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European potential towards a circular built environment -The role of pre-demolition audit

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Abstract

Construction and Demolition Waste represents about one third of all waste produced in the European Union and it includes all types of materials arising from excavation, construction and demolition activities. The EU Waste Framework Directive imposes to all Member States to achieve a minimum C&D waste recovery target of 70 % by 2020.

This study analyses the current C&D waste management in Member States in order to identify options to improve recycling. In particular, the focus is on pre-demolition audit and its role towards achieving a circular economy in the built sector. The most important indicators that may affect the transition to a circular built environment are data collection, legislation, framework and market conditions. These categories are evaluated with arbitrary scores that allow to understand what aspects need to be improved in order to achieve a 100 % recycling quota. The results demonstrate that some countries have a certain linearity between recycling capacity and C&D waste handling, while others show conflicting values due to data collection problems, insufficient sanctions and control measures and unspecific legislation. The Member States' approach to pre-demolition audit is also assessed with arbitrary scores that consider the compulsory, the application field and the specificity. The analysis indicates as pre-demolition audit is a crucial step in improving management and disposal of demolition materials, especially hazardous.

In Italy, the compilation of a pre-demolition audit is not mandatory at national level, but Italian legislation is very strict with regard to the removal and disposal of hazardous building materials. The case study analysed in the thesis concerns the management of asbestos during the demolition of the remaining parts of Polcevera viaduct in Genoa, which partially collapsed on 14 August 2018. The analysis highlights critical issues, as the Italian legislation, which sometimes shows inconsistent aspects and the importance of waste audit during the pre-demolition phase. In fact, the adoption of a mandatory pre-demolition audit allows to improve the management of information on the elements and materials existing in a building to be demolished, facilitating the decision-making process around the best demolition sequence and the treatment of subsequent waste flows.

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List of acronyms

ARPAL	*Agenzia regionale per la protezione dell'ambiente ligure*
C&D	Construction and demolition
D.G.R.	*Decreto della giunta regionale*
D.Lgs	*Decreto legisltivo*
D.M.	*Decreto ministeriale*
EC	European Commission
ELoW	European list of waste
EU	European Union
H	Hazardous
ISPRA	*Istituto superiore per la protezione e la ricerca ambientale*
ISTAT	*Istituto nazionale di statistica*
M.O.C.F.	*Microspia ottica contrasto di fase*
MS	Member States

MUD	*Modello Unico di Dichiarazione ambientale*
NACE	*Nomenclature statistique des activités économiques dans la Communauté européenne*
NH	Non-hazardous
PAH	Polycyclic Aromatic Hydrocarbon
PCBs	Polychlorinated biphenyls
SEM	Electron scanning microscope
WFD	Waste Framework Directive

1. Introduction

This thesis shows the results of a research conducted on the different approaches adopted by the 28-EU countries towards the management of waste generated in the process of demolition and construction of structures. The aim is to verify the current distance of Member States from the recycling target of at least 70 % of C&D waste, as required by Waste Framework Directive. In order to monitor the development in regenerative practices to close loops of urban materials and resource flows in the built environment sector, a first step is the assessment through pre-demolition audits of the possibility for removal and reuse of components and building materials.

The first analysis of this study is on the current situation of C&D waste in European Union. According to the latest Eurostat data available for the year 2016, Member States generated a total of 366 Mio.Mg of waste, excluding waste arising from soil and dredging spoil. Non-hazardous C&D waste represents 97 % of the total amount of waste produced, while 3 % is characterized by hazardous waste. The most representative material flow in this context is that of mineral waste and the most commonly used treatment operation is recycling, both for hazardous and non-hazardous mineral waste.

The European potential towards a circular built environment has been assessed by considering recycling as the only option for recovery. Backfilling and energy recovery operations have not been taken into account because they do not directly increase the achieving of the circular economy in the built sector and official statistics suffer from uncertainty. The recycling performance of countries is influenced by drivers/barriers as legislation, data quality, framework and market conditions. These aspects have been evaluated with arbitrary scores in order to obtain a comparison between the recycling performance of each European country and its C&D management capacity.

In this context, the pre-demolition audit phase plays a predominant role. The audit scheme considers the following aspects: quantity and quality of material, contaminations and impurities, state and conditions of elements and materials, monetary value estimation of the reuse components and costs of selective recovery of identified building elements and materials for reuse. In 2018, the European Union published guidelines for the drafting of pre-demolition audit, providing guidance on the objectives and structure; the specific and detailed implementation is decided by each Member State. In some EU countries pre-demolition audit is mandatory, in others voluntary or not performed. A Member States C&D waste audit performance matrix has been created in order to highlight the interaction with the C&D waste recycling percentage and understand how pre-demolition audit influence the whole management performance.

The last chapter describes the current situation in Italy in terms of C&D waste. ISPRA is the organization responsible for collecting waste data and reporting the statistics to be provided to Eurostat. In 2016, the C&D waste generated in Italy was 55 Mio.Mg. After an initial analysis of the legislative context, data quality and treatment of this type of waste, the management and disposal of asbestos-containing materials in accordance with national laws were investigated. In particular, the demolition of the Polcevera viaduct is reported as a case study, highlighting how waste, especially waste containing asbestos, was removed and disposed of during the deconstruction activities. It is also assessed whether a pre-demolition audit, currently recommended only in some Italian regions, can actually improve waste handling, increasing transparency and the possibility of controlling the materials flows in this sector.

2. EU statistics about C&D waste management

The Waste Framework Directive [1] stipulates a legal system for waste treatment in the European Union, designed to protect the environment and the human health. It emphasizes the necessity of adequate techniques to manage, reuse and recycling waste, aimed at reducing resource pressures and improving their use. The Directive has introduced as a target for EU-28 Member States, the recycling and recovery of the 70% of C&D waste by 2020.

Directive 2008/98/EC was amended by Directive (EU) 2018/851. Article 3 of the new Directive [2] introduces the definition of construction and demolition waste, described as ‹‹ waste generated by construction and demolition activities ››; there are also the introduction of the definition of material recovery and backfilling and information about waste prevention and measures to contrast waste generation. Article 11 specifies that ‹‹ Member States shall take measures to promote selective demolition in order to enable removal and safe handling of hazardous substances and facilitate re-use and high-quality recycling by selective removal of materials, and to ensure the establishment of sorting systems for construction and demolition waste at least for wood, mineral fractions (concrete, bricks, tiles and ceramics, stones), metal, glass, plastic and plaster. ››

The Commission Decision of 3 May 2000 [3] established the European list of waste (ELoW). The Waste Framework Directive refers to this classification, based on the sector or process that originate waste. Code 17 characterizes the "construction and demolition waste (including excavated soil from contaminated sites)". According to the Regulation (EC) 2150/2002 [4] on waste statistics, Member States must report statistical data on waste generation and treatment following the statistical waste nomenclature EWC-Stat. The waste generation data are classified by waste categories and business generating activity, referring to NACE activities [5]. For construction sector, the code is NACE F and the EWC-Stat code 12.1 represents mineral waste from construction and demolition. The waste treated values are shown according to waste categories and treatment operations. All the data are reported distinguishing non-hazardous and hazardous waste. Appendix 1 of this study reports the correlation between the EWC_Stat and ELoW for the category 12.1, based on the "Table of equivalence" described in Annex III of the Commission Regulation [6].

2.1 C&D waste generated

Eurostat data reported in the following chapter refers to C&D waste generated in the construction sector (NACE F) in 2016 [7].

The total amount of C&D waste generated in 2016 by 28-EU countries was 366 Mio.Mg, excluding soil and dredging spoil, and it can be classified into three macro-groups of waste:

- Non-hazardous mineral waste, with 313 Mio.Mg;
- Other non-hazardous waste, with 12 Mio.Mg;
- Hazardous waste, with 40 Mio.Mg.

The graph in Figure 1 shows the percentages of each type of waste generated in 2016 in European Union. The inert waste represents the most important material flow arising from the built environment. The percentage of non-hazardous waste is much bigger than that of hazardous waste. However, the environmental impacts associated with hazardous substances is very significant and the correct knowledge of this stream is fundamental in the C&D waste management.

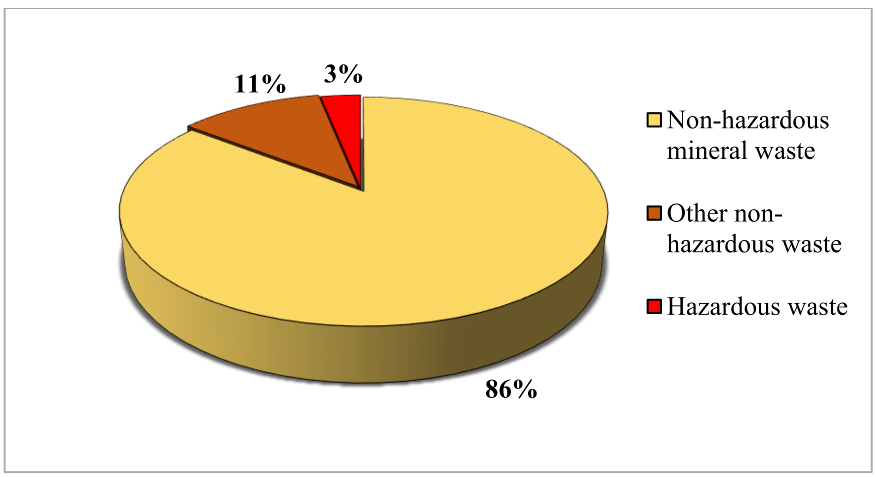

Figure 1: Percentages of C&D waste generated by 28-EU countries in 2016

2.1.1 Non-hazardous C&D waste generated

Concrete, ceramics and bricks represent 90 % of non-hazardous waste generated by Member States in 2016, following by metals with 5 % and wood with 2.5 %.

As shown in the graph below, Germany was the biggest contributor in the total non-hazardous C&D waste production, with 98 Mio.Mg. The red line represents the European average of C&D waste generated and demonstrates that the majority of the countries produced less than 14 Mio.Mg of non-hazardous waste.

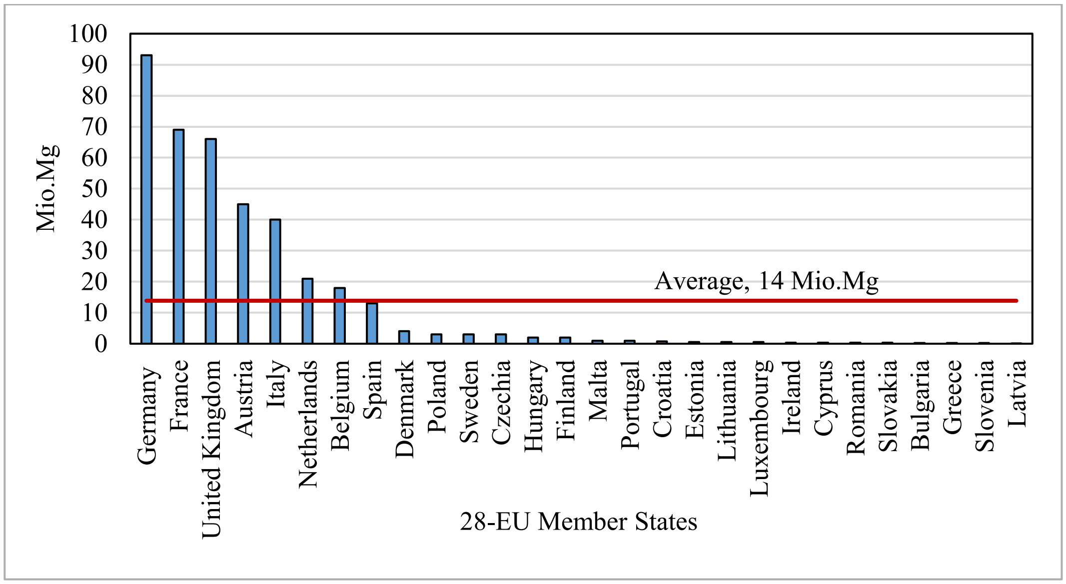

Figure 2: Non-hazardous C&D waste generated by each Member State in 2016

2.1.2 Hazardous C&D waste generated

In 2016, the total amount of hazardous waste generated from the construction sector was 12 Mio.Mg, 3 % of the total C&D waste produced. This stream groups:

- Contaminated mineral waste, 85 % of the total hazardous waste generated in 2016;
- Asbestos containing materials, 13 %;
- Contaminated mixed materials, 1 %;
- PCB containing materials and contaminated wood, less than 1 %

The definition of hazardous mineral waste classified with the Eurostat code 12.1, covers inert, glass, plastic wood containing hazardous substances; coal tar, tarred products; contaminated insulation materials and other hazardous C&D waste (see Appendix 1). It represents the biggest amount of hazardous waste with 9 Mio.Mg in 2016 following by asbestos containing materials (EWC_Stat code 12.2) with 1 Mio.Mg. The other hazardous C&D waste is comparatively not important in terms of masses, but its dangerousness for human health and ecosystem is significant.

The amount of hazardous waste generated by each European country is presented in Figure 3. Germany, Netherlands and France generated a larger proportion of hazardous C&D waste than the European average value, while more than 50 % of European countries produced a quantity of waste close to 0 Mio.Mg.

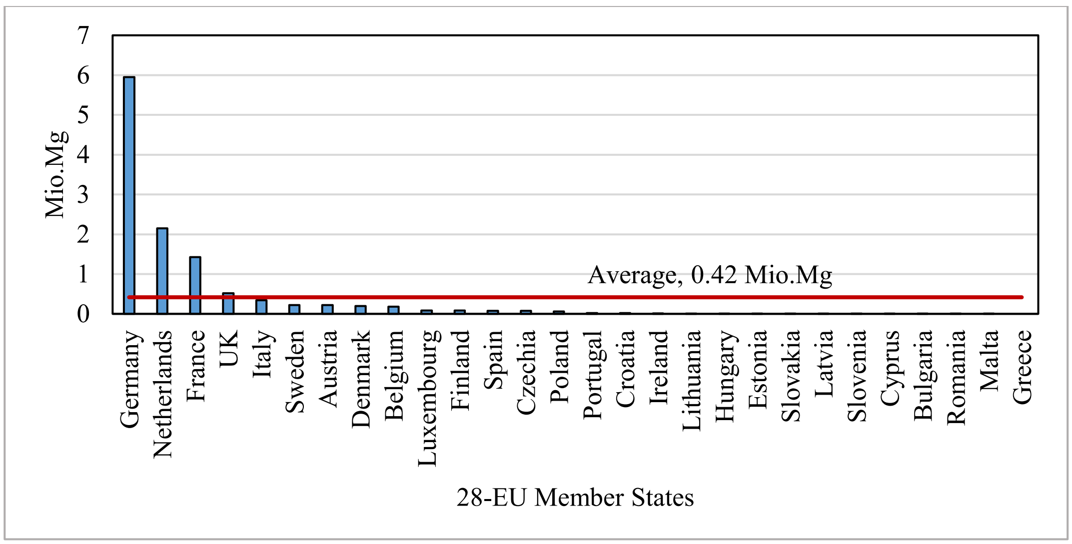

Figure 3: Hazardous C&D waste generated by each Member State in 2016

Considering Eurostat data, each European country reported null values of generated hazardous glass waste in 2016, with the exception of Spain that produced 1 Mg. This is probably due to coding errors linked to the unclear distinction between this type of waste and hazardous mineral C&D waste, described by the Eurostat category 12.1 [8].

There are other cases of absence of registered amount of hazardous C&D waste:

- Bulgaria, Cyprus, Greece, Latvia reported null values of contaminated mineral waste from the construction sector (12.1);

- Ireland, Greece and Romania reported null value for asbestos containing materials;
- 36 % of European countries reported null values of hazardous containing PCB waste;
- Greece didn´t generate hazardous waste in the built sector in 2016.

These anomalies are presumably caused by underestimation or underreporting. This aspect will be deepened in next chapters.

2.2 Mineral C&D waste treated

In the built environment, recycling, energy recovery, backfilling and landfilling or other disposals are the waste management operations considered according to Eurostat Database. The Directive 2008/98/EC gives the next definitions:

- «'recovery' means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy. […]
- 'recycling' means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations; […]
- 'disposal' means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. »

The waste category analysed in this chapter is the 12.1 "Mineral waste from construction and demolition" [9], because it represents the biggest waste stream in the built sector, as seen in the previous chapters. The reference year is 2016.

2.2.1 Non-hazardous mineral C&D waste treated

In 2016, most of non-hazardous mineral waste produced during construction and demolition works were recycled.

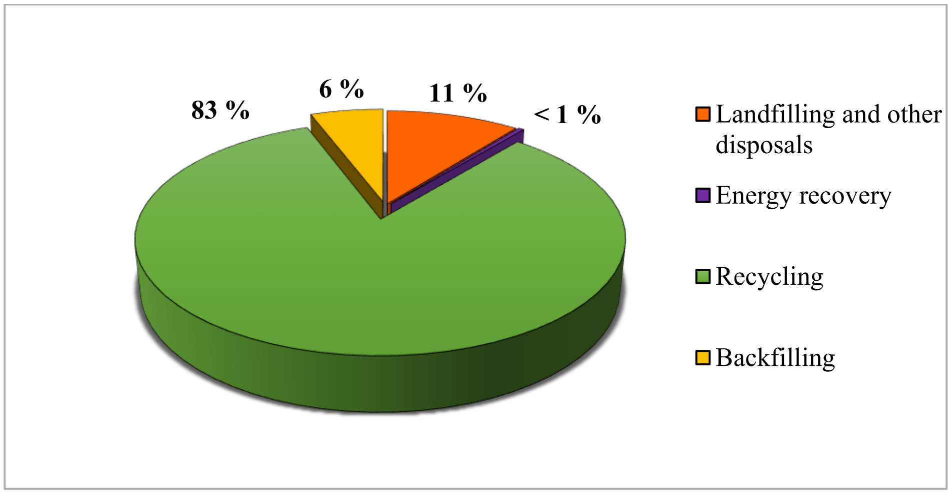

Figure 4: Mineral C&D waste treatment operations in EU in 2016

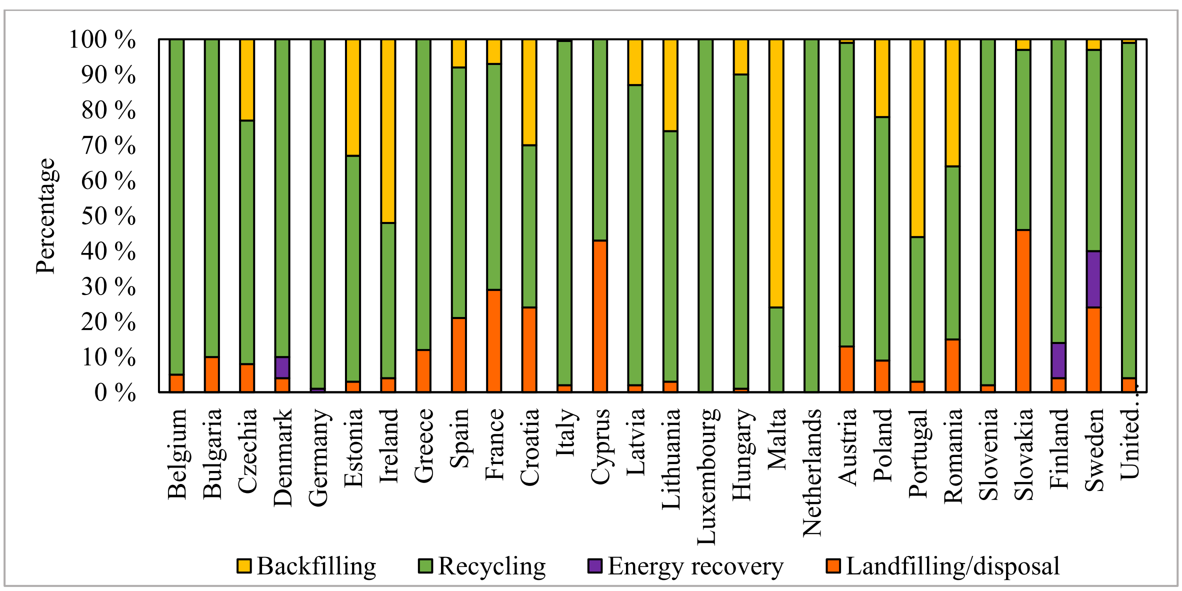

Figure 5: NH waste management summary by Member States in 2016

As shown in Figure 5, recycling is the primary treatment method in most of the European countries. In particular, Member States with the highest recycling rate are the same with best practice in terms of C&D waste treatments [8]. In 2016, Netherlands, Luxembourg, Belgium, Italy, Slovenia and United Kingdom recycled more than 95 % of treated mineral waste. This waste category is recycled to produce secondary raw materials, used as road materials or in foundations. The landfilled amount of C&D mineral waste was less than the 50 % in each country, but it was anyway significant in States like Slovakia and Cyprus. Energy recovery is the solution less used for the inert waste treatment. In the reference year, Sweden recovered energy from 15 % of the mineral waste treated, following by Finland with 10 % and Denmark with 6 %. In Malta, the most common treatment operation is backfilling; here, the backfilling rate was equal to 76 % in 2016. Portugal and Ireland backfilled more than 50 % of mineral waste treated, while 30 % of Member States did not use this kind of treatment operation.

2.2.2 Hazardous mineral C&D waste treated

In 2016, hazardous C&D mineral waste were mainly recycled, whereas landfilling was chosen as a second option, as shown in Figure 6. It is interesting to note as the percentages of backfilling and energy recovery are inverted compared to those referred to non-hazardous waste.

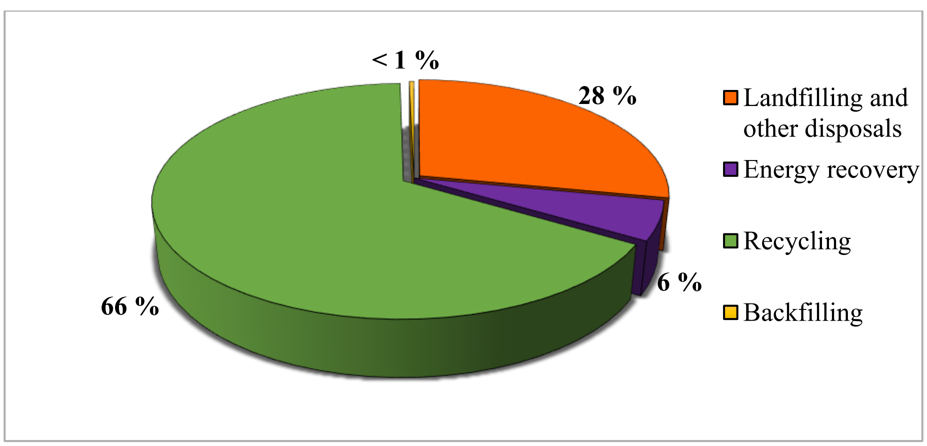

Figure 6: Mineral C&D waste treatment operations in EU in 2016

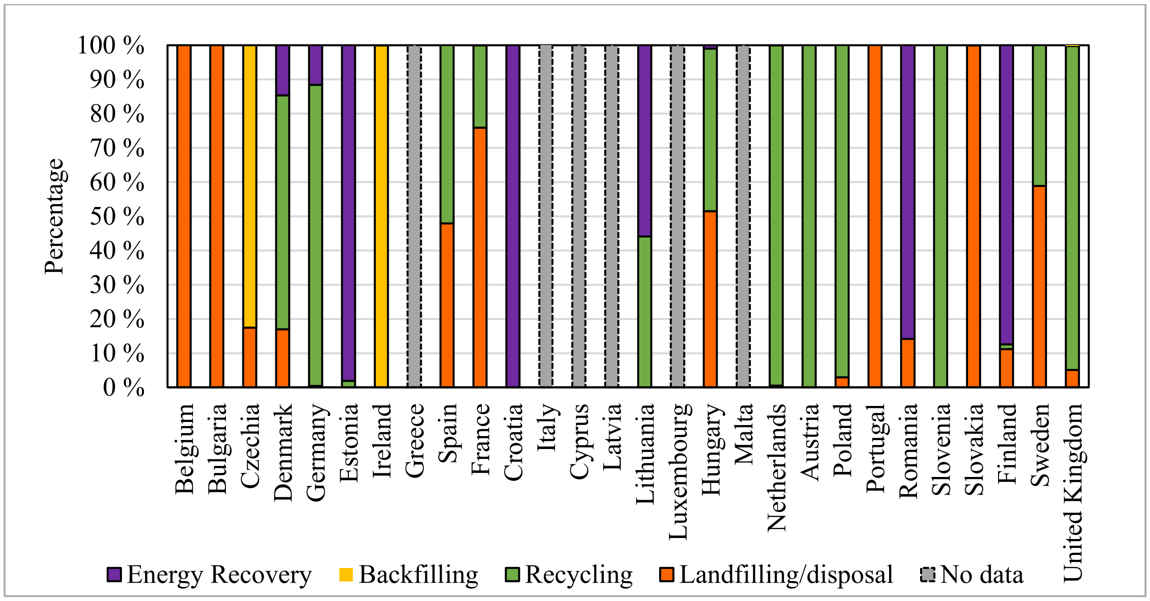

Figure 7: NH waste management summary by Member States in 2016

Figure 7 shows the percentages of waste management methods used to treat hazardous mineral waste by each Member State for the year 2016. Cyprus, Greece, Latvia, Luxembourg and Malta did not reported values of hazardous waste treated. Belgium, Bulgaria and Slovakia landfilled all the treated waste, while in Croatia, Estonia, Romania and Finland the primary treatment method is energy recovery. Countries with a mature legislation on C&D waste, as Denmark, Germany, Austria, United Kingdom recycled more than 90 % of hazardous mineral waste treated.

3. Current C&D waste management in MS

European Directive 2008/98/EC established that the target for preparing for re-use, recycling and other types of material recovery, including backfilling operations using inert waste as a substitute for other materials is 70 % by weight. According to 2016 waste statistics, only two countries do not reach this goal, whereas the European average value is 90 %, as shown in Figure 8.

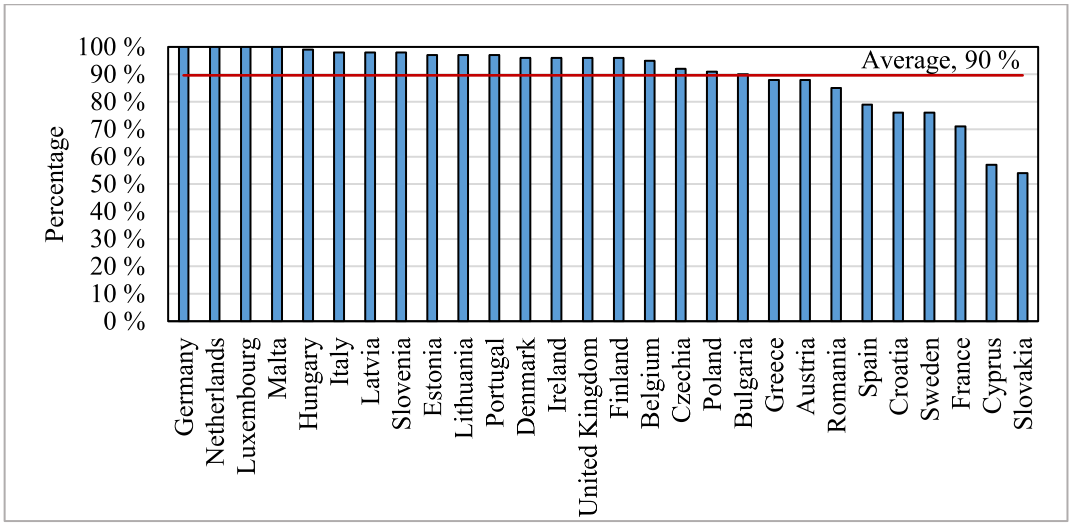

Figure 8: Recovery rate of NH C&D mineral waste in 2016

3.1 Backfilling rate

Directive (EU) 2018/851 [2] defines backfilling as « any recovery operation where suitable non-hazardous waste is used for purposes of reclamation in excavated areas or for engineering purposes in landscaping. Waste used for backfilling must substitute non-waste materials, be suitable for the aforementioned purposes, and be limited to the amount strictly necessary to achieve those purposes. ». The C&D waste recovery target imposed by Waste Framework Directive allows Member States to consider also backfilled waste into the computation of their national C&D waste recovery rate. In Annex II of Directive (EU) 2018/851, the category R5 includes the recycling and recovery of inorganic materials different from metals and includes those prepared for re-use, recycling of construction materials, backfilling and soil cleaning.

The following diagram shows the recovery rate of non-hazardous mineral waste produced by construction and demolition activities, including or excluding backfilling.

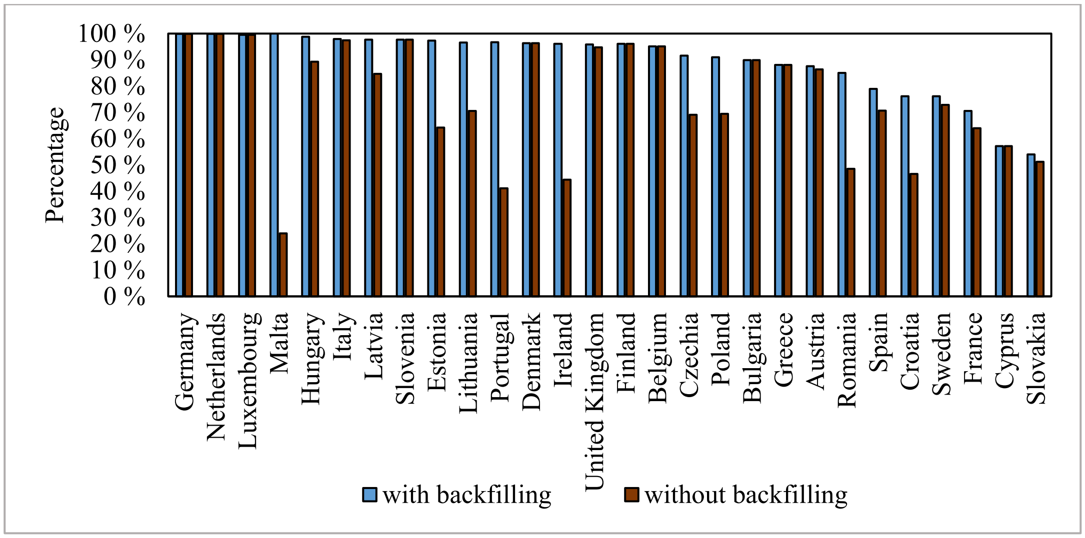

Figure 9: Recovery rate of NH mineral C&D waste in Member States in 2016

In countries as Germany, Belgium, Denmark, Italy, Luxembourg, Netherlands, Slovenia, Finland, United Kingdom the recovery rate registered in 2016 is over 95 % also without backfilling. Romania, Estonia and Croatia backfilled respectively 36 %, 33 %, 30 % of the total amount of mineral waste recovered. Portugal and Ireland backfilled more than 50 % of recovered mineral waste. In these countries, it is the primary C&D waste management method used to meet the WFD target. In 2016, Malta registered a mineral C&D waste recovery rate of 100 %, but 76 % is characterized by backfilling. Here, the reaching of the EU recovery target is based to a large extent on backfilling of C&D waste.

3.1.1 Interpretation of backfilled data

Despite the introduction of the definition of backfilling in the new Directive, some experts question this kind of recovery operation because there is an improper estimation of C&D waste backfilled data [10]. The consequence is the lack of a harmonized application of this recovery method. The waste hierarchy defined by the Waste Framework Directive collocates recycling before backfilling and specifies that Member States should promote measures to obtain high-quality recycled materials. This is in contrast with the definition of backfilling that is not a high-quality recovery process. Some studies have excluded this management method from C&D waste recovery target because it is not clear if backfilling is considered as a recycling operation or as a low-quality recovery. Overall, there is an uncertainty linked to official C&D waste statistics, which also raises a difficulty to make a proper comparison between Member States waste handling methods. The "EU Construction & Demolition Waste Management Protocol" [11] suggests backfilling as the last C&D waste recovery option because the materials should be pre-treated to avoid environmental impacts.

The inclusion of this operation within the WFD target allows 28-EU countries to achieve a recovery rate of 70 % by maintaining a low recycling rate and masking the landfill as backfilling. With reference to 2016 data, if backfilling quota was excluded from the definition of recovery rate, Malta, Estonia, Portugal, Czech Republic, Poland, Romania, Croatia, Cyprus, Slovakia would not achieve the objective imposed by the Directive.

3.2 Recycling rate

Construction and demolition activities generate the most amount of waste. However, it is also one of the sectors with the highest recycling potential. The most recent data provided by the Eurostat Database refer to the year 2016 and shows that lot of Member States recycled a high percentage of non-hazardous mineral waste. The European average value is 74 %, above the target fixed by the Waste Framework Directive; however, in some countries the recycling rate for this waste is still below 50 %, as highlighted in Figure 10.

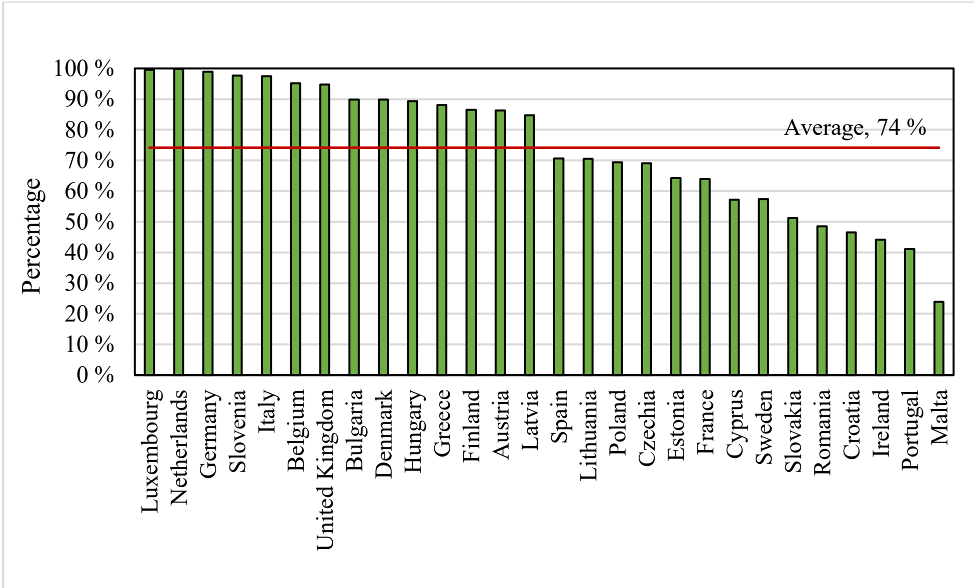

Figure 10: Recycling rate of NH mineral C&D waste in MS in 2016

In this study, only recycling was considered as a treatment operation to be improved in order to achieve a circular economy in the built sector. In fact, among the treatment operations mentioned by Eurostat Database, recycling is the only one that really allows the achievement of this target. Data from recycling plants are seen to be more reliable than data from backfilling operation that is not a high-quality waste treatment. Energy recovery from non-hazardous mineral waste incineration is just used in the Nordic countries (Denmark, Finland, Sweden and Germany) as a recovery operation, but in small percentages and it is probably used mainly for insulating materials that are considered into the Eurostat category 12.1. For these reasons and for those mentioned in the previous paragraph, backfilling and energy recovery have been neglected in the analysis of this report.

3.2.1 Influencing factors

The main barriers or drivers to recovery performance of C&D waste in the 28-European countries are due to several reasons linked to data quality, legal, framework and market conditions that characterize the current European situation.

DATA QUALITY

The Regulation (EC) No 2150/2002 on waste statistics establishes the framework for the production of harmonized Community statistics on waste. Starting with the reference year 2004, the Regulation requires EU Member States to provide data on waste generation, recovery and disposal every two years. «The Regulation defines the data to be submitted and the quality required, but does not stipulate a specific method of drawing up waste statistics, which are thus compiled in a multimethod environment. [..] In their quality reports, Member States describe their data by referring to quality elements commonly used in the European Statistical System and set out in Regulation (EC) No 1445/2005 on the quality of waste statistics. » [4] This means that 28-EU countries are free to use their own administrative sources or surveys to collect data and to complete their quality reports, while the classification used is the same. Each Member State refers to his existing methodology and survey to provide C&D waste generated and treated data. The report defines also how the data quality analysis is checked. However, the heterogeneity of C&D waste data collection does not allow conducting a direct comparison between the several Member States. The reported values validation is liability of Eurostat and 28-EU countries authorities.

Data collection methods that include surveys, administrative sources and statistical estimations are set by each Member State. This means that the reported data are difficult to compare and that some methodologies are more robust than others. Despite the use of a single classification, the quality of the Eurostat data is strongly influenced by the quality of the sources and methods used to collect them.

LEGAL CONDITIONS

Legal and regulatory aspects are one of the most important points to understand the great differences between Member States as regards generation and treatment of C&D waste [8]. As a whole, Eurostat data show a higher C&D waste management performance in countries with a robust, clear and specific legislation. Legal weakness hinders the achievement of a high waste recovery target. Member States applied C&D legislation in several periods, with dissimilar specificity, and a different approach in its application. Furthermore, the current legislative state shows that in most European countries environmental issues are regulated and inspected by local authorities.

The level of implementation of C&D waste policy and the diversion of waste from landfill depends heavily on legal enforcement degree and fiscal measures adopted by each country. All these aspects have a negative or positive influence on C&D waste management performance of Member States.

FRAMEWORK AND MARKET CONDITIONS

The profitability of C&D waste recycling depends also on the entity of the treatment capacity of each Member State and the presence of a robust market for recycled products. The scarcity of recycling facilities, the infrastructures inadequacy along with the knowledge environmental gaps and the lack of experience and competence obstacle the European movement towards zero waste. Time, contractual requirements, cost of transport and cost needed to separate waste streams are other central factors that do not bring construction companies to promote reuse or sorting demolition. The sorting rate is directly linked to space conditions, need for more labour and costs, complexity of buildings and presence of many composite materials.

The Government has a fundamental role in this field, not only from the financial and legal point of view but also through the development of quality assurance systems for recycled materials such as certification procedures and the increase of control practices for the traceability of materials. These aspects directly influence the development of the recycled materials market and the companies involved confidence in the requirements of these materials.

3.3 Pre-demolition audit

Pre-demolition audit can be considered a first step towards recycling and appropriate C&D waste management. The aim of this first step is to collect information on the elements, the quantities, possible treatment path of the building materials. It can be used for planning and optimizing deconstruction following the five-tier hierarchy, based on giving priority to the most environmentally operations and defined in the Article 4 of the Waste Framework Directive.

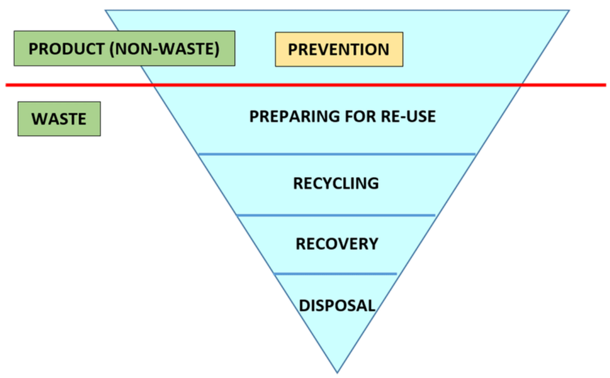

Figure 11: Waste management hierarchy defined by European Commission [12]

In 2018, the European Commission published the European Waste Audit Guideline [13], based on the DG Grow final report [14]. This Guideline provides information about the best way to structure the "waste audit", based on the evaluation of the C&D waste flows deriving from demolition, construction, renovation of a building or infrastructure. The Figure 12 represents the recommended scheme for the pre-demolition audit process.

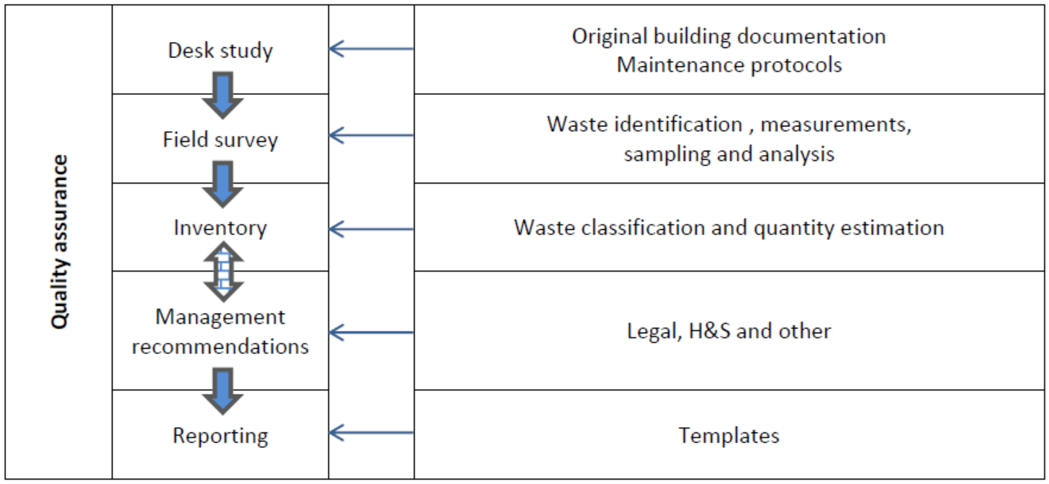

Figure 12: Scheme of waste audit [13]

The *desk study* consists on the analysis of the documentation concerning the building to be demolished. The aim is to collect projects, site drawings, maintenance and renovations documents to understand the data of the building realization and the construction methods used. During this phase, it is important to comprehend the type of materials, installations and furniture and their location for planning the field survey and for complete the materials and elements inventories. The knowledge of the age of the building and the restructuring is essential to recognize possible hazardous materials. Swedish [15] and Austrian [16] guidelines provide a list of structural and non-structural elements that can contain hazardous substances. It could be used as an aid to evaluate and quantify the hazardous elements found in site and to prevent safety issues during the field survey. The accesses and the surroundings can give information about the conditions for storage, transport and management of the waste streams.

The *field survey* allows to inspect visually all the parts of the site to be demolished. In this phase, the experience of the auditors is essential to collect data useful for the inventory. Sampling and laboratory analyses are requested for suspicious hazardous materials. During the site visit, it could necessary to evaluate the nature, the condition and the amount of the materials also through non-destructive and destructive techniques. The European Guidelines give examples of techniques that could be needed. In addition, to ensuring consistency between data retrieved during the desk study and those investigated in site, it is a good practice to take picture and measures that will be included in the final inventory and to inspect the building when it is no longer occupied.

The *inventory* is based on desk study and field survey and repots the materials and elements assessment, in order to decide the best waste management operation. It includes the type and quantification of waste arising from the demolition, their European waste code and description. It is important to extent this study to all levels of the building, to understand the location of each type of material, mostly those hazardous.

« The waste audit can be completed with *recommendations* on how to perform waste management on site » [13] as national and regional conditions for the removal and management of hazardous materials, reuse and recycling possibilities, conditions for storage, transport, treatment and safety plans.

The *final report* must summarize the information collected during the desk study, the site visit and must describe:

- The scope and the characteristic of the project, the site location and history;
- The list of documents available and summary of management recommendation;
- The summary of the waste audit and the explanation of the techniques, sampling and laboratory analysis used during the site visit;
- The inventory of materials, waste fractions arising from demolition, the list of hazardous waste and the description of precautionary measures to be applied.
- The inventory of elements with reference to the quantity, quality conditions and potential reuse rate.

The documents studied provide templates that can be used to complete pre-demolition audits.

4. Evaluation of C&D waste management in MS

This chapter shows the research methodology and the results deriving from the evaluation of the different behaviours of the Member States with respect to C&D waste management.

4.1 Research methodology

The most important source of this study is *Resource Efficient Use of Mixed Wastes* led by Deloitte for the European Commission, in association of some of the most significant research groups in the built environment. In addition, the reports that highlight the C&D waste management by each EU country, have been consulted.

The macro-factors that influence the C&D waste management performance of MS are data, legislation, framework and market conditions, as already mentioned. These were divided into sub-groups in order to highlight the major barriers for each country. Also, they were classified with scores from 4 (high) to 1(poor), as shown in Table 1. These scores are arbitrary and based on literature sources.

Table 1: Meaning of the scores for each considered category

MOST INFLUENTING FACORTS		SCORES			
		4 (HIGH)	3 (GOOD)	2 (MODEST)	1 (POOR)
DATA	**Quality and methods**	Robust methodology: best practice for data collection and reporting.	Clear and consistent waste collection and reporting. Good data quality.	Lack of accuracy and statistical control of reported data.	Not consolidated systems of data collection; absence of quality checks and control.
	Material traceability	Detailed systems with specific statistics on waste, in compliance with legislation.	Developed system for tracking C&D waste along the process chain.	Lack of waste generation control regarding type of materials or type of company.	Large quantities of un-tracked waste. Lack of data transparency and reporting.
LEGISLATION	**Maturity and specificity**	Advanced and optimized legislation focused on all themes of legislation.	Specific legal framework for the C&D waste management.	C&D waste management laws with gaps and terminologies issues.	Responsibilities not clearly defined; lack of laws specific to C&D waste management.
	Application and fiscal measures	Tax and ban on landfilling. Strict rules to avoid illegal dumping.	Development of a taxis system. Adequately invested resources.	No implementation of existing legal framework. Sanctions rarely applied.	Lack of inspections and legal actions to contrast illegal practices.
	Harmonized national laws	Absence of contradictions between national and regional legislation.	Limited contradictions between national and regional legislation.	Controversial concepts, different interpretation between regions.	Lack of coordination between different region laws.
FRAMEWORK AND MARKET CONDITIONS	**Treatment capacity**	Capacity to treat also non-household waste.	Sufficient capacity to treat household waste.	Sufficient capacity to treat household waste, but mainly ending to landfills	Lack of treatments plants and landfills to dispose inert waste or hazardous waste.
	Economic incentives	Regulatory, financial incentives and projects to extend the circular economy.	Regulatory, financial incentives and further research to improve C&D waste management.	Investment sources insufficient and lack of pro-active initiatives.	No economic incentives and public procurement for C&D waste recycling.
	Secondary materials market	Robust market. Great confidence in recycled materials quality.	Programs that support this sector and that improve stakeholders´ mentality.	Lack of confidence in high-level recycled products and limited market demand.	Lack of interest at Government level and absence of market demand.

4.2 Results of collected data

Table 2 shows the matrix correlating the most influencing factors in C&D waste management and consequently the recycling rate and the attitude of each country towards them. Some countries have predominantly high scores while others are at an early and growing level.

Table 2: Member States C&D waste management performance matrix

MS	DATA		LEGISLATION			FRAMEWORK AND MARKET CONDITIONS		
	Quality and methods	Material traceability	Maturity and specificity	Application and fiscal measures	Harmonized national laws	Treatment capacity	Economic incentives	Secondary materials market
AT	4	4	4	3	4	3	2	2
BE	2	3	4	3	1	3	3	3
BG	2	1	2	1	1	1	1	1
HR	2	1	1	1	3	1	1	1
CY	2	1	3	1	3	1	1	1
CZ	3	2	2	2	4	3	2	1
DK	3	3	4	4	4	3	3	2
EE	3	1	2	2	3	3	1	1
FI	2	3	3	4	4	4	4	2
FR	3	3	4	2	3	1	1	2
DE	4	4	4	3	2	4	4	2
EL	2	1	3	1	3	1	1	1
HU	3	2	2	2	2	1	1	1
IE	1	1	4	2	4	3	2	2
IT	2	2	3	2	2	3	2	1
LV	1	1	1	1	2	1	2	1
LT	3	1	2	1	3	1	1	1
LU	3	3	3	3	3	1	1	1
MT	1	1	1	1	3	1	2	1
NL	4	4	4	4	2	4	3	2
PL	4	2	1	1	3	2	1	1
PT	4	1	3	1	3	3	2	1
RO	1	1	1	1	2	1	2	1
SK	4	2	2	1	3	1	1	1
SI	3	2	3	2	1	1	2	2
ES	3	3	3	1	2	4	1	1
SE	2	3	4	3	4	2	3	2
UK	3	3	4	4	4	1	4	3

The graph in Figure 13 shows the influence of the aspects considered in this study on the recycling rate of non-hazardous C&D mineral waste provided by Eurostat for the year 2016. The ordinate axis shows the sum of the arbitrary scores derived from Table 3 because each factor influences and interacts with the others and no action alone can reduce waste generation, improve waste management and increase recovery rates.

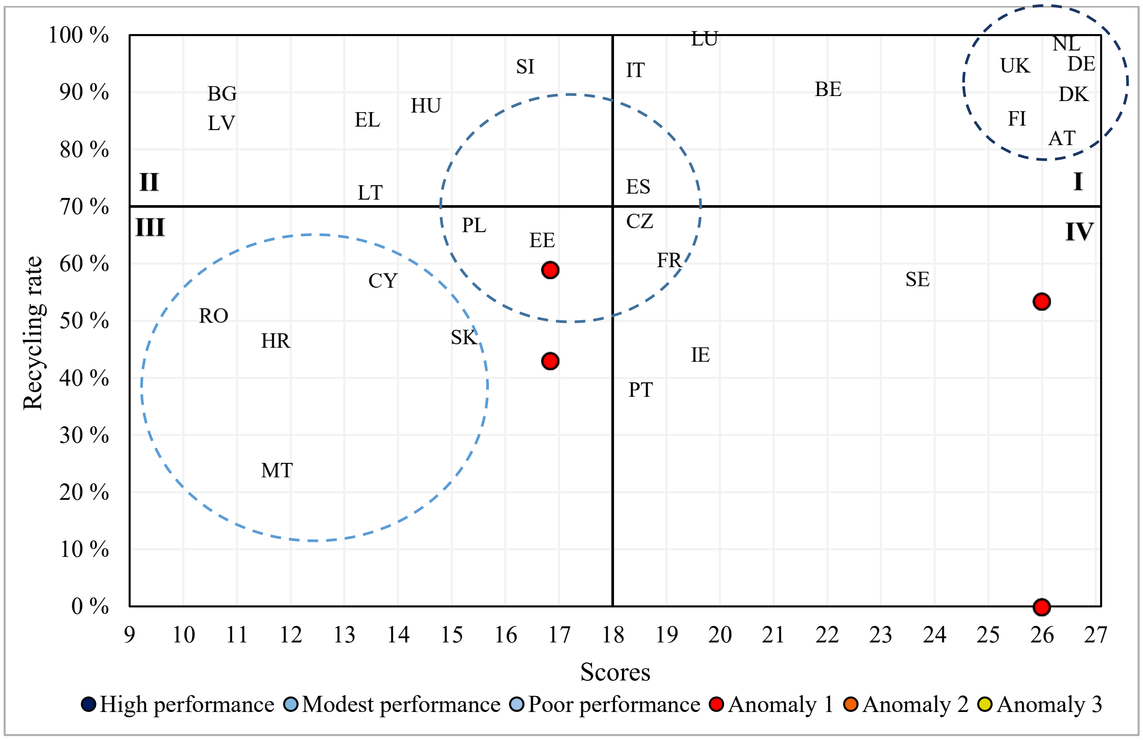

Figure 13: Interaction between C&D recycling rate and management performance of each MS

• In the graph above, it is possible to distinguish three groups of Member States with a quite coherent behaviour between the two considered parameters:

- Countries with high recycling performance in terms of data collection, maturity of legislation and treatment plants (dark blue dots). As reported in Appendix 2, these countries are also those that collect and report more than 10 Mio.Mg C&D waste generated per year;
- Member States that have a modest recycling rate and limited performance in C&D waste management, market and treatment (blue dots);

- Member States with a recycling rate lower than 70 % and that are still at an early stage in terms of sourced administration and waste handling (light blue dots). These countries, as described by the graphs in Appendix 2 reported a total amount of non-hazardous mineral waste from C&D lower than 1 Mio.Mg in 2016.

Countries as Austria, Germany and Netherlands established a robust data collection methodology and a standardized and efficient waste tracking. The Austrian Waste Management Act (AWG) obliges waste owners and treatment facilities to register type, quantity, origin and location of waste. Hazardous waste generated must be reported and all waste data are transmitted to the Electronic Data Management System [17]. Germany adopted an input-oriented approach: treatment facilities report the quantities of waste to the statistical offices of the individual *Länder*, which send the statistics to the Federal Statistical Office. Furthermore, in Germany the quality control is verified by external organizations [18]. Instead, in those countries as Romania and Malta and that are lagging behind in the adoption of more consolidated systems, the quality of the data is reflected in the C&D waste recycling performance [8].

Austria, Denmark, Germany and UK have developed specific and mature legislation on C&D waste that investigates all the aspects that lead to an improvement in the management of such waste. The achievement of the circular economy in all sectors is a primary objective for German companies, scientific institutions and political authorities. The Economy Act 2012 promotes the adoption of the circular economy to protect human health and the environment from the impacts caused by waste production and management. In accordance with the priorities defined by the five-tier waste hierarchy, Germany focuses research and funding on the prevention and recycling of high-quality materials [19].

Member States with the strongest waste management system are those with a recycling target that overcomes 90 %. The real strength of these countries is represented by the enforcement measures applied at national or regional level. The authorities monitor and apply specific penalty to avoid illegal landfilling. Netherlands, Belgium and Denmark, for example, instituted the landfill ban to reduce the amount of waste disposed and to improve reuse and recycling, the higher levels of the waste hierarchy. Romania, in the other hand, has a waste policy not specifically applied to C&D waste. In Poland, demolition companies do not consider the C&D waste management a priority because of the lack of a robust legislation and Spain or Bulgaria are characterized by contradictions between national and local administration [8].

The influence of the lack of harmonized national laws on the C&D waste collection and management can be proved with the example of Belgium. In this country, there are several differences that characterized the legislation among its regions. The Federal Government has limited responsibilities in the environmental management field but all regions have adopted a specific and mature legal framework for C&D waste recovery. The three regions and the Federal public administration are working closely together to try to improve this situation but the lack of a harmonized legislation still represents an obstacle [20]. As shown in Figure 36 of Appendix 2, despite the fact that Belgium generates about 20 Mio.Mg of non-hazardous mineral waste, it treats just 2 % of it. The main cause is the discrepancy between the three regions' policy. The Flemish Region uses a robust data collection methodology and the materials tracking systems can be considered example of best practice. *Tracimat* is a system from Flanders that certifies the selective demolition process and, through a detailed traceability system, examines what happens to the waste that derive from demolition. In this region, pre-demolition audit is mandatory. In Brussels Capital Region, C&D waste data collection system presents some limitation as double counting and generated waste values based on hypothesis. The sources highlight as barriers also the lack of data reported as being treated as those on site recycled and internal recycling. In this region, mineral waste is exported for treatment. In Walloon Region, the statistics about C&D waste are not complete [20]. The general C&D waste management in Belgium is very good, but still a little far from that shown by countries such as the Netherlands, Germany and United Kingdom.

Another influent point is the treatment capacity of each Member State. The term “treatment” includes processing plants and landfills for inert, non-mineral non-hazardous waste and hazardous waste. Countries with a high C&D waste recycling performance both in terms of collection and treatment as Austria, Germany, Finland can treat more waste than self-produced. Figure 14 illustrates the spread of the processing plants that treat one or more waste streams in Austria [17].

Federal Province	Plants
Burgenland	12
Carinthia	23
Lower Austria	88
Upper Austria	75
Salzburg	39
Styria	46
Tyrol	103
Voralberg	20
Vienna	12
Austria (2013, total)	**418**

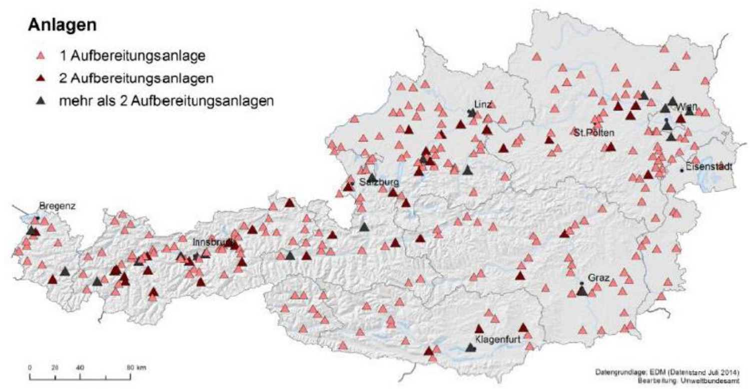

Figure 14: C&D waste plants in Austria in 2013 [17]

In Poland, where the C&D waste performance is modest, the treatment capacity is sufficient to treat C&D waste produced domestically but it is possible to note that it depends mostly on the presence of landfills. Figure 15 shows the number of landfills for hazardous, non-hazardous inert waste and non-inert waste, the number of glassworks and cement plants in Poland in 2009 [21].

Figure 15: Polish C&D waste plants in 2009 [21]

In Luxembourg, where the recycling quota is 100%, the real problem is the lack of space, which results in lack of treatment plants and landfills. In Figure 13, Luxembourg is in the first quadrant, but behind the other Member States because of the low scores registered in the field "framework and market conditions". The absence of treatment facilities causes the non-use of recycled materials and the researches in this field are not encouraged. Figure 16 shows the limited presence of inert waste landfills in this country [22]. Eurostat data (Figure 7) report null values of hazardous mineral waste treated in Luxemburg in 2016. Here, all the hazardous waste is exported because of the absence of landfills for this material stream.

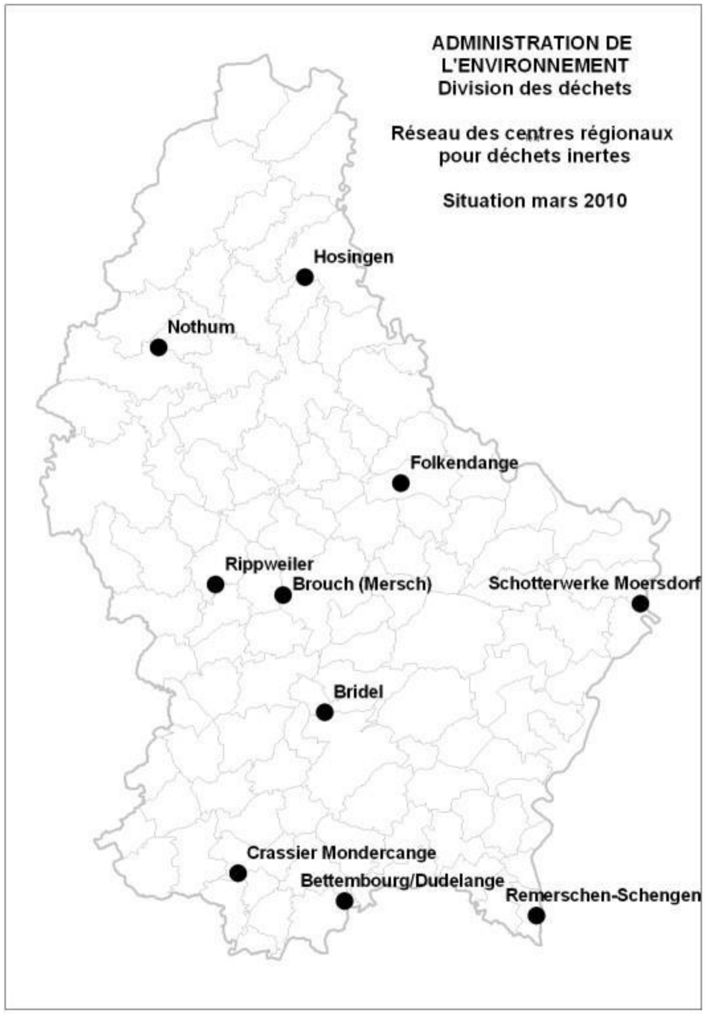

Figure 16: Landfills for inert waste in Luxembourg in 2010 [22]

Croatia, Romania and Slovakia suffer from a lack of infrastructures and facilities to cope the current production of C&D waste. In addition, the transport costs are high. In Malta, there are no landfills for hazardous waste. This explains the reason why Eurostat data report 0 tons of mineral and hazardous waste treated for each treatment operation in 2016. In addition, Malta prefers backfilling as an inert waste handling operation and non-mineral waste is exported due to the lack of facilities. In France, one of the main barriers for achieving good C&D waste management performance is the absence of treatment plants and a low territorial network. The consequences are the grow of illegal practices and a modest C&D waste management performance despite the high scores in terms of data quality and legislation [8].

• The red points in Figure 13 represent Member States that achieve a high recycling rate, but they still seem to be at a growing stage in the built field. These “anomalies”, as shown by the scores in Table 1, are probably due to underestimation or under-reporting issues of C&D waste generated or confusion in reporting those treated. Apart from economic incentives and market reasons, the fields that have the lowest score in all these countries are material traceability, application/ fiscal measures and treatment capacity. There are issues in the collection and reporting of C&D waste generated; legislation is characterised by several gaps and contradictions and the obligations and penalties are not sufficient to encourage the respect of the law. Greek legislation is specific on C&D waste management, but an effective application of it does not exist. In this country, the obligations to report data refer mostly to treated quantities. Unclear responsibilities and the lack of control reinforce illegal landfilling that is a big problem in these countries. Another aspect is the limited presence of C&D waste management industries. Greece and Latvia do not have sufficient landfill capacity for this type of waste [8]. This explains the absence of data regarding the mineral hazardous waste treated in these Member States for the year 2016.

The orange dots in Figure 13 characterize Italy and Slovenia, where more than 95 % of non-hazardous mineral waste was recycled in 2016. The scores shown in Table 1, however, illustrate a modest maturity level in C&D waste management. Italy suffers from a problem of underestimation of waste generated and there is not a legislation specific on C&D waste management, as described later in chapter 7. In 2016, Slovenia reported a recycling rate of 98 %, which is very high compared to the interest and level of C&D waste handling shown by the Government and stakeholders. The main barriers to sustainable management are linked to: poor quality of the data reported; quantities of waste inadequately registered; presence of illegal landfills; lack of correspondence between the various decrees regulating waste management.

For the countries that characterize the second quadrant of the graph in Figure 13, the good results in terms of recovery and recycling rate do not constitute a driver for improving legislation on C&D waste management. The high recycling rate declared seems to be an obstacle to the adoption of a more specific legislation, stricter control measures and the support of economic incentives. Considering fixed the recycling rate values reported, with an increase in C&D waste management performance these countries would move horizontally towards the first quadrant. However, it could be possible that, with the adoption of a more mature legislation and a better data collection methodology, these countries may fall vertically in the graph, because of a decrease of the recycling quota; in fact, the actual methodologies used for data collection are mostly based on hypothesis and lot of these countries suffer from illegal landfilling.

• The yellow dots in Figure 13 indicate Member States that have a good C&D waste management performance score; however, they report relatively low statistics of recycled mineral waste.

In Sweden, the recycling rate is still low, while waste management and administration are very good. According to the sources analysed, this discrepancy is mainly due to errors in reporting data, problems with the interpretation of the target set by the European Directive and the C&D waste treatment operations used. Here, 15 % of non-hazardous mineral waste, probably mostly insulation materials, is incinerated in plants where energy is recovered; recycling facilities are sufficient to treat domestically generated waste while there is an overcapacity of incinerators. Additionally, in places where the population density is poor waste generated is low and consequently is not treated with advanced recycling technologies; here, C&D waste are down-cycled or disposed in landfills [23].

According to Eurostat data, in 2016 Ireland recycled only 44 % of the mineral waste treated and treated almost twice as much as the C&D waste generated (Appendix 2). The waste generated is collected through surveys and the data quality is characterized by some gaps and errors. In addition, sources show that licensed companies do not report 100 % of the generated waste from construction and demolition practices. This aspect and the presence of a temporary storage where waste is deposed for long time and not reported in the national database, could explain the divergence between C&D waste treated and generated. The reason of the low recycling rate is mostly that in Ireland the primary treatment operation for non-hazardous C&D mineral waste is backfilling (52 %) [24].

In Portugal, there is a specific legislation on C&D waste management and the inspection rules are well specified, but there are also contradictions in some legal concepts and definition. Portugal have established a robust and concrete data collection methodology, but suffer from a lack of a valid data tracking system [25]. This combined with illegal practices and the lack of controls leads to a reduction in the amount of C&D waste recycled. Furthermore, in Portugal 56 % of non-hazardous mineral waste is backfilled.

These three countries, with the adoption of recycling as primary C&D waste treatment operation and a better data collection methodology, would increase the recycling quota and move vertically towards the first quadrant of the graph in Figure 13.

Table 3 shows the sum of the scores given to Member States for each category analysed.

Table 3: Scores deriving from Member States performance

FACTORS	SCORE	POSITION
Data quality and methods	74	GOOD
Material traceability	59	MODEST
Maturity and specificity of laws	77	GOOD
Application and fiscal measures	57	MODEST
Harmonized national laws	78	GOOD
Treatment capacity	58	MODEST
Economic incentives	54	MODEST
Secondary materials market	41	POOR

Categories described as “good” are those with a total score higher than 70. Obviously, the reason of these values is linked to high scores reported in these categories by some Member States. It also observed that the lowest result is represented by the category “secondary materials market”. The issue of marketable recycled C&D waste is mainly associated with the absence of information and/or certification on the mechanical performance of recycled products and the lack of financial support or other incentives from public and private sources to improve the secondary materials market. There is also scepticism towards potential human health risks and the environment. The development of a recycled products market is also hampered by other factors:

- The transport over long distances requires high costs and affects negatively the environment;
- The cost of emerging technologies is often bigger than the cost of the technologies currently used;
- Recycling costs are higher than disposal costs.

The creation of a market for recycled and reused materials and the increase of the demand for these products depend heavily on the existence of appropriate environmental legislation and policies. A robust long-term government policy stimulates investment on the C&D waste recycling field and increases investors´ confidence in the quality of these materials. Therefore, this factor will grow in accordance with the development of all the others. In particular, the aspects that would be increased are those with the score “modest” that depend on the role of public authorities and that allow to lay the groundwork for the achievement of the circular economy in the built environment.

5. Evaluation of waste audit approach by MS

Pre-demolition audit is a tool from which Member States should start to try to achieve the C&D waste goal imposed by the Waste Framework Directive.

5.1 Research methodology

Arbitrary scores were assigned to the variables shown in Table 4 to highlight the influence of the pre-demolition phase on C&D waste management of Member States. These were chosen considering the mandatory pre-demolition phase on a national and local scale, its specificity and application. The countries with the highest score apply a national mandatory waste audit following the requirements established by European Union and implementing them with their own specific guidelines. Letter A groups together those Member States that consider pre-demolition audit a crucial step in the design of a building demolition or renovation and provide guidance on how to apply and formulate it. Group B represents those states that specify the need to include pre-demolition audit in the planning of demolition projects, but do not provide particular recommendations. For Group C no information was found on this tool.

Table 4: Meaning of the scores assigned per group

GROUP	DESCRIPTION	SCORE
A	Mandatory, national, specific Guidelines (+)	4
	Mandatory, local, specific Guidelines (+)	3.75
	Voluntary, national, specific Guidelines (+)	3.5
	Voluntary, local, specific Guidelines (+)	3.25
B	Mandatory, national	2.75
	Mandatory, local	2.5
	Voluntary, national	2.25
	Voluntary, local	2
C	No data	1

5.2 Results of collected data

The European Guidelines represent the starting point for the implementation of waste audits. The specific and detailed realization of the pre-demolition phase is decided on national or local level by each EU country. Figure 17 illustrates which European countries implement mandatory or voluntary waste audits and which of them do not provide relative data. Eleven countries have introduced mandatory waste audits in their legislation. However, for some of Member States, there is a limited application. In some cases, pre-demolition audit is voluntary or mentioned in the waste management plan without specific recommendations, in other cases it is regulated at regional level or limited to hazardous wastes.

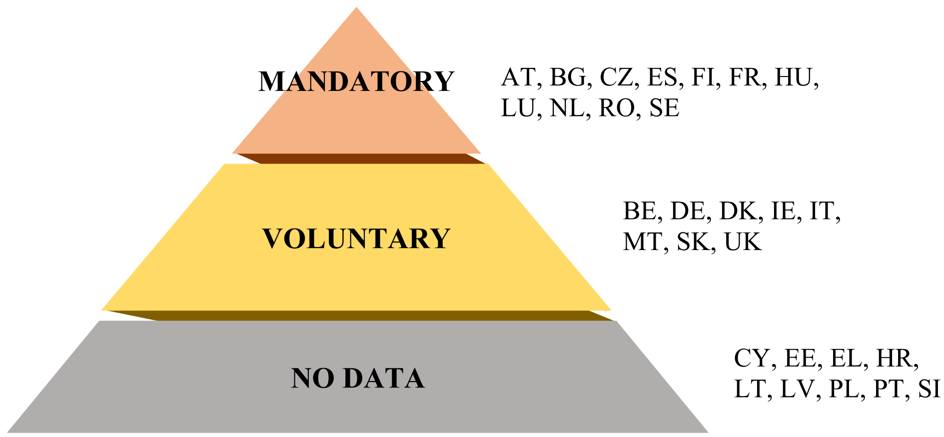

Figure 17: Pre-demolition audit in Member States

Table 5 highlights Member States with mandatory or voluntary pre-demolition audit, as well as information about their own specific Guidelines, the characteristics of these documents and the values of the scores in accordance with the evaluation provided in the previous section.

Table 5: Pre-demolition audit approach by the 28-EU countries

Member State	PRE-DEMOLITION AUDIT			Scores
	EU Guidelines / (+)		Notes	
	National	Local		
Austria	yes (+)	-	Focus on HW and over a specific size	4
Belgium	-	yes (+)	Flanders: non-residential buildings > $100m^2$	3.25
Bulgaria	yes	-		2.75
Czech Republic	yes	-		2.25
Denmark	yes (+)	-	Focus on PCB containing materials	3.5
Finland	-	yes (+)	Focus on constructions built before 1994	3.75
France	-	yes		2.5
Germany	-	yes	Focus on hazardous waste	2
Hungary	yes	-		2.75
Ireland	yes	-		2.25
Italy	-	yes	Veneto and Lazio	2
Luxembourg	yes (+)	-	Treatment according to waste hierarchy	4
Malta	-	yes		2
Netherlands	yes (+)	-	buildings > 10 m^3	4
Slovakia	yes	-		2.25
Romania	yes	-		2.75
Spain	-	yes (+)	Basque country	3.75
Sweden	yes (+)	-	Focus on hazardous waste	4
United Kingdom	yes (+)	-	BREEAM	3.5
Croatia, Cyprus, Estonia, Greece, Latvia, Lithuania, Poland, Portugal, Slovenia	-	-	No data	1

(+) Countries with national or local Guidelines more specific than the European ones.

Pre-demolition audit is mandatory in about 40 % of the EU countries. In Cyprus, Estonia, Greece, Croatia, Lithuania, Latvia, Poland, Portugal and Slovenia there are no data available on waste audit. Mandatory pre-demolition phase and the presence of well performed waste audits can positively influence factors such as data quality, legislation and market conditions that in turn may have an important impact on C&D waste recycling performance in each European country. Member States that currently have a developing legal framework, insufficient material traceability and anomalies in data reported are likely those that did not involve waste audits in C&D waste management plan or those where pre-demolition audit is hardly implemented (Malta, Czech Republic, Slovakia). Instead, high recovery rates have been recorded in Member States that implemented proper practices in terms of data quality and C&D waste management plan, including pre-demolition audit guidelines.

Figure 18 shows the correlation between the scores arbitrarily given to each Member State regarding the pre-demolition phase (Table 4) and the recycling rate. In this way, it is easier to understand if the development and improvement of this phase can improve the C&D waste management performance in European Union.

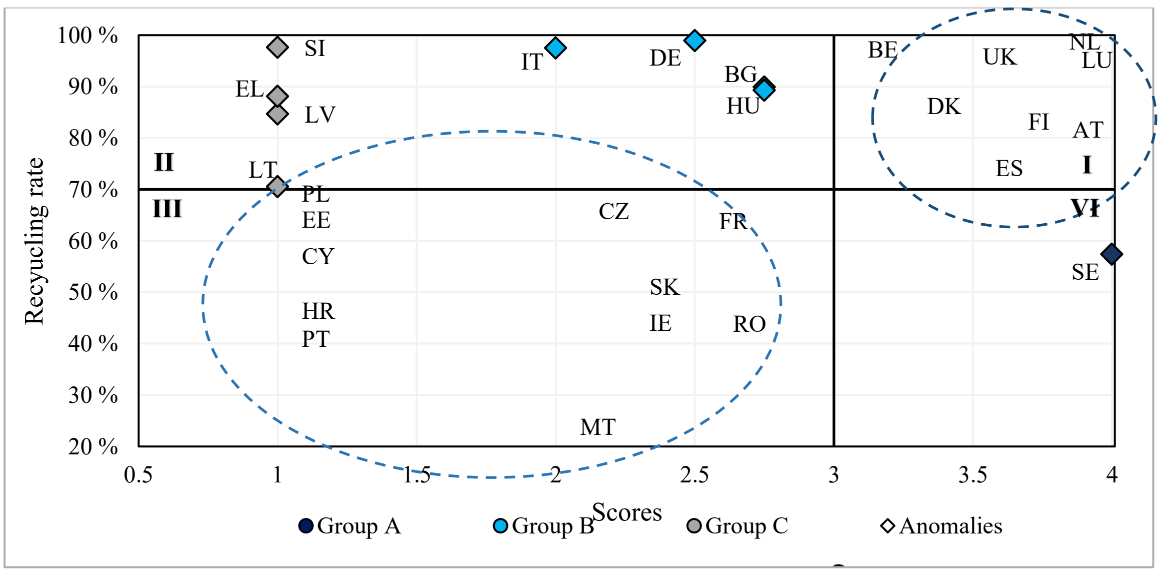

Figure 18: Interaction between C&D waste recycling rate and waste audit performance in MS

The figure above can be divided into four parts that correspond to the four quadrants.

• The first quadrant is characterized by Member States that have implemented the European guidelines with their own specific guidelines and where pre-demolition phase is mandatory or voluntary at national or local scale. These countries present a C&D waste recycling rate greater than 70 %.

These Member States implemented European Guidelines with elements as:

- Thresholds [26]
  Denmark: Waste audit mandatory for buildings where there are traces of PCBs and built between 1950 and 1977.
  Finland: Independent audit on hazardous waste for building built before 1994 and with a floor area > 100 m^2.

- Skills and certification for the auditors and traceability systems [26]
  Spain, Basque country: Only an authorized professional can perform the first waste audit. The second one is part of the contract between the property and the demolition company
  Belgium: *Tracimat* is a system that certifies the selective demolition process and, through a detailed traceability tool, examines what happens to the waste that derived from demolition.

- Hazardous materials
  Sweden: Appendix 1 of Swedish Construction Federation guidelines: list and handling of hazardous wastes:
  Austria: In the Austrian standard ÖNORM B3151 there is a list of C&D materials containing hazardous substances (removal before demolition).

- Templates or electronic tools for evaluating waste streams
  Sweden: Appendix 9 [27] of Swedish Construction Federation guidelines: waste management plan.
  United Kingdom: The Code of Practice [28] developed by BRE provide a series of templates that could be used before the demolition of the building.

- Waste sorting [8]
  Finland: Sorting collection and recycling are organized for eight waste flows. Denmark: The separation of eight categories of waste is compulsory.

Austria, for example, has a national mandatory pre-demolition audit. The Federal Minister for Agriculture and Forestry, Environment and Water Management publishes every six years the Federal Waste Management Plan. The latest version is from 2017. Recycled Construction Materials Regulation issued in January 2016 includes the multitude of previous regulations about C&D waste handling and treatment and gives specific requirements for demolition and waste sorting to improve recycling and use of secondary raw materials. This Regulation is supported by technical requirements and standard guidelines for recycling. The Austrian standard ÖNORM B 3151 "Dismantling of buildings as a standard method of demolition" establishes the tasks to perform a pre-demolition audit, specific information about auditors and templates. Furthermore, there is a list of contaminants to be removed and their possible location in the building. In this country, there are also non-legislative instruments as best practices, guidelines, recommendations used as a support in C&D waste management.

• The fourth quadrant is characterized by Sweden. It is a country with strong legislation, a good waste traceability system and it is a promoter of initiatives to encourage C&D waste recycling and sustainable management. The Swedish Environmental Protection Agency is a government agency that has the task of drawing up national plans regarding waste prevention. The Building Code [SFS 2010:900] describes waste management in the demolition of buildings. The Swedish Ordinance on PCB [SFS 2007:19] regulates the management of PCB-containing products found in buildings and In Sweden's Waste Plan 2012-2017 C&D waste is a priority. The Swedish Construction Federation updates periodically the "Resource and waste guidelines during construction and demolition". These Guidelines provide information on how to do a pre-demolition audit, the people involved, their responsibilities and the identification and handling of hazardous waste. As regulated by *Plan-och bygglag* (2010:900), it is mandatory to perform a pre-demolition audit with a waste management plan and to report information on hazardous waste identification and handling, reuse and recycling of materials. Despite this great attention and commitment to managing this waste stream, the recycling rate is low. This discrepancy is also evident in the graph in Figure 13. The reasons, as explained above, seem to be related to errors in reporting statistics on waste generated and treated and the use of other treatment methods. From the analysis of the current situation, adopting a better system of data collection and increasing resources and recycling techniques, Sweden would move in both graphs towards the first quadrant.

• The third quadrant groups those countries where pre-demolition audit is not performed (group C) and where it is voluntary or mandatory but there are no specific guidelines for this phase (B). Furthermore, the sources show that in these countries waste audits are very often not carried out because there is a lack of controls by the competent authorities. In Poland, for example, the most important laws are the Act on Waste and National waste management plan, at national and regional levels. The Poland legislation is characterized by the lack of specific document dedicated to C&D waste Management. There are national or regional obligations with regard to sorting and separate collection for different materials but without specific mention to C&D waste. Collected hazardous waste separately from the other C&D materials is mandatory but there are no laws or guidelines that rules the pre-demolition audits. All these Member States reported a recycling rate less than 70 %. There are many aspects related to the recycling capacity of individual countries, but the graph shows that the pre-demolition audit also influences the C&D waste management performance. By increasing the factors previously analysed and adopting specific guidelines to carry out pre-demolition audits making them mandatory at national or local level, the recycling quota of this kind of waste could increase and these countries could move towards the first quadrant.

• The second quadrant includes Member States with a high recycling rate but a modest or poor approach to waste audits. These countries also show a low C&D waste management performance in terms of collected data quality, legislation and treatment capacity (Figure 13). There is a correlation between the two graphs shown in Figure 13 and in Figure 18; in fact, the countries without a linear trend between the analysed parameters are the same in both diagrams. The transition to the first quadrant involves lot of factors that result not consistent with the high recycling rate provided to Eurostat.

In Italy, the C&D waste management plans and strategies are developed at regional and provincial levels. The article 196 of the D.Lgs 152/2006 [29] specifies that regions have the responsibility on arranging the regional waste management plans and almost all Italian regions have planned specific C&D waste requirements. It is compulsory to collect and manage hazardous waste but there are no obligations on the preparation of inventories about C&D hazardous materials, with the exception of asbestos containing materials. In some regions, pre-demolition audits are required. In Lazio the "*Prime linee guida per la gestione della filiera di riciclaggio, recupero e smaltimento dei rifiuti inerti"* [30] were published in 2012. These Guidelines describe the C&D waste management plan that must be presented when approving the demolition project. This plan should contain the description of the working processes, the estimate of the waste amounts produced by homogeneous type, their classification with the European waste code and indication on the authorized facilities that could receive the waste produced during the demolition. In Veneto, the Annex A "*Modalita' operative per la gestione dei rifiuti da attivita' di costruzione"* [31] of the D.G.R.V n. 1773, 28 August 2012 gives information about the assessments to be made during the preliminary survey, including the type and the characteristics of the site and the presence of dangerous substances. There is also the description of managing methods of some hazardous materials that could be found during the demolition of a building. The pre-demolition phase includes the removal of dangerous substances and reusable components but there are no specific guidelines that describe how to perform this phase.

Comparing the two graphs analysed in Figure 13 and in Figure 18, the most evident difference is represented by Germany. This is the country that generated more C&D waste in 2016 and recycled 99 % and 88 % of non-hazardous and hazardous mineral waste treated respectively. Legal requirements are advanced and the public sector support the development of the circular economy in the built field. Here, pre-demolition is mandatory at local level but there are no specific guidelines. This explains the position of this country in the diagram in Figure 18; Member States were evaluated with scores that consider the compulsory, application field and specificity of pre-demolition audit because it was possible to find information about these aspects through literary sources. Here, it is mandatory to perform the *Schadstoffkataster* that could be considered as an example of good practice in terms of evaluation, quantification and analysis of hazardous materials and it is used to remove specific materials before the demolition of the buildings. However, before the buildings' demolition, German companies are not obliged to carry out the inventory of the elements or the inventory of non-hazardous materials, as suggested by European Guidelines.

The *Schadstoffkataster* performed in Hamburg is usually ordered and paid by the constructing company and the aim of the document is the examination and evaluation of hazardous substances, materials and components. The structures investigated are usually multi-storey offices, since they represent the most common type of building in the centre of Hamburg. The structure of document is the following:

- Description of the building;

- List of pollutants investigated: asbestos, PCB, artificial mineral fibre, hazardous wood, brominated flame retardants, PAH, tar, fuel oils;

- Official regulations and pollutants limits;

- Responsibilities and safety measures taken;

- Photo-documentation: the pictures give details on the inspected elements, their location and description and information on the presence or absence of hazardous substances. The photographs make easier the work of the company when performing the demolition.

- Analysis results: information about samples, sampling location, investigated element and hazardous substances detected or their content.

6. Practices for further improvement

The adoption of a clear, specific and mature legislation on C&D waste management is essential for the achievement of the Directive targets. It is the first step towards a better result in terms of recycling and reuse of waste. Many Member States have defined compliance, accountability and sanctions requirements in C&D waste management in their legislation, but the real problem is the application of these laws and the “actual” tax measures carried out. For many EU countries, the main issue is the absence of resources to improve the existing C&D waste laws.

Member States with a “thin” legislation should involve strict rules regarding generation and management of C&D waste, specific parts on hazardous waste, regulations affecting safety and health issues, definition of powers and responsibilities, public procurement, standardization; a developed legislation allows to minimize human safety issues and environment pollution. This requires the investment of resources.

The imposition of landfill taxes has enabled countries, such as Denmark, to reduce landfilled C&D waste by encouraging the development of new recycling technologies. In the Netherlands, the landfill of certain types of waste has been prohibited. The mentioned countries show a proper C&D waste management and high recycling rates. The imposition of taxes on landfills may be a financial incentive to promote the recycling market; on the other hand, taxes should “be adapted” to the economic situation of the country in order to avoid the opposite effect with the increase of illegal landfills.

The potential C&D waste recycling and recovery is influenced by economic and technic resources available to Member States, as well as the technological context and market conditions. Un-confidence of stakeholders in the use of reclaimed materials and lack of certification over recycled products performance represent a common barrier to circular economy in Europe. As reported by Eurostat [32], only 12 % of recycled products were used by Member States in 2016. Public authorities have a key role in this context. In fact, the development of a secondary materials market is due to:

- A clear and specific legislation that can ensure greater awareness of the management and recognition of potentially hazardous substances, whose presence hinders the re-use of materials as well as causing a risk to human health and the environment.
- The presence of sanctioning systems to ensure proper enforcement of laws and an educational process to improve cultural attitudes towards non-compliance with the legislation.
- Financial benefits to create incentive for recycling and reuse.
- Appropriate tools for the traceability of materials, quality certification systems for recycled products. In France, the *Syndicat National des Entreprises de Démolition* (SNED) elaborated the C&D waste traceability software *Investigo* that allows industries to have a waste register for any demolition following the French laws.
- Obligations in terms of selective demolition, on-site and off-site sorting.

As reported in Figure 13, improving the legal conditions and the material traceability systems, the quality of C&D waste data would increase. Overestimation, underestimation or double counting issues reported by Member States are linked to the necessity of higher data quality and level of detail. Establishment of a unique and standardized European system of data collection based on already existent and appropriate used by some EU countries could be a good practice. This methodology should include surveys and administrative resources and a system of data control and correction should be established at Community level. Country-by-country data should provide information on waste generation and treatment at site level, activity (construction, demolition and refurbishment), material and recovery operation (reuse, recycling, backfilling, energy recovery and disposal).

Data quality levels are conditioned also by the unclear definition of backfilling. This is an important aspect, especially for those countries where the recovery rate strongly depends on the backfilling rate. The European Commission should plan, prepare and propose a stronger description and harmonization of the European legislation, starting with a unique definition of C&D waste and backfilling operation, equal for all Member States. These recommendations would lead to a better clarification and collection of C&D waste statistics, making it easier to break down barriers to recycling in this sector.

6.1 Pre-demolition audit

Pre-demolition audit is an important step to increase sustainable C&D waste management since it affects every macro-factor necessary to improve the waste recycling rate. It allows quantifying the amount of reclamation from several parts of a building to be demolished and providing a benchmark for reuse, recycling targets and performance monitoring.

The most advanced European legislations about C&D waste management include mandatory pre-demolition audits that are incentives to reduce waste landfilling and to create greater awareness of the environmental benefits at building level.

The adoption of a pre-demolition audit by the companies can improve the demolition activity. It is a support for planning of demolition, decontamination and waste management and gives companies and contractors involved useful information through which design the work. Combined with selective sorting at source (selective demolition practices), it allows to obtain pure flows of homogeneous material from the demolition of a structure. Mixed waste decreases and consequently also its diversion to landfill.

The knowledge of what materials are present and in which quantity prior the demolition or refurbishment of buildings is a driver for obtaining better quality and level of detail of C&D statistics on a project scale. This produces positive impacts on Eurostat statistics on waste from demolition activities. Standardised and certified construction products through quality assurance systems increase the stakeholder´s knowledge and confidence on high-quality recycled materials composition and create the conditions for the development of secondary materials market.

The presence of contaminated C&D materials obstacles the development of a strong market for recycled and reused products. This aspect is strictly connected to the national or local legislation of the country. All Member States have established obligations for the separate collection and management of all hazardous waste streams, but in some cases, these materials are not identified and handled separately.

6.1.1 Best Practices

It is noteworthy that the majority of EU countries applies waste audit only in specific cases, i.e. some building types/hazardous materials or without considering furniture and installations. A good practice would be to extend the materials and products assessment prior to demolition to all type of buildings and infrastructures without size thresholds, and to compute the number of reusable elements.

<u>HAZARDOUS WASTE</u>

In terms of material recycling or reuse from the deconstruction processes, it is of great importance to know which parts of the building contain hazardous substances. This waste must be handled and removed according to regulatory requirements. The knowledge of the local and national laws is essential to avoid environmental and human health concerns, as well as legal problems.

During a building demolition, dangerous substances and contaminants may be studied, separated at source and handled in an environmentally careful way before the demolition; in order to obtain pure recycling and reusable materials, hazardous waste may not be mixed with each other and sorted from other waste. The removal of dangerous substances includes also the decontamination of potentially recycling materials from hazardous particles to avoid healthy and safety issues for workers and increase the market´ trust on the quality of recycled materials. A proper management and removal of hazardous waste not only avoids the spread of dangerous substances into the environment but also encourages the design of standardised treatment technologies.

Each step of pre-demolition audit is fundamental to quantify the hazardous materials. It is necessary to know the building age and the date of eventually renovation or maintenance operations. Local regulations and the knowledge of the period in which the use or imports of specific contaminants were prohibited help auditors to identify hazardous materials. Also, the materials quality and the colour, the workers' experience and obviously the samples results provide important information on the presence of dangerous materials.

Swedish Guidelines [15] dedicate a chapter to the description of materials and products that could be hazardous. The aim is to provide a further aid prior to pre-demolition audit phase and to give information about contaminants characteristics, in which materials they can be found and how they should be handled. Furthermore, Appendix 1 [33] of these guidelines supplies a list of contaminants, examples of occurrence, the reference waste code and possible handling operations. Appendix 5 [34] describes materials and products from demolition and the hazardous substances that they could contain. Table 6 provides examples of construction materials that can be contaminated with regard to the type of pollutant and the reference ELoW code. It is based on Kretsloppsrådet's guidelines that give information on handling operations based on Sweden legal requirements.

Other dangerous elements not mentioned in Table 6 could be:

- Roofing materials and sidings may contain asbestos;
- Electrical products may be handled as hazardous waste/ as contaminated by asbestos, mercury, oil, coal tar;
- Ceiling, ceiling tiles, tile adhesive and grout may contain asbestos;
- Refrigerators, freezers, air conditioners may present traces of refrigerants or asbestos if they are old;
- Thermostats, switches may contain mercury;
- Old smoke detectors, emergency lighting systems contain batteries and/or radioactive materials;
- Eternit and acoustic tiles, old floor coverings may contain asbestos;
- Roofing felt may present tar.

Table 6: Summary of potential contamination of C&D waste from Swedish Guidelines

Material	Element	Contaminant	EWC
Concrete 17 01 01	Blue concrete	Radon	17 01 06*
	Oil containing concrete	Oil	17 01 06*
	Painted concrete	PCB	17 09 02*
	Concrete with tar paper	PAHs	17 01 06*
Tiles and Ceramics 17 01 03	Tiles with orange, red, yellow shadows	Cadmium	17 01 06*
	Glazed tiles	Lead contaminants	17 01 06*
Wood 17 02 01	Pressure impregnated timber and sleepers	Arsenic, Copper or Chromium contaminants, Creosote, Pentachlorophenol	17 02 04*
	Painted wood	Lead contaminants	17 02 04*
	Timber	Dry rot or Pesticides	17 02 04*
Glass 17 02 02	Insulated window panes with sealing compounds	PCBs	17 02 04*
	Lamps	Mercury	17 02 04*
Plastic 17 02 03	Plastic profiles and pipes	Cadmium	17 02 04*
	Plastic parts of fans	Brominated flame retardants	17 02 04*
Metals 17 04	Sheet metals painted	Asbestos	17 06 05*
	Buried cables	Oil, coal tar	17 04 10*
	Cables with oil	PCBs	17 04 10*
Insulation materials 17 06 04	Insulation with sprayed asbestos, Condensation insulation	Asbestos	17 06 01*
	Insulation of fire doors	Asbestos	17 06 01*
	Gaskets (boilers and pipe systems)	Asbestos	17 06 01*
	Cellular plastic insulation	Brominated flame retardants, CFCs	17 06 03*
	Insulation fills	PAHs, radon, heavy metals	17 06 03*
Gypsum 17 08 02	Gypsum wallboard (painted)	Lead contaminants	17 08 01*
		Asbestos	17 06 05*
Bituminous mixtures 17 03 02	Asphalt	PAHs	17 06 03*
Mixed construction and demolition waste 17 09 04	Joint compounds	Lead contaminants, PCB	17 09 03*
	Roofing felt	PAH, tar	17 09 03*
	Textiles	Brominated flame retardants	17 09 03*

<u>AUDITORS</u>

Auditors should be qualified experts who perform pre-demolition audits availing of their experience and knowledge. They should have a basic understanding of demolition techniques, national and regional legal requirements, construction materials and hazardous substances, waste treatment, reusability of deconstructed building components and the recyclability of separated materials. It is a best practice that a team of experts carries out pre-demolition audit. Most of waste audit guidelines recommend the independence of the auditors from the interests of the owner or contractor. Knowledge about local markets and standardization system is also important. For instance, Finland and Sweden demand certification for experts on asbestos and hazardous substances. The certification systems include basic educational courses, work experience and exams [26].

TEMPLATES

Pre-demolition audit allows estimating the different material streams arising from the demolition and refurbishment of a structure, giving recommendations for the treatment of harmful substances and the planning for reuse, recycling and recovery of materials. In Appendix 3 of this study there are some examples of pre-demolition audit templates deriving from the summary of the different sources analysed.

In the process of assessing the environmental, social and economic sustainability performance of new buildings, existing buildings, renovation projects or major masterplan projects, one of the most internationally relevant certifications is BREEAM (Building Research Establishment Environmental Assessment Method). This certification is based on standards developed by BRE (Building Research Establishment), a leading UK group of researchers, scientists, engineers and technicians who provide products, standards and qualifications to create a safe, efficient, productive and sustainable built environment. Since 1996, BRE has conducted more than fifty audits with the objective of maximising the reuse and recycling of products resulting from the demolition of a building.

7. Current C&D waste management in Italy

Art. 184 of Legislative Decree N. 152/06 (part IV) explains the principle by which waste is classified:

- according to origin in municipal or special;
- according to hazardous characteristics in hazardous or non-hazardous.

In particular, the Decree classifies as special "waste deriving from demolition and construction activities, as well as hazardous waste deriving from excavation activities, without prejudice to the provisions of Article 184-bis on by-products".

7.1 C&D waste data collection

In Italy, the national production of special waste is quantified from the information contained in the *Modello Unico di Dichiarzione Ambientale* (MUD) databases relating to annual declarations collected in accordance with sector legislations by ISPRA (*Istituto Superiore per la Protezione e la Ricerca Ambientale*).

The MUD is the tool with which the annual communication to the waste register is carried out; it is a fulfillment that allows collecting data on waste by municipalities, produced by companies and institutions, transported, brokered, marketed and subjected to treatments aimed at recovery or disposal. The DPCM of 24 December 2018 approved the MUD for the year 2019. The Decree consists of a single article and four annexes, the first of which contains all the instructions for filling in, from the obligated parties, to the simplified communication, up to the specific communications for individual types of waste. Legislative Decree N. 152/06 provides some exemptions from the obligation to declare the production of waste. For example, agricultural enterprises specified in the Italian Civil Code and self-employed professionals who do not operate in the form of enterprises and who also produce hazardous waste or enterprises that produce non-hazardous waste and have 10 or fewer employees are not obligate to complete the MUD. This exemption causes an underestimation of generated waste compared to reality because the construction and demolition companies are mostly small enterprises. For this reason, it is clear that the development of the MUD database cannot provide complete information on the non-hazardous waste generation. In order to overcome the lack of information resulting from these exemptions, ISPRA has integrated MUD data using specific estimation methodologies. These methods have only been applied to certain production sectors for which a lack of information has been identified. For this reason, the integrated data may still be underestimated.

The quantification of non-hazardous C&D waste generated in 2016 was carried out with a specific methodology described by ISPRA [35]. The production values were derived from the data declared in the MUD and related to management operations, without considering the intermediate steps of the management cycle in order to avoid a double counting. Mass balances have been carried out on the waste produced and declared in order to exclude from the quantification those in stock produced during the previous year. On the other hand, the amount of non-hazardous C&D waste in storage at the producer's facility at the end of the reference year was taken into account.

The calculation of the hazardous waste quantity was based on data reported in the MUD. The material recovery rate was calculated assuming that the annual production of non-hazardous C&D waste is equivalent to the quantity of C&D waste sent for recovery or disposal, excluding the amount of waste subject to intermediate management operations in order to avoid data duplication.

The counting of treated waste also is based on the MUD that has to be compiled by waste treatment operators; for this reason, it may happen that the same waste is counted twice if waste is managed in multiple treatment operations. Another critical aspect is that some Italian regions provide detailed information on waste generation and treatment while for other regions data are scarce and the estimation quantities of C&D waste misses accuracy.

7.1.1 C&D waste generated

ISPRA official statistics on waste generated refer both to the generation of C&D waste by reference to Chapter 17 of Commission Decision of 3 May 2000 and to waste generated by economic activities. In this study, only national statistics on special waste generated by groups of economic activities are reported in accordance to Eurostat C&D generated waste data analysed in the previous chapters.

The data grouped by economic activity are reported according to the identified classification by Nace Rev. 2, from which the national version Ateco 2007 established by the National Statistical Institute (ISTAT) is derived. For construction sector, the NACE code is F, to which the Ateco codes 41-43 correspond.

The source of the Italian statistics shown in this chapter is *Rapporto Rifiuti Speciali, Edizione 2018* led by ISPRA. In 2016, the total production of special waste in Italy was 125 Mio.Mg, of which 44 % is represented by C&D waste with about 55 Mio.Mg (including soil and dredging spoils).

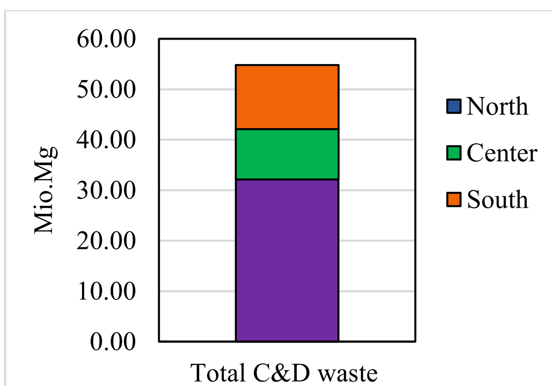

Figure 19: Total C&D waste generated by geographical macro-area in Italy in 2016

Figure 23 shows that in 2016, the North of Italy generated 59 % of the total C&D waste with 32 Mio.Mg while the Center and the South of the country generated 18 % and 23 % of the total amount with at least 10 and 13 Mio.Mg respectively.

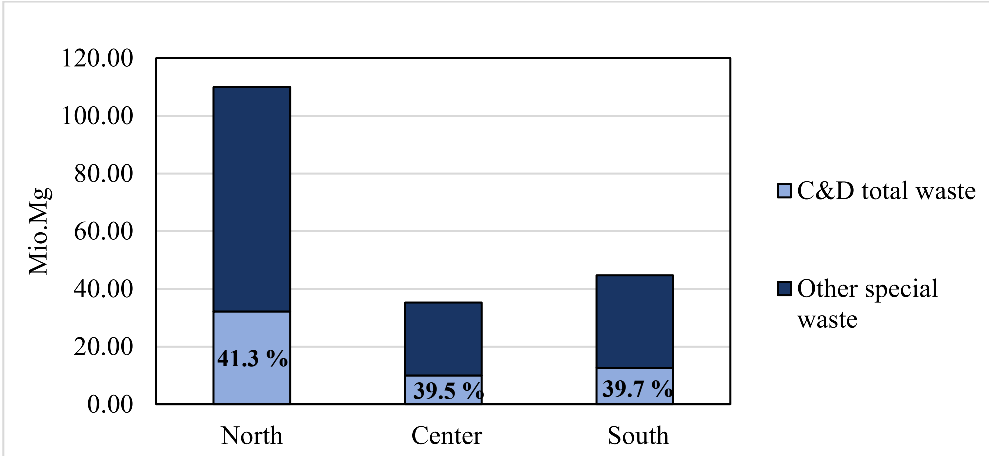

Figure 20: Total special waste generated by geographical macro-area in Italy in 2016

In Figure 24 it is possible to note that at the macro area level, in 2016 waste from construction and demolition activity represented 41.3 % of total waste produced in the North, while in Central and Southern Italy this percentage was 39.5 % and 39.7 % respectively. The other productive activities that generated special waste in 2016 were: chemical industry; manufacture of non-metallic mineral products; metallurgical industry; manufacture of metal products; food and beverage industry; other manufacturing activities; waste treatment, remediation and sewerage; energy, water, gas supply; trade; service activities; mineral extraction; agriculture.

According to ISPRA database, in 2016 the excavated soils represented 71 % of non-hazardous C&D waste generated in Italy while mixed waste from construction and demolition and other non-hazardous waste were 16 % and about 12 % respectively. Hazardous waste, on the other hand, consisted of 68 % of asbestos-containing waste (17 06 05* and 17 06 01*), about 18 % of dangerous insulating materials (17 05 03*) and 14 % was represented by other types of waste (17 0 204*, 17 03 01*, 17 05 07*, 17 06 03* and 17 09 03*).

7.1.2 C&D waste treated

In 2016, waste landfilled was about 3 Mio.Mg, of which 2.5 Mio.Mg was non-hazardous and represented 24 % of the total waste disposed at national level. In particular, 67 % of C&D waste was disposed in landfills for inert waste, 25 % in landfills for non-hazardous waste and 8 % in landfills for hazardous waste. Data analysis by geographical macro-area shows that 66 % of C&D total waste is operated in facilities located in the north of the country, 15 % in the Centre and about 19 % in the South, as shown in Figure 25. In the regions of Molise and Campania there are not landfills for this type of waste [35].

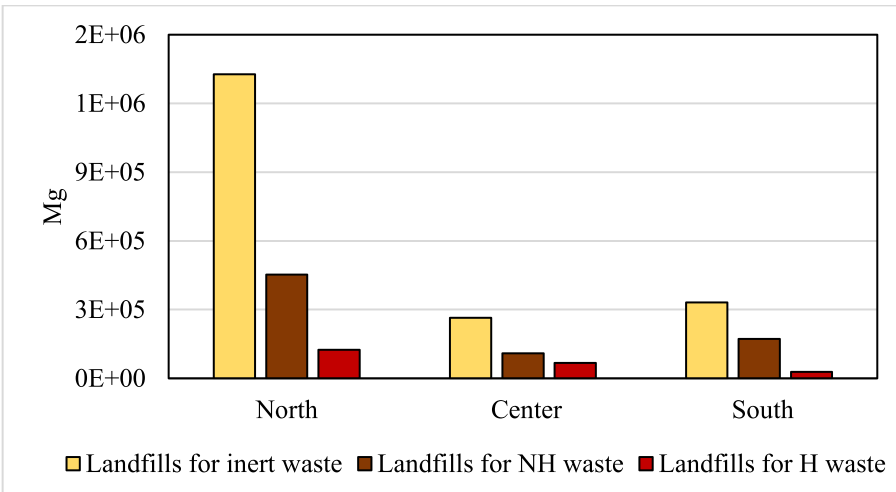

Figure 21: C&D waste landfilling by geographical macro-area in Italy in 2016

As reported by ISPRA [35] non-hazardous special waste sent for recovery/disposal operations consists mainly of "Waste from construction and demolition operations" (Chapter 17 of ELoW) and waste from waste treatment" (Chapter 19 of ELoW). In particular, 59 % of the non-hazardous waste recovered is waste from Chapter 17 and the treatment of this type of waste is in line with the production data. Considering C&D hazardous waste, the quantity recovered in 2016 was 5 % of the total amount of special hazardous waste recovered in Italy in that year.

7.2 National legislation on C&D waste

In Italy there is no specific national legislation on waste deriving from construction and demolition activities. Waste management plans are developed at region level. The management of this waste is regulated through parts of laws that have been enacted over the years. For example, [8]:

- D.M. 5/2/98 (amended by Decree 5/4/06 n. 186) reports type, origin, characteristics of waste and products obtained through recovery, recovery activities of non-hazardous waste subject to simplified recovery procedures;
- D.M. n°203 of 8/5/2003 identifies rules and definitions so that the regions adopt provisions, aimed at public bodies and companies with a prevalent public capital, including service management companies, which ensure that manufactured goods and goods made from recycled material cover at least 30 % of annual requirements;
- D.P.R 120/2017: Regulation on simplified rules for management of excavated land and rocks;
- Law no. 98 art. 41 of 9 August 2013 defines the matrices of material used for backfilling;
- *Circolare* 15/7/05 n. 5205 Green Public Procurement shows the rules for re-use of excavated materials through administrative documents called "*Piani di Utilizzo*";
- D.L. 12-9-2014 n. 133 art. 34: Amendments to Legislative Decree No. 163 of April 12, 2006 to simplify procedures for the remediation and safety of contaminated sites; it specifies that excavated materials can be re-used in situ if the concentrations of pollutants inside these materials don't overcome the legislation limits.

D.Lgs 152/2006 is the most important Italian law with regard to waste. Article 199 of the Decree establishes general rules for the implementation of regional waste management plans. The regional plans have to promote measures to reduce quantity, volume and hazardousness of waste and to avoid soil and water pollutions. Waste management plans must include measures to prevent waste production and promote reuse, recycling and recovery.

In Italy the responsibilities regarding the monitoring and enforcing waste legislation and the imposition of landfill taxes are done mainly at regional and provincial level; regional and national laws do not establish obligations for selective demolition and on-site/in facilities sorting. There are no separate collection obligations for different materials while C&D hazardous waste must be separated and collected according to legal requirements.

7.3 Framework and market conditions

The absence of obligations for separation at waste source and for the use of selective demolition operations are barriers for the development of a secondary materials market due to a reduction of the quality and homogeneity of recycled products. The taxes on landfilling are established at regional level and they are not high enough to hinder the illegal practices and to develop the recycled materials economy. Italy suffers from a lack of economic incentives for the development of a recycled products market derived from this sector; this issue is also increased by the lack of demand for recycled products and the limited knowledge of the properties and characteristics of these materials.

7.3.1 C&D treatment facilities

Italy was classified as a Member State with a sufficient treatment capacity, but landfills still play a major role in the management of these material flows.

In 2008, *FISE Assoambiente* prepared a report, based on a survey covering the whole country, that provides a complete census of waste treatment plants existing in Italy. Recovery plants for non-hazardous waste (municipal, special and construction and demolition waste) were 5 884 with an authorized treatment capacity of approximately 137.6 Mio.Mg. The North counted 4 102 treatment plants, the Center 1 005 while the South 777. It is evident lack of homogeneity in the availability of waste recovery facilities. Regarding the treatment of hazardous waste, the study reported 21 landfills authorized for disposal and 81 recovery facilities. The North of the country was characterized by 38 recovery plants at the beginning of 2008, while the Center and the South 19 and 24 respectively. In addition, 136 other disposal facilities authorized for the treatment of both hazardous and non-hazardous waste were counted.

Table 7: Landfills for C&D waste [36]

ITALIA: DISCARICHE PER RIFIUTI DA COSTRUZIONE E DEMOLIZIONE					
					Inizio 2008
	Numero discariche				
Gestione	Conto proprio	Conto terzi	n.d.	Totale	Capacità residua (m³)
TOTALE (1)	53	126	150	329	41.990.133
NORD	24	102	115	241	14.011.941
CENTRO	3	7	7	17	4.719.134
SUD	26	17	28	71	23.259.058

(1) Esistono altre 83 discariche di cui non è disponibile la capacità residua

Table 7 shows the number of landfills for C&D waste in Italy in 2008. A total of 329 landfills with a residual capacity of 41 990 133 m^3 were counted; 73 % of C&D waste landfills are located in the North, where the highest C&D waste production is also recorded.

7.4 Focus on asbestos and asbestos containing materials

Asbestos is a fibrous material characterized by natural mineral fibers belonging to the silicates and the mineralogical series of serpentine (chrysotile or white asbestos) and amphiboles (crocidolite or blue asbestos). It is a carcinogen and the presence of asbestos fibers in the environment inevitably leads to damage to human health. In the past, asbestos has been widely used as an insulating material and, secondly, as a reinforcement and support material for other synthetic products. In 1992, Italy introduced a complete ban on the use of asbestos. However, the release of asbestos fibers from pre-existing structural elements inside buildings may occur due to slow deterioration of materials containing asbestos or direct damage to them by the occupants or for maintenance works.

7.4.1 Italian legal framework

The Law 27/03/1992 n. 257 [37] "*Norme relative alla cessazione dell´impiego dell´amianto*" prohibits the extraction, production and marketing of asbestos. It introduces support measures for workers and companies and regulates the treatment, disposal and the export of asbestos and products containing it. According to the law, each region must approve a plan for environmental protection, decontamination, disposal and reclamation of this contaminant.

The Ministry of Health established a series of decrees of technical nature about the intervention criteria, operational and safety procedures for reclamation interventions, risk assessment methods. The first is the D.M. 6 September 1994 [38] "*Normative e metodologie tecniche di applicazione dell´art. 6, comma 3, e dell´art. 12, comma 2, della legge 27 marzo 1992, n. 257, relativa alla cessazione dell´impiego dell´amianto*."

D.Lgs. 9 April 2008 n. 81 [39] "*Testo unico sulla salute e sicurezza sul lavoro*" and subsequent amendments and additions, organically regulate all Italian legislation on asbestos replacing from 30 April 2008 Legislative Decree 257/06. The *Capo III, Titolo IX* of the Decree describes the protection against risks related to exposure and defines:

- Application field (art. 246): work activities that may involve exposure to asbestos for workers, such as maintenance, removal of asbestos or materials containing asbestos, disposal and treatment of asbestos waste, and cleaning up of the areas concerned.
- Definition of asbestos (art. 247).
- Employer's obligations (section II): the Employer is the person responsible for ascertaining the presence of asbestos-containing products before the beginning of any work (art. 248); he is also responsible for carrying out the asbestos risk assessment as part of the preparation of the Risk Assessment Document, in order

to protect the health of the workers. The Employer is responsible for the protection and prevention measures to be taken (art. 251), the periodic monitoring of the asbestos fibers' concentration in the air (art. 252) and the hygiene measures that must be put in place to safeguard the workers' health (art. 253).

- Article 256 is about demolition or asbestos removal works.

The current legislation on asbestos sanctions is therefore composed of Law 257/92, Legislative Decree 81/08 and Legislative Decree 152/06. Law 257/92 lays down penalties for the export, import, marketing and production of asbestos. Sanctions are provided for anyone who intervenes on asbestos-containing products or carries out asbestos reclamation without respecting the emission limits or the necessary registration in the Register of Environmental Managers. The Legislative Decree 81/08 sets penalties for those who carry out remediation activities (removal, encapsulation or confinement) in the absence of the necessary communications. Legislative Decree 152 of 2006 establishes penalties for the transport, illegal disposal or abandonment of hazardous waste.

Regional plans and laws have also been enacted over the years for environmental protection, asbestos disposal and reclamation.

7.4.2 Management of asbestos containing materials in the built sector

In the built sector, asbestos has been used mainly for fire protection, thermal and acoustic insulation and as reinforcement for concrete in buildings. The first step in the management of asbestos is its characterization, i.e. the verification of the actual presence, its classification and location. This obligation is valid for any type of building, public or private in which it is presumed that there are asbestos materials (certainly structures built before 1992).

D.M. 6 September 1994 defines the standards and technical methodologies for risk assessment, control, maintenance and reclamation of materials containing asbestos in building structures. The Decree divides materials containing asbestos into three categories and provides a list of the main materials that may be present in buildings, with their characteristics of asbestos content and friability, as shown in Table 8. Materials that can be crumbled or reduced to powder by simple finger pressure are defined as friable, while hard materials that can be crumbled or reduced to powder only by the use of mechanical tools are called compact.

Table 8: Main types of materials containing asbestos and their friability [38]

Tipo di materiale	Note	Friabilità
Ricoprimenti a spruzzo e rivestimenti isolanti	Fino all'85% circa di amianto Spesso anfiboli (amosite, crocidolite) prevalentemente amosite spruzzata su strutture portanti di acciaio o su altre superfici come isolante termo-acustico	Elevata
Rivestimenti isolanti di tubazioni o caldaie	Per rivestimenti di tubazioni tutti i tipi di amianto, talvolta in miscela al 6-10% con silicati di calcio. In tele, feltri, imbottiture in genere al 100%	Elevato potenziale di rilascio di fibre se i rivestimenti non sono ricoperti con strato sigillante uniforme e intatto
Funi, corde, tessuti	In passato sono stati usati tutti i tipi di amianto. In seguito solo crisotilo al 100%	Possibilità di rilascio di fibre quando grandi quantità di materiali vengono immagazzinati
Cartoni, carte e prodotti affini	Generalmente solo crisotilo al 100%	Sciolti e maneggiati, carte e cartoni, non avendo una struttura molto compatta, sono soggetti a facili abrasioni ed a usura
Prodotti in amianto-cemento	Attualmente il 10-15% di amianto in genere crisotilo. Crocidolite e amosite si ritrovano in alcuni tipi di tubi e di lastre	Possono rilasciare fibre se abrasi, segati, perforati o spazzolati, oppure se deteriorati
Prodotti bituminosi, mattonelle di vinile con intercapedini di carta di amianto, mattonelle e pavimenti vinilici, PVC e plastiche rinforzate ricoprimenti e vernici, mastici, sigillanti, stucchi adesivi contenenti amianto	Dallo 0,5 al 2% per mastici, sigillanti, adesivi, al 10-25% per pavimenti e mattonelle vinilici	Improbabile rilascio di fibre durante l'uso normale. Possibilità di rilascio di fibre se tagliati, abrasi o perforati

According to point 1b of D.M.06/09/94, the inspection program inside buildings may be carried out as follows:

- Research and verification of technical documentation available on the building;
- Direct inspection of materials to identify those which are friable and potentially containing asbestos;
- Verification of the conservation state of friable materials;
- Sampling of suspect friable materials;
- Mapping of areas where asbestos-containing materials are present;
- Recording of all the collected information in special sheets showed in Annex 5 of the Decree, to be kept as documentation and to be issued to building’s responsible.

Once an initial inventory of the presence of asbestos has been carried out, following Article 12, paragraph 5 of Law 257/92 and the rules techniques of D.M.06/09/94, the owner of the building must perform a specific risk assessment on the possible dispersion of asbestos fibers from materials. The risk assessment is based on: visual inspection (evaluation of type and condition of materials, factors that may lead to future damage or deterioration and factors affecting fiber diffusion and exposure of individuals) and environmental monitoring (measurement of the asbestos fibers concentration inside the building and comparison with legal limits).

In case of rooms used for work activities, the results of this evaluation shall be formalized in the "Worker health and safety risk assessment" document, referred to Articles 17, paragraph 1, letter a), 28 and 29 of Legislative Decree 81/08.

As a result of the risk assessment, the owner of the building and/or the employer has to draw up an inventory containing all data necessary to identify the risk to the occupants of the building connected to the presence of asbestos. This inventory shall be conducted using specific census sheets defined by the reference legislation (Annex 5 of D.M.06/09/94) and must be formally delivered to the ASL responsible for the territory. In the inventory, the owner of the building has to classify each asbestos containing material found into one of the following categories defined by the Decree itself:

- Integral materials not susceptible to damage: there is no danger of asbestos fibers being released or exposure of occupants. In this case, no remediation is required, but it is necessary to periodically check the condition of the materials and the respect of maintenance and cleaning procedures;
- Integral materials susceptible to damage: there is danger of a potential release of asbestos fibers. If it is not possible to reduce significantly the risks of damage, a remediation intervention should be taken into account.
- Damaged materials: there is a danger of asbestos fibers being released with possible occupant exposure. In these situations, a specific action to be implemented in short time is necessary.

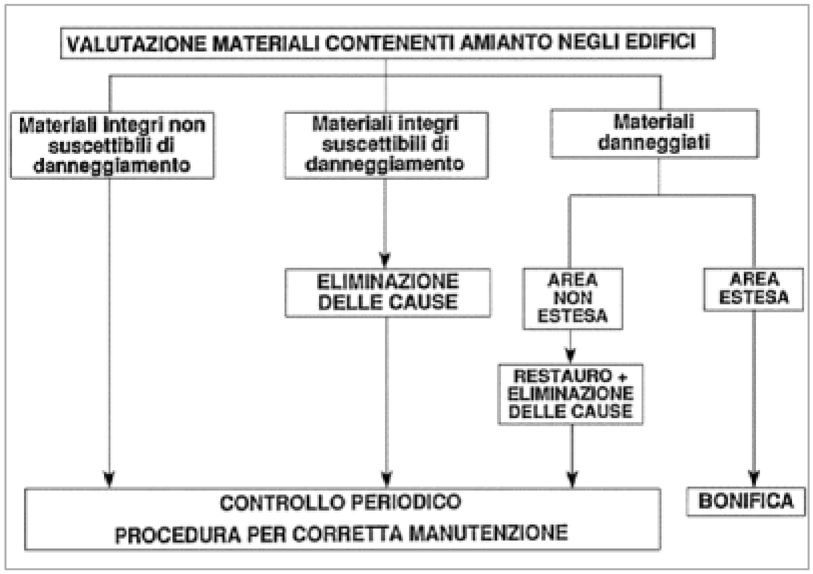

Figure 22: Decision-making for asbestos in buildings [38]

There are two possible measures to be performed depending on the state of the material [38]: RESTORATION OF THE MATERIALS (the asbestos is left in place without any intervention of reclamation; the damaged areas are repaired and/or eliminated) and RECLAMATION by removal, encapsulation or confinement of asbestos. The Decree, in fact, defines three types of reclamation operations authorized by law: REMOVAL (removal and landfilling of asbestos); ENCAPSULATION (the object is not removed but encapsulated in order to avoid any contact with the outside by applying an "encapsulating" paint in several layers. The characteristics and composition of encapsulating paints have been defined by DM 20/08/1999); CONFINEMENT (the product is not removed but it is encapsulated with a physical barrier composed of building materials such as walls, panels, insulating materials).

After the detection of the presence of asbestos-containing materials in the building, it is necessary to perform a control and maintenance Plan in order to reduce potential issues for the people exposed. The aims of the program are to maintain asbestos-containing materials in good condition, prevent the release of fibers, intervene correctly when a release occurs and verify periodically the condition of materials containing asbestos. All the activities must be controlled and planned by a responsible person. The Decree describes also the measures to be adopted during maintenance activities and safety measures to be observed during remediation work.

Art. 256, Chapter III, Title IX of D.Lgs. 9 April 2008 n. 81, defines the requirements in case of demolition or asbestos removal work. If the building to be demolished contains asbestos, the company must be authorized in accordance with Legislative Decree 152/06 "Environmental regulations". D.Lgs.152/06 specifies that any company that carries out the removal and the disposal of any type of waste must be entered in the National Register of Environmental Managers, set up by the Ministry of the Environment. The demolition of asbestos-containing products must be planned on the basis of a Work Plan and the contents of this plan are defines in paragraph 4 of article 256 of D.Lgs. 81/08.

- The demolition cannot be carried out without first removing the asbestos present without risk of dust dispersion in the environment. The asbestos removal from the building before its demolition may be omitted only whether such removal could not constitute a greater risk to workers than that asbestos-containing materials are left in place. It is obviously a task of the company employer evaluating the minor or major hazard of the removal prior to the demolition of the building.
- Dismantlers or removers must be equipped with Appropriate Personal Protective Equipment.
- It is specified the obligation, at the end of the work, to verify, also through appropriate measurements, the lack of asbestos residue at the demolition site.
- Measures for the protection of workers and third parties must be planned; the start date, the planned duration, the place where the work will be carried out, the techniques used to remove asbestos, the characteristics of the equipment or devices intended to be used must be specified.

A copy of the work plan shall be sent to the competent authority at least 30 days before the start of work. If, within that period, the competent authority does not make a reasoned request to supplement or amend the work plan and does not issue an operational prescription, the employer may carry out the work.

7.4.3 Disposal of asbestos containing waste

Legislative Decree no. 152/2006, Article 182, paragraph 5 specifies that waste disposal activities in landfills are governed by Legislative Decree No 36 of 13 January 2003, implementing Directive 1999/31/EC. Annex 2 of D.M. 27/09/2010 [40], amended by D.M. 24/06/2015, defines eligibility criteria for landfill asbestos waste. In particular, this kind of waste may only be delivered in the following types of landfill:

(a) landfill for hazardous waste, dedicated or with a specific cell;
(b) landfill for non-hazardous waste, dedicated or equipped with a single-dedicated cell for waste identified by the ELoW code 17 06 05*; for other types of waste containing asbestos, subjected to treatment processes, in accordance with D.M. 248 of 29/07/2004 and with values showed in Table 1 of that Decree verified with established frequency by the competent authority at the treatment plant.

Annex 2 of D.M. 27/09/2010 establishes the acceptance criteria at landfill sites for non-hazardous waste of treated asbestos-containing waste (asbestos content $\leq$ 30 % by weight; apparent density > 2 g/cm3; relative density > 50 %; release index < 0.6) and provides specific arrangements and criteria for asbestos-containing waste disposal. The deposit must take place directly inside the landfill in specific cells and must be carried out in order to avoid the materials crushing. The cells must be cultivated using sectors or trenches. They must be spaced in order to allow the passage of vehicles avoiding the asbestos materials shredding. In addition, to avoid the dispersion of fibers, the storage area must be covered with appropriate material both daily and before each compaction. If the waste is not packed, it must be regularly irrigated. The materials used for daily coverage must have plastic consistency, so as to adapt the shape and volume of the materials to be covered and to constitute an adequate protection against fiber dispersion, with a soil layer of at least 20 cm of thickness. In the landfill activities as perforations that can cause a fiber dispersion must not be performed. A map with the location of the asbestos containing area must be prepared and appropriate measures must be taken to avoid contact between waste and people. In the final coverage, the landfill area will have to be green reclaimed and not be affected by superficial excavation works.

Considering ISPRA analysis [35], in 2016 there were 21 operational landfills disposing of asbestos-containing waste, 17 landfills for non-hazardous waste and 4 for hazardous waste; of these facilities, 6 (3 for non-hazardous waste and 3 for hazardous waste) dispose of other types of asbestos waste in addition to construction materials containing asbestos. Most landfills are localized in the South with 9 plants (8 for non-hazardous waste and 1 for hazardous waste). In the North there are 7 plants (5 for non-hazardous waste and 2 for hazardous waste), and in the Centre 5 (4 for non-hazardous waste and 1 for hazardous waste). The asbestos containing materials landfilled in 2016 were equal to 231 Mio.Mg and represent about 2 % of the total amount of waste disposed and 18 % of total waste dangerous. 58 % is landfilled in the North, 25 % in the Center, 17 % in the South. The biggest quantity is made up of construction material waste containing asbestos, about 95 % of the total waste landfilled.

7.5 Case study: demolition plan of Polcevera viaduct

In Genoa the Polcevera viaduct, known as Morandi bridge, was built between 1963 and 1967 by *Società Italiana per Condotte d'Acqua SpA* on a project by engineer Riccardo Morandi. The horizontal structures were made by prestressed reinforced concrete. The towers and piers, instead, were in ordinary reinforced concrete.

On August 14, 2018 the section of the bridge over the Sampierdarena river and industrial area, about 250 meters long, collapsed together with the western support pier (pier 9). The collapse divided the bridge into two sections. The west side section consisted of piers 3, 4, 5, 6, 7, 8; this part of the bridge was curved and in a highly industrialized area where the buildings were extremely close to the deck. The east side section consisted of piers 10 and 11. It was a "balanced system" in which each part was statically independent. Below pile number 10 there were many houses expressly evacuated. The area around pile 11, on the other hand, was much less urbanised.

As described in *Relazione Generale* [41], the demolition phases of Polcevera viaduct were planned on the basis of a specific documentary study of the artefact. The Report describes:

- Preliminary site activities as load tests to verify the stability conditions of the bridge, surveys, material characterization, preparation of the operating;
- Project operations for the safety measures of the two parts of the bridge;
- Description of the operational sequences of the demolition of civil housing and industrial buildings below the deck;
- Steps for dismantling and demolition of western and eastern sections of the bridge;
- Disposal plan and management methods for the resulting materials from the demolition of the bridge, the structures and the buildings.

The design phase was carried out in three phases:

- Preliminary: initial phase in which different operational demolition scenarios have been planned in order to define the most suitable demolition methods for each part of the viaduct.
- Final technical-economic feasibility: more concrete development of the techniques defined in the previous phase; identification of critical issues and related solutions.
- Executive: final design phase in which all the technical aspects of the work are analysed in detail.

During the executive design phase, a series of work plans and technical reports have been drawn up in which the planning of the activities carried out before, during and after the demolition of the structures is provided in detail. In particular, the Environmental Report [42] provides an assessment of the potential impacts on the different matrices and components involved in the demolition.

7.5.1 Management of asbestos-containing materials

Since the bridge and surrounding buildings were built before 1992, year in which the use of asbestos in construction was banned, investigation campaigns were planned to remove and dispose of hazardous substances before the demolition.

CIVIL AND INDUSTRIAL BUILDINGS

Before the demolition of the two western and eastern sections, the buildings located in the red zone were demolished. No underground parts or foundations were destroyed. The deconstruction planning of civil and industrial buildings provided for the strip out of all supplementary construction elements that could be easily removed by hand by the staff in order to differentiate as much as possible the resulting material before the real demolition. The deconstruction activities started only after the certificate of the reclamation of materials containing asbestos and the certificate of electrical disconnection of the buildings.

The company IREOS S.p.A. carried out the reclamation activities of asbestos containing materials in the eastern buildings. The working plan is described *in Piano di lavoro materiali contenenti amianto friabile caseggiati via Porro - levante* [43] and *Piano di lavoro materiali contenenti amianto compatto caseggiati via Porro - levante* [44]. The documents provide detailed information on:

- List of asbestos containing materials, their volume, dimensions and weight for each building analysed;
- Description of the site preparation, measures taken to prevent risks to human health and description of executive activities for the removal of elements;
- Description of personal protection means, materials and equipment used;
- Photo-documentation;
- Attachments with description of the company, certifications and technical data sheets of the equipment used.

Compact asbestos has no tendency to develop free fibres; according to the operational procedure adopted, the company has decided not to carry out environmental sampling. The compact material removed has been classified as special hazardous material with ELoW code 17 06 05* (construction material containing asbestos).

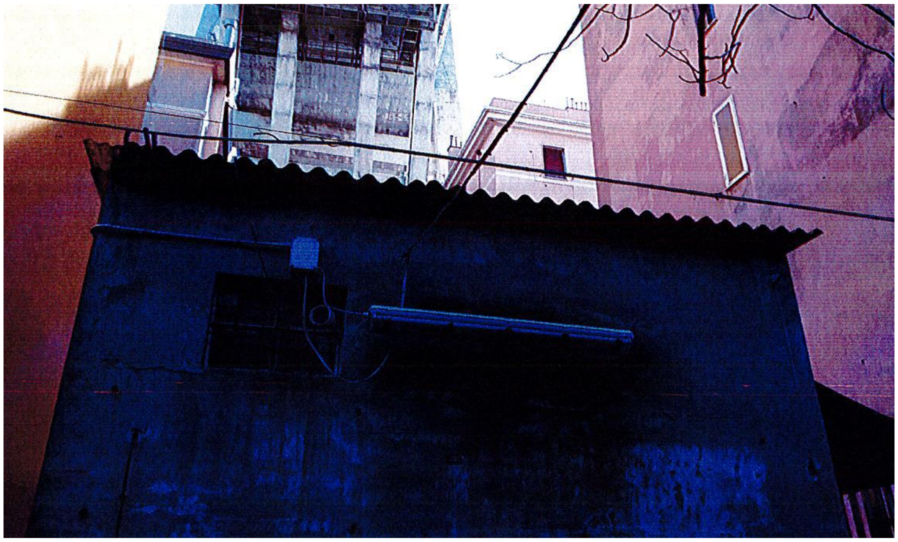

Figure 23: Example of roof in asbestos cement [44]

In case of materials with friable asbestos, the legislation provides for the measurement of asbestos fibres concentration inside the building through environmental monitoring. The monitoring was conducted through mobile samplers equipped with a cellulose nitrate membrane with porosity of 0.8 μm and diameter of 25 mm. The duration was about 4 hours (2 l/min). The analyses were carried out with M.O.C.F. as described in D.M. 6/9/94. Initially a monitoring was carried out in the operational area to determine the background value. During the reclamation, daily sampling was carried out (1 inside the operating zone and 1 outside). After the removal of contaminated elements, the company performed monitoring inside the operating zone. The removed material has been classified as special hazardous material with ELoW code 17 06 01* (insulating materials containing asbestos).

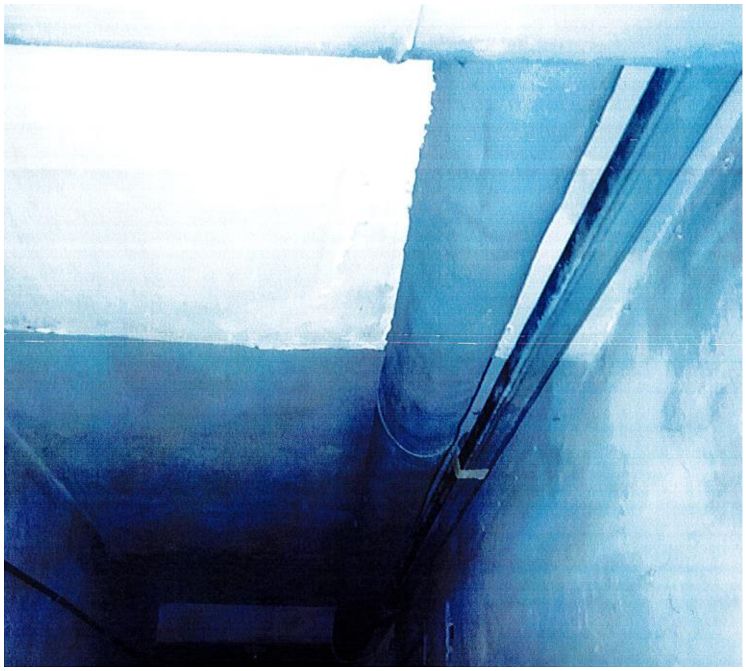

Figure 24: Insulating pipes containing friable asbestos [43]

The disposable materials (gloves, polyethylene consumables) were bagged and disposed of with asbestos-containing materials with EloW code 15 02 02* (absorbents, filter materials -including oil filters not otherwise specified- wiping cloths, protective clothing contaminated by hazardous substances).

SITE AREA ARRANGEMENT

The area below the viaduct, in particular for the eastern section, was characterized by the presence of ballast potentially containing asbestos on which the railway tracks were installed. The *Piano di lavoro amianto per predisposizione area di cantiere (incapsulamento ballast) – levante* [45] describes the asbestos reclamation operations (securing rail ballast and possible hot spot removal) in view of the subsequent demolition and management of the bridge. The intervention area was about 15 000 - 20 000 m^3 and railway ballasts were surface treated with red "encapsulating" product, in compliance with the requirements of D.M. 20/08/99. The removal of the crushed stone was carried out prior to soil excavation at the points where the foundations of the towers used to secure the 10 and 11 piles could insist. The report describes the operating procedures envisaged for the removal of the ballast. There is also the description of the results of the materials analysis.

Monitoring activities were conducted through mobile samplers equipped with cellulose nitrate membrane with porosity of 0.8 μm and diameter of 25 mm. The duration of the sampling was 4 hours and the analyses were performed with M.O.C.F. reading. 4 samples were taken for each working day at the 4 cardinal points with reference to the excavation area.

With regard to disposal operations, the document gives information on the possible ELoW codes:

- 17 05 07* (track ballast containing hazardous substances) if the material removed is classified as special hazardous according to regulations;
- 17 05 08 (track ballast other than those mentioned in 17 05 07) if it is not dangerous.

<u>WESTERN SECTION</u>

The following operations were planned for the demolition of the western section [41]:

- lowering the buffers to the ground using strand jacks and cantilevers;
- demolition of stack 8 by explosive;
- dismantling stacks 1-7 by crane and excavators.

To assess the feasibility of the stack 8 demolition using explosives, a series of core drillings was made all along the pylon to verify the presence of asbestos in concrete.

N°Campione	AREA CROLLO PONTE MORANDI - GENOVA		Amianto Presenza - Assenza	Amianto tipologia	Amianto concentrazione DM 06/09/94 All. 1/B mg/Kg
4710/19	Ponte Morandi - pila 8 - montante 3 quota 3.70m	25/02/2019	ASSENTE	-----	
4711/19	Ponte Morandi - pila 8 - montante 2 quota 3.70m	25/02/2019	ASSENTE	-----	
4773/19	Ponte Morandi pilone 8 montante 1 quota 3.70 m	25/02/2019	PRESENTE	CRISOTILO	<120
4774/19	Ponte Morandi pilone 8 montante 4 quota 3.70 m	25/02/2019	ASSENTE	-----	
4793/19	Ponte Morandi pilone 8 montante 5 quota 3.70m	26/02/2019	ASSENTE	-----	
4794/19	Ponte Morandi pilone 8 montante 6 quota 3.70m	26/02/2019	ASSENTE	-----	
4795/19	Ponte Morandi pilone 8 montante 7 quota 3.70m	26/02/2019	ASSENTE	-----	
4796/19	Ponte Morandi pilone 8 montante 8 quota 3.70m	26/02/2019	ASSENTE	-----	
4912/19	Ponte Morandi pilone 8 montante 5 quota 20m	26/02/2019	ASSENTE	-----	
4913/19	Ponte Morandi pilone 8 montante 6 quota 20m	26/02/2019	PRESENTE	CRISOTILO	<120
4914/19	Ponte Morandi pilone 8 montante 7 quota 20m	26/02/2019	ASSENTE	-----	
4915/19	Ponte Morandi pilone 8 montante 8 quota 20m	26/02/2019	ASSENTE	-----	
5158/19	Ponte Morandi pilone 8 montante 5 quota 37m	27/02/2019	ASSENTE	-----	
5159/19	Ponte Morandi pilone 8 montante 6 quota 37m	27/02/2019	ASSENTE	-----	
5160/19	Ponte Morandi pilone 8 montante 7 quota 37m	27/02/2019	ASSENTE	-----	
5161/19	Ponte Morandi pilone 8 montante 8 quota 37m	27/02/2019	PRESENTE	ANFIBOLO	<120
5213/19	Ponte Morandi Pilone 8 Montante 1 Quota 20 metri	28/02/2019	PRESENTE	CRISOTILO	<120
5214/19	Ponte Morandi Pilone 8 Montante 4 Quota 20 metri	28/02/2019	ASSENTE	-----	
5215/19	Ponte Morandi Pilone 8 Montante 4 Quota 20 metri	28/02/2019	ASSENTE	-----	
5216/19	Ponte Morandi Pilone 8 Montante 4 Quota 20 metri	28/02/2019	ASSENTE	-----	
5303/19	Ponte Morandi pilone 8 montante 1 quota 37	01/03/2019	ASSENTE	-----	
5304/19	Ponte Morandi pilone 8 montante 2 quota 37	01/03/2019	PRESENTE	CRISOTILO	<120
5305/19	Ponte Morandi pilone 8 montante 3 quota 37	01/03/2019	PRESENTE	CRISOTILO	<120
5306/19	Ponte Morandi pilone 8 montante 4 quota 37	01/03/2019	ASSENTE	-----	
5694/19	Ponte Morandi Pila 8 Ponente S1	06/03/2019	ASSENTE	-----	
5695/19	Ponte Morandi Pila 8 Ponente S2	06/03/2019	ASSENTE	-----	
5696/19	Ponte Morandi Pila 8 Ponente C1	06/03/2019	ASSENTE	-----	
5697/19	Ponte Morandi Pila 8 Ponente C2	06/03/2019	ASSENTE	-----	
5698/19	Ponte Morandi Pila 8 Ponente C3	06/03/2019	ASSENTE	-----	
5699/19	Ponte Morandi Tampone S2	06/03/2019	PRESENTE	CRISOTILO	<120
5700/19	Ponte Morandi Tampone soletta ST1	06/03/2019	ASSENTE	-----	
5701/19	Ponte Morandi Tampone soletta ST3	06/03/2019	ASSENTE	-----	
5702/19	Ponte Morandi Tampone fronte P	06/03/2019	ASSENTE	-----	

Figure 25: Asbestos in the stack 8 - Results inert analysis [46]

Figure 31 shows the results of asbestos research analysis conducted by ARPAL on counter-samples. The control analyses carried out by ARPAL showed that out of 33 samples: 67 % were "asbestos-free"; 33 % resulted containing asbestos, but with a concentration below the detection limit of 120 mg/kg. The investigations carried out by the Extraordinary Commissioner have shown that: 76 % of the samples taken from the viaduct were "asbestos-free"; 23 % of the samples resulted containing asbestos, but with a concentration below the detection limit of 120 mg/kg; only 1 % (3 samples) were found with a concentration greater than 120 mg/kg, but in each case well below the legislation threshold equal to 1 000 mg/kg (Table 1 of Annex V, Part IV, Title V of D.Lgs 152/2006).

The lithology of Liguria is often characterized by the presence of lithological components belonging to the group of the "green stones" or "green marbles", so called because of the natural mineral content of the family of amphiboles and asbestos serpentines. The presence of these minerals has always been a typical characteristic of quarry aggregates extracted in this area, commonly used for the packaging of concrete for the construction industry, and used in large infrastructure works and in civil construction. Investigations carried out by the Commissioner Extraordinary and ARPAL highlighted that concrete mix consisting exclusively of certain sections of the Polcevera viaduct were characterized by these aggregates. So, the presence of asbestos traces in the artefacts derived from the natural geological properties of the materials used at the construction time [46].

Based on the results of the analyses carried out, it was considered more precautionary to demolish the stack 8 without explosion. A suitable operating method was therefore defined to mitigate any possible risk of release or dispersion of asbestos, which involves dismantling the stack by crane.

A monitoring activity was planned to verify that the proposed activities did not result in diffusion of airborne asbestos fibres in the environment and to identify warning and hazard concentration levels.

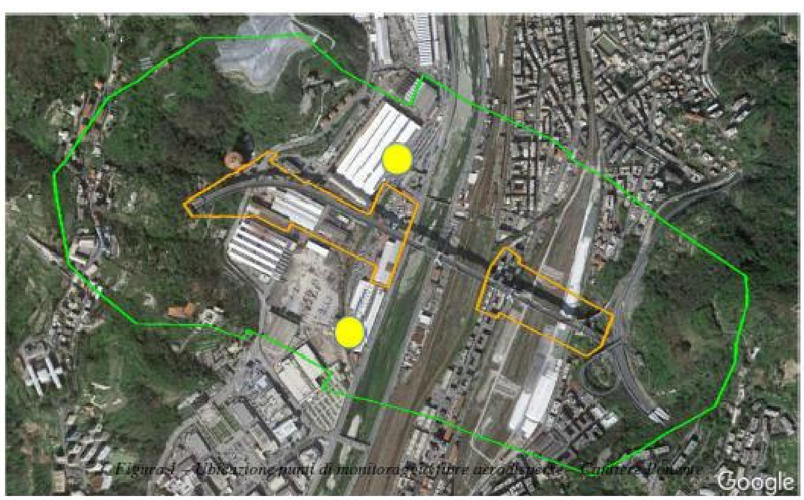

Figure 26: Location of airborne fibers monitoring points - Western part [47]

The environmental fund was measured before the start of the activities. Before the demolition works, sampling was planned at the two locations indicated in Figure 32 for a total of 15 days and a duration between 5 and 7 hours. During the demolition phase, sampling has been scheduled in the two workstations with weekly frequency, while, at the end of all demolition activities, a post-operam monitoring was carried out in the same stations and in the same way for a duration of 3 days.

EASTERN SECTION

The demolition project for piers 10 and 11 was developed in collaboration with the Polytechnic of Turin and the company specialising in demolition with explosives. During the simultaneous explosion of the two piles, the monitoring of the airborne fibres was carried out in 8 stations [48]. The sampling was realized using a high-volume sampler with a polycarbonate membrane. The membranes were analysed with the scanning electron microscope. The CUT OFF control threshold was equal to 0.5 ff/l. The simulation of airborne asbestos fibres concentration indicated that the average concentration of the first 4 hours after the explosion was less than 0.5 ff/l in almost the whole area outside the construction site.

Figure 27: Location of airborne fibers monitoring points - Eastern part [47]

In the pre and post demolition phases, a monitoring activity equal to that carried out for the western site was planned. During the demolition of the buildings, daily environmental monitoring was carried out at regular intervals. During the explosive demolition of the bridge piers, sampling was planned on the day on which such activity was scheduled, for the two previous days and for the two days later.

7.5.1.1 Overview of samples results

The main thresholds for asbestos are:

- Directive (EC) No 2008/98 [1], updated to Directive (EC) No 851/2018 [2] on waste: if a material is classified as waste and the asbestos concentration is less than 0.1 % (1 000 mg/kg), it is considered as "non-hazardous".
- Regulation (EC) No 1272/2008 [49], updated by Regulation (EU) No 2017/776 [50], on classification, labelling and packaging of substances and mixtures: if the asbestos in a mixture is in a concentration below 0.1 % (1 000 mg/kg), it is not classified as hazardous.
- EPA (United States Environmental Protection Agency): Drinking Water Standards: 7 million fibres per litre [51].
- WHO (World Health Organization - Air Quality Guidelines, 2000) [52]: the reference limit value in the outdoor living environment for the concentration of dispersed asbestos is set in 1 fibre/litre air, measured in SEM (electron scanning microscope).
- D.P.R. 120/2017 [53]: the maximum concentration limit in excavated soil and rock for use as by-product is 1 000 mg/kg.

The results obtained during the airborne asbestos monitoring campaign showed a maximum concentration value of about 0.45 fibre/litre in the western site and 0.2 fibres/litre in the eastern site.

Table 9 gives information on the results of the analysis conducted on processing water, water in soil and excavated soil. The results obtained have always demonstrated the absence of asbestos fibres or the presence of asbestos below the thresholds. In particular, the samples deriving from processing water resulted asbestos-free. From the analysis of groundwater and superficial water, two samples presented asbestos but under the fixed limit. All excavated soil samples analysed showed traces of asbestos, but below the threshold of 1 000 mg/kg.

Table 9: Results from processing water, water in soil and excavated soil analysis [54]

ACQUA DI LAVORAZIONE				
TOTALE CAMPIONI	AMIANTO SOPRA SOGLIA 7'000'000 ff/l	AMIANTO ASSENTE	AMIANTO SOTTO SOGLIA	ENTE
n.1 taglio cantilever 5	NEGATIVO	n.1 campione		Università di Genova DISTAV
n.1 taglio tampone 4	NEGATIVO	n.1 campione		Università di Genova DISTAV
n.1 taglio tampone 5	NEGATIVO	n.1 campione		Università di Genova DISTAV
ACQUA NEL TERRENO				
TOTALE CAMPIONI	AMIANTO SOPRA SOGLIA 7'000'000 ff/l	AMIANTO ASSENTE	AMIANTO SOTTO SOGLIA	ENTE
n.8 piezometri	NEGATIVO	n.7 campione	n.1 campione = 5'346 ff/l	Progetto Pergenova
n.2 acque superficiali	NEGATIVO	n.1 campione	n.1 campione = 16'037 ff/l	Progetto Pergenova
TERRA DA SCAVO				
TOTALE CAMPIONI	AMIANTO SOPRA SOGLIA 1000 mg/kg	AMIANTO ASSENTE	AMIANTO SOTTO SOGLIA	ENTE
n.36 asse Viadotto Polcevera	NEGATIVO		n.36 campioni < 120 mg/kg	Politecnico Torino DIATI
n.4 area futura pila 11	NEGATIVO		n.4 campioni < 120 mg/kg	Politecnico Torino DIATI
n.1 area futura pila 12	NEGATIVO		n.1 campione = 355 mg/kg	Politecnico Torino DIATI

The analyses on the samples extracted from the bridge artefacts were conducted by the *Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture* (DIATI) of Polytechnic of Turin. As shown in Table 10, in all the concrete elements studied, the asbestos detected did not exceed the threshold of 1 000 mg/kg.

SEM surveys showed that about 76 % of the samples analysed were asbestos-free, about 23 % had asbestos below the instrumental detectability limit 120 mg/kg, and approximately 1 % of samples had asbestos above 120 mg/kg, with a maximum of 245 mg/kg.

Table 10: Results from concrete analysis [54]

Elemento	n. campioni	AMIANTO SOPRA SOGLIA	AMIANTO ASSENTE	AMIANTO SOTTO SOGLIA
TAMPONE 2	15	NEGATIVO	n.12 campioni	n.3 campioni < 120 mg/kg
TAMPONE 3	14	NEGATIVO	n.11 campioni	n.3 campioni < 120 mg/kg
TAMPONE 4	19	NEGATIVO	n.17 campioni	n.2 campioni < 120 mg/kg
TAMPONE 5	14	NEGATIVO	n.14 campioni	
TAMPONE 6	13	NEGATIVO	n.11 campioni	n.1 campioni < 120 mg/kg; n.1 campione = 200 mg/kg
TAMPONE 7	14	NEGATIVO	n.13 campioni	n.1 campioni < 120 mg/kg
TAMPONE 8	11	NEGATIVO	n.11 campioni	n.1 campione < 120 mg/kg; n.1 campione = 165 mg/kg; n.1 campione = 245 mg/kg
PILA 1	8	NEGATIVO	n.5 campioni	n.3 campioni < 120 mg/kg
PILA 2	21	NEGATIVO	n.15 campioni	n.6 campioni < 120 mg/kg
PILA 3	27	NEGATIVO	n.20 campioni	n.7 campioni < 120 mg/kg
PILA 4	32	NEGATIVO	n.29 campioni	n.3 campioni < 120 mg/kg
PILA 5	32	NEGATIVO	n.31 campioni	n.1 campioni < 120 mg/kg
PILA 6	32	NEGATIVO	n.13 campioni	n.19 campioni < 120 mg/kg
PILA 7	32	NEGATIVO	n.19 campioni	n.13 campioni < 120 mg/kg
PILA 8	42	NEGATIVO	n.35 campioni	n.7 campioni < 120 mg/kg
PILA 9 detriti	4	NEGATIVO	n.4 campioni	
PILA 10	59	NEGATIVO	n.47 campioni	n.12 campioni < 120 mg/kg
PILA 11	34	NEGATIVO	n.21 campioni	n.13 campioni < 120 mg/kg

7.5.2 Disposal plan

During the pre-demolition phase, disposal in landfills has been provided for hazardous waste containing asbestos and recovery and multi-functional disposal for recoverable materials. The *Relazione Generale* specifies the need to manage about 100 000 Mg of waste, resulting from all demolition activities. The following estimates are shown:

Eastern part:

- 20 000 m^3 of waste from the bridge demolition waste, ELoW code 17 01 01 (concrete);
- 5 000 m^3 of waste from civil buildings' furniture, furnishings, fixtures, etc.;
- 10 000 m^3 of civil buildings demolition waste, ELoW code 17 09 04 (mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03);
- 100 m^3 of waste asbestos containing materials, ELoW codes 17 06 01* (insulation materials containing asbestos) and 17 06 05* (construction materials containing asbestos).

Western part:

- 14 000 m^3 of waste from the bridge demolition waste, ELoW code 17 01 01 (concrete);
- 10 000 m^3 of industrial demolition waste, ELoW codes 17 09 04 (mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03), 17 01 02 (bricks) and 17 01 01 (concrete).

The disposal project considered as a priority the reduction of waste and its transformation into secondary raw materials to be used directly at the place of production, after verification of compliance with legal limits. In particular, it considered: disposal or recovery of waste from strip-outs and asbestos-containing materials; disposal in the landfill for hazardous waste "Barricalla" in D1 (located in Collegno -TO) for materials containing asbestos in concentrations above 1 000 mg/kg; recovery on site (after treatment with an authorized plant or in several external authorized plants) of demolition debris, after analytical characterization and verification of compliance with the limits set for inert recovery plants.

The best solution in order to reduce the environmental impacts for transport and disposal is the transformation of debris into secondary raw materials for reuse on site or at regional sites. The processing stages of the authorized crushing plants were:

- Deferrization and sending the iron to an authorized plant for cutting and recovery;
- Volumetric reduction of the detritus;
- Waste processing with production of secondary raw materials through crushing and sorting, disposal of processing waste (analytical checks);
- Reuse of secondary raw materials on site for the construction of construction site tracks, levelling and protection works.
- Transfer of secondary raw materials to a third company as part of already approved local construction works.
- Sending any fraction of waste to a duly authorized recovery or landfill facility.

Preliminary to the use of the mobile plant, the project provided for the collection of rubble samples to verify the classification of waste as non-hazardous, to be subjected to the leaching test as per Annex 3 of Ministerial Decree no. 186 of 05/09/06 [55] and to be compared with the limits indicated by the mentioned decree. If the representative sample had been found not to comply with the regulatory limits, the material could not have been certified as a secondary raw material. If even one of the reference limits is exceeded, the relative materials had to be considered unsuitable for reuse and sent to authorized recovery or disposal plants according to ordinary procedures (Art. 208 D.Lgs 152/06) [41]. In particular, the threshold for the asbestos concentration laid down in the Decree is 30 mg/l. The samples analyses showed that the asbestos detected was below the thresholds defined by the regulations, but exceeding the limit imposed for the leaching test it was not possible to reuse much of the demolished material as secondary raw material. For example, although there was a need to create areas of debris or levelling material within the demolition site, it was not possible to use the material from the deconstruction of the buildings because it did not comply with the limits imposed by the regulations. The rubble was bought with a consequent economic and environmental impact, due to the transport of a quantity of material equal to tens of thousands of m^3.

The official documents on the program for the reuse of the materials deriving from the demolition of the viaduct and the buildings, show the summary authorization scheme for the storage and subsequent recovery of the material:

- activities of placing in reserve (R13) at the "Campasso" site of 50 000 m^3 of special non-hazardous waste from the demolition of the Polcevera viaduct and interfered houses;
- activity of placing in reserve (R13) of 27 000 m^3 of special non-hazardous waste at the site for the reconstruction of the Polcevera Viaduct on the western side;
- recovery activity (R5), for reprofiling project of the construction site areas of 27 000 m^3 of special non-hazardous waste, at the construction site area for the reconstruction of the Polcevera Viaduct, west side;
- treatment (R12) and storage (R13) at the site Compursone (Genoa East) of 35 000 m^3 resulting from the demolition of the Polcevera viaduct on the A10 Motorway and 9 000 m^3 of materials from the former Peninsula, with maximum instantaneous storage of 25 000m^3.

The storage in reserve R13 constitutes a preliminary and instrumental operation for a different and subsequent activity, that of recovery in terms of R1 to R12. Since August 2019, a total of 60 000 m^3 arising from the Polcevera viaduct demolition have been reused.

7.5.3 Discussion

In Italy, pre-demolition audit is not mandatory but, as the case study shows, as part of the planning of demolition projects for the Polcevera viaduct, all the work activities were planned in detail, from the description of the demolition methods used to the classification and potential destination of waste. All the original documentation and maintenance protocols have been collected. Architectural plans and technical drawings were reported in order to obtain useful information to design the field survey and to draw up the demolition methods. During the field investigation, elements were removed from the civil buildings and samples of potentially hazardous materials were taken. A full assessment of the materials was carried out, an estimate of the waste streams from the various planned activities was made and photographs of the details were included to make the reports easier to read. The executive projects, therefore, contain many aspects foreseen in the European guidelines for the preparation of a pre-demolition audit.

As specified by the European Union ‹‹ the waste audit should also consider any relevant legislation such as the requirements for environmental permits if waste is to be used on-site or any waste that may be hazardous and which needs to be managed in accordance with specialized waste legislation ›› [13]. On the other hand, it must facilitate and maximize the recovery of materials and components arising from the demolition or refurbishment of structures for useful reuse and recycling, minimizing environmental impacts.

These two aspects are contrasting in the management of materials deriving from the demolition of the Polcevera viaduct. About 98 % of the rubble coming from demolition, in particular in buildings, was characterized by inert material which, with appropriate processing, could be reused in construction, earthmoving or to fill disused quarries also present in the Genoa area. Despite this, only a small part of the debris from the demolition of the Morandi bridge was reused in the construction system, because the law requires that it be treated as inert material and then sent for disposal as waste. This contrasts with the intention of increasing the reuse of materials in the construction sector and the containment of environmental impacts linked to the transport of large quantities of debris and the disposal of waste. The case study in question highlights how the set of Italian rules governing the subject of waste constitutes a rather vast and articulated reference framework with some elements of overlap and contradiction. The absence of specific regulations governing the management of this waste amplifies these contradictions, such as the high restrictions on waste, hazardous waste, and regulations for shredding during construction site activities.

In this context, the preparation of a pre-demolition audit could help to make specific recommendations on material management, to focus on the possibilities of recycling and reuse, by identifying the type and quantity of elements and materials that will be dismantled and/or demolished. This document provides a preliminary understanding of the reuse potential of the structure and components, defines opportunities for closed loop reuse and material recycling and assesses the costs and benefits for materials that can be reused in their original form, recycled or landfilled.

In Italy, the management of asbestos in construction is very detailed, but guidelines should give on how to identify other hazardous substances that may be present in construction. The evaluation of materials before the buildings' demolition aims to present reliable data about the type and amount of waste produced. In this way, after or during demolition it is possible to verify if hazardous waste is correctly removed or if it is hidden and the presence of discrepancies found in the initial estimate. Pre-demolition audit also provides details on waste streams and on the composition of the several typologies of buildings that could also be used as useful information to improve and make more specific the C&D legislation, as in the Italian case.

8. Conclusion

The aim of this study was to assess European potential for a circular economy in the construction and demolition sector, highlighting the most influential aspects and different approaches adopted by the 28-EU countries. Above all, the pre-demolition phase was analysed as a fundamental step towards a correct and circular C&D waste management.

The analysis conducted does not consider backfilling as recovery operation because it doesn´t help the development of circular economy in the built environment and obstacles the increase of recycling companies. This choice shows that, despite the European average recycling rate was 75 % in 2016, some Member States did not reach the target imposed by the Waste Framework Directive because their recovery rate was highly dependent on the backfilling quota. In addition, data from recycling plants are considered to be more reliable than data from backfilling operations, which are often affected by uncertainties. For these reasons, the study was performed by comparing C&D waste management by

Member States to their recycling rate. In this way, it was also possible to better define which data provided to Eurostat are characterised by clear over- or underestimates.

The results obtained demonstrate that the increase of C&D recycling quota and management performance of Member States should start from the unification of a robust political will, including mature and realistic targets, with the investment of resources, finances and implementation of control measures. The public partner should create the conditions for the C&D waste recycling market to flourish through legislation, appropriate material quality assurance mechanisms and the development of more advanced technologies. While laws are clearly in place, other aspects such as the implementation of existing legislation, the introduction of possible landfill bans to increase recycling activities and the introduction of specific recycling targets should be improved in line with the ambitions of the circular economy.

The most advanced European legislations adopted a mandatory pre-demolition audit. It allows obtaining pure waste streams from the buildings' demolition. The consequence is an increase of material traceability, waste data quality at project scale and secondary material markets with the increase of stakeholders´ confidence of recycled products. Obviously, the drafting of a pre-demolition audit involves the adoption of selective demolition methods, separation of materials at source, analysis and inspections that involve costs and increase the working time set by contractual conditions. In addition, this phase allows to evaluate the potential reuse and recycling of materials and elements which, however, encounter obstacles such as: the possibility of reuse by the same customer at local level or sales at local level; the presence of treatment plants close to the demolished site to cushion the impacts due to transport; the presence of a market for secondary raw materials. All the factors analysed are therefore linked and one directly affects the other in the whole C&D waste management.

The case study of the demolition of the Morandi bridge shows that in Italy the management of hazardous materials, in particular asbestos, is legislated in a very specific way. During the demolition works, plans were drawn up for the analysis and monitoring of potentially dangerous elements. In addition, the reuse and recycling of materials resulting from the deconstruction of the structures were planned. Despite this, a large part of the inert material demolished was managed as waste as required by national legislation. This criticality highlights how specific and consistent legislation on construction waste is needed in Italy and how the presence of a specific and mandatory pre-demolition audit can benefit the management and disposal of materials.

The methodological research presents critical points, which could be developed in a future study. In fact, the scores assigned to the categories analysed are arbitrary, qualitative and not weighted according to the evaluation of the individual performance of the Member States; the meaning of each score assigned also derives from an average of the approaches that the Member States have adopted towards the factors considered. In addition, other influential aspects such as new recycling technologies, Green Public Procurements, business context could be taken into account for a more complete assessment.

9. Appendices

9.1 Appendix 1: Correlation between EWC_Stat and ELoW codes

Data sets collected by Eurostat to classify waste are based on the European Waste Classification for Statistics (EWC-Stat). The following tables show the equivalence between the EWC_Stat and ELoW (European List of Waste) codes for waste generated by the NACE Rev. 2 Section F (construction sector).

Table 11: EWC_Stat and ELoW codes, Non-hazardous waste from construction sector

EWC_Stat	Description	ELoW	Description
W121	Mineral waste from construction and demolition (non-hazardous)	17 01 01	Concrete
		17 01 02	Bricks
		17 01 03	Tiles and cables
		17 01 07	Mixture of concrete, brick, ceramics
		17 05 08	Track ballast
		17 08 02	Gypsum-based materials
		17 03 02	Bituminous mixtures
		17 06 04	Insulation materials
		17 09 04	Mixed C&DW
W061	Metallic, ferrous	17 04	Metals
W062	Metallic, non-ferrous		
W063	Metallic, mixed		
W071	Glass	17 02	Wood, glass, plastic
W074	Plastic		
W075	Wood		

Table 12: EWC_Stat and ELoW codes, Hazardous waste from construction sector

EWC_Stat	Description	ELoW	Description
W121	Mineral waste from construction and demolition (hazardous)	17 01 06*	Contaminated inert mixtures
		17 08 01*	Contaminated gypsum
		17 05 07*	Contaminated track ballast
		17 03 03*	Coal tar and tarred products
		17 02 04*	Contaminated glass, plastic, wood
		17 06 03*	Contaminated insulation materials
		17 09 01*	CDW with mercury
		17 09 03*	Other contaminated materials
W12B	Other mineral waste	17 06 01*	Insulation materials with asbestos
		17 06 05*	Construction materials with asbestos
W077	Waste with PCB	17 09 02*	CDW containing PCB

9.2 Appendix 2: NH mineral C&D waste generated, treated and recycled by MS

The following data derived from Eurostat Database. The reference year is 2016.

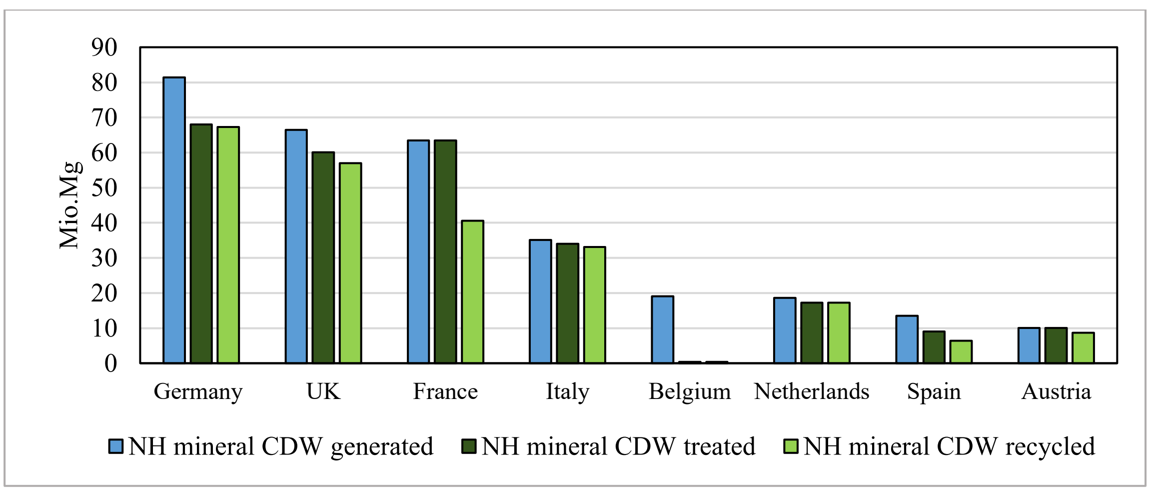

Figure 28: MS that generated more than 10 Mio.Mg of NH mineral C&D waste in 2016

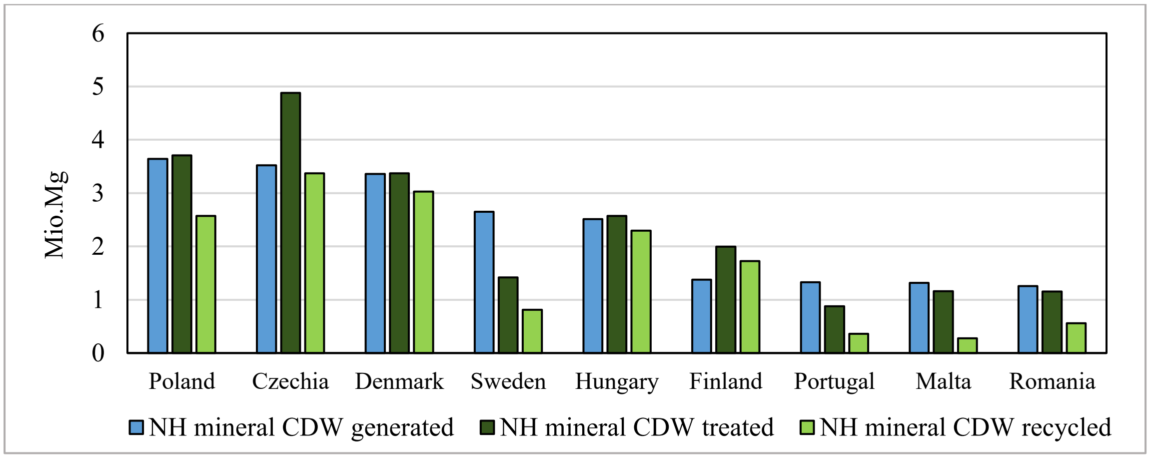

Figure 29: MS that generated more than one Mio.Mg of NH mineral C&D waste in 2016

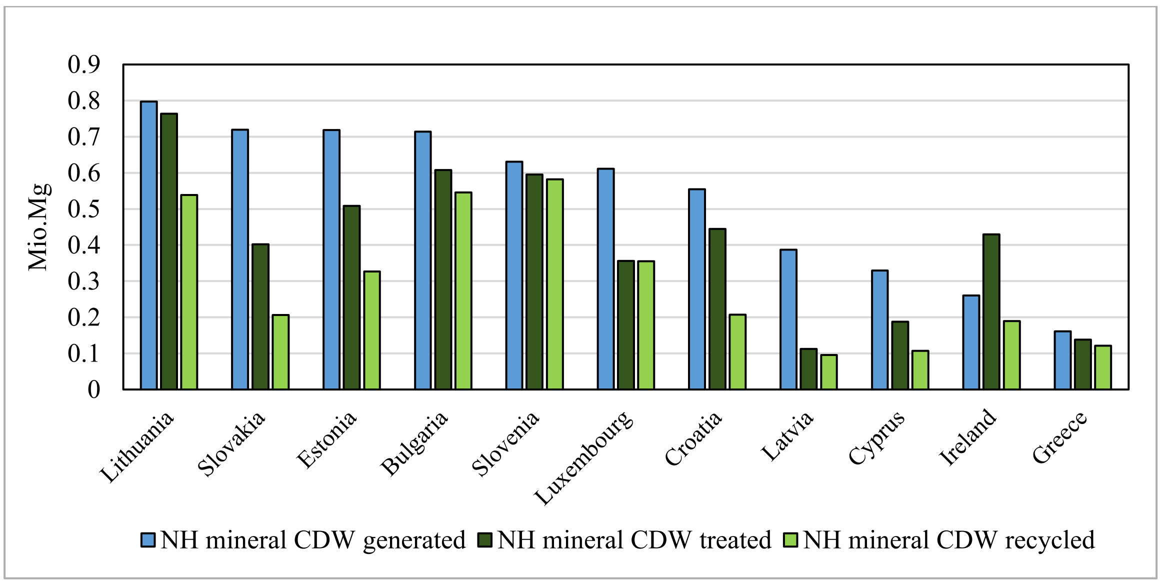

Figure 30: MS that generated less than one Mio.Mg of NH mineral C&D waste in 2016

9.3 Appendix 3: Pre-demolition audit templates

The inventory of waste materials and elements is usually reported using templates. These tables can be used also to collect details about the project and information from the desk study and field survey.

Table 13: Poject details [28]

Project reference	
Project location	
Project type	Demolition / refurbishment
Structure type	House / multi-storey offices / factory, etc.
Approximate age of structure	
Client details (company requesting the audit)	
Floor area of demolition	
Cost of demolition	
Scope of demolition /refurbishment	Summary of what parts of structures to be demolished /refurbished

The *desk study* consists on the analysis of the documentation concerning the building to be demolished. The aim is to collect projects, site drawings, maintenance and renovations documents. The accesses and the surroundings can give information on the conditions for storage, transport and management of the waste streams.

Table 14: Desk study

Site drawings	
Maintenance doc.	
Renovation doc.	
Information about accesses and surroundings	Conditions for storage, transport and management of the waste streams
Photographs	
Other information	Structural and non-structural elements, hazardous substances, surveys

The *field survey* allows to inspect visually all the parts of the site to be demolished. Sampling and laboratory analyses are requested for suspicious hazardous materials. During the site visit, it could necessary to do non-destructive and destructive techniques.

It is a good practice to take picture and measures that will be included in the final inventory and to inspect the building when it is no longer occupied.

Table 15: Field survey

Date	
Inspectors	
Non-destructive techniques	NO/YES, Typology
Destructive techniques	NO/YES, Typology
Surveys	NO/YES, Typology
Suspected of hazardous substance	NO/YES, location, elements
Photographs	
Limitations	Safety issues, limited accessibility, places still occupied during the site visit, etc.

Table 16: Inventory of non-hazardous materials

BUILDING:
LEVEL:
Other relevant information:

TYPE OF MATERIAL	ELoW CODES	AMOUNT & UNIT	WASTE MANAGEMENT OPTIONS	HANDLING PRECAUTIONS	DESTINATION (treatment plants/landfill)	LEGAL STORAGE, TRASPORT CONDITIONS
Concrete	17 01 01					
Bricks	17 01 02					
Tiles and ceramics	17 01 03					
Inert (mixtures)	17 01 07					
Wood	17 02 01					
Bituminous mixtures	17 03 02					
Metals	17 04					
Insulation	17 06 04					
Gypsum	17 08 02					
General waste	17 09 04					
Other waste						

Table 17: Inventory of hazardous materials

BUILDING:
LEVEL:
Other relevant information:

TYPE OF MATERIAL	ELoW CODES	AMOUNT & UNIT	WASTE MANAGEMENT OPTIONS	HANDLING PRECAUTIONS	DESTINATION (treatment plants/landfill)	LEGAL STORAGE, TRASPORT CONDITIONS
Mixture of hazardous inert	17 01 06*					
Hazardous glass, plastic and wood	17 02 04*					
Bituminous mixtures with coal tar	17 03 01*					
Coal tar and tarred products	17 03 03*					
Metals with hazardous substances	17 04 09*					
Cables with oil, coal tar and other	17 04 10*					
Insulation material with asbestos	17 06 01*					
Insulation material with h. substances	17 06 03*					
C&D waste with asbestos	17 06 05*					
Contaminated gypsum-based materials	17 08 01*					
C&D waste with mercury	17 09 01*					
C&D waste with PCB	17 09 02*					
Other contaminated C&D waste	17 09 03*					

If the contamination is superficial, it is possible to decontaminate the materials and evaluate the possibility to reuse or recycling it. On the other hand, a good option may be the incineration in plants where energy is recovered, for example for insulation materials or contaminated wood. The removal and handling of dangerous materials depends on the requirements imposed by national/regional laws.

Table 18: Inventory of elements

AREA	ELEMENT	MATERIAL & WASTE CODE	m^2 / m^3 / tonnes	CONDITION	REUSABLE	POSSIBLE MARKETS	OTHER HANDLING
Ex. First floor, Room 1	Doors	Wood 17 02 01			YES / NO	On site, web sites, companies, etc.	Recycling, Incineration, Landfill, etc.
	Stairs						
	Windows						
	…						

Best practice:

- Photo-documentation to provide details on the inspected elements, their location and description and information about the possibility of reusing.
- If the element contains hazardous substances, the auditors should add to the inventory the typology of dangerous substances, the analysis results, their specific location and the legal requirements followed to remove and manage hazardous waste.
- In order to obtain a more detailed pre-demolition audit, the number, length, depth, height of the elements found in the building should be calculated.

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