landfills for inert waste was EUR 53.35/ton in 2013. The average landfill tax for inert landfills was of EUR 12.73/ton.

A differentiated tax system for non-inert waste was applied. It depended whether they come from a certified crushing facility and whether the waste stream is not flammable

Landfill tax	Type of waste	EUR/ton
Residues from certified crushers	Flammable	2.45
	Not flammable	1.35
Delivered by others	Flammable	61.11
	Not flammable	32.59

Wallonia

Landfill Tax applies to non-hazardous and hazardous waste as summarized:

Price by tons excluding VAT	Soils with max 5% of stones	Land sorting with 5 to 30% of inert waste	Land sorting with more than 30% of inert waste
CAT (recycling)	5.40 € / 6.40 €	8.60 € / 9.60 €	10.90 € /11.90 €
	Soils	Ultimate inert waste	Other waste are not authorized in CET
CET (landfill)	7.23 €	85.96 € (including taxes)	/

Case Study 35: Landfill tax in Denmark

Denmark

In addition to a landfill tax of 475 DKK/ton (64 €/ton), since 1997 a "ban" on landfilling of waste suitable for incineration is in force.

Comparison of landfill taxes for CDW in EU Member States

EU Member state	Landfill tax for CDW
Austria	9.2 €/t
Belgium (Flanders)	12.73 €/t
Belgium (Wallonia)	7.23 €/t
Bulgaria	14.3 €/t
Czech Republic	19 €/t
Denmark	64 €/t
Estonia	29.8 €/t
Finland	55 €/t
France (general tax on polluting activities)	40 €/t
Greece	40 €/t
Hungary	28 €/t
Ireland	75 €/t
Italy	10 €/t
Latvia	13 €/t
Lithuania	7.14 €/t
Luxembourg	varies per municipality
Poland	2.7 €/t
Portugal	4.3 €/t
Romania	4.5 €/t
Slovakia	6.6 €/t
Slovenia	19.2 €/t
Spain (Catalonia)	3 €/t
Sweden	54 €/t
The Netherlands	13 €/t

3.3.4 Enforcement measures

The enforcement of legislation is very important to achieving the objectives of each regulatory instrument. Most MS have clearly defined responsibilities for CDW legislation enforcement. Enforcement regarding CDW practices is primarily the responsibility of the local and/or regional government, as is monitoring and ensuring that stakeholders are following policies and set guidelines. Appropriate sanctions are also essential for effective enforcement. Even if responsibilities are clearly defined for controlling compliance with the requirements, a lack of technical and human capacity is often pointed out as the main reason for the ineffectiveness of control measures. In summary the following mistakes should be avoid in order to establish high level of enforcement performance:

- Not relying on local authorities in charge of inspections related to environmental legislations;

- Not engaging the public in assisting the enforcement authorities;
- Lack of technical and human capacity;
- The penalties are not high enough to really discourage the illegal practices as a proper waste management is perceived as being more costly.

One of the most successful ways of effective control is to monitor the application of regulatory requirements for waste management when approving construction activities in the form of obligation for setting up a Waste Management Plan or obtaining an environmental permit prior to construction permitting. Another option is requiring the establishment of a bond when issuing planning or construction licenses to ensure compliance with the obligations imposed by the standard or regulation of the recovery and disposal activities of construction and demolition waste. These instruments provide for the possibility of both pre-approval of the activities before they are carried out, control during construction as well as subsequent control. The case studies below present these measures applied at the country level in the EU, including obligations to establish site waste management plans in the UK, Spain and Slovenia; and the establishment of an information system for tracking the path of CDW in the Netherlands.

Case Study 36: Site waste management plan in the UK

Site waste management plan in the UK

In England, prior to 2014, The Site Waste Management Plans Regulations placed obligations on the client (other than domestic clients) and the principal contractor for any construction project with an estimated cost of more than £300'000. A site waste management plan (SWMP) should initially be prepared by the client before construction begins, although they may commission a member of the consultant team to do this on their behalf. It should describe how materials will be managed efficiently and disposed of legally during the construction of the works, explaining how the re-use and recycling of materials will be maximized. This involves estimating how much of each type of waste is likely to be produced and the proportion of this that will be re-used or recycled on-site, or removed from the site for re-use, recycling, recovery or disposal.

It is the joint responsibility of the client and the principal contractor to ensure that a site waste management plan is in place before construction begins and to ensure that it is enforced.

The principal contractor should:

- Ensure that the requirements of the site waste management plan are included in sub-contracts;
- Arrange suitable site induction, information and training of personnel to ensure that the plan is implemented;
- Take all reasonable steps to prevent unauthorized disposal of the waste by others;
- Update the plan as the works progress to reflect the actual handling of waste;
- At the end of the project (within 3 months) reconcile the planned handling of waste against what actually happened and provide an explanation of any differences.

For large projects (with an estimated cost of more than £500'000), the principal contractor should record in detail how each consignment of waste was handled.

There is no formal notification or approval process for site waste management plans, however the local authority may require submission of site waste management plans as part of the planning process.

However, following a comprehensive government review of 21'000 regulations on different themes, Site Waste Management Plans are no longer compulsory for construction projects in England (from December 1, 2013). They may still be required for BREEAM assessments or by the local planning authority, and may be considered an environmentally responsible initiative by the main contractor or by the client.

The Site Waste Management Plan Regulations were repealed as the Government felt that the impact on reducing construction waste, diverting it from landfill and reducing fly-tipping was minimal; along with a view that the industry was also better equipped to self-regulate following 4 years of SWMPs implementation. There was also a belief that construction businesses will prevent and recover CDW due to the related business benefits. It is interesting that many large construction companies have continued to implement SWMPs (or something similar) on a voluntary basis.

Case Study 37: Development of a waste management model for each construction project in Spain

Development of a waste management model for each construction project in Spain

Nationally, Spain has the Royal Decree (105/2008) which requires the inclusion and development of a waste management model for each construction project which should include the drawing up of a **waste management report**, developed during the design phase of the project and a **waste management plan**, developed during the planning of the construction works. A mandatory **deposit** is required by law prior to demolishing buildings, which is reimbursed after proving that the demolished buildings' CDW was lawfully managed.

These national provisions have been transposed into regional law after adaptation to regional considerations. Both Catalonia and Basque regions have legislation for waste management plans which extend the Royal Decree.

In Catalonia, the plan must identify all those actions which should be considered to minimize the work to prevent the generation of construction and demolition waste during the construction phase or reduce production. In the Basque Country, there is an obligation to include a study of construction and demolition waste management during the planning of the construction works.

Both regions have also transposed the Royal Decree's specification on deposits. In Catalonia, the waste producer must submit a deposit of EUR 11/ton (with a minimum of EUR 150) for CDW upon the issuing of their license. The waste producer is reimbursed after proving lawful management of CDW.

In Basque, there is a bond for the producer which is linked to obtaining a building permit, in order to ensure proper management of CDW. The calculation of the amount of the deposit is based on the cost of the construction and demolition waste management (that is elaborated in detail in a study required by the legislation) and should represent 120% of the said cost. The calculation of the amount of the deposit may represent 60% of waste management cost if materials that generate less waste are used during the execution of the works or in cases of sustainable building. In order to verify these extremes, the characteristics of the project have to be analyzed to verify that the data from the waste management study are adequate. The guarantee, which may be constituted in cash,

in public debt securities, by means of a guarantee, by means of a surety insurance contract or any other legally valid form, have to be made available to the municipal body in charge of granting the urban license. The return of the deposit should only take place upon request of the obliged person and after documentary proof of the correct management of the waste generated during the works . In the event that adequate waste management is not proven, and without prejudice to the application of the sanctioning regime provided for in the Waste regulations, the depository entity of the bond, may alternatively execute the necessary actions for the correct management of the same and, if this is not possible, allocate the amount of the deposit to carry out environmental improvement actions in the municipality. Those who are registered in the Register of organizations adhering to the Community Environmental Management and Audit System, EMAS, are exempt from providing the guarantee.

Case Study 38: Construction waste plan in Slovenia

Construction waste plan in Slovenia

If the construction of a new facility, reconstruction of a facility, replacement construction or removal of a facility requires the acquisition of a building permit in accordance with the regulations governing the construction of facilities, the investor must attach a construction waste management plan to the project for obtaining a building permit. The construction waste plan must include information on:

- Elimination of hazardous construction waste;
- Separate collection and processing of construction waste on-site;
- Anticipated volume of excavated material;
- Quantities and types of construction waste;
- Planned methods of processing construction waste.

The construction waste management plan must take into account the guidelines in relation to the anticipated quantities of construction waste and the methods of their treatment.

Case Study 39: Information system for tracking the path of CDW in the Netherlands

Information system for tracking the path of CDW in the Netherlands

The Netherlands and some other MS have established systems (i.e. consignment registers) to ensure the traceability of CDW: this is the ideal path to provide reliable statistics and to avoid double counting. The principle is that companies that have a waste-permit are statutorily required to register each of their waste as far as they are transported. When a waste transport has actually taken place, the shipped weight is linked to the “waste stream code” and stored in the register. Hence, this easily allows quantifying each waste stream leaving or entering any company.

3.3.5 End-of-waste – legislation and standards regarding recycled materials

Currently, the construction industry uses almost no secondary materials. The secondary material is material that has ceased to be waste through appropriate preparation and processing (taking into account EN15804) and can therefore be used as a substitute for primary materials. In the Netherlands, a leading country in the circular economy, secondary materials account for only 3-4% of all construction materials used in buildings.

When materials are separated during the demolition of buildings, they are classified as waste and their use for construction is regulated by legislation different from that covering construction materials, which makes reuse in construction difficult. The environmental and health risk assessment of the use of CDW in construction falls within the framework of national and EU waste legislation. The technical aspects of the use of CDW in construction, on the other hand, are regulated by the Construction Products Regulation, CPR (EU, Regulation N° 305/2011). To promote recycling, CDW may cease to be classified as waste and instead be given the status of "end-of-waste" so that the waste becomes a product. In this way, its use will no longer be regulated by waste legislation, but will be fully covered by product legislation. National end-of-waste criteria for CDW have the greatest impact on the use of mineral waste. The concept of end-of-waste reduces the administrative work required to obtain CDW recycling permits and was introduced to make the use of CDW more attractive by increasing confidence in its quality. However, only a few countries (Austria, Belgium, France, the Netherlands the United Kingdom, etc.) have developed end-of-waste criteria for CDW. EoW legislation supports the recycling markets in the EU by creating a level playing field for all actors (industry, administration), thus increasing legal certainty. The case studies below present in detail the requirements for recycled construction material in Austria and Denmark.

Case Study 40: Requirements for production and use of recycled construction material in Austria

Requirements for production and use of recycled construction material in Austria[61]

Production and use of recycled construction materials in Austria is regulated by the Recycled Construction Materials Ordinance which requires applying quality-assured deconstruction and demolition process. The types of waste that are authorized to be used as raw materials for the production of recycled construction materials are listed in Annex 1 of the Ordinance. Contamination with hazardous substances (for example asbestos or superficial mineral fiber) shall be avoided as far as possible, in order to obtain a high-quality material. Waste fractions, where contamination is known or suspected, are not allowed to be used for the production of recycled construction materials.

The following steps are necessary for the quality-assurance process,:

- **Inspection of input material (waste to be recycled).** The producer of the recycled construction material is obligated to carry out a visual control upon acquisition of the waste. In particular, the producer has to verify, if the waste is suitable (sorting accuracy, free of contamination) for the manufacturing of the recycled construction material. The documentation of the examination of contaminants and undesired substances, the recovery concept and the confirmation of release are required for the control.

[61] Recycling Building Materials Ordinance (Austria) https://www.ris.bka.gv.at/GeltendeFassung.wxe?Abfrage=Bundesnormen&Gesetzesnummer=20009212

Fulfillment of quality requirements. The producer of recycling construction materials is obligated to observe the quality requirements, which are fixed in the Recycled Construction Materials Ordinance. Furthermore, the constructional requirements, according to the state of the art construction engineering practices, have to be fulfilled and observed. Admixture with natural rock material is only allowed, when the mixing ban is observed.

- **Quality assurance**. According to the Recycled Construction Materials Ordinance, environmental compatibility has to be given all time during the procedure of recycling constructions materials. This quality assurance is taking place in one out of three procedures:
  - Standard process;
  - Single batches;
  - Quality assurance for particular types of waste (special aggregates from traffic areas, steelworks slags, technical bulk material).
- **Designation of the quality-assured recycled construction materials.** The produced materials have to be explicitly indicated as recycled materials. The designation has to follow Appendix 2 and to refer to the quality classes given therein. If the recycled materials are transferred to third parties, it is obligatory to indicate information concerning designation, the application range and banned uses. This information has to be indicated on the packaging itself or, in case of a material without packaging, on a supplementary sheet. Additionally, the designation has to be given on the invoice and on the delivery note.
- **End-of-waste of the quality-assured recycling construction materials.** The end-of-waste state, due to the Recycled Construction Materials Ordinance is only intended for recycled construction materials of the quality class U-A. The materials with those characteristics lose the waste status as soon as the producer hands them over to third parties. Recycled construction materials from another quality class are only allowed to lose their waste status, according to the Austrian Waste Management Act 2002, when they are used or installed as permitted.
- **Recording and reporting duty.** Producers of recycling construction materials are legally obligated to document such procedures (Austrian Waste Management Act 2002 and Waste Balance Ordinance). The record has to include data concerning the type, quantity, origin and fate of the waste. In this context, the deliveries of recycled building materials must be documented, so that the evaluation and control of the quantities of recycled building materials and recycled construction products manufactured and delivered are made possible.

There are two cases when recycled construction materials from another quality class (different from class U-A) lose their waste status:

- If for the respective product (including designation of the product) there are the EU end-of-waste criteria such as scrap metals;
- If for the respective product (including designation of the product) there are national end-of-waste criteria such as recycled wood.

<u>The end-of-waste for iron, steel and aluminum scrap</u>

EU *Regulation N° 333/2011 establishing criteria determining when certain types of scrap metal cease to be waste*, regulates the end-of-waste for iron, steel and aluminum scrap across Europe. The scrap is then no longer regarded as waste if it is transferred from the producer to another owner and:

- The iron, steel and aluminum scrap obtained during the recovery process as well as the waste sent for recovery meet certain criteria set out in the annexes of the ordinance,
- The recovery process itself is carried out in accordance with criteria, defined in more detail in the annex to the ordinance, and

- The producer or the importer has drawn up a declaration of conformity and is using a quality management system.

The producer or the importer must ensure that the requirements of Regulation N° 333/2011 are complied with and must issue a **declaration of conformity** with certain information for each scrap shipment. This declaration of conformity must be carried by the producer or the importer during transport to the next owner and handed over to the next owner of the scrap shipment. Furthermore, the producer or the importer must **keep records, evidence** and declarations of conformity for at least seven years and present them to the competent authority on request. Storage in electronic form is permitted.

The producer must also apply a **quality management system** that demonstrates compliance with the criteria for the end-of-waste. The quality management system shall include a set of documented procedures concerning: waste acceptance control; monitoring of the treatment processes and techniques; monitoring of quality of scrap metal resulting from recovery operation (including sampling and analysis); effectiveness of radiation monitoring; feedback from customers; record-keeping of the results of monitoring; review and improvement of the quality management system; training of staff.

<u>The end-of-waste for recycled wood products</u>

For recycled wood there is national end-of-waste criteria specified in an Ordinance of the Federal Minister for Agriculture, Forestry, Environment and Water Management on the recycling of waste wood in the wood-based materials industry (Recyclingholzverordnung).

The end-of-waste for recycled wood is linked to the intended use. Recycled wood products may only be used in plants for the production of wood-based materials. When producing recycled wood for which the waste owner wants to declare the end-of-waste, the ÖNORM EN15358 "Solid secondary fuels – Quality management systems - Special requirements for use in the production of solid secondary fuels" including a quality management system with external quality assurance must be applied. If these requirements are met, the waste regime ends with the declaration.

The waste owner has to create a certificate of assessment and to send it to the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology. A prerequisite for the creation of the assessment certificate is compliance with a quality assurance system that meets the legal requirements. Evidence of assessment must comply with the requirements of Appendix 3 of the Ordinance. Waste wood that is to be recycled in the wood-based materials industry must comply with the requirements provided in Appendix 1. This procedure only applies to the types of waste which may be used for recycling listed in Appendix 1.

If recycled wood products are passed on, a valid assessment certificate including identification must be transmitted and the waste owner must be informed that they meet the end-of-waste criteria for use in plants for the production of wood-based materials.

Waste owners who declare the end-of-waste must report annually to the Federal Ministry for Climate Protection, Environment, Energy, Mobility, Innovation and Technology about the type and quantity of the recycled wood products, the changes in the intended recipients of the past year or any changes that are likely to occur, as well as the results of an external control. The Federal Minister of Agriculture, Forestry, Environment and Water Management must be allowed to inspect the records upon request.

Use of recycled CDW without a specific environmental permit in Denmark[62]

There is a possibility for recycling CDW without a specific permit under the Environmental Protection Act, provided the CDW is sorted, unpolluted and processed.

CDW can be used, without a specific permit under the Environmental Protection Act, provided that the conditions stipulated in Statutory Order N° 1662/2010 on recycling of residual products and soil in building and construction work and on recycling of sorted, unpolluted CDW are met.

In the Statutory Order, uncontaminated CDW is defined as CDW with a high degree of certainty, that the waste does not contain polluting materials or substances to such an extent or of such a nature and concentration that the use of the waste may have an adverse impact on the environment or human health.

3.3.6 Measures to increase recycled content in construction products

Despite all the measures to increase the re-use and recycling of CDW taken in recent years, the building sector hardly uses any secondary materials – in the Netherlands, for instance, secondary materials only represent 3–4 per cent of all materials used in buildings. Therefore, despite high recycling rates, the recycling of CDWW is largely downcycling.

Requirements for recycled content in the construction materials used in new constructions could boost the uptake of secondary materials in the construction sector. Such requirements are already applied in different forms, either as voluntary or legally-binding requirements in GPP (where usually minimum recycled content is set), building certifications schemes, standards and technical specifications for construction materials used in specific designation (e.g. for the use in highways), that usually contain maximum allowed recycled content.

The usual reluctance of builders to use products that do not have certification of tested performance should not be an issue for construction products with recycled content since these can be tested and certified against EN standards. However, compared to manufactured products, the sample for testing taken from salvaged materials should be larger so that it is representative.

Different EU countries introduced measures to increase the recycling content in products, including the Netherlands, which does so in a voluntary fashion through the Green Deal; and Italy, which introduced a mandatory minimum of **thirty percent** of the annual uptake earmarked for purchase through public procurement to be of products and goods made with recycled materials. Finally, Austria introduced standardized guideline for recycled materials**.** The case studies are presented in detail below.

Case Study 42: Green Deal prescribing recycled content in concrete in the Netherlands

Green Deal prescribing recycled content in concrete in the Netherlands

Concrete Agreement was signed by about fifty leading producers, recycling and construction companies. The national Government, Rijkswaterstaat, the Rijksvastgoedbedrijf, ProRail and the province of South Holland have committed themselves to the *requirement to prescribe at least 5%*

[62] Chapter 2 of the Statutory Order N° 1662/2010 https://www.retsinformation.dk/eli/lta/2010/1662

recycled content for all new concrete. This minimum requirement will be further increased by the clients in the coming years. The companies have agreed with the Government that before 2030 all concrete that is released during renovation and demolition will be used again in high-quality new concrete.

Coarse aggregate obtained from demolition works can be used to (partially) replace natural aggregates in high-grade concrete applications. European standards, such as EN206: Concrete – Specification, performance, production and conformity; and EN12620: Aggregate for concrete allow the use of recycled materials in concrete. Their use in different applications is regulated by national standards. Up to 20 per cent substitution of virgin aggregates with concrete waste is not considered to lower the new concrete's properties or influence its workability, for example, requiring more water in mixing. The use of more than 50 per cent of concrete waste triggers the need for further testing to prove acceptable properties and the concrete is usually only suitable for certain applications. The Dutch standards and guidelines, for example, allow up to 50 per cent by volume of the stony fraction of concrete aggregates for certain applications to be recycled, while in Belgium up to 20 per cent by volume of the coarse aggregate fraction is acceptable under certain conditions without additional testing or proofing. Standards also set limits for the content of bricks and tiles and impurities in recycled aggregate in concrete. Replacement rates that go further than the current standards are technically feasible if the right measures are taken – selective demolition, adapted milling processes, extra processing of the aggregates, and/or adapted water management in the mix formulations.

Case Study 43: Mandatory use of recycled materials by the public authorities in Italy

Mandatory use of recycled materials by the public authorities in Italy

In Italy, the Ministerial Decree of the Ministry of Environment from n.203 (DM 203/03) introduced mandatory use of recycled materials by public bodies and companies with prevalently public capital. It requires that at least **thirty percent** of the annual uptake earmarked for purchase through public procurement should be of products and goods made with recycled materials. The catalogue of products and goods obtained from recycled material is prepared and updated at least once a year. In addition to being in the catalogue the products must be readily available and their price should not exceed that of the corresponding products and goods containing virgin raw materials by a percentage defined by an inter-ministerial working group.

The person who intends to request registration of a product or asset in the catalogue has to submit an application specifying the waste codes of the waste from which the recycled material is made (according to European waste catalogue), the percentage of waste in the recycled material, documented by means of a declaration by a professionally qualified certifier as well as a technical report indicating any differences in performance between the goods or product made from recycled material and similar goods or products made with virgin materials. Products included in the catalogue indicate this on the label. The products in the catalogue are subject to periodic checks by the professional associations in the respective sector to verify the compliance of the data declared in the application.

All public bodies and companies with prevalently public capital must be identified by the Regions, including the National Waste Observatory.

The technical parameters and their limit values that shall be fulfilled by the different product

categories are defined through Circulars issued by the Ministry of Environment.

The Circular 15/7/05 n. 5205 containing "*Indications for operations in the construction, road and environmental sector, pursuant to Ministerial Decree 8 May 2003 n. 203*", was issued for the application, in the construction, road and environmental sectors. The performance characteristics of the recycled aggregates differ depending on the intended use and for each intended use there are different limit values defined in attachment C of Circular 15/7/05 n. 5205. The following intended uses are listed in the Circular 15/7/05 n. 5205:

- A.1 recycled aggregate for the construction of the embankment of earthworks of civil engineering, having the characteristics shown in attachment C1;
- A.2 recycled aggregate for the construction of road, railway, airport and civil and industrial aprons, having the characteristics indicated in annex C2;
- A.3 recycled aggregate for the construction of foundation layers of transport infrastructures and civil and industrial yards, having the characteristics indicated in attachment C3;
- A.4 recycled aggregate for the realization of environmental recovery, and filling, having the characteristics indicated in annex C4;
- A5 recycled aggregate for the creation of accessory layers (having an anti-capillary, antifreeze, draining function, etc.), having the characteristics indicated in Annex C5;
- A.6 recycled aggregate compliant with the harmonized standard UNI EN12620:2004 for the preparation of concrete with resistance class Rck ≤15 Mpa, according to the indications of the UNI 8520-2 standard.

The parameters that cause major problems and influence the quality of the final products are:

- 1. Quality of the fines (it is evaluated by the equivalent in sand): presence of harmful fines, such as silts and clays, responsible for the plastic behavior of the mixture;
- 2. Shape index: presence of elongated granules;
- 3. Fragmentation resistance (Los Angeles test): presence of soft elements, such as e.g. bricks, an important parameter for determining the variability of the granulometry of the recycled material.
- Eco-compatibility

The Circular sets the weight limit imposed by technology. The technology used for the production of recycled aggregate does not impose particular limits. The **maximum limit** of inert waste is therefore equal to 100%. The **minimum limit** of inert waste in recycled aggregates is 60%. The technology used for the production of the conglomerate recycled bituminous imposes a minimum limit of 20% of waste inert from scarification. The actual amount of waste must be declared in the scope of the application

Another example of a product group contained in the catalogue is wood and furniture which is regulated by Circular of the Ministry of Environment dated December 3, 2004, published in the Official Gazette N° 294 dated December 16, 2004. It covers (in a non-exhaustive manner) chipboard panels; MDF; poles.

The technology used for the production of recycled material in this sector generally imposes maximum limits on the weight of waste, diversified according to the types of product; these limits can go up to 100%. These limits are identified in the Circular as follows: chipboard panels: a limit equal to 90% of the weight of the recycled material is assumed; MDF: a limit of 90% of the weight of the recycled material is assumed; poles: a limit equal to 100% of the weight of the recycled material is assumed.

It also defines the minimum percentage of waste contained in the recycled material. The content of

waste in the products relating to the wood and furniture sector cannot be less than 60% of the total weight of the product itself.

Case Study 44: Standards and technical specifications for recycled CDW materials in Austria

Standards and technical specifications for recycled CDW materials in Austria

Standards and technical specifications are important drivers for the incorporation of reclaimed and recycled content in construction products. In Austria, the technical requirements for construction and environment are formulated in one system of rules and a **standardized guideline for recycled materials** which help creating a legally binding framework covering broad range of aspects, such as structural engineering (stability, strength, rigidity of built structures), environmental compatibility, structural requirements for construction materials, etc.

To be considered as quality-assured, construction materials with recycled content intended to be used in new construction must meet certain requirements specified in regulations and standards, and be subject to testing to prove fulfillment of the quality provisions. The product has to simultaneously meet the following requirements:

- To improve **structural engineering,** according to the Recycled Construction Materials Ordinance, recycled building materials in quality classes UA, UB or UE may be added in subordinate (minor) quantities (i.e. <50%);
- To be environmental compliant by fulfilling the requirements of the Federal Waste Management Plan 2017;
- To meet the structural requirements for:
  - natural aggregates for production of unbound and hydraulically bound mixtures for civil engineering and road construction (ÖNORM B3132);
  - natural aggregates for concrete (ÖNORM B3132);
  - natural aggregates for asphalt (ÖN B3130).
- In addition to fulfilling the abovementioned national standards, the product has to meet the EU harmonized standards as specified in CPR. The national ÖNORM standards serve to implement harmonized European standards by addressing special geographical, topographical and climatic conditions that prevail in Austria - EN13242 (ÖN B3132), EN13043 (ÖN B3130) EN12620 (ÖN B3131);
- To be dismantling-compliant: fulfills ÖNORM B3151 "Demolition";
- To be compliant with environmental law: fulfills the recycling building materials ordinance;
- To be construction technology-compliant: fulfills ÖNORM B3140 "Recycled aggregates";
- To be construction product compliant according to EU Construction Products Regulation: fulfills CE marking requirements.

3.4 Comparison of the case studies with the current situation in Croatia and assessment of possible implementation

The measures for recycling of CDW and reduction of waste generation, as well as and their applicability in the Croatia context, are explored in the tables below.

Table 21: Recycling of CDW and reduction of waste generation in Croatia-measures.

Recovery targets	The targets for the recycling and material recovery of construction and demolition waste stem from European legislation, and Croatia is making very good progress. However, more action is needed to prioritize recycling over backfilling. All the measures listed below will contribute to this goal.
Mandatory selective deconstruction and pre-demolition auditing and deconstruction reporting	Croatian legislation (Ordinance 69/2016 on construction waste and waste containing asbestos) regulates separation of materials for reuse, hazardous materials and prohibits mixing of separated waste but it does not list materials, for which selective deconstruction is mandatory. There is also a reference that these requirements should be ensured through the legislation governing construction, construction project documents, maintenance, reconstruction or removal of the building (Article 9, first sentence). However, approval of pre-demolition plans is not required. This measure would have significant impact on CDW quality and quantities sent for recycling, thus its gradual implementation should start in the short term first with less strict obligations for separation of major components before demolishing the building. In mid to long term these requirements could be made stricter step-by-step.
Landfill restrictions	Landfill tax is currently under consideration and this is appropriate measure to encourage separation and recycling of CDW.
Enforcement measure	Approval of site waste management plans and subsequently surveillance of their implementation is a measure applied in several EU countries including in neighboring Slovenia. The measure will require involvement of authorities that issue construction permits in the process of control but this will not create significant financial burden for the administration of the measure. Therefore, it could be implemented in short to midterm.
End-of-waste - legislation and standards regarding recycled materials	The Register for the abolition of waste status of Croatia contains several cases of CDW that have become products decided on a case-by-case basis, since end-of-waste criteria have not been set at either Union or national level (in accordance with Article 6, paragraph 4 of the Waste Framework Directive). The arguments for issuing end-of-waste status to these products could be used for compiling national end-of-waste criteria for certain construction products. Adoption of national criteria will require research for setting limit values and laboratory testing but it will have great impact on the use of mineral waste and will create legal certainty (in contrast to the case-by-case assessment currently applied), therefore the development should start in short term.
Measures to increase recycled content in construction products	Increase of recycled content in products and construction works could be achieved by different instruments such as legally-binding requirements in GPP (where usually minimum recycled content is set), building certifications schemes, standards and technical specifications for construction materials used in specific areas. Currently such requirements are not in force in Croatia. Best approach would be for gradual introduction starting first with voluntary agreements between

	the Government and the construction industry and later progressing to a mandatory use in publicly funded projects accompanied with development of standards specifying the maximum allowed content of recycled waste without compromising the properties of construction materials and construction works.

4. Best practice in the field of CDW from a country with frequent natural disasters

This chapter presents practices and policies on the management of CDW deriving from the collapse of buildings and infrastructure caused by earthquakes, from the perspective of a more circular economy, particularly downstream (recycling) and upstream measures (prevention of disaster waste).

4.1 Definition of disaster waste

Depending on their nature and severity, natural disasters can create unexpected, large volumes of debris and waste. Disaster events such as e.g., earthquakes can cause the destruction of buildings and infrastructure, suddenly generating enormous amounts of waste debris with a very heterogeneous composition.

Typically, with earthquakes, structures collapse 'in-situ', i.e. floor slabs collapse on top of each other, trapping waste within damaged buildings and structures[63]. This can lead to challenges in sorting out hazardous waste (e.g., asbestos) from non-hazardous (e.g., general building rubble). Collapsed buildings may overlap across streets, making access difficult for the search, rescue and relief operations. The waste, which literature refers to as **disaster waste**, can overwhelm existing solid waste management facilities and impact other emergency response and recovery activities[64]. If poorly managed, waste can have significant environmental and public health impacts and affect the overall recovery process.

The largest component in urban disaster waste, especially for earthquakes, would meet the peacetime classification of construction and demolition (CDW) waste. But disaster waste resulting from the collapse of buildings and infrastructure, can also become very heterogeneous and contain other waste than what can usually be found in CDW. The UN Guidelines on disaster waste management defines disaster waste and its **composition**[65], which can include:

- Concrete, steel, wood, clay and tar elements from damaged buildings and infrastructure;
- Household furnishings; parts from the power and telephone grids such as electrical poles, wire, electronic equipment, transformers;
- Parts from water and sewage distribution systems;
- Natural debris such as clay, mud, trees, branches, bushes, palm tree leaves;
- Chemicals, dyes and other raw materials from industries and workshops;
- Waste from relief operations.

[63] UNEP/OCHA (2013). Disaster Waste Management Guidelines. Second Edition. Available at: DisaterWM_guidelines.pdf (unep.org)

[64] Charlotte Brown, Mark Milke, Erica Seville (2011). Disaster waste management: A review article. Waste Management, Volume 31, Issue 6, 2011, Pages 1085-1098, ISSN 0956-053X. Available at: (https://www.sciencedirect.com/science/article/pii/S0956053X11000596).

[65] UNEP/OCHA (2013). Disaster Waste Management Guidelines. Second Edition. Available at: DisaterWM_guidelines.pdf (unep.org)

Some components of this waste stream pose a potential health risk in peacetime which could be exacerbated post-disaster where volumes are significantly increased. These include asbestos, arsenic-treated woods[66], gypsum leaching[67][68] and organic pollutants[69][70].

4.2 Recycling disaster waste in a circular economy

The recycling of disaster waste is of interest to the circular economy, and especially due to the big fractions that are generated, and can be recovered. However, the problem of waste management and recycling is more complex than in peacetime.

The heterogeneous nature of waste and its potential contamination with hazardous components can increase **the complexity of the problem related to managing disaster waste** from the collapse of buildings and infrastructures. As with waste composition and nature, the quantity of waste will vary based on the type of disaster and the built environment impacted. The environmental and safety/health impact of disaster waste can be relevant[71], so that management operations become utterly important. Uncollected building rubble from damaged buildings can impede access and restrain the rehabilitation & reconstruction activities, so such quick operations become priority. Dumping of waste in inappropriate areas and/or proliferation of scattered dump sites, even if temporarily, can cause potential human health and injury risks from dump sites too close to settlements, especially from hazardous materials. The excessive amounts of waste to be managed, and eventually the emergency status where normal peacetime operations are impeded can also cause a collapse of municipal solid waste services, lack of collection service and uncontrolled dumping of waste. Finally, asbestos sheet exposure in collapsed structures or in the re-use of asbestos for reconstruction can pose immediate health risks associated with inhalation.

Managing and recycling disaster waste can be therefore more challenging that in peacetime.

However, many components of disaster waste can be recycled. Materials can be used in a number of post-disaster applications including soil for landfill cover, aggregate for concrete, and plant material for compost (fertilization and slope stabilization)[72]. **The benefit of recycling disaster debris** is shown in many ways and is evident in the analysis of many past disaster cleanups[73]. The operations associated with disaster waste management – demolition, private property clearance, curbside collection, transportation, temporary staging areas, recycling, disposal – can be implemented in a variety of ways

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[66] Dubey, B., Solo-Gabriele, H.M., Townsend, T.G., 2007. Quantities of arsenic-treated wood in demolition debris generated by Hurricane Katrina. Environ. Sci. Technol. 41, 1533–1536.

[67] USEPA, 2008. Planning for natural disaster debris. In: Office of Solid Waste and Emergency Response and Office of Solid Waste (Eds.).

[68] Jang, Y.-C., Townsend, T., 2001a. Sulfate leaching from recovered construction and demolition debris fines. Adv. Environ. Res. 5, 203–217.

[69] Jang, Y.-C., Townsend, T.G., 2001b. Occurrence of organic pollutants in recovered soil fines from construction and demolition waste. Waste Manag. 21, 703–715.

[70] Charlotte Brown, Mark Milke, Erica Seville (2011). Disaster waste management: A review article. Waste Management, Volume 31, Issue 6, 2011, Pages 1085-1098, ISSN 0956-053X. Available at: (https://www.sciencedirect.com/science/article/pii/S0956053X11000596).

[71] UNEP/OCHA (2013). Disaster Waste Management Guidelines. Second Edition. Available at: DisaterWM_guidelines.pdf (unep.org)

[72] Channell, M., Graves, M.R., Medina, V.F., Morrow, A.B., Brandon, D., Nestler, C.C., 2009. Enhanced tools and techniques to support debris management in disaster response missions. In: US Army Corps of Engineers (Ed.), Final Report ed. Environmental Laboratory US Army Engineer Research and Development Center, Vicksburg, MS.

[73] Charlotte Brown, Mark Milke, Erica Seville (2011). Disaster waste management: A review article. Waste Management, Volume 31, Issue 6, 2011, Pages 1085-1098, ISSN 0956-053X. Available at: (https://www.sciencedirect.com/science/article/pii/S0956053X11000596).

with varying degrees of public and contractor participation. The organization of the physical works has implications on the speed of recovery, resource availability and management of public health hazards, as well as on **the possibility to reuse and recycle the material** resulting from the different operations.

To summarize, recycling of CDW after disasters includes different benefits, but can also be challenging and barriers can be identified, as shown in the table below[74][75][76].

Table 22: Benefits and barriers of recycling CDW disaster waste.

Benefits	Barriers
- Reduction of landfill space used - **Reduction of the quantity of raw material used in re-build** - **Revenue from recycled debris** - Reduction in transportation for raw materials and debris - **Availability of material** for the recycling - Job creation (for developing countries in particular).	- Time to collect and process the materials - Unavailability of specialized processing equipment - Inability to physically separate the materials - Lack of desire to offset raw material use in rebuild - **Costs** relative to other disposal methods - Unavailability of **markets** to absorb large quantities of material - **Effect of surplus materials on existing recycling markets** and the need for establishment of post-disaster markets - Logistics involved; space requirements and associated land-use issues - **Existing regulation** - Economics of post-disaster recycling

In order to assess the recyclability of disaster waste, it can be useful to answer a number of questions when dealing with the recycling of CDW disaster waste[77]:

- What are the main factors that affect the feasibility of recycling post-disaster?
- When is on-site or off-site separation more effective?
- What is the best approach to improve recycling effectiveness of disaster waste?

[74] Baycan, F., Petersen, M., 2002. Disaster Waste Management – C&D Waste. Annual Conference of the International Solid Waste Association.

[75] Lauritzen, E. K., 1998. Emergency construction waste management. Saf. Sci. 30, 8.

[76] Solis, G. Y., Hightower, H. C., Sussex, J., Kawaguchi, J., 1995. Disaster Debris Management. Final Report ed., British Columbia: The Disaster Preparedness Resources Centre, The University of British Columbia for Emergency Preparedness Canada.

[77] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021.

4.2.1 Main factors affecting the feasibility of recycling disaster waste

Several factors can affect a community's ability to recycle disaster waste[78]. These include:

- **the volume of waste,** and especially the increased volumes that can be generated as a result of a disaster such as an earthquake;
- **the degree of mixing of waste,** which can become heterogeneous;
- **the human and environmental health hazard** generally increases with the management of disaster waste, compared to the conditions in peacetimes;
- the **areal extent of waste**, which can be very extended depending on the entity of the earthquake;
- the community priorities, including the need to recover the disaster area for community needs;
- the **availability of funding mechanisms** to fund the management, recovery and recycling operations;
- the **existing regulations** are usually adopted in peacetime, but typically also regulate the management and recycling of waste in non-peacetimes.

These factors can positively or negatively affect the economic feasibility of recycling, since they can play a relevant role in the decisions related to the management of debris waste – which might be very different compared to the management of waste in peacetimes. The relevant factors and how these can positively or negatively affect recycling are summarized in the table below.

[78] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021.

Table 23: Factors affecting recycling of disaster waste.

	Negative factors affecting recycling possibilities	Positive factors affecting recycling possibilities
Waste volume	- **Capital costs** from the establishment of more recycling facilities and temporary staging areas - Reduced value of the material due to increased availability of recycling materia**l** (demand surge) (Muir-Wood, 2012; ICNZ, 2013) - **Competitive landfill market** with large capacity (disposal costs of large quantities can be more favorable than recycling) - **Additional labor resources** will be needed. Labor resources are constrained in a post-disaster environment so recycling could create undesirable delays in the recovery if adequate resources cannot be found	- Costs may decrease if **economies of scale** improve (more waste there is, then the more likely the cost of establishing additional processing facilities will be justified) - High volumes of waste, coupled with **limited available land area** for disposal and a peacetime dependence on incinerators (with their limited capacity) can make recycling essential for the recovery effort - If there is **limited landfill or incineration capacity**, disposal costs could increase making recycling economically more attractive - In areas of **high unemployment**, high volumes of waste can provide the economies of scale and impetus to establish recycling programs that provide valuable employment and skill development opportunities
Degree of mixing of waste	- **Highly mixed wastes** significantly reduces the economic feasibility of recycling, increases the difficulty of producing quality recyclables and makes it potentially hazardous - Recyclable wastes can become contaminated with **hazardous material** (e.g. disaster waste contaminated with asbestos). Hazards during the recycling process must be considered too, especially for temporary storage	- **Lower contamination** and hazardousness of waste makes recycling easier
Areal extent of waste	- Increased **distances** between waste source and recycling facilities and end-product markets – e.g. when the earthquake affects an extended area	- Smaller geographical areas, all other factors being equal, will make recycling more favorable
Community priorities	- Negative social impact of placing disaster management sites close to disaster-affected communities. Community discontent with the proximity, and associated noise, dust, and vibrations etc.	- Recycling is likely more feasible where facilities are close to the affected areas

Funding mechanisms	- Funding providers often employ strict reporting and monitoring requirements and this reduces the viability of recycling in previous events	
Regulations	- Where recycling is unfeasible, laws that unconditionally enforce recycling may penalize a community. Peacetime recycling mandates need to consider implications during disaster responses and, if necessary, a disaster exclusion clause could be added	- Strong recycling mandates and appropriate incentives can help ensure that recycling is feasible after a disaster. Waste disposal levies, for example, can improve the economics of recycling.

4.2.2 On-site VS off-site separation

The disaster waste can be separated directly on the site during the removal operations, or off-site – meaning that the waste is first transported in a storing facility, and then it is separated there. The main structural decision that waste managers must make when planning a disaster waste management recycling system is whether or not to source separate recyclable materials. It is possible to have a mixed model where selected materials are separated on-site while the rest goes to an off-site separation facility. However, some considerations need to be made to decide whether it is more convenient to separate the waste on-site or off-site. This necessarily **affects the quality of recycling.**

Four factors have been identified for having the largest impact on on-site versus off-site recycling:

(1) Time constraints and the need to remove more or less quickly the debris from the affected area. Off-site separation offers quicker debris removal from the site of the disaster, whereas on-site separation might slow down the recovery process.

(2) Resource availability is important to consider. Off-site separation requires suitable temporary staging areas and processing facilities close to the affected area. Off-site separation also requires sufficient trucks to move waste quickly from affected areas to the staging area(s). On-site separation depends on suitable resources to separate wastes on-site. For demolition, this is the availability of demolition equipment and trained personnel.

(3) Degree of mixing of wastes. Off-site material separation is generally more effective where waste is highly mixed. On the contrary, on-site separation is more effective where waste is not highly mixed (more homogeneous composition).

(4) Human and environmental hazards. This can be particularly important particularly, where residents are required to participate in on-site separation.

Different constraints exist for sorting the waste both on-site and off-site, which makes the decision complex, and needs to be evaluated on a case-to-case basis. The table below summarizes the constraints of the on-site VS off-site separation:

Table 24: Main constrains of on-sites VS off-site separation.

Method	Constraints
On-site separation	Can significantly slow down the process of removal of the debris[79]. On-site separation is dependent on suitable resources to separate wastes on-site. For demolition operations, this includes the availability of demolition equipment and trained personnel (as the area and the buildings could be unstable). On-site separation requires sufficient vehicles to carry all the separated materials and a road network that supports trucks travelling to a multitude of different recycle markets.

[79] Sachdeva, 2010

	Trying to separate highly mixed waste on-site would lead to longer debris removal times, increased hazard expo-sure and likely increases in costs. If hazardous waste is detected, this can pose health risks that are less manageable on-site. On-site separation also means there are thousands of work sites in and around inhabited communities, each posing a risk to workers and communities. The more waste is handled at these sites, the longer communities are exposed to risks.
Off-site separation	Off-site separation requires suitable temporary staging areas and processing facilities close to the affected area. Off-site separation also requires sufficient trucks to move waste quickly from affected areas to the staging area(s). Materials such as asbestos, gas cylinders, petrochemicals, paints, pesticides etc., can easily become mixed in the general debris destined for later separation and recycling. The risk of contamination can increase in cases where authorities choose to relax regulations post-disaster to facilitate a quicker clean-up.

4.2.3 Approaches to improve recycling effectiveness of disaster waste

Even if the best recycling strategy is adopted, it will only be successful if it is managed well. Different considerations can be made to decide what management approach to be undertaken.

Several **debris management planning guidelines exist**, which generally give a range of technical and management options for disaster waste. These include collection and transportation, temporary debris storage, recycling, disposal, and hazardous waste management. To be more specific, the following aspects play a role in the management of disaster waste[80].

Planning in advance for disaster debris and waste management is also crucial to ensure effective and coordinated operations during, and after the emergency. Proper planning can increase proper recycling. The first, important measure is to have a **disaster waste management plan**. Ideally, disaster

[80] UNEP/OCHA (2013). Disaster Waste Management Guidelines. Second Edition. Available at: DisaterWM_guidelines.pdf (unep.org)

waste management plans should be developed before a disaster event. However, frequently plans are only formulated after a disaster has struck.
To plan a disaster waste management system, waste compositions and quantities must be estimated. As highlighted, the composition can become very heterogeneous. As with waste composition and nature, the quantity of waste will vary based on the type of disaster and the built environment impacted. Waste quantities can be calculated in the planning phase. **Pre-disaster waste estimations** are beneficial in both pre-disaster planning and post-disaster response. In order to define disaster waste management plans *ex ante*, simulation models are needed to predict different levels of emergency using GIS/hazard maps[81] such as GIS-based seismic hazard prediction system for urban earthquake disaster prevention planning, and calculation of **debris volume/weight per house or per unit floor area**[82]**.** This means, that combining GIS mapping of inhabited areas with seismic maps can provide estimates on the quantities of generated waste based on different scenarios (e.g. based on different magnitudes of the earthquake)[83].
Typically, the management of disaster waste (regardless of whether it was planned or not in advance) is described in the literature in three phases[84]:

- Emergency response (debris management to facilitate the preservation of life, provision of emergency services, removing immediate public health and safety hazards such as unstable buildings, etc.), includes the removal of immediate threats to public health and safety;
- Recovery (debris management as part of restoring lifeline restoration and building demolition); in this phase, the majority of the disaster-generated waste will be managed;
- Rebuild (debris management of wastes generated from demolished buildings and used in re-construction) is the longest phase and can last up to 10 years or even several decades.

Through thorough planning of the various phases, it is possible to optimize the different processes and operations, which will also allow better management of the disaster waste. The first important point is related to the different waste treatment options. Choosing different treatment options in various phases can determine how the waste can be recovered. While it is difficult to anticipate the plethora of disaster impacts that waste managers would have to face, it is crucial to consider likely scenarios and corresponding waste management approaches. In terms of recycling, pre-planning will help to identify the required resources: personnel, trucks, staging and disposal sites, and recycling facilities, etc. Ensuring suitable existing technologies and markets for recycled materials e.g., aggregates, is part of this process. **Pre-arranged contracts and rates with contractors** have been identified as an important feature in facilitating effective clean-ups. Another option could be to use state-owned disposal facilities to regulate recycling by limiting the disposal of waste containing recyclable material. The payment structure of contracts can also impact how much recycling is carried out, and therefore **recycling targets can be set in the contracts**[85].

[81] USEPA, 2008. Planning for natural disaster debris. In: Office of Solid Waste and Emergency Response and Office of Solid Waste (Eds.).
[82] Hirayama, N., Kawata, Y., Suzuki, S., Harada, K., 2009. Estimation procedure for potential quantity of tsunami debris on tsunami earthquake disasters. In: Sardinia 2009, Twelfth International Waste Management and Landfill Symposium. CISA Publisher, S. Margherita di Pula, Cagliari, Italy.
[83] Zhai, Yongmei, Shenglong Chen, and Qianwen Ouyang. 2019. "GIS-Based Seismic Hazard Prediction System for Urban Earthquake Disaster Prevention Planning" *Sustainability* 11, N°. 9: 2620. https://doi.org/10.3390/su11092620
[84] JEU, 2010. Joint Environmental Unit Disaster Waste Management Guidelines, Final Draft ed
[85] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021.

Since waste separation may become impractical as clean-up and recovery became the first priority, **temporary sites can be used for storing, sorting, and processing**. it is particularly important to have sites identified as potential staging areas, especially when it is necessary to remove waste quickly after an event for search and rescue or due to health and safety reasons. **Temporary staging sites** can provide extra time to appropriately sort, recycle (off-site separation, see also above) and dispose of the waste. However, the expense of double handling of waste and acquiring land can be a limiting factor in their use. **Pre-disaster identification of temporary storage** sites has been suggested by many authors as a way of avoiding this potential adverse effect. Factors requiring consideration include space requirement, environmental factors, noise and dust, pre-disaster site identification, land-use planning issues and cost. The selected site should ensure access for heavy equipment, protection of environmentally sensitive areas, and logistical efficiency[86].

4.2.4 Framework conditions affecting the viability of recycling of disaster waste

Solid waste management legislation typically governs demolition procedures, waste handling, transportation, disposal, etc. However, in the wake of a disaster, these peacetime laws can cause significant delays in the clean-up process. Strict environmental laws in the European context are reported to have prevented necessary recycling staging sites and disposal sites from being permitted until months after an earthquake. Many disaster waste management plans highlight the need for **emergency legal waivers on solid waste regulations**. For instance, where recycling is unfeasible, laws that unconditionally enforce recycling may penalize a community. Peacetime recycling mandates the need to consider implications during disaster responses and, if necessary, a disaster exclusion clause could be added. Strong recycling mandates and appropriate incentives can help to ensure that recycling is feasible after a disaster. For instance, it might be good to keep landfilling levies to ensure competitive recycling prices, even if in some cases the landfills levies are removed to lower the waste management costs in emergency times. However, it is often unclear to what degree and in what circumstances legal or regulatory relaxations are acceptable.

Also, if the disaster waste management strategy does not align with peace-time regulations then new regulations may be required. For example, in L'Aquila, waste managers found it difficult to manage the waste as they were restricted by existing EU waste codes. Waste could not be moved unless it was appropriately coded, and there was no code for mixed earthquake waste. A **special law had to be written to allow the movement of mixed earthquake waste**[87].

Waste ownership can also act as a potential legal issue. Waste ownership issues are of concern when private property owners are not able to participate in the clearing of their own property, and revenue is then generated from recycling activities. The importance of the individual owner has also been noted. There is considerable evidence of recycling of CDW debris by the individual home-owner[88].

All in all, legislation and regulation have the potential to significantly impact the efficiency and effectiveness of disaster waste management and recycling and may inhibit efficient and effective

[86] Karunasena, Gayani. (2011). Sustainable Post-Disaster Waste Management: Construction and Demolition Debris. 10.1002/9781444344943.ch14.

[87] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021

[88] Karunasena, Gayani. (2011). Sustainable Post-Disaster Waste Management: Construction and Demolition Debris. 10.1002/9781444344943.ch14.

waste handling. However, in-depth reviews of country-specific laws are required to fully understand the impact in different contexts.

Another important point concerns **the financial viability of recycling**. This is linked, at first, to w**ho is responsible for cleaning up.** In some countries, like Italy, private property clean-up or demolition is the responsibility of the property owner/insurance, and curbside collection and disposal is the responsibility of the municipality. Hence, private citizens might be required to carry the costs for cleaning up[89]. The recovery of costs through recycling offers interesting opportunities, however, it might not always be so simple for private citizens to participate in recycling.

In order to increase recycling, special **reconstruction funds** can be adopted. In Italy, for instance, a recovery fund was introduced[90] after the earthquake in central Italy in 2016 for a total value of 200 million Euro in order to speed up the clean-up and reconstruction process. Private citizens can apply to the fund. The fund also promotes recycling and recovery, as long as the by-product and end-product criteria and concentration limits for hazardous substances conform to the legislation.

Obviously, the market for recycling disaster waste also needs to be promoted, despite the many constraints highlighted in the previous paragraphs. The lack of confidence for recycled materials due to low perceived quality, and the potential presence of hazardous materials, can be overcome through the application of **standards for material recycling** (for a broad review on international standards for CDW see also chapter 4.6).

4.3 Further approaches for the management of disaster waste

4.3.1 Waste prevention

Proper management of debris waste also goes through waste prevention. There are basically two ways to prevent buildings and infrastructures from collapsing and becoming waste following an earthquake:

- By building seismic buildings;
- By renovating old buildings and adapting them to seismic norms (retrofitting).

Earthquake-resistant structures are intended to withstand the largest earthquake of a certain probability that is likely to occur at their location at a certain point in time (exceeded probability in a return period). Hence, one of the crucial aspects in determining the design of seismic action is to assign the **seismic hazard level of a certain site**[91]. For most applications **of the building seismic codes as the standards EN1998 (see below)**, the hazard is described in terms of a single parameter, i.e. the value of the **reference peak ground acceleration**, agR, on type A ground (ground type A corresponds to rock or other rock-like geological formation, including at most 5m of weaker material at the surface). For each seismic zone the reference peak ground acceleration, agR, corresponds to the reference probability of exceedance in 50 years, PNCR, of the seismic action for the no-collapse requirement. Therefore, the **mapping of the seismic zones** in a country needs to allocate the risk for buildings to collapse as a result of an earthquake.

[89] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021

[90] DECRETO-LEGGE 17 ottobre **2016**, n. 189 Interventi urgenti in favore **delle** popolazioni **colpite dagli eventi sismici** del **2016**.

[91] G. Solomos, A. Pinto, S. Dimova (2008). A REVIEW OF THE SEISMIC HAZARD ZONATION IN NATIONAL BUILDING CODES IN THE CONTEXT OF EUROCODE 8. Support to the implementation, harmonization and further development of the Eurocodes. JRC 48352. Available at: https://eurocodes.jrc.ec.europa.eu/doc/EUR23563EN.pdf

Once the seismic zones (and the agR) are clear, it is possible to operate with the building **seismic codes.** Seismic codes (or earthquake codes) are building codes designed to protect property and life in buildings in case of earthquakes, such as the EN Eurocodes.

In the EU, **t**he **EN Eurocodes** are a series of 10 European Standards, EN1990 - EN1999, providing a common approach for the design of buildings and other civil engineering works and construction products. They are the recommended reference for technical specifications in public contracts. Under the Public Procurement Directive[92] it is **mandatory that Member States accept designs to the EN Eurocodes**. The EN Eurocodes will become the standard technical specification for all public works contracts. If proposing an alternative design, one must demonstrate that it is *technically equivalent* to an EN Eurocode solution.[93]

In particular, the **EN1998 Eurocode 8** applies to the design and construction of buildings and other civil engineering works in **seismic regions**. Its purpose is to ensure that in the event of earthquakes[94]:

- human lives are protected;
- damage is limited;
- structures important for civil protection remain operational.

The table below provides the list of Eurocodes to protect property and life in buildings in case of earthquakes.

Table 25: Eurocodes for protection of property and life in buildings in case of earthquakes.

EN1998-1:2004	Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions and rules for buildings
EN1998-2:2005	Eurocode 8: Design of structures for earthquake resistance – Part 2: Bridges
EN1998-3:2005	Eurocode 8: Design of structures for earthquake resistance – Part 3: Assessment and retrofitting of buildings
EN1998-4:2006	Eurocode 8: Design of structures for earthquake resistance – Part 4: Silos, tanks and pipelines
EN1998-5:2004	Eurocode 8: Design of structures for earthquake resistance – Part 5: Foundations, retaining structures and geotechnical aspects
EN1998-6:2005	Eurocode 8: Design of structures for earthquake resistance – Part 6: Towers, masts and chimneys

Special structures, such as nuclear power plants, offshore structures and large dams, are beyond the scope of EN1998. EN1998 contains only those provisions that, in addition to the provisions of the other relevant EN Eurocodes, must be observed for the design of structures in seismic regions. It complements in this respect the other EN Eurocodes.

[92] DIRECTIVE 2004/18/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of March 31, 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts.

[93] https://eurocodes.jrc.ec.europa.eu/showpage.php?id=215

[94] https://eurocodes.jrc.ec.europa.eu/showpage.php?id=138

Secondly, buildings can be retrofitted to improve the structure to resist earthquakes. There are several retrofitting techniques to improve the seismic behavior of buildings. Among them, the most implemented strategies are based on the strengthening and stiffening systems and enhancing the building's deformation capacity, including e.g. reinforcing anchorage and bracing of components, introducing moment-resistant frames, column strengthening, local stiffness reduction, energy dissipation systems, etc. [95]. The nature of each intervention must be tailored to the specific building.

Obviously, retrofitting of buildings requires intervention from civil engineering to perform the structural changes. This process can be expensive, for private citizens as well as for public authorities. Retrofitting of buildings can be promoted by means of economic instruments, such as subsidies for the public infrastructure, and **incentives or tax-waivers for retrofitting** for private citizens i.e. owners of buildings. In Italy, for instance, the government introduced subsidies to the Regions for public infrastructure and incentives to private citizens (Sismabonus)[96]. The Sismabonus was specifically introduced by the government to speed up the recovery from the consequences of the earthquake that hit the center of Italy in 2016. It foresees that private citizens can have a tax reduction for the retrofitting of existing buildings; and tax deduction, since 2017, for the purchase of a new home that is anti-seismic located in areas classified with high and mid earthquake hazards.

4.3.2 Land reclamation

Besides recycling, one of the possible approaches for managing disaster waste, is also **land reclamation and engineering fill**, although there are concerns over the potential for hazardous wastes to be inadvertently included in the fill. Contamination and/or variability in fill composition could also lead to structural instability of the fill-in time-[97]. However, the choice of disaster waste treatment options should not only include costs but also environmental and engineering risks. For example, land reclamation or engineering fill projects which use disaster recycled materials may not be able to achieve the same level of environmental and structural quality control as in peacetime. The likely speed of processing the materials and difficulty in separating mixed disaster-generated waste both contribute to increased project risks.

4.4 Disaster waste management case studies

4.4.1 The earthquake in l′ Aquila (Italy) in 2009[98]

On April 6, 2009, the Abruzzo region in Italy was struck by a 6.3 magnitude earthquake. 314 people died and an estimated 70,000 residents were forced to evacuate (Dolce, 2009). L'Aquila has a high proportion of historic multi-storey unreinforced masonry buildings. Approximately 25% of the 72,000 damaged buildings required complete demolition (Dolce, 2010). The demolition and repair program would generate an estimated four million tons of debris with the intention to recycle the aggregate from the waste (estimated70–80% of the waste).

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[95] Requena-García-Cruz M-V, Morales Esteban A, Durand-Neyra P, Estêvão JMC (2019) An index-based method for evaluating seismic retrofitting techniques. Application to a reinforced concrete primary school in Huelva. PLoS ONE 14 (4): e0215120. https://doi.org/10.1371/journal. pone.0215120

[96] https://www.agenziaentrate.gov.it/portale/documents/20143/233439/Sisma+bonus+le+detrazioni+per+gli+interventi+antisismici_Guida_Sisma_Bonus.pdf/ee5ec719-05ae-0584-897e-f60d34060498

[97] Karunasena, Gayani. (2011). Sustainable Post-Disaster Waste Management: Construction and Demolition Debris. 10.1002/9781444344943.ch14.

[98] Charlotte Brown, Mark Milke (2016). Recycling disaster waste: Feasibility, method and effectiveness. Resources, Conservation and Recycling. Volume 106,2016, Pages 21-32, ISSN 0921-3449, https://doi.org/10.1016/j.resconrec.2015.10.021.

Barriers:

- Limited number of temporary storage facilities (for separating and storing recyclables) available;
- Strict environmental regulations slowed the establishment of additional storage and processing facilities;
- Strict environmental regulations also made it difficult to identify suitable sites for using the recycled crushed aggregate as engineering fill (typically quarry remediation);
- Absence of standards for use of recycled aggregate in construction;
- Limiting the available end markets;
- Low price quarried material available at a lower cost than recycled aggregates.

Despite these barriers, **recycling was actively carried out**. Initially, authorities detailed that demolition material should be sorted at temporary storage facilities. This was later changed to on-site separation (at the demolition site). As a result, the rate of debris removal reduced from approximately 600 t/day to 100–200 t/day. Strong recycling mandates and appropriate incentives can help to ensure that recycling is feasible after a disaster. Waste disposal levies, for example, can improve the economics of recycling. It is interesting to note that following some disasters, such as the Christchurch earthquakes, the waste levy has been waived to lower the waste management costs. While that goal is admirable, the removal of the waste levy also reduces the economic feasibility of recycling relative to disposal. Therefore, it could potentially encourage landfilling.

4.4.2 The earthquake in central Italy in 2016

Between August 2016 and January 2017 three seismic events took place involving 4 Regions (Marche, Umbria, Lazio, Abruzzo) and about 140 municipalities and 8.000 km^2 were affected. Specifically, on August 24, 2016, a magnitude 6.2 earthquake hit the Apennines Mountains in central Italy, devastating the small towns of Amartrice, Accumoli and Pescare del Tronto. At least 293 lives were lost. It has been estimated that 2.720 tons of waste resulted from the collapsing of buildings, of which 57,14% was collected until May 2019.

Post-disaster management

In May 2017, nine months after the first earthquake, the rubble collected was less than 4%. Some main reasons behind this delay were identified:

- Regulatory changes (in April 2017: rubble management is regional matter; dl 189/2017);
- Difference between Regions, not all justifiable by regional specificities (lack of coordination of good practices);
- Lack of advanced planning (disaster management plans), so that for instance it took a few months to identify and authorize temporary sites suitable for delivering the rubble;
- Lack of coordination between demolition (e.g. of unstable buildings) and collection.

The involved Regions were unprepared despite the fact that the effort needed to manage disaster waste, and the likelihood of such events to happen was well known.

Concerning the efficiency of recycling following the reconstruction operations, art. 28 of the Law Decree 189/2017 sets out the provisions for the management of waste as follows:

- “to limit the volume of waste by recovering the materials that can be usefully used as new raw material to be made available for reconstruction following the damage caused by the

seismic events. If the materials cannot be employed, then the revenue of their sale is transferred as a contribution to the Municipality from which these materials come".

Although there is little to no data on the real use of recycled aggregates in the areas of the earthquake, it would appear that the aggregates **did not follow the landfill route**. The waste managers directly, or indirectly through the sale to authorized companies, produce **certified recycled aggregates** that are made available mostly for road foundations.

Different approaches were adopted by different regions. While the Marche Region approved a resolution in December 2017 to facilitate the use of recycled aggregates. (with a risk of saturation of the sites of the companies to which the aggregates have been delivered), Umbria Region has urged Municipalities to use the aggregates that are produced in the same temporary storage site. In Abruzzo, private companies sold waste for 2-3 euros per ton, while In Lazio everything was left to the free market.

The benefits of recycling are clear. Recycled aggregates must guarantee quality in relation to each intended use through the CE marking. The reuse of aggregates it's convenient, so it was noted that the **recycled aggregate costs on average from 30 to 50% less** than landfilling. The cost of the recycled material is EUR 3.00/ton, while Landfilling costs on average, including eco-tax, EUR 12.00/ton. Environmental benefits are also clear, so that if landfilling was used, the public rubble alone would fill the Colosseum 3 times (1 million cubic meters) or cover about 14 hectares of a quarry face about 20 meters high.

4.5 Instruments for the management of CDW disaster waste in a circular economy

The following policy measures are identified for the management of CDW disaster waste in a circular economy.

4.5.1 Regulatory

- **Emergency legal waivers on solid waste regulations**
    - Peace-time recycling mandates need to consider implications during disaster responses and, if necessary, a disaster exclusion clause could be added (where recycling is unfeasible, laws that unconditionally enforce recycling may penalize a community).
    - Strong recycling mandates and appropriate incentives can help to ensure that recycling is feasible after a disaster (e.g. keep landfilling levies, that in some cases are removed to lower the waste management costs in emergency times).
- **Standards for the use of recycled aggregate in construction**
    - They can promote recycling, especially to overcome potential presence of hazardous material, and low perceived quality of recycled material.
- **Waste ownership**
    - Ensure that private property owners can participate in the clearing of their own property and revenue is then generated from recycling of the debris.

4.5.2 Economic

- **Mobilization of funds for the recovery that promote recycling**

- The fund should also include recycling and recovery, as long as the by-product and end-product criteria and concentration limits for hazardous substances conform to the legislation.

- **Consolidation of the market for recycled CDW**
  - Through coordinated policies and regulations.

4.5.3 Waste management options for material recycling and recovery

- **On-site VS off-site (temporary storage) separation of the material for recycling**
  - Time constrains;
  - Resource availability;
  - Degree of mixing waste;
  - Human and environmental hazard.

- **Land reclamation and engineering fill**

  Use the debris as levelling fill for new housing developments.

4.5.4 Prevention

- **Adequate normative for the construction of seismic buildings**
  - Building earthquake-resistant structures intended to withstand the largest earthquake of a certain probability that is likely to occur at their location in a certain time.

- **Economic incentives for remediating seismic deficiencies**
  - Subsidies to the Regions for public infrastructure and to private citizens, for existing building and building in construction.

4.5.5 Planning

- **Disaster waste management plans**
  - Disaster waste quantities, estimations (*ideally, ex ante*);
  - Pre-arranged contracts and rates with contractors;
  - Targets for recycling in the procurement contracts (as GPP measure);
  - Identification of temporary sites (to be used for storing, sorting and processing).

4.6 Croatia: Management of CDW after the Zagreb earthquake in March 2020

Croatia **does not have specific legislation related to CDW disaster management** but there are decisions and plans that are adopted from the side of the Government and the Ministry of Economy and Sustainable Development regarding the management of CDW in case of an earthquake.

On March 22, 2020, an earthquake of magnitude 5.4 propagated in the area around the capital Zagreb, destroying many buildings and causing remarkable damage. More than one year and a half after the

event, the total amount of waste that can be brought in connection with the Zagreb earthquake is estimated at 50,000 tons, and most of that waste is in storage and waiting to be processed at the crusher. The waste generated by the Petrinja earthquake, since the earthquake occurred at the end of the year, will be estimated in 2022 – in the first half of 2021, about 80'000 m^3 of waste was received.[99]

In response to the earthquake event in the area of Zagreb in 2020, decisions were adopted by the government to manage the waste under extraordinary circumstances. The decisions include:

1. Ministry of Economy and Sustainable Development: Plan for the implementation of waste management measures after the earthquake in the Sisak-Moslavina County.
2. Government of the Republic of Croatia: Decision on the adoption of the Program of measures for the reconstruction of buildings damaged by the earthquake in the area of the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County (OG 99/2021).
3. Government of the Republic of Croatia: Conclusion regarding the implementation of waste management measures after the earthquake in the Sisak-Moslavina County (OG 4/2021).

The first two decisions are presented in detail below.

1) Plan for the implementation of waste management measures after the earthquake in Sisak-Moslavina County

Based on the Government Conclusion, the Ministry of Economy and Sustainable Development, in cooperation with the Fund for Environmental Protection and Energy Efficiency, adopted in January 2021 the **Plan for the implementation of waste management measures after the earthquake in Sisak-Moslavina County**[100]. The plan defines post-earthquake waste management activities.

In order to start the reconstruction of the earthquake-affected areas, it is necessary to clean all locations where buildings collapsed and properly dispose of construction and other waste in accordance with the circular economy. The intention is to use as many valuable properties of waste, i.e. to various types of household waste are collected separately, in order to send the collected waste for further processing. The key to this is the efficiency of communal services, but also the information of citizens, by which the Fund instructs citizens on how to deal with waste after the earthquake.

The plan contains:

- Expected situation after the earthquake and waste management proposal;
- Organization of the waste management system for the rehabilitation of the area after the earthquake;
- Duties of the Fund;
- Obligations of utility companies;
- Obligations of local self-government units;
- Instructions to citizens on waste management.

The duty to sort waste and treat CDW in accordance with the circular economy and regulations on waste management is prescribed as follows:

CDW waste management:

[99] Draft of the Revision of the Croatian National Waste Management Plan from 2017 - 2022

[100] Plan for the implementation of waste management measures after the earthquake in Sisak-Moslavina County

- Construction waste/demolition waste is collected by a utility company or other authorized company according to if necessary;
- Citizens/companies participating in the clean-up are obliged to separate waste containing asbestos from construction waste/demolition waste and hand it over separately;
- Construction waste is collected and sorted on real estate for temporary storage of waste or on separate areas at existing landfills;
- When sufficient quantities are collected, it is necessary to hire a company authorized to process construction waste using a mobile recycling plant. The obtained material is made available to the local self-government unit to be used in repairing the damage caused after the earthquake or for filling roads or other purposes for which it can be utilized;
- For collected and processed construction waste, it is necessary to keep records of quantities in tons or m^3 (weighing or geodetic survey).

Construction waste containing asbestos

- Construction waste containing asbestos should be separated at the location of the facility where the waste is found;
- Invite an authorized collector who will submit it for processing in accordance with regulations.

Funding:

The Fund for Environmental Protection and Energy Efficiency has provided funding for waste management measures for earthquake-affected areas. The fund finances the collection, transport, separation and treatment of waste, as well as the purchase of necessary equipment. The goal is to send as much useful waste as possible for further recovery, and not for it to end up in landfills.

2) Decision on the adoption of the Program of measures for the reconstruction of buildings damaged by the earthquake in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County.

The Government Decision on the adoption of the Program of measures for the reconstruction of buildings damaged by the earthquake in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County[101] states the duty to act with CDW in accordance with regulations on the circular economy.
Extracts from the Decision:

Disposal of demolition material and construction waste

Demolition material:

- That has a use-value is not considered waste.
- Is collected, sorted and prepared for use on the construction site or on the real estate determined by the decision for the purpose of temporary storage.
- That can be used in the area affected by the disaster is made available to the county and/or local self-government unit, i.e. the City of Zagreb for the needs of use in repairing the damage or in reconstruction or other purposes.

[101] Program of measures for the reconstruction of buildings damaged by the earthquake in the City of Zagreb, Krapina-Zagorje County, Zagreb County, Sisak-Moslavina County and Karlovac County

Construction waste

- Citizens and companies participating in the clearing of the area affected by the disaster are obliged to separate waste containing asbestos and hazardous construction waste from construction waste and manage such separated waste in accordance with the regulations governing waste management.
- for collected and processed construction waste it is necessary to keep records in accordance with the regulations governing waste management.

In praxis, the disaster waste is managed as follows:

Financial resources for crisis assistance are provided by the Government through the Fund in order to ensure that municipal waste management companies have the technical and financial capacity to continue to operate and efficiently manage CDW. The fund finances the collection, transport, separation and treatment of waste, as well as the procurement of necessary equipment. The goal is to send as much useful waste as possible for further recovery, for it not to end up in landfills. **Post-earthquake waste management activities** are carried out by the Fund and the Ministry of Economy and Sustainable Development in cooperation with local municipal companies, in coordination also with the Civil Protection Headquarters. **The implementation of the measures is being monitored** by MESD and the State Inspectorate. Coordination and supervision of the post-earthquake CDW waste management. Keeping records of the CDW quantities is the responsibility of the State Inspectorate. Finally, **Local self-government units** are responsible for CDW collection and management; and **public or private municipal companies** are collecting, storing and managing CDW.

5. Recommendations for Croatia

In order to formulate recommendations for Croatia, an overview of the construction and CDW sectors is first provided, including data on waste generation and management, and current policies.

Recommendations are then formulated, taking into account the presented case studies for the different phases of the life-cycle and their applicability in Croatia. The recommendations of policies and measures include:

- Construction materials of the future/Buildings of the future.
  - Production of sustainable construction materials;
  - Circular design of buildings and construction works;
  - Sustainable construction and renovation of buildings;
  - Sustainable use and maintenance of buildings.
- Recycling of CDW/Reduction of quantities of CDW – international good practices.

Policies and measures are presented as obligatory or voluntary measures as well as short-term, mid-term and long-term measure reflecting the possibilities of application in Croatia.

5.1 Overview on the construction sector in Croatia

The construction sector is the sector with the largest consumption of raw material quantities and with the highest share of 35% of total waste in the EU[102]. The sector has great potential in applying the circular economy principle throughout the life cycle of the construction products and a great potential for recycling. It is one of the resource-intensive sectors focused on in the EU Circular Economy Action Plan.

The revised EU waste directives (Waste Framework Directive, Landfill Directive, Packaging and Packaging Waste Directive and Directive on Electrical and Electronic waste) that came into effect in July 2018, as well as the Single-Use Plastics Directive adopted in June 2019, which has been transposed into the national legislation by the new Waste Management Act (OG 84/2021).

Adequate implementation of the EU best-practice guidance documents is important for achieving circularity in the construction sector, such as:

- EU Construction and Demolition Waste Management Protocol which offers methods of reducing generation of construction waste;
- Guidelines for waste audits before demolition and renovation works of buildings which encourages the use of used or recovered construction materials, products and construction elements.

Croatia has recognized construction waste as a special category of waste in the Waste Management Act, and the construction waste management system has been identified as a **priority area** in the next planning period.

[102] https://ec.europa.eu/growth/industry/sustainability/buildings-and-construction_en#:~:text=The%20construction%20sector%20is%20responsible,of%20total%20national%20GHG%20emissions

Figure 3: CDW sector and its footprint in Croatia

Croatia is missing strategies, action plan to address circularity in the construction sector. However, **Croatia is planning to develop a five-year Circular Economy Action Plan on Construction and Demotion Waste** to introduce a higher level of circularity in the Building Sector. The cases of Ireland, that prepared a waste action plan for a circular economy with CDW as a priority stream, and Malta, that prepared a construction and demolition waste strategy (see Task 4), could be used as examples for Croatia on how to set such plans.

Croatia has not yet achieved the EU Construction waste target. According to the Waste Framework Directive, by 2020, the preparation for re-use, recycling and other material recovery 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.

The calculated **recovery rate of construction waste for Croatia in 2020 was 60%[103].** This is a decrease compared to 2019 when the CDW recovery rate was 67%[104]. The reason for that is explained by additional waste from multiple earthquake events, reduced amount of construction waste metal exported for recycling, pandemic operating conditions of operators resulting in higher amounts of waste in storage, and better quality of waste reporting[105]. It should be pointed out that the recovery rate data cannot be considered fully reliable due to the lack of recorded data. Improvements are expected with the expansion and enhancement of the CDW infrastructure and enhanced supervision[106].

[103] Proposal of the Waste Management Plan of the Republic of Croatia for the period 2017-2022 Years - Revision for the Period 2022

[104] Construction Management Report waste in 2019

[105] Proposal of the Waste Management Plan of the Republic of Croatia for the period 2017-2022 Years - Revision for the Period 2022

[106] Construction Management Report waste in 2019

On a per capita basis, **about 300 kg/cap of CDW was reported for Croatia in 2018** and about 1.970 kg/cap for EU-27. So, the per capita CDW generation in Croatia is 85% less compared to EU-27 per capita generation by mass. Regarding the hazardousness of waste, Croatia reported 99% (297 kg/cap) non-hazardous and 1% hazardous waste (5 kg/cap). The share of non-hazardous and hazardous wastes by volume is close to the EU-27 share of 98% vs. 2%.

Table 26: Estimated quantities of generated and treated construction waste, for the period from 2015 to 2020. Source: MESD, 2021.

Year	Estimated amount of construction waste generated (t)	Amount of treated CDW (t)
2015	1'189'316	881'555
2016	1'226'073	879'000
2017	1'225'263	994'645
2018	1'243'642	911'443
2019	1'365'066	1'076'662
2020	1'399'193	1'144'214

The constant raising trend of the amount of generated and treated CDW. A further increase in the amount of generated CDW is envisaged due to the continuous increase in construction works as well as due to the remediation of the consequences of the earthquakes that hit Croatia several times during 2020.

It is estimated that in 2020 the largest share in the generated construction waste was[107] as follows:

- Mineral non-hazardous construction waste (44.5% - not including excavations);
- Earth, stones and dredging waste (37.7%);
- Mixed construction and demolition waste (17.7%);
- Concrete, bricks, tiles/ceramics (17.4%);
- Metals and their alloys (15.9%);
- Bitumen mixtures, i.e. old asphalt (9.2%);
- Other types of waste (represented by about 2%);
- Hazardous waste (1.4%).

It should be pointed out that there is a lack of sufficient and reliable data on the generation of CDW in Croatia. The quantities of construction waste reported by waste producers make up only about 30% of the actual amount of the generated construction waste. The amount of CDW is determined by estimates. In the Annual Report on Waste Management 2019, it is stated that the calculated rate cannot be considered reliable data due to insufficient knowledge of construction waste flows, because part of the construction waste is not managed in accordance with regulations, thus such flows remain unknown and unrecorded. It was concluded that there is a need to conduct a new statistical survey that would be used to better determine the amount of certain types of construction waste, and more intensive involvement of relevant institutions, primarily the State Inspectorate and the Ministry of Economy and Sustainable Development[108].

[107] Proposal of the Waste Management Plan of the Republic of Croatia for the period 2017-2022 Years - Revision for the Period 2022

[108] Construction Management Report waste in 2019.

Type of treatment of the total treated waste in 2020[109]:

- Recovery (excluding backfilling) 60.2% (688’485.5 t);
- Waste landfilling 24.7% (282’629.8 t);
- Backfilling 15.0% (172’202.0 t); and
- Other procedures 0.1% (896.9 t).

The largest share in the recovery process is the process of recycling inorganic materials such as the processing of mineral waste on a crusher and the process of recycling scrap metals[110]. More action is needed to lessen landfilling and to prioritize recycling over backfilling. The current CDW management infrastructure is inadequate, thus it is necessary to increase the amount of infrastructure for the CDW treatment and ensure an even distribution across the country in accordance with the CDW flows and the amount.

Inadequate CDW management occupies a large volume in landfills and results in environmental pollution, e.g. by illegal landfilling in the environment. In order to use CDW great potential for circularity Croatia would need to **increase the efficiency of separate collection of CDW** as well as additional infrastructure is needed for separate collection, sorting and recovery of CDW. Effectively separate hazardous materials from construction waste to enable a higher recycling rate.

More advanced **measures to prevent the generation of construction waste and to encourage the reuse of demolition materials are needed**, such as a further development of exchange of waste materials (e.g. Croatian Waste Exchange). The introduction of eco-design in the design of construction products can affect the prevention of construction waste. More advanced measures to facilitate the reuse and high-quality recycling of targeted materials are needed, including more advanced economic instruments that influence CDW management. The introduction of eco-labels is not yet recognized as significant by producers and consumers. GPP could be used to bring more circularity in the construction sectors. It would be also necessary to **develop a competitive secondary material market** which enables and increases the demand for secondary materials in the construction sector. This is also achieved by ensuring confidence in the quality of secondary materials that need to be assured and certified. Promoting sustainable construction would bring more circularity in the construction sector. Sufficient and reliable data on buildings and CDW streams need to be ensured.

Croatia has made progress in the **construction waste treatment**. There is a continuous increase in the amounts of CDW being treated. In the recovery procedures, the process of recycling construction waste increased, also significantly increasing the amount of recycled aggregate obtained by revoking the status of waste after the recycling process. A number of companies use the possibility of achieving the **status of by-products and the possibility of revoking the status of waste**, which contributes to the prevention and reduction of waste. Certain by-products were used in road construction, backfilling or cement production. [111]
The amount of CDW recovery will continue to increase as the CDW management system is continuously being upgraded by adopting more advanced policies and legislation, adopting better CDW waste management practices as well as by expanding CDW infrastructure and increasing the number of CDW management companies.

[109] Proposal of the Waste Management Plan of the Republic of Croatia for the period 2017-2022 Years - Revision for the Period 2022.
[110] Construction Management Report waste in 2019.
[111] Proposal of the Waste Management Plan of the Republic of Croatia for the period 2017-2022 Years - Revision for the Period 2022.

5.2 Recommended Measures for Croatia

In general, the road that needs to be taken for full introduction of the circular economy in the construction sector is long and requires gradual **implementation of measures in the short, medium and long term**.

Policy measures should be aimed both to ensure a sufficient amount of construction waste of sufficient quality to be suitable for the production of new construction products (in competition with the extraction of virgin raw materials) and to ensure market demand for products manufactured from recycled construction waste (in competition with products made from virgin raw materials). Construction waste prevention should be implemented in parallel with the measures to recycle construction waste and to create a market for recycled waste products. The results of waste prevention will become more visible in the long run, so prevention measures should be taken at the earliest stage. Since the prevention measures require the creation of new business models and changes in consumer habits, their implementation has been postponed to later stages – in the medium and long term.

5.2.1 Short term measures

At present, **the selective demolition of buildings and the separation of construction waste by type of material are not sufficiently applied and the waste is mixed, which makes it difficult to use it for the production of new construction products**. Most of the construction waste is used for backfilling operations, which is a material recovery operation, but does not lead to the replacement of natural materials in the production of high grade construction products.

The aim of the measures in the first stage is to increase recycling at the expense of limiting backfill activities by introducing stricter requirements for backfilling and economic instruments. To this end, it will be **necessary to achieve further separation of mixed mineral waste**, which is a mixture of concrete, bricks, tiles and ceramics (code 17 01 07 of the European Waste Catalog) or even mixed construction and demolition wastes containing mortar, plaster, recyclable (metal, plastics, paper, wood, etc.) and hazardous wastes (code 17 09 03). During this initial stage, it is not necessary to strive to use all waste materials in the production of new products (upcycling) by separating all components suitable for high-grade applications (concrete, bricks, tiles) from the mixed waste. It would be more realistic if mixing of waste during demolition is still allowed, but there should be an obligation that the fractions that prevent the use of mixed waste for activities other than backfilling are separated from the mixture by applying simple mechanical operations such as sieving and crushing. In this way a mixture of concrete, bricks, tiles can be separated by sifting mortar and plaster and the resulting mixture can be used (instead of backfilling) for higher-grade construction works in underlayment, for landscaping, in gabions and mattresses, embankments, drainages, etc.

At this stage taking into account the requirements of *Ordinance 69/2016 on construction waste and waste containing asbestos*, it is **not recommended to introduce stricter obligations for selective deconstruction or mandatory sorting at source (during repair and construction**). Operators must be able to assess which waste is to be separated and recycled in order to meet material recovery targets. In the short term, before the introduction of measures such as mandatory GPs and minimum recycled content, recycling will be limited to materials for which there is market demand. Criteria and rules for the reuse of construction waste such as bricks, tiles, windows, pavers, curbs should be introduced at this stage.

In order to encourage recycling, **restrictions on backfilling must be introduced**, such as:

- Waste being used in backfilling must meet the requirements of the investment project of the construction, which must be proven by test reports (e.g. grain size, plasticity index, Proctor "density-humidity", CBR, etc.);
- The person carrying out material recovery by backfilling must have a permit for waste treatment with code R10 to keep records and submit reports on the quantities and types of waste;
- Construction waste that is backfilled have to be inert;
- The construction waste being used in backfilling has to undergone a pre-treatment before recovery and/or preparation for re-use.

It is recommended to adopt **national end-of-waste criteria at this stage**. In the first place, the types of waste that do not pose a risk to the environment and have good construction characteristics (e.g. the list of waste in Annex 1 of the Austrian Recycled Construction Materials Ordinance) can be defined, and at the same time strict requirements are set for them (e.g. requirements for Quality class UA of Austrian Recycled Construction Materials Ordinance) in order to ensure that they are suitable for use in all construction applications (whether as aggregates for unbound application, hydraulic, or bituminous use). Only a limited amount of waste will meet these requirements. In the medium term, the scope can be extended by defining lower limit values of the parameters for using recycled CDW in specific construction applications that allow the use of waste that does not meet the stringent requirements.

The **separation of hazardous waste both before demolition and during construction or repair work must be enforced at the earliest stage**. After the separation of hazardous waste, mixed construction waste will be suitable for both low grade backfilling and for use in a number of construction applications.

Proposed short term recommendations to increase the recycling rate of the materials in construction sector as well as the recycling options are presented in the table below.

Table 27: Short term recommendations to increase the recycling rate and possible recycling options.

CDW type	Mandatory separation?	Utilization in	Quantity
17 01 01 (concrete)	No Separation if there is market demand or if needed for the Recovery target	Upcycling: both in bound or unbound applications for e.g.: As aggregate in low-strength concrete and reinforced concrete elements, in cement stabilization	Low
17 01 02 (bricks)		reuse	Low
17 01 03 (tiles)		reuse	Low
17 01 07 (mix: 17 01 01 + 17 01 02 + 17 01 03)	Yes (simple technologies for separation of plaster will be readily available)	Recycling: Backfills in pipelines and cable routes; underlayment; pavements of park alleys; flooring of sports facilities (ceramic aggregates); bicycle lanes, for landscaping, in gabions and mattresses, embankments, drainages etc.	High
17 02 01 (wood)	No Separation if there is market demand or if needed for the Recovery target	recycling, reuse	Medium
17 02 02 (glass)		recycling	Low
17 02 03 (plastics)		recycling	Low
17 04 XX metals		recycling	High (magnet separation after crushing)
17 05 04 (soil and stones)	Yes (not within 70% recovery target)	Backfilling	High
		Upcycling - as aggregate for concrete (crushed stones only)	Low
17 08 02 (gypsum)	landfilling under stricter condition (H_2S emitter)	recycling	Very low (further R&D needed)
17 03 02 (asphalt)	Yes (recycling technologies are readily available); Ban on backfilling (not inert)	Upcycling: in situ (hot or cold recycling) with addition of new asphalt or bituminous emulsions	High
		milled asphalt concrete with addition of polymers - for stabilization of banquets	
		without pre-treatment: as pavement for temporary and service roads, as well as for drainage layers of parking lots, storage areas, etc.	
Hazardous waste	Yes	Disposal	All

The recycling rate will increase if the measures to increase the separation and recycling of materials are accompanied by measures to stimulate demand for products made from recycled materials. A **summary of short-term measures** is presented below:

- Prevention and increase of the demand for recycled and non-hazardous CDW:
  - Tracking and phasing out of hazardous content in construction products;
  - Recognition of the Standard for Design for Disassembly and adaptability as national standard;
  - Consultations with stakeholders and Voluntary agreements on circular design, minimum recycled content;
  - Methodology for assessment of the future value of buildings;
  - Lower tax for restoration of old buildings in tourist areas;
  - Take-back schemes established by bigger manufacturers.
- Increase the supply of CDW suitable for recycling and production of new products:
  - Recovery targets prioritizing recycling;
  - Landfill restrictions (tax and bans);
  - End-of-waste - legislation and standards regarding recycled materials;
  - Obligatory separation of mixed mineral fraction (17 01 07) and asphalt (17 03 02). Introduction in the legislation of pre-demolition auditing and deconstruction report.

5.2.2 Midterm measures

In the medium term, the transition from material recovery with the purpose of landfill diverting to a circular economy must take place. It is recommended to **introduce measures for further separation of more types of recyclable materials from construction waste**, but to avoid material recovery, and rather **promote reuse**.

It is recommended to make the **separation of more materials mandatory from the demolition of buildings as well as during construction and repair work**. Special attention must be paid to concrete, which must be separated from the mineral components during demolition in order to be used as an aggregate in low-strength concrete.

The introduction of a **quality assurance system and a waste tracking system** will allow tracking the path of construction waste to its final destination. This will allow lower quality grades of waste (similar to quality grades UB, UE, HB, BB, BC and BD of Austrian Recycled Construction Materials Ordinance) to be defined, which are suitable for specific construction applications (e.g. HB class of Austrian Recycled Construction Materials Ordinance, which is suitable for aggregates exclusively for the production of concrete from strength class C 12/15).

In parallel with the introduction of strict requirements for separation and recycling, measures must be implemented to ensure the sale of products from recycled construction materials. In the medium term, **GPP should become mandatory for publicly funded projects**. In addition, existing certification schemes, building passports, application of Building Information Modeling, Eco-labels, should be used as project evaluation criteria. Minimum recycled content in construction products and construction works should also be required for publicly funded projects.

Proposed short term recommendations to increase the recycling rate of the materials in construction sector as well as the recycling options are presented in the table below.

Table 28: Midterm recommendations to increase the recycling rate and possible recycling options.

CDW type	Mandatory separation?	Utilization in	Quantity
17 01 01 (concrete)	Yes	Upcycling: both in bound or unbound applications for e.g.: As aggregate in low-strength concrete and reinforced concrete elements, in cement stabilization	High
		Recycling: backfills in pipelines and cable routes; underlayment; pavements of park alleys; flooring of sports facilities (ceramic aggregates); bicycle lanes, for landscaping, in gabions and mattresses, embankments, drainages etc.	Low
17 01 02 (bricks)	Yes	Reuse Recycling: backfills in pipelines and cable routes; underlayment; pavements of park alleys; flooring of sports facilities (ceramic aggregates); bicycle lanes, for landscaping, in gabions and mattresses, embankments, drainages etc.	High
17 01 03 (tiles)			High
17 02 01 (wood)	Yes	recycling, reuse	High
17 02 02 (glass)		recycling	High
17 02 03 (plastics)		recycling	High
17 04 XX metals		recycling	High
17 05 04 (soil and stones)	Yes	Backfilling	High
		Upcycling – as aggregate for concrete (crushed stones only)	Low
17 08 02 (gypsum)	Yes	recycling	Medium/High (depend on technology progress)
17 03 02 (asphalt)	Yes (recycling technologies are readily available); Ban on backfilling (not inert)	Upcycling: in situ (hot or cold recycling)	High
		milled asphalt concrete with addition of polymers	
		without pre-treatment: as pavement for temporary and service roads, as well as for drainage layers of parking lots, storage areas, etc.	
Hazardous waste	Yes	Recycling	Medium/High (depend on technology progress)

A summary of mid-term measures is presented below.

- Prevention and increase the demand for recycled and non-hazardous CDW:
    - Eco-design of construction products (involvement of stakeholders in the drafting process of the Commission regulations);
    - National database of EPD proving environmental claims;
    - Catalogues of renewable materials;
    - Mandatory GPP criteria (in several types of construction works);
    - Certification of buildings as criteria in GPP;
    - Building passports as criteria in GPP;
    - Requiring application of Building Information Modeling in GPP;
    - Eco-labels as criteria in GPP;
    - Minimum recycled content in construction products and construction works.
- Increase the supply of CDW suitable for recycling and production of new products:
    - Tax on raw materials;
    - Mandatory selective deconstruction and source separation for more materials;
    - Reduced criteria for the use of waste in specific construction applications (definition of quality classes);
    - Mandatory site waste management plan.

5.2.3 Long term measures

During the previous (mid-term) period all possible measures to impose separation and recycling should already be implemented and **there should be an increased supply of recycled materials on the market**. However, supply will not be enough to meet demand, as in the construction sector the product life cycle is significantly longer and the generation of waste from products designed to facilitate recycling is delayed. Increased waste generation of construction products and buildings designed for circularity is expected in the long run. Therefore, measures to **create a market for recycled products must continue** in the next (long term) stage.

During this stage the requirements for design for disassembly, reparability, durability, reduction of the amount of materials used in construction works, use of reclaimed materials, design for sharing and flexibility should become mandatory when designing construction products and buildings. GPP should be extended also in the phase of operation of buildings through mandatory Performance based contracts.

A summary of long-term measures is presented below:

- Requiring Environmental Performance Assessment in “CE” marking and "C" marking (EU's CPR and national Regulation);
- Mandatory assessment of Environmental Performance in construction permitting;
- Design for disassembly and adaptability to be required by the building code;
- Performance based contracts in GPP.

5.2.4 Recommendations for governance framework to sustain the inter- and intra-ministerial collaboration and to promote CE approach

The newly established Committee for the Circular Economy can provide support and guidance related to circular transition in the construction sector. The Committee can coordinate cooperation between the public, private, academic and civil sectors that have competences and possess expertise related to the construction sector. The leading institution is the Ministry of the Economy and Sustainable Development, with the support of the Ministry of Physical Planning, Construction and State Assets. Also, other relevant institutions and associations could be involved, such as representatives of local and regional government, business associations, chambers of commerce, including academic experts, civil associations and representatives of private firms operating in the construction sector in order to get a comprehensive overview and multidisciplinary approach.

The following supporting stakeholders should also be involved in the decision-making process: the Chamber of Commerce, the Croatian Employers' Association, the Association of Towns and Municipalities, the Croatian Association of Counties, the Environmental Protection and Energy Efficiency Fund, the Faculty of Civil Engineering, the Faculty of Architecture, the Croatian Chamber of Trades and Crafts, the Croatian Chamber of Architects, the Croatian Chamber of Civil Engineers, the Croatian Bank for Reconstruction and Development, the Croatian Employers' Association, private construction and construction waste management firms and civil associations.

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