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RE4 Project

REuse and REcycling of CDW materials and structures in energy efficient pREfabricated elements for building REfurbishment and construction

D1.4

Overview on the current status on policy measures and regulatory frameworks

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Abstract:	This report outlines EU policies and regulations about prefabricated elements integrating recycled materials from CDW. The scope of this deliverable is to analyse technical regulation and legislation and policy measure among the EU countries, underlining critical aspect and proposing recommendations to ensure the developing of CDW materials among the production of prefabricated elements, and the improving of prefab construction market.
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ACRONYMS & ABBREVIATIONS

ARV	The excavation, dismantling and recycling organisation Switzerland
BAFU	Swiss Federal Office for the Environment
BDF	Federal Association of German Prefabricated Buildings
BREE	Building Research Establishment
BREEM	Building Research Establishment Environmental Assessment Method
CAGR	Compound Annual Growth Rate
CEN	European Committee for Standardisation
CPR	Construction Products Regulation
CDW	Construction and Demolition Waste
DoP	Declaration of performance
EN	European standard
EAD	European Assessment Documents
ETA	European Technical Assessments
EU	European Union
FOEN	Federal Office for Environment
GEAR	Guide of recycled aggregates
GGBFS	granulated ground blast furnace slag
HS	Harmonised system
hEN	Harmonised European Standard
LCA	Life-cycle assessment
LCC	Life-cycle cost
LEED	Leadership in Energy and Environmental Design
LNEC	National Laboratory of Civil Engineering
MRA	Mixed Recycled Aggregate
QDF	Quality association Deutscher Fertigbau
PCI	Product Complexity Index
PCR	Product category rules
RC	Reinforced Concrete
RA	Recycled Aggregates
RCA	Recycled Concrete Aggregates
RMA	Recycled Masonry Aggregate
SBS	Structural Business Statistics
UEPG	European Aggregates Association
UK	United Kingdom
USGBC	U.S. Green Building Council
WP	Work Package
yoy	Year over year

1. EXECUTIVE SUMMARY

I. Deliverable D1.4 (Overview on the current status on policy measures and regulatory frameworks) provides an overview of technical regulation and legislation, and policy measure concerning prefabricated elements integrating recycled materials from construction and demolition waste (CDW). This is done both at European and at national level, with the aim to underline barriers and drivers linked to them. Meeting this objective has been possible only by the correlation between technical information and market analysis. Data from Taiwan has also been collected, thanks to the contribution of the extra-EU partner NTUST.

II. The **objectives** of this report are:
- Analyse technical regulation and legislation regarding CDW and prefabricated elements;
- Map market of CDW and prefabricated construction;
- Define barriers/drivers linked to current measures, regulations and legislation.

III. This report is useful for several **stakeholders**: first for RE^4-Project partners involved in the development of the innovative prefabricated elements, and then for anyone involved in the production of prefabricated elements and constructions.

IV. The **methodology** used is based on a four-stage approach (1. Definition of information/data to search for; 2. Information/data collection; 3. Information/data analysis; 4. Drivers/barriers definition) to collect and analyse technical and market data information necessary for the assessment of the current situation regarding technical regulation and legislation on the use of CDW in prefabricated elements, within the EU countries and Taiwan (the extra-EU country involved in the Project).

V. The **structure of the report** is composed of the following chapters:
Chapter 1 (Executive summary) gives the main points of the report, focusing on the main conclusions of the document.

Chapter 2 (Introduction) gives a brief description of RE^4, and summarises the final scope of the report.

Chapter 3 offers an **overview of the methodology** used in carrying out this study, describing the general approach used, the main phases and the methodology used to analyse market data.

Chapter 4 analyses **Technical regulation and legislation** about CDW, materials from CDW, prefabricated elements and construction, collecting information from EU Member States and Taiwan, focusing mainly, on technical aspects.

<u>CDW.</u> The Waste Framework Directive 2008/98/EC aims to have 70% of CDW recycled by 2020. However, with the exception of a few EU countries, only about 50% of CDW is currently being recycled. The good news is that some EU countries have already developed and implemented a framework, which leads to a recycling rate of up to 90% [2]. Most of the studied countries also have policies and regulation specifically targeting CDW management.

Specific technical standards for CDWs were found only in a few European countries, including Austria, Italy and Switzerland. Particularly, in Switzerland there are technical specifications for the recycling and recovery of each kind of mineral CDW.

Materials form CDW. The mineral fraction of CDW is the main used in construction application as recycled aggregates. Even if in some European Countries the "*end of waste*" status is not define for CDW, the European technical standards (EN) on aggregates used in construction, define "**recycled aggregates**" as "*aggregate resulting from the processing of inorganic material previously used in construction*", so they are subjected to specific tests and controls. As EN standards on aggregates are harmonised standards, all recycled aggregates are subjected to CE marking, before their commercialisation, according to the Construction Products Regulation CPR 305/2011/EU. At national level, several countries have their specific instruction standards provided additional provisions for the national application of European standards, such as Hungary, Italy, Netherlands, Portugal, Switzerland. In Taiwan national standards regulates mostly the use of industrial recycled materials as filler and aggregates in concrete production.

Focusing on the use of recycled aggregates for concrete, the standard **EN 206:2013+A1:2016** *Concrete - Specification, performance, production and conformity*, classifies recycled aggregates based to their composition: Type A and Type B, following the concrete aggregate standard, **EN 12620:2002+A1:2008** *Aggregates for concrete*. It limits the use of the two different type according to the concrete exposure class to which they are to be placed. EN 12620 provides that coarse recycled aggregates shall be examined for the purpose of identifying and estimating the relative proportions of the constituent materials according to **EN 933-11** *Tests for geometrical properties of aggregates - Part 11: Classification test for the constituents of coarse recycled aggregate*. The fine fraction (0 - 2 mm), i.e. filler aggregates, of the recycled aggregate is not specifically mentioned, neither in the aggregate standard, EN 12620, nor in the concrete standard, EN 206. Thus, no specific rules for this are given but there are not any prohibitions either.

As EN 206:2013 is not a harmonised standard it refers to additional provisions in force in the country in which the concrete is produced and used. Therefore, recycled aggregates for concrete are subjected to several quality standards, depending on the national legislation. Comparing the different national classification of recycled aggregates based on their composition it can define three typology of recycled aggregates: RCA recycled aggregate concrete, RMA recycled masonry aggregate and MRA mixed recycled aggregate. The prevalent one is the typology RCA. Also the required geometrical, physical, mechanical and physical characteristics differ from the various national regulations. About geometrical characteristics, main evidences of the comparison are: compliance with specifications of particle size, shape and distribution is crucial to assure high- quality concrete; limits are most often specified for fines content and then for flakiness index; in contrast, the maximum aggregate size and crushing value are seldom mentioned; various standards do not include any geometric requirements at all for recycled aggregates; only the British Standards limits maximum aggregate size for RCA and RMA, most regulations do not permit the use of fine RCA. About physical characteristics, density and absorption are the ones most widely included, regardless of aggregate type; less frequently, bulk density, specific gravity and losses of ignition are required. The mechanical specification that is most frequently included in the standards is the Los Angeles abrasion coefficient. Soundness also appears in the norms. However, in all cases, it is required for RCA and in some cases, for ceramic and mixed recycled aggregates. Finally, the most frequently required chemical characteristic included ones pertain to the chloride and sulfate content of the aggregate. The reason for this is that these chemicals can potentially lead to the corrosion and deterioration of hardened concrete. Also mentioned are the presence of substances, such as clay lumps, soft particles and lightweight particles, which can prove harmful to the setting and hardening of concrete. Finally, the presence of organic matter is also mentioned. Chemical requirements are most frequently specified for RCA.

No specific standards at European and national level are presents about technical rules on the use of **recycled wood** for construction applications. Only the European Panel Federation (EPF), which has members in 25 European Countries, has developed two recommendations on the use of recycled wood, and most European wood manufacturers apply these standards for the use of recycled wood for the production of wood-based panels.

Prefabricated elements (with or without CDW materials). Each prefabricated concrete element for construction has its own specific product European Standard, and all these standards are harmonised, so that the market of precast concrete elements is well controlled at European level. About the use of recycled CDW materials in prefabricated concrete elements, only the European Standard EN 13369:2013 provides information and requirement about the use of reclaimed crushed and recycled coarse aggregates, which can be used mixed in concrete with other aggregates, postponing to the EN 206 for further prevision about the use of recycled aggregates in concrete mixture. As the above mentioned specific product European Standards refers to the general European Standard EN 13369 for concrete requirements and conformity control testes, it clear that the use of recycled aggregates in all type of prefabricated concrete elements is allowed and regulated.
About national technical standard and regulations on prefabricated concrete elements, the research has found few specific national standards and only in Hungary there are specific product standards for on the use of recycled materials from CDW (crushed brick), for the production of prefabricated elements.

Wood prefabricated elements are governed mainly at European level, but no specific standard provides the use of recycled CDW materials for the production of them. National technical regulations were found only in Croatia, Germany and United Kingdom. In this last country there is a particular regulation about wood recycling in panelboard manufacturing industry.

Prefabricated masonry elements are deals with only in Germany, where the standard DIN 1053-4 contains constructive notes and information on the provision of the stability verification for the individual prefabricated components, including transport and assembly as well as for the building.

Prefabricated construction. At European level the design of prefabricated constructions follows the European Standards EUROCODES, which specifies how structural design should be conducted within the European Union. Particularly, **Eurocode 1. Part 1.3 - EN 1992-1-3** *Precast Concrete Elements and Structures* gives a general basis for the design and detailing of concrete structures in buildings made partly or entirely of precast elements; **Eurocode 5 – EN 1995** *Design of timber structures* describes how to design buildings and civil engineering works in timber, using the limit state design philosophy. At national level, in most European countries, there are several building regulation, setting general provisions for building, regarding construction, health, safety and aesthetics, but none of them refer specifically to prefabricated constructions. Consequently, the normal technical regulations and legislation in place for construction as a whole should also hold for anything concerning prefabricated construction.

At the end of this study about technical regulations and legislations on prefabricated constructions/elements and constituent materials, It is possible to establish a relationship between the norms, defining a complete design approach, as in Figure 1. A complete overview of the collected technical regulations and legislations is reported in Annex 1. It also contains information on any drivers and barriers to the development of prefabricated elements with recycled materials form CDW.

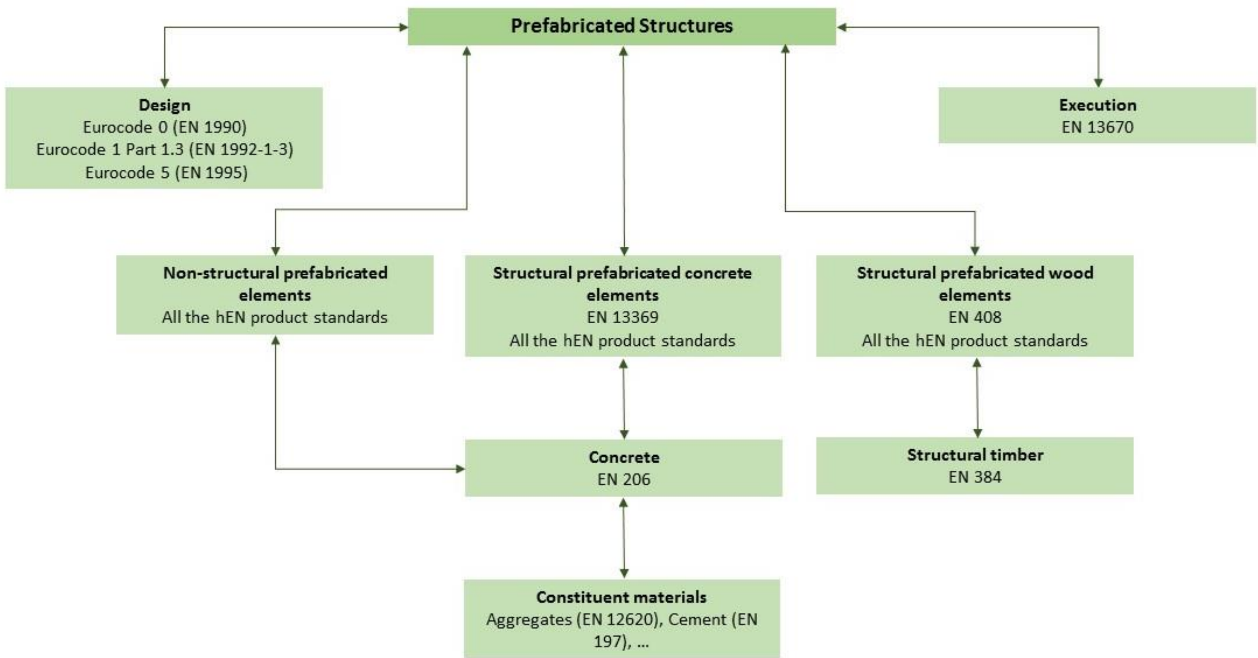

Figure 1 – Technical standards relationship for prefabricated constructions

Chapter 5 analyses **Policy measures** about materials from CDW, prefabricated elements and construction, identifying and describing best practices and initiatives at European and national level. At European level the main policy measures (direct and indirect), which encourages the use of CDW and prefabricated elements are:

- Waste Framework Directive (2008/98/EC)
- EU Green Public Procurement (GPP) instrument
- Directive 2010/31/EU (Energy Performance of Buildings Directive – EPBD).

One of the objectives of the ***Waste Framework Directive*** **(2008/98/EC)** is to provide a framework for moving towards a European recycling society with a high level of resource efficiency by achieving by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste recycling or re-use. Today, only 50% of CDW are recycled, far from the objectives determined in the European Directive for 2020. Aware of this situation, the European Countries are implementing national policies to prevent the waste that can be avoidable and to promote measures to increase recycling and recovering.

Among the EU ***Green Public Procurement*** **(GPP)** instrument, the most recently criteria regard "Office Building Design, Construction and Management" [29]. These criteria state that the production of construction products is responsible for one of the most significant environmental impacts. In this respect the recycling and re-use of construction materials and products, as well as whole building elements, can contribute to reducing environmental impacts and development of a circular economy. Therefore the criterion B 10.2 *Incorporation of recycled content in concrete and masonry*, defines the minimum value of 15% of recycled content and/or by-products for the main building elements. The incorporation of the recycled content criterion has to be applied during the detailed design and performance requirements procurement phase. Moreover, recycled content has to be verified during construction of the building or major renovation works procurement phase by means of a contract performance clause. With this aim, the criterion *Monitoring the recycled content* has been introduced in the procurement phase of *Construction of the building or major renovation works*.

According to the ***Energy Performance of Buildings Directive*** – **EPBD (DIRECTIVE 2010/31/EU)**, the EU has agreed on ambitious Energy and Climate targets for 2020 and beyond to reduce greenhouse gas emissions, increase the share of renewable energies and improve energy efficiency, setting the target of 20%. Therefore, with regard to these targets, in several analyzed case, States or Municipalities support of housing and development of industry subjects, with the participation to research projects founded by EU. These programs encourage building under several conditions:

- Use of material with minimal energy use and minimal CO_2 emissions
- Use of lightweight materials
- Use of renewable sources and recycled materials in large extent
- Use of constructions allowing easy separation of materials and their removal.

The energy efficiency requirements, fixed by the EPBD, have also driven every European country to implement their energy codes for newly constructed or renovated buildings, creating sometimes a new building code for sustainable housing, as in the case of the UK, and others, adding a whole chapter to their existing building codes – as in the case of Germany and the Netherlands.

Other relevant instruments which promote the use of prefabricated construction elements and recycled materials from CDW, are the certification protocols, as at international as at national level. Therefore they are voluntary instruments, but increasingly used worldwide. The main international certification protocols are:

- **BREEM - Building Research Establishment Environmental Assessment Method**
- **LEED - Leadership in Energy and Environmental Design**.

Both of them are based on the assessment of buildings depending on different performance levels, mainly based on the sustainability of buildings, as in construction as in maintenance phase. Re^4 products could contribute to the allocation of a good score within several categories, such as "materials and resource", "resources and energy" and "Indoor environmental quality", depending on the certification protocol in use.

At national level, most relevant policy measures are:

- The Recycling Competence Centre in Estonia, which aims to improve quality of recycling and the market of CDW recycled products;
- The Environmental Link (Law No. 221 of December 28, 2015) and the new Code of Practices (D.Lgs. 18th April 2016, n.50) in Italy, which defines criteria to be followed in the demolition and for the materials used in the construction site and excavations, establishing the quantity of recycled materials to used and of materials to be recycled;
- The Guide of recycled aggregates (GEAR) in Spain, which has prepared technical recommendations and operation instructions applicable to all aggregates from CDW, to be used as materials for construction;
- Several policy measures for refurbishment of existing prefabricated buildings, such as in Bulgaria, Italy, Lithuania and Slovenia;
- Researched projects, founded by EU, which involve national institutions with the aim to develop innovative prefabricated elements with recycled materials from CDW. The most interesting ones are **InnoWEE** *Innovative pre-fabricated components including different waste construction materials reducing building energy and minimizing environmental impacts*, **REBIRTH** *Promotion of the Recycling of Industrial Waste and Building Rubble for the Construction Industry* and **ECO-SANDWICH**. InnoWEE involves as partners the National Building and Civil Engineering Institute of Slovenia and the Greek Municipality Varis-Voulas-Vouliagmenis, and it has the aim, among the others, to development of ventilated façade claddings based on the geopolymer technology. The aim of REBIRTH is to increase and improve the recycling of industrial and construction and demolition waste for re-use as new regenerated construction material and it involves the Slovenian National Building and Civil Engineering Institute. ECO-SANDWICH project is supported by the Croatian Ministry of Environment and Nature Protection and the Ministry of Construction and Physical Planning, and it aims to developed an innovative prefabricated wall panel using recycled construction and demolition waste and mineral wool produced with an innovative sustainable technology, achieving a reduction of primary energy consumption in the building stock due to its enhanced insulation and ventilation properties.

Chapter 6 analyses **characteristics of the prefabricated construction sector** both from the point of view of the market of prefabricated elements and constructions and from the point of view of identifying the most common types of prefabricated buildings at European level with particular attention to the use of CDW in prefabricated elements production.

Exports/imports of prefabricated elements. Chapter start to analyse to the import and export of prefabricated elements (with or without CWD content). The construction sector is confirmed as the main reference market for all sub-contractors of building materials. Scope is to assess size and market shares of different segment, especially given the crisis of the construction sector.

Market conditions/costs and benefits. The prefabricated sector has many strengths, construction industry is becoming ever more interested in increasing the use of offsite modern methods of construction (MMC) within the private housing sector as a solution to current quality and efficiency problems. However, the penetration of the market is still limited, especially for prefabricated elements and structures with a content of secondary material from the demolition and construction waste. Penetration on market is also given by the simultaneous presidency of political (strategy and effort), legislative (clear normative about recycling and harmonized normative on quality of treatment process), economic (tax for landfill or economic incentive to recycling waste of construction and demolition) and cultural (awareness of stakeholders involved). Aim of the analysis is to evaluate the internal and external conditions in terms of costs and benefits, which may favour the market launch of prefabricated elements with aggregate content from the construction waste sector.

In order to make recycled aggregate competitive to natural aggregate and to close the building materials cycle by recycling CDW in high-grade applications, it is necessary to increase its market value through properties, application possibilities and price. Germany, followed by UK, the Netherlands, France, Belgium and Switzerland, led the market of recycled materials supplying. In these countries, costs and benefits of the market are related to government measures (Taxes and levies) to make natural aggregates (and their landfill) more expensive than recycling it. The presence of standards requiring treatment for recycled ensure both the circulation and marketing of a high-quality product, and fulfil requirements and quality standards equal to the primary raw. These are most important to undermine the market circulation of recycled materials, which usually bear higher costs due to improper treatment and recycling processes. These factors can making secondary building materials derived from recycled material particularly attractive to the market with respect to the primary virgin building material and could justify the creation of a large supply chain and a large market for the collection and sale of waste materials. In these countries, construction materials producers are benevolent to sell recycled materials, because they recognize the large future market.

Per contrast, especially for those countries where there is a great deal of availability on the primary material market (such Romania), the absence of a clear and strong regulatory framework, and of financial leverage to send CDW for recycling, limiting market expansion. In these countries, there is a lack of awareness of the various stakeholders involved in the supply chain, because using recycled CDW for new constructions is not very well perceived, and the actors in the construction sector tend to prefer the use of primary raw material, which they perceive as having higher quality than secondary (recycled CDW) materials.

Construction sector make up.

Potential of prefabricated constructions. In this chapter, the main conditions, that could give new competitiveness to the construction sector, have also been observed, considered a major consumer of intermediate products (raw materials, chemicals, electrical and electronic equipment, etc.). The crisis in the construction sector has affected all EU-28 countries, although to varying degrees. All countries have experienced a decline in construction production, which may vary from a remarkable reduction observed, for example, in Latvia, Slovenia or Portugal to stable and / or growing activity levels registered in the Netherlands, Belgium or Sweden. For the sector, competitiveness depends on new technologies and production techniques able to increase the degree of innovation in the sector and to be able to adequately support it in to the transition to a resource-efficient and low-carbon economy. In this context, prefabricated construction market could have a greater penetration in the segment of residential and non-residential construction. Finally, chapter analyze the Prefabricated construction sector characteristics from the point of view of the market of prefabricated elements and constructions, identifying the most common types of prefabricated buildings at Community level with particular attention to the use of CDW in prefabricated elements production.

Prefabrication typology. In order to evaluate the possible growth of the prefabricated construction market in all European countries, the diffusion level and the types of prefabricated structures existing in them are fundamental. The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials sizes and typology, and the technique adopted for their manufacture and use in building. Prefabricated structural systems can be divided according of the used of materials, methods, structural configuration or dimensions. The main materials used for prefabricated constructions are:

- concrete (reinforced, prestressed, cellular, lightweight, etc.),
- steel,
- wood
- plastics.

According to the conceptual dimension, prefabricated systems can be categorized as:

- open prefabricated system, based on the use of the basic structural elements to form whole or part of a building, such as reinforced concrete channel units. Hollow core slabs, hollow blocks, precast elements, cellular concrete slabs, prestressed/reinforced concrete structural elements (slabs, beams, columns…), etc.;
- mekano system in which the components are not interchangeable with the components of another system. The components are produced as the certain parts of a package and cannot be replaced.

In practical dimension, prefabricated systems can be categorized as:

- **Frame systems**: prefabricated systems that comprise structural, load-bearing elements such as walls and slab elements. One of the dimensions of these elements is greater

than the other dimensions. The basic framework exchanges stacks through interconnected auxiliary parts or individuals;
- **Panel systems**: prefabricated systems that comprise structural, load-bearing elements such as walls and slab elements. Two dimensions are greater than the third one. Panel System is one of the prefabrication systems ideal for straight, curved or angled facade applications and has an elegant and light appearance with smooth rounded edges. Prefabricated panel is set in position and layer of cement or mortar are connected to both sides;
- **Cells systems**: systems that comprise three-dimensional (3D) cellular units. Cells system is a modern system where burden bearing dividers give the essential vertical backing and horizontal solidness for floors. Outside divider boards, lift centres or staircases are utilized to give the obliged longitudinal dependability. Connecting parts, for example, floors, rooftops and pillars are bolstered by the heap bearing dividers or facade divider. In cells system, components are conveyed to site 'in the nick of time;
- **Combined systems**: prefabricated systems that use different types of elements stated above together.

The analysis of the diffusion of prefabricated constructions, techniques and based materials among the EU countries and Taiwan, has shown that there is generally a low diffusion level of prefabricated constructions and frame system and panel system are the most popular; particularly, in northern countries, timber prefab are more diffused. Panel system is used in many countries, and it is characterized mainly by multi-floor building, constructed among 1950-1960 years. Modular system diffusion is under development in several countries, as manufacturers have understood the usefulness of this technique, in terms of construction time, product quality, installation easiness, energy efficiency and sustainability.

Used of CDW materials for prefabricated elements. In Europe, there is no developed market for the use of CDW recycled materials in prefabricated elements. Concerning the use of recycled aggregates in the prefabrication sector, there are only experimental researches that prove the possibility to realize prefabricated elements with recycled aggregates. The use of CDW materials for prefabricated elements is a strategy that affects the whole project of construction sector from its start, rather than being just a selection of products or technologies applied later on. International reports have extolled its virtues as a valuable part of the built environment. Prefabricated elements from CDW promote a successful industry in construction sector producing high quality, well designed, affordable, functional and inspiring residential and commercial infrastructures for satisfied customers. Prefabricated elements containing recycled CDW are perceived as a new technological concept for sustainable development in construction sector. It dramatically reduces costs in spheres where it is necessary and needed and reduce overall financial costs. It substantially protects environment and reserve raw materials. Due to recyclability of this materials, the source of material is inexhaustible and principles of circular process of materials are employed.
First example about the use of CDW materials for prefabricate elements is the prototype developed during the project **ECO-SANDWICH**. The product is an innovative ventilated

prefabricated concrete wall panel with integrated mineral wool insulation and recycled materials from CDW [59].

Another research project is developing with the aim to develop ventilated façade claddings based on the geopolymer technology and incorporating selected CDW. It is **InnoWEE** project "*Innovative pre-fabricated components including different construction and demolition Waste materials reducing building Energy consumption and minimising Environmental impacts*", funded from the European Union's Horizon 2020 research and innovation program under grant agreement No 723916.
Among the research project on the use of CDW materials for prefab elements, funding from the European Union's H2020 framework program for research and innovation under grant agreement, there is also **MORE-CONNECT**. Objective is to develop and to demonstrate technologies and components for prefabricated modular renovation elements in five geo-clusters in Europe. Particularly, product innovation includes the selection of sustainable materials and sustainable detailing based on LCA, including recycling of materials, bio-based materials, flexible, disassemble, and the use of secondary materials.

VI. **Chapter 7**, defines **barriers/drivers** linked to current measures, regulation and legislation, analysed in the previous chapters. The main **conclusions** are:

- European technical standards are gone towards the use of prefabricated elements with recycled materials from CDW, such as the case of standard EN 13369:2013 which provides rules about the use of recycled aggregates in prefabricated concrete elements;
- Most prefabricated elements are regulated by harmonised European Standards therefore, CE marking is obligatory for them;
- Sustainable principles of the European policy measures drive indirectly towards the diffusion of prefabricated elements with recycled materials from CDW;
- Among EU28 countries the main external factors, such as economic incentives, regulatory framework, presence of infrastructure and labour skills, positively or negatively determines market performance. Harmonization is needed from the point of view of incentives and the quality of second materials and prefabricated elements.

The main **recommendations** to promote the use of prefabricated elements with CDW materials in constructions, in short term at European level, are:

- **Codes and Enforcement**: Establish and effectively enforce standards related to waste reuse targets, and codes to increase the efficient use of prefabricated elements and provide standard definitions about these in construction sector.
- **Disclosure and Transparency**: Transparently disclose information and data to support informed decision making, help build market demand for prefabricated elements in construction sector.
- **Market Forces**: Support construction sector about materials recycling and promote innovation that increases the reuse of them, significantly reduces costs, and increases utilization of prefabricated elements in the construction sector.

The document is complemented by **references** section and **3 annexes** (Annex 1. Technical regulations and legislations – Policy measures; Annex 2. Statistical databases; Annex 3. Countries framework).

2. INTRODUCTION

2.1 Background - RE⁴ objectives

The **overall goal of the RE^4-Project** is to promote new technological solutions for the design and development of structural and non-structural pre-fabricated elements with a high degree of recycled materials and reused structures from partial or total demolition of buildings. The developed technologies will aim towards energy-efficient new construction and refurbishment, thus minimizing environmental impacts. The RE^4-Project targets the demonstration of suitable design concepts and building elements produced from CDW in an industrial environment, considering perspective issues for the market uptake of the developed solutions. The technical activities will be supported by LCA (life-cycle assessment) and LCC (life-cycle cost) analyses, certification and standardisation procedures, demonstration activities, professional training, dissemination, commercialisation and exploitation strategy definition, business modelling and business plans. The overarching purpose is to develop a RE^4-prefabricated energy-efficient building concept that can be easily assembled and disassembled for future reuse, containing up to 65% in weight of recycled materials from CDW (ranging from 50% for the medium replacement of the mineral fraction, up to 65% for insulating panels and concrete products with medium mineral replacement coupled with the geopolymer binder). The reusable structures will range from 15-20% for existing buildings to 80-90% for the RE^4-prefabricated building concept.

2.2 Scope of the report and links with other Project Deliverables

The deliverable **D1.4** (**Overview on the current status on policy measures and regulatory frameworks**) belongs to Task T1.3 of Work Package (WP) 1 *Mapping and analysis of CDW reuse and recycling in prefabricated elements*. **WP1** concerns the need for a baseline study to define a collective outline and map the current best practices related to various aspects of reuse and recycling of CDW in prefabricated elements (including technological, standardisation issues and policy measures). The specific objectives of WP1 are the following:

- Reviewing and mapping current situation of re-use and recycling of different CDW materials, processes and technologies, with specific reference to prefabricated elements;
- Reviewing current European legislation regarding CDW in general, specifically legislation and current situation in the countries of the partners, including costs of landfill disposal;
- Providing inputs to feed the DSS function related to possible end-uses (WP2).

The scope of this report is to give an overview of the current status of policy measures and regulatory frameworks at different levels, related to prefabricated elements integrating recycled materials from CDW, including:

- technical regulation and legislation regarding CDW and prefabricated elements;
- barriers/drivers linked to current measures, regulation and legislation.

In order to pursue that aim, a market analysis is essential, both at the level of CDW and at the level of prefabricated elements and constructions.

The analysis carried out in the present report regarding technical standards and regulations on CDW and prefabricated elements will be at the basis of the development of **Deliverable D1.5 Certification**

framework, which is a template with the needed certifications of the final product of the RE[4] project.

2.3 Geographical scope and level of detail

This report focuses on EU-28 Member States and one non-EU Country (Taiwan). The countries involved in RE[4] as project partners are Belgium, the Czech Republic, Germany, Italy, Sweden, Spain, United Kingdom, and Taiwan. The information contained in the following chapters is structured at two levels: the first one sets the topic framework at European level and at the second level a focus on national situation is reported, were available.

2.4 Who should read this report

This report is useful for RE[4] project partners involved in the development of the innovative prefab elements, and also for stakeholders involved in the production of prefabricated elements and constructions.

2.5 Structure of the document and contents

In order to fulfil the abovementioned objectives, this report is broken down into the following chapters:

Chapter 1 (Executive summary) gives the main points of the report, focusing on the main conclusions of the document.

Chapter 2 (Introduction) gives a brief description of RE[4] and summarises the final scope of the report.

Chapter 3 offers an **overview of the methodology** used in carrying out this study, describing the general approach used, the main phases and the methodology used to analyse market data.

Chapter 4 analyses current situation about **Technical regulation and legislation** on CDW, materials from CDW, prefabricated elements and construction, collecting information from EU Member States and Taiwan, focusing mainly, on technical aspects.

Chapter 5 analyses **Policy measures** about materials from CDW, prefabricated elements and construction, identifying and describing best practice and initiative at European and national level.

Chapter 6 analyses **characteristics of the prefabricated construction sector** both from the point of view of the market of prefabricated elements and constructions and from the point of view of identifying the most common types of prefabricated buildings at Community level with particular attention to the use of CDW in prefabricated elements production.

Chapter 7 defines **barriers/drivers** linked to current measures, regulation and legislation, analysed in the previous chapters.

The document is complemented by a section of **references** and **3 annexes** (Annex 1. Technical regulations and legislations – Policy measures; Annex 2. Statistical databases; Annex. 3. Countries framework).

3. APPROACH AND ASSESSMENT METHODOLOGY

3.1 Description

CETMA and the other involved project partners developed a four-stage methodology to collect technical and market data information necessary for the assessment of the current situation regarding technical regulation and legislation on the use of CDW in prefabricated elements, within the EU countries and Taiwan (the extra-EU country involved in the project):

1. **Definition of information/data to search for**. This stage includes: the definition of a **list of countries** to be considered and **partners responsibilities** for data collection in those countries, the **identification of data and information** to be collected and analysed and the definition of a **timeline** for the assessment activity.

   Table 1 shows the distribution of countries among involved partners.

Table 1. Countries distribution among involved partners.

Country	Partner in charge
Austria	ROS
Belgium	ACR+
Bulgaria	CETMA
Croatia	CETMA
Cyprus	QUB
Czech Republic	FENIX
Denmark	CBI
Estonia	CETMA
Finland	CBI
France	ACR+
Germany	ROS
Greece	CETMA
Hungary	CETMA
Ireland	QUB
Italy	CETMA
Latvia	CETMA
Lithuania	CETMA
Luxembourg	CETMA
Malta	ACR+
Netherlands	CETMA
Poland	FENIX
Portugal	ACCIONA
Romania	CETMA
Slovakia	FENIX
Slovenia	CETMA
Spain	ACCIONA
Sweden	CBI

Switzerland[4]	ROS
United Kingdom	QUB
Taiwan	NTUST

Table 2 list out the information to be collected, made from task leader CETMA and sent to the other involved partners.

Table 2. List of information to be collected.

Level	Sublevel	Title
1		**Technical regulation and legislation**
	1.1	CDW – Concrete, bricks, tiles and ceramic, asphalt, wood, gypsum
	1.2	Materials from CDW (aggregates, binders, reinforcement…)
	1.3	Prefabricated elements (with or without CDW materials)
	1.4	Prefabricated construction
2		**Policy measures**
	2.1	Materials from CDW
	2.2	Prefabricated elements (with or without CDW materials)
	2.3	Prefabricated construction
3		**Prefabricated Construction Sector characteristics**
	3.1	Exports / imports of prefabricated elements
	3.2	Market conditions / costs and benefits
	3.3	Construction sector make up
	3.4	Use of CDW materials for prefabricated elements

2. **Information/data collection**. This activity involves all the afore-mentioned partners, who have collected the required information, searching among national and European sources, in direct and indirect way. As shown in 8 References, the main sources are website of institutional or literature portal. The methodology used for market data details is described in the following § 3.2.
3. **Information/data analysis**. All the collected information and data have been analysed to decide which were the more relevant ones and then the list of information was filled in.
4. **Drivers/barriers definition**. After receiving the contributions of all involved partners, the task leader elaborated information so as to define drivers/barriers linked to the current measures, regulation and legislation.

3.2 Market data analysis methodology

The project's development aimed at achieving an adequate qualitative and quantitative market framework, mainly focused on the manufacture of prefabricated elements identified by structural and non-structural elements of wood, lime, plaster and concrete. Aluminium, iron, and plastic have not been taken into consideration. However, sector data is available for these product categories.

[4] Even though Switzerland is not EU country, it has been decided to extend this study to it.

How was the data collected?

Data on prefabricated constructional elements in the European Union (EU), comes from the Eurostat database. The quantitative results are combined with the outcome of the literature research (desk study) and by partners' contribution.

Which sources were consulted and used?

Analyses are based on results of the PRODCOM survey; International Trade (COMEXT) and other data, from the Structural Business Statistics (SBS) database.

What analyses were conducted?

The PRODCOM database contains the data on annual production sold in terms of value of production of prefabricated buildings elements, while export and import data is provided by the international trade database. The two databases were harmonised through a link table between the PRODCOM codes and the Harmonised System (HS) Code. Finally, the SBS database was used, referring to some key variables (like turnover or value added) from which one can see how much wealth is created, how much workforce is used to generate such wealth, how this business develops, and the weight that this has on the entire industrial sector, and thus how it contributes to the growth of the overall economy.

Which indicators were built?

The analyses conducted aim to sum up a sample, and to facilitate presentation and reading, the prefabricated elements were grouped into homogeneous macro-categories, and the different countries were grouped together. To make the survey easily repeatable, the link tables between the two databases are reported in the Annex 2. The indicators are predominantly descriptive, and investigate activities such as exports, imports, market size and growth.
Finally, the correlation between the amount of waste generated by the construction industry and the added value of the construction sector has been investigated. The methodology used is a simply regression analysis based on the theoretical model is derived from suggestions of the literature available [1], this analysis aim to understand and weight this relationship between production of CDW to value added of construction.

Table 3. Overview of methodology to collect and analyse the data.

Items	Eurostat – PRODCOME, International Trade, Structural Business Statistic
Variables collected	Some components are defined as deflated values of production, import and export. Some others are corrected for indicators of value added and turnover.
Sampling	Prefabricated elements for constructional purpose in concrete, cement and plaster Prefabricated Buildings Code: C162; C232_C233_C235_C236_C237 The weights used for aggregation at product level are based on the weights derived from the PRODCOM survey
Sector	NACE_Rev.2 - Code: Manufacturing_C162; C232_C233_C235_C236_C237 Code : Construction_ F41_F42_F43
Period	2010 -2016 (or 2015, depending on the type of database)

Details about consulted databases are reported in Annex 2.

4. TECHNICAL REGULATION AND LEGISLATION

From 1 of July 2013 construction products, manufactured and supplied in conformity with a harmonised European Standard (hEN), can only be placed on the European Union (EU) market if they fulfil the requirements established by **Regulation (EU) No 305/2011** on the marketing of construction products. The **Construction Products Regulation (CPR)** lays down the basic requirements for the construction works. Construction products should comply with the basic requirements in order to be incorporated in a construction work.

The **CPR** proposes tougher rules on the construction industry, unifies Member States' position on the industry and intends to improve three important areas regarding:

- Clarification of the basic concepts and of the use of CE marking;
- Simplification of the procedures, so as to reduce the costs incurred by enterprises, in particular small and medium sized enterprises; and
- Increasing credibility for the whole system.

With regard to the scope of the CPR 305/2011/EU, the Regulation defines what a construction product is and allows for 35 areas of classification for a construction work. All products are to be classified into one of the classifications and tested based on the requirements of each classification. A voluntary method of CE marking through the use a European Technical Assessment (ETA) is available for those products which are not covered by or do not comply with a hEN. This is principally intended to be a stop-gap situation until an appropriate applicable hEN is drafted and published. Construction products can only be CE marked if they are supplied in conformity with a hEN or an ETA. Therefore, some construction products, which are within the scope of European Standards but have not been harmonised, cannot be CE marked.

Construction products mean any product or kit that is produced and placed on the market for incorporation in construction works in a permanent manner, including both buildings and civil engineering works.

Among the major innovations introduced by the New EU Regulation 305/11 there is, for works, the requirement of "**sustainable use of natural resources**", according to which "Construction works must be designed, constructed and demolished so that the use of natural resources is sustainable and in particular guarantees the following: (a) the reuse or recyclability of construction works, their materials and parts after demolition; (B) the durability of construction works; (C) the use, in construction works, of environmentally compatible raw and secondary materials".

According to this new requirement, the EN Europeans Standards have been updating with the introduction of recycled materials among the constituent materials of a construction product.

4.1 CDW – Concrete, bricks, tiles and ceramic, asphalt, wood, gypsum

The **Waste Framework Directive 2008/98/EC** aims to have 70% of CDW recycled by 2020. However, with the exception of a few EU countries, only about 50% of CDW is currently being recycled. The good news is that some EU countries have already developed and implemented a framework, which leads to a recycling rate of up to 90% [2]. Table 4 lists the waste codes legal framework for common CDW in this study:

Table 4. Waste codes legal framework for CDW [3][i]

Waste type	Waste status	Waste code
Concrete	Non-hazardous	17-01-01
Bricks	Non-hazardous	17-01-02
Tiles and ceramics	Non-hazardous	17-01-03
Concrete, bricks, tiles and ceramics (alone or in mixtures) containing hazardous substances	Hazardous	17-01-06*
Concrete, bricks, tiles and ceramics in mixtures, containing no hazardous substances	Non-hazardous	17-01-07
Asphalt: Bituminous mixtures containing coal tar	Hazardous	17-03-01*
Other bituminous mixtures	Non-hazardous	17-03-02
Wood - untreated	Non-hazardous	17-02-01
Gypsum materials containing hazardous substances	Hazardous	17-08-01*
Other gypsum materials	Non-hazardous	17-08-02

(*) An asterisk at the end of a code means the waste is hazardous

In **Germany**, the "**Ordinance on Requirements for the Recycling and Elimination of Waste Wood** (Altholzverordnung – AltholzV)" specifies four categories of waste wood:

i. Wast wood category A I: untreated or merely mechanically treated waste wood which, when used, was not impregnated with wood-impregnating substances,
ii. Waste wood category A II: glued, painted, coated, varnished or otherwise treated old wood without halogenated organic compounds in the coating and without wood preservatives,
iii. Waste wood category A III: waste wood with organo-halogen compounds in the coating without wood preservatives,
iv. Waste wood category A IV: waste wood treated with wood preservatives, such as railway thresholds, piping masts, hop bars, piles, and other waste wood which cannot be attributed to waste wood categories A I, A II or A III due to its pollution, except PCB waste wood (limit value is not defined).

In the case of a mixture of different types of waste wood, the requirements for recycling are determined by the highest category of waste wood. [4]

Proper regulation of CDW (concrete, bricks, tiles and ceramic, asphalt, wood and gypsum) management requires that ownership of the waste is clear, in line with existing national legal frameworks and contractual terms between initial building and infrastructure owners, the (demolition) contractor, the intermediate holder (e.g. sorting operator), the final recycling operator and the end user of the recycled products. Such clarity is a condition for any transactions in the value chain – and attains trust between all actors involved [5].

However, there are still many EU countries where the management of CDW is at an early stage, requiring a long way to achieve the success of countries with higher levels of development.

Even if the Waste Framework Directive 2008/98/EC has been transposed and implemented (at different levels: national, regional or local) in all EU Countries, as detailed in Deliverables D1.1 and D1.2, no specific technical regulations and legislations, in place for CDW in European Countries, were found by RE^4 partners, except for Austria, Italy and Switzerland.

In **Austria**, the **Recycled Construction Materials Regulation**, which came into force on 1 January 2016 and was last changed on 28 October 2016, has the main aim to guarantee environmentally compatible Reinforced Concrete (RC) building materials and legal certainty for their users and producers.

Specific requirements for recycling-oriented demolition and separation as well as manufacture and construction with recycled construction materials are determined. Furthermore, a link to a new Austrian standard on the use of recycled aggregates (ÖNORM B 3140) is established. This standard covers a wider range of end uses than EN 12620. [6]

In **Italy**, technical regulations about CDW can be found in **DM 5/02/98 and s.m.i.** In particular, it provides that only *"... waste consisting of bricks, plaster and conglomerates of reinforced concrete and not, including railway crossings and trams and reinforced concrete poles coming from railway lines, telematic and electrical, and fragments of road coatings, provided asbestos-free, can be started to produce secondary building materials by mechanical and technologically interconnected steps of grinding, screening, granulometric selection and separation of the metal fraction and of undesirable fractions for obtaining inert grafts of grain size with suitable and selected granulometry, with verification of the conformity of the disposal test elute.*" In that sense, such waste from construction and demolition can be considered secondary building materials, which can be marketed and reused freely also for the formation of road signs and substrates.

As evidenced by the cited Decree, and in particular by the subsequent major changes, a fundamental stage of verification and validation is represented by the "***assignment test***" (**Article 9 of DM 5 February 1998**), which must be carried out with the same standards as **UNI 10802:2013** *Waste - Liquid, granular, pasty and sludge wastes. Manual sampling, preparation and analysis of elutes*. The analytical method with which to perform this test is prescribed by **UNI EN 12457-2** *Waste characterisation. Leaching. Compliance test for granular and sludge waste disposal. Part 2*. [7]

In **Switzerland**, the Swiss Federal Office for the Environment (BAFU) issued the **Directive for the recycling of mineral construction waste** in 1997, which has been revised and expanded since 2006. [8]

The directive establishes the ecological requirements for the recycling of mineral construction waste. The aim is a high-quality, environmentally-compatible use of recycled materials. In this way, the acceptance of the recycling products and thus the securing of the sales markets are improved by material qualities which meet the ecological and structural requirements.

The Directive is applied only to mineral construction wastes, and for them it defines four waste categories: asphalt removal, road breaking, concrete demolition and mixed demolition.

In 2006, the Federal Office for Environment (FOEN) published the "**Guideline for the use of mineral construction waste**", which regulates how mineral construction waste is to be sorted, labelled, treated and quality controlled before it is used to create new RC materials.

Technical specifications for the recycling and recovery of CDW are contained in Swiss standards:
– SN 640 740a General information;
– SN 640 741a Recovery of asphalt;
– SN 640 742a Recovery of roadbreak;
– SN 640 743a Recovery of concrete demolition;
– SN 640 744a Recovery of mixed demolition.

4.2 Materials from CDW (aggregates, binders, reinforcement…)

Concerning the waste classifications of the European List of Waste, construction and demolition waste covers a very wide range of materials. Particularly interesting is the mineral fraction of CDW. When treated by recovery plants, it is suitable to substitute "natural" or "virgin" materials (aggregates) in the realization of infrastructure artefacts or civil engineering works. To enable further recovery of waste in general and of construction and demolition waste in particular, it seems to be essential to separate and sort out defined fractions during construction and demolition processes. Selective demolition processes and on-site separation are the techniques commonly used to produce 'high quality' waste fractions, which have the potential to be reused as construction material.

The application fields of the aggregates can be, roughly, divided into two main categories:

- unbound applications, (road construction, railway ballasts, etc.) using coarse materials;
- bound applications, where the mixture contains a binding agent, such as concrete, bitumen or a substance which has binding properties in contact with water, such as cement (concrete, mortar, etc.).

As far as possible uses are concerned, the recycled aggregates find their typical destination in:
- civil engineering earthworks;
- road and railway works.

The road works are definitely a field in which the use of recycled aggregates can be largely applied, in replacement of the primary ones.

The recycled aggregates can be used for the construction of foundation layers and for road foundations or road embankments, in the form of granulometrically stabilized unbound mixtures.

Recycled aggregates, just like natural aggregates, do not all possess the same characteristics therefore, according to their specific performances, they are more or less suitable for a certain use. It is therefore of great importance to know their properties and their behaviour with regard to various factors (such as mechanical stress, exposure to cycles of freeze-thaw or to water etc.); instead knowing their origin is of no importance.

Even if in some European Countries the "*end of waste*" status is not defined for CDW, the European technical standards (EN) on aggregates used in construction, define "**recycled aggregates**" as "*aggregate resulting from the processing of inorganic material previously used in construction*", so they are subjected to specific tests and controls.

Aggregates in Europe are governed by the European official document on Construction Products: **Construction Products Regulation CPR 305/2011/EU** of 9 March 2011, laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC on the Approximation of Laws, Regulations and Administrative Provisions of the Member States on Construction Materials, under which fall all kind of conventional and unconventional aggregates.

Under the CPR 305/2011/EU, several products with recycling potential are covered by harmonised European standards (hEN). Currently these standards cover the performance of a product per se (e.g. structural stability, fire safety, emission of dangerous substances) no matter if the materials used are primary or secondary materials. However, the ongoing discussion at EU and national level on covering environmental performance in hENs and the development of horizontal product category rules (PCR) in a European standard has motivated several technical committees belonging to the European Committee for Standardisation (CEN) to assess if and how reliable information on recycled content could be addressed in specific hENs for construction products.

The introduction of the CE marking for building materials and the publication of harmonised standards for aggregates have officially ruled out traditional distinction of the aggregates according to their nature, requiring materials to be evaluated only for their performance characteristics.

To confirm this, the standard **EN 206:2013+A1:2016** *Concrete - Specification, performance, production and conformity*, even if classifies recycled aggregates based to their composition, it limits the use of the two different type, according to the concrete exposure class to which they are to be placed, following the concrete aggregate standard, **EN 12620:2002+A1:2008** *Aggregates for concrete*. Since this standard is harmonised, the recycled aggregate shall be CE-marked.
The CE marking, therefore, enables to compare recycled aggregates to natural ones and to replace them with each other without distinction (for the uses set by the designer).
Recycled aggregates with the CE marking are, to all intents and purposes, construction materials. [10]
Therefore, according to EN 12620, products covered by harmonised European standards that might have significant potential of using recycled materials are:

- Rc = Concrete, concrete products, mortar & concrete masonry units
- Ru = Unbound aggregate, natural stone & hydraulically bound aggregate
- Rb = Clay masonry units (i.e. bricks and tiles), calcium silicate masonry units & aerated non-floating concrete
- Rg = Glass. [9]

Compliance with such standards must be guaranteed by control of the whole recovery process, from the management of incoming waste, through the productive process and applied technologies, to the product requirements. [11]

Technical requirements for the use of mineral CDW in the production of aggregates are also addressed by the individual CEN Aggregate Product Standards, which set clear quality requirements for the different types of applications (e.g. aggregates for concrete, aggregates for mortar, aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction, etc.), and ensure that the end-products are durable and meet their technical specifications. All these standards clearly address "aggregates from natural, recycled and manufactured materials".
Harmonised norms for the EC marking of natural, recycled and manufactured aggregates are:

- **EN 12620** *Aggregates for concrete*
- **EN 13043** *Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas*
- **EN 13055** *Light aggregates*
- **EN13139** *Aggregates for mortar*
- **EN 13242** *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*
- **EN 13285** *Unbound mixtures - Specifications*
- **EN 13383** *Armourstone - Part 1: Specification*
- **EN 13450** *Aggregates for railway ballasts*.

Recycled aggregates characterisation is performed using the existing standards for natural aggregates, and additionally with:

- **EN 993-11** *Tests for geometrical properties of aggregates – Part 11: Classification test for the constituents of coarse recycled aggregate*
- **EN 1744-6** *Tests for chemical properties of aggregates – part 6: Determination of the influence of recycled aggregate extract on the initial setting time of cement.* [12]

As far as prefabrication facilities are concerned, the standard **EN 13369** *Common rules for precast concrete products*, which is the basis of the product standards in this sector, mentions three types of recycled materials: washed aggregate and crushed aggregate, which originate from their own factory, and recycled aggregate, defined as "*resulting from processing of inorganic materials previously used in construction*". As EN 13369 mentions recycled aggregate, but with the reservation "Alternative provisions are in development in the upcoming version of EN 206-1 and should be considered", only the use of coarse recycled aggregate is allowed in concrete production. Moreover, recycled aggregate should not be used in concrete for which durability requirements are higher than those for the concrete from which the recycled aggregates originate. This is however not required for concrete in exposure classes X0, XC1 and XC2, which encompasses most indoor concretes. [13]

Therefore, following **EN 206**, classification of coarse recycled aggregates is carried out according to the concrete aggregate standard, **EN 12620**, relying on sorting and classification of the crushed recycled construction products, which is not only concrete.
For the classification, according to **EN 12620** the coarse recycled aggregates shall be examined for the purpose of identifying and estimating the relative proportions of the constituent materials according to **EN 933-11** *Tests for geometrical properties of aggregates - Part 11: Classification test for the constituents of coarse recycled aggregate*.
However, EN 206 gives recommendations in an informative annex (E) regarding requirements for these properties for recycled coarse aggregates to be used in concrete. It proposes two classes of coarse recycled aggregates, Type A and Type B, with different composition requirements (Table **5**. The recommended allowed amount of them depends on the exposure class of the concrete in which it shall be used. For the most severe environments, it is recommended to not use recycled coarse aggregates at all. In exposure class X0, the mildest one, up to 50% of the coarse aggregate can be recycled aggregate of Type A or B. For exposure classes between these extremes (XC1, XC2, XC3, XC4, XF1, XA1, XD1), 30% of type A may be used. Type B may, in addition to X0, only be used in those

classes slightly more exposed or susceptible to carbonation (XC1, XC2) with an amount up to 20%. Use of Type B is also restricted to lower strength classes ≤ C30/37 (compressive strength in MPa). Note that the percentages are given as percent of the coarse aggregate, not of the total aggregate content. Therefore, 50% of the coarse aggregate, which normally constitutes around 50% of the total aggregate content in concrete, entails that the maximum amount would be 25% of the total aggregate content. For a normal concrete this entails that the maximum allowed recycled aggregate is around 20% of all dry concrete constituents. The values of 30% and 20% of the coarse aggregate leads go 12% and 8% respectively of the dry concrete constituents.
The fine fraction (0 - 2 mm), i.e. filler aggregates, of the recycled aggregate is not specifically mentioned, neither in the aggregate standard, EN 12620, nor in the concrete standard, EN 206. Thus, no specific rules for this are given but there are not any prohibitions either. A possible interpretation of this may be that if the recycled filler aggregate fulfils the same requirements as filler aggregates of natural aggregate, they may be used in the same way. The requirements on the fine aggregate or filler is mainly chemical requirements, such as maximum amount of chlorides, sulphur and sulphates and restriction of constituents which alter the rate of setting of the concrete.

Table 5. Composition of recycled aggregates for concrete according to EN 206:2013

	Symbol	**Constituent material**	**Content (%)**	**Category**
Type A	Rc	Concrete, concrete products, mortar, Concrete masonry units,	≥ 90	Rc_{90}
	Ru	Unbound aggregate, natural stone and hydraulically bound aggregate		
	Rcu	Rc + Ru	≥ 95	Rcu_{95}
	Rb	Clay masonry units (i.e. bricks and tiles), Calcium silicate masonry units, Aerated non-floating concrete,	≤ 10	Rb_{10-}
	Ra	Bituminous materials,	≤ 1	Ra_{1-}
	FL	Floating material in volume	≤ 2	LL_{2-}
	X	Other: Cohesive (i.e. clay and soil), Miscellaneous: metals (ferrous and non-ferrous), non-floating wood, plastic and rubber, Gypsum plaster	≤ 1	XRg_{1-}
	Rg	Glass		
Type B	Rc	Concrete, concrete products, mortar, Concrete masonry units,	≥ 50	Rc_{50}
	Ru	Unbound aggregate, natural stone and hydraulically bound aggregate		
	Rcu	Rc + Ru	≥ 70	Rcu_{70}
	Rb	Clay masonry units (i.e. bricks and tiles), Calcium silicate masonry units, Aerated non-floating concrete,	≤ 30	Rb_{30-}
	Ra	Bituminous materials,	≤ 5	Ra_{5-}
	FL	Floating material in volume	≤ 2	LL_{2-}
	X	Other: Cohesive (i.e. clay and soil), Miscellaneous: metals (ferrous and non-ferrous), non-floating wood, plastic and rubber, Gypsum plaster	≤ 2	XRg_{2-}
	Rg	Glass		

EN 206:2013 is not a harmonised standard, so it refers to additional provisions in force in the country in which the concrete is produced and used. CEN members, through their national application of EN 206:2013, outline, in a national annex, rules based on historical experience for the use of cements in concrete for specific applications, e.g. they limit the use of certain cement types in the different exposure classes. In many cases, these rules also extend to the use of various additional cement constituents (inorganic materials) deemed appropriate for such applications. Below there is a description of the main characteristics of recycled aggregates for concrete, comparing the standard requirements at European and national level.

4.2.1 Physical properties of recycled aggregates

Recycled aggregate products, composed of concrete (ceramic and/or stone) or masonry, or mixtures of the two, are subject to several quality standards, depending on the national legislation. For example, for recycled aggregate concrete fabrication, at least 90% of input aggregates must be clean concrete (the Netherlands, United Kingdom and Denmark require at least 95% of concrete-originated aggregates). Contaminants, either organic or from other sources, are limited to 1% in the most strict countries (Germany, Belgium, Switzerland). The maximum percentage of contaminants allowed in concrete made with recycled aggregates is 1.5% under most regulations. Some regulations, such as those of Germany and Portugal, consider two recycled concrete qualities, allowing a given masonry aggregate content which cannot exceed 30%; although organic content and other contaminants (covering light materials) must always be kept below 1.5%. This regulation analysis shows that recycled concrete fabrication standards are very tight, which implies a thorough quality control in CDW separation and especially in purity control of the concrete aggregate fraction. Following the criteria derived from the European Standard EN 933-11 *Tests for geometrical properties of aggregates - Part 11: Classification test for the constituents of coarse recycled aggregate*, it's possible to combine and integrate various classification of recycled aggregates, comparing different national standards and guidelines (Table 6). [14]

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Table 6. Classification of recycled aggregates based on composition (in %) [14]

Country	Standard / guideline	Standard class	Unified class	Concrete	Masonry	Natural Aggregate	Organic material	Contaminants /impurities	Lightweight materials	Fines
Belgium	PTV 408	Crushed concrete debris	RCA	> 90	< 10	-	0.5	0.5 (a)	n.a.	n.a.
		Crushed mix debris	MRA	> 40	> 10	-	0.5	1 (a)	n.a.	n.a.
		Crushed brickwork debris	RMA	< 40	> 60	-	0.5	1 (a)	n.a.	n.a.
Denmark	DS 2426	GP1	RCA	> 95	-	-	n.a.	n.a.	n.a.	n.a.
		GP2	MRA	> 95	-	-	n.a.	n.a.	n.a.	n.a.
Germany	DIN 4226-100	Type 1	RCA	> 90	< 10		n.a.	1 (b)	n.a.	1
		Type 2	RCA	> 70	< 30		n.a.	1 (b)	n.a.	1.5
		Type 3	RMA	< 20	> 80	< 20	n.a.	1 (b)	n.a.	3
		Type 4	MRA		> 80 (c)		n.a.	1 (b)	n.a.	4
Netherlands	CUR	ARH	RCA	> 95	< 5	-	n.a.	0.1	n.a.	-
	NEN 5905	ARH	RCA	< 80	-	< 20	n.a.	n.a.	0.1	3
Portugal	LNEC E 471	ARB 1	RCA	> 90	< 10	(d)	n.a.	0.2 (e)	1	n.a.
		ARB 2	RCA	> 70	< 30	(d)	n.a.	0.5 (e)	1	n.a.
		ARC	MRA	> 90		> 10	n.a.	1 (e)	1	n.a.
Spain	EHE-08	RCA	RCA	-	< 5	-	0.5	(f)	1	2
Switzerland	SIA 2030	BC	RCA	-	< 3	-	n.a.	1	n.a.	n.a.
		BNC	MRA	-	-	-	n.a.	2	n.a.	n.a.
United Kingdom	BS 8500-2	RCA	RCA	> 95	< 5	-	n.a.	1 (g)	0.5	5
		RA	MRA	-	< 100	-	n.a.	1 (g)	1	3
	BRE Digest	RCA I	RMA	-	< 20	> 80	n.a.	5	1	n.a.
		RCA II	RCA	< 20	-	> 80	n.a.	1	0.5	n.a.
		RCA III	MRA	< 10	< 10	> 80	n.a.	5	2.5	n.a.
	RILEM	Type I	RMA	-	< 100	-	1	5	1	3
		Type II	RCA	< 100	-	-	0.5	1	0.5	2
		Type III	RCA	< 20	< 10	> 80	0.5	1	0.5	2

Notes:
RCA: recycled concrete aggregate
RMA: recycled masonry aggregate
MRA: mixed recycled aggregate
n.a.: no limit available in the standard or guideline
(a) Less than 5% of bituminous material in all types.
(b) For bituminous materials 1% in all types.
(c) 20% bituminous materials and others.
(d) Included in the percentage of recycled concrete aggregate,
(e) Contaminants of bituminous materials. ARB 1 < 5%; ARB 2 < 5%; ARC < 10%.
(f) Bituminous materials < 1%; glass, metals, plastics, etc. < 1%;
(g) Bituminous materials, RCA < 5%; RA < 10%.

Table 7 shows the geometric requirements in the standards and guidelines according to recycled aggregate (RA) type. As can be observed, compliance with specifications of particle size, shape and distribution is crucial to assure high- quality concrete.

According to Table 7, limits are most often specified for fines content and then for flakiness index. In contrast, the maximum aggregate size and crushing value are seldom mentioned. Finally, various standards do not include any geometric requirements at all for RA. Only the British Standards limits maximum aggregate size for RCA and RMA. Most regulations do not permit the use of fine RCA. [14]

Table 7. Geometrical requirements for recycled aggregates in standards and guidelines [14]

Country	Standard / guidelines	Maximum size of the aggregate	Recycled sand content	Shape index	Flakiness index	Sand equivalent index	Fines content	Shell content
EUROPE	EN 12620			RCA	RCA	RCA	RCA	
Belgium	PTV 408				RCA RMA MRA		RCA RMA	RCA RMA MRA
Germany	DIN 4226-100						RCA RMA MRA	
Italy	NTC 2008		MRA	RCA MRA	RCA MRA	RCA	RCA MRA	
Netherlands	NEN 5905							RCA
Portugal	LNEC E 471		MRA		RCA		RCA MRA	MRA
Spain	EHE-08		RCA		RCA	RCA	RCA	
United Kingdom	BS 8500-2	RCA RMA					RCA RMA	
	RILEM		RCA RMA				RCA RMA	

Table 8 shows the physical characteristics of recycled aggregates (RA) in national standards and guidelines, according to RA type. As can be observed, density and absorption are the ones most widely included, regardless of aggregate type. [14]

As shown in Table 8, the physical properties in practically all of the regulations for RCA are oven- dry density and absorption. Those that appear less frequently are bulk density, specific gravity and losses of ignition. Despite density and absorption being two of the main characteristics that define RA quality, there are regulations that do not include density or any of its variants. Others do not include absorption either. The BS 8500-2 standard does not mention any of these properties. [14]

Table 8. Physical characteristics for recycled aggregates in standards and guidelines [14]

Country	Standard / guidelines	Oven-dry density	Surface dry density	Bulk density	Specific gravity	Absorption	Losses of ignition (LOI)
EUROPE	EN 12620	RCA					
Belgium	PTV 408	RCA RMA				RCA RMA	
Denmark	DS 2426	RCA	MRA				
Germany	DIN 4226-100	RCA RMA MRA				RCA RMA MRA	
Italy	NTC 2008	RCA					
Netherlands	CUR	RCA RMA					
	NEN 5905					RCA	
Portugal	LNEC E 471			RCA	MRA	RCA	MRA
Spain	EHE-08					RCA	
United Kingdom	BS 8500-2						
	RILEM	RCA MRA				RCA MRA	

4.2.2 Mechanical properties of recycled aggregates

The mechanical properties of the original materials have a significant impact on the mechanical performance of concrete made with RA. Table 9 shows the mechanical requirements specified in the standards and guidelines, depending on RA type. As can be observed, the mechanical performance of RA is mainly defined in terms of its Los Angeles abrasion coefficient and soundness. These tests are only performed on the coarse fraction of the aggregate, and the results are extrapolated to the fine fraction. [14]

Table 9. Mechanical specifications for RA in standards and guidelines [14]

Country	Standard/Guidelines	Los Angeles abrasion coefficient	Soundness
EUROPE	EN 12620	RCA	
Belgium	PTV 406	RCA RMA MRA	
Denmark	DS 2426		
Germany	DIN 4226-100	RCA RMA MRA	
Italy	NTC 2008	RCA MRA	RCA MRA
	NEN 5905	RCA	
Portugal	LNEC E 471	RCA	
Spain	EHE-08	RCA	RCA
United Kingdom	BS 8500-2		
	RILEM	RCA MRA	

The mechanical specification that is most frequently included in the standards is the Los Angeles abrasion coefficient. Soundness also appears in the norms. However, in all cases, it is required for RCA and in some cases, for ceramic and mixed RA. [14]

4.2.3 Chemical suitability of recycled aggregates

Table 10 shows the chemical requirements for RA in the various standards and guidelines. As can be observed, the most frequently included ones pertain to the chloride and sulphate content of the aggregate. The reason for this is that these chemicals can potentially lead to the corrosion and deterioration of hardened concrete. Also mentioned are the presence of substances, such as clay lumps, soft particles and lightweight particles, which can prove harmful to the setting and hardening of concrete. Finally, the presence of organic matter is also mentioned. Chemical requirements are most frequently specified for RCA. [14]

Table 10. Chemical requirement of recycled aggregates in standards and guidelines [14]

Country	Standard / guidelines	Sulphate			Chloride			Light-weight particles	Clay humps	Organic matter
		Water-soluble	Acid-soluble	Total	Acid-soluble	Water-soluble	Total			
EUROPE	EN 12620	RCA	RCA	RCA	RCA					
Belgium	PTV 406	RMA MRA	RCA	RCA RMA MRA	RCA RMA MRA	RMA MRA		RCA RMA		RCA RMA MRA
Denmark	DS 2426						MRA			
Germany	DIN 4226-100	RMA MRA	RCA		RCA MRA	RMA MRA	RMA MRA			
Italy	NTC 2008	RCA	RCA MRA	RCA MRA	MRA					
Netherlands	NEN 5905			RCA	RCA					RCA
	CUR	RMA	RCA		RCA RMA			RCA		RCA RMA
Portugal	LNEC E 471	RCA	RCA MRA	RCA MRA	RCA MRA	MRA	MRA	RCA MRA		RCA
Spain	EHE-08		RCA	RCA		RCA	RCA	RCA	RCA	
Switzerland	SIA 2030	RCA	RCA	MRA	MRA		RCA MRA			
	OT 70085		RCA MRA		RCA		MRA			
United Kingdom	BS 8500-2	RMA	RCA RMA	MRA				RCA RMA		
	BRE Digest 433		RCA	RMA		RMA				
	RILEM	RCA	RMA			RMA		RCA RMA		RCA RMA

National technical regulations and legislations on CDW-recycled aggregates

A brief outline of the current situation of existing technical regulations and legislations about CDW-recycled aggregates is reported below.

In **Austria**, the **ÖNORM B 3140: 2016 06 01** *Recycled aggregates for unbound and hydraulically bound applications as well as for concrete* is setting specific requirements on recycled aggregates for asphalt and surface treatments for roads, airfields and other traffic areas according to the categories of ÖNORM EN 13043 due to the specific geographical, topographical and climatic conditions prevailing in Austria. There is currently no regulation on the use of recycled aggregates in building construction.

In **Belgium** the following situation exists at national and regional level:

- In **Flanders**, the 'eenheidsreglement' (23/11/2011) established a management system for recycled granulates, including a demolition management system that aims to guarantee quality and a system for the certification of the recycled aggregates.
- In **Brussels**, the Brussels-Capital Region Government Decree of 16/03/1995 established a mandatory recycling system for the stony and sandy fraction. Additionally, there is a requirement to use this material for use as a secondary raw material on different projects. [15]
- A national standard, **PTV 406 Technical Prescription** *Recycled aggregates from construction and demolition waste* also exists, and it regulates the composition of the recycled aggregate that could be used in concrete production. Three RA classes are defined, as defined in Table 6. The coarse recycled concrete aggregate fraction (CRCA) can be used in the exposure class X0 and XC1, and Belgian environmental classes E0 and E1. Concrete produced with these aggregates should have a maximum strength class limited to C25/30; when higher strength classes and different exposure conditions are used, the technical validity should be experimentally demonstrated. The maximum allowed substitution ratio is 20% in volume of the total coarse aggregates in the mixture. [12]

In the **Czech Republic**, the following national technical regulations and standards are in force:

- **Act 22/1997 on Technical Requirements of Products**, according to which it is possible to use specific CDW as aggregates for railway construction, as backfilling material for disposal of mines, construction fill, rehabilitation of mine dumps and as railway ballast and service roads for mining operations; it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials;
- **Act 634/1992 on Consumer Protection** which states that a seller is obliged to sell products of required quality;
- **Act 258/2000 on Public Health Protection**: a producer or importer of a product, that will come in direct contact with water, is obliged to provide accreditation according to specific rules;
- **Government Decision 591/2006** on minimum requirement regarding the safety and health protection during the construction activities.

The **Estonian** building product standard **2325-CPD-0038**, following the specification of EU standard **EVS-EN 13242:2006+A1:2008**, is applied for recycled aggregates.

The Waste Recycling Competence Centre is putting forward a plan to establish certification criteria for crushed concrete for the production of recycled aggregates. This endeavor is still at the planning stage but the Competence Centre would like to speed up the process. [16]

In **Finland**, the national application standard for EN 206, **SFS 7022**, the recommendations regarding recycled aggregate for use in concrete given in EN-206 are accepted without any modifications, both as regards the requirements on quality and properties of the recycled aggregate and how much can be used under different conditions.

In **France**, in the building sector, the use of recycled material to make concrete has been authorised since 2012, but not in every type of work. For example, **norm NF EN 206-1/CN**, published in December 2014, allows for 20% substitution of natural gravel by recycled gravel in concrete subjected to common exposure classes. For road works, standardisation is more advanced, and 60% of concrete is currently recovered in road underlay. [17]

In **Germany**, the DAfStb guideline "**Concrete according to DIN EN 206-1 and DIN 1045-2 with recycled aggregate grains according to DIN 4226-100**", classifies recycled aggregates into four types: concrete rubble (Type 1), demolition debris (Type 2), masonry rubble (Type 3) and mixed rubble (Type 4). Therefore, in the coarse of the harmonization of technical standards by the elaboration of European standards, DIN 4226-100: 2002-02 has been transferred to **DIN EN 12620: 2008-08** in large parts (structural parameters). The DAfStb guideline has been adapted accordingly. The updated version from 2010 is "**Concrete according to DIN EN 206-1 and DIN 1045-2 with recycled aggregates according to DIN EN 12620**".

Concrete rubble (Type 1) or demolition debris (Type 2) can be used in the production of structural concrete (Exposure classes X0, XC1-XC4, XF1-XF3 and XA1 in accordance with EN 206:2013+A1:2016), whereas masonry rubble (Type 3) or mixed rubble (Type 4) can only be used in non-structural concrete. The maximum replacement levels of virgin aggregate by concrete rubble (Type 1) or demolition debris (Type 2) are set at 35% and 25% for manufacturing C25/30 and C30/37 concrete, respectively.

Because the requirements for the contents of recycled aggregates from Annex G of the DIN 4226-100: 2002-02 (Environmental Impact Assessment) were not taken over, in the DAfStb-guideline, edition 09/2010, is determined that recycled aggregates according to DIN EN 12620 do not have environmental impact, in particular on soil and ground water. However, it is currently not clear which limit values should be used to assess the environmental compatibility of recycled aggregates. Neither the currently valid standardisation, nor the DAfStb-guideline or the German Institute for Structural Engineering (abbr. DIBt), which is the publisher of the building catalogues (Bauregellisten), comment on this. [18]

In **Hungary**, CDW aggregates follow different technical regulations and standards, depending on their applications:

CDW used in road construction

- *General geotechnical rules of Roads and Motorways of E - 06:02:11 UT* (**2007 ROAD 2-1222**)
- *Road Coarse structures for unbound and hydraulically bound base layer design E- 06:03:52 UT* (**2-3207 ROAD : 2007**)

Bricks and tiles

- **JM2/01** *Main wall slabs made from crushed brick*. It's a guidance for pre-made rigid, lightweight concrete production in accordance with MSZ EN 206-1:2002.
- **JM2/02** *Pre-made light concrete slabs for basements made with addition of crushed brick*. It's a guidance for pre-made light concrete slabs for basements production in accordance with MSZ EN 206-1:2002.
- **JM2/03** *Indoor floor tiles made from crushed bricks*. It's a guidance for indoor tiles made from crushed bricks in accordance with MSZ EN 206-1:2002.

Construction materials with CDW

- **JM3/01** *Guidance on CDW re-use*. It applies to construction materials containing hydraulic or bituminous binders and mineral wastes not containing binders;
- **JM3/02** *Guidance*. It's applies for re-use of CDW from structural engineering and materials without binders
- **JM3/03** *Guidance*. It's applies for re-use of CDW from structural engineering and materials with cement binders. [19]

In **Italy**, the suitability for specific use in road construction, is defined by **UNI 11531-1: 2014** *Standard for recycled aggregates used for civil engineering works and road construction*.

About the use of Recycled aggregates in concrete production, the current **Technical Standards for Construction**, issued by **D.M. January 14, 2008** (Suppl. Ord. N.30 GU 04-02-2008 n.29) states that "*Aggregates obtained from the processing of natural, artificial or recycled materials conforming to the European harmonized standard **UNI EN 12620** are suitable for the production of concrete for structural purposes and for aggregates lightweight, harmonized European standard **UNI EN 13055-1***" (in section 11.2.9.2. Aggregates). Pursuant to Presidential Decree No. 246/93, the certificate of conformity of such aggregates, uses system 2+ in structural concrete.

The same rule states that the use of large recycled aggregates is subject to limits depending on the origin of the recycled material and on the concrete class, and that the mixture of concrete packed with recycled aggregates is preliminarily qualified and documented by appropriate laboratory tests. [20]

It's important to underline that among the origin of recycled material there is "*Re-use of internal concrete in qualified prefabricated establishments*", too.

The current standard **UNI 11104** *Concrete – Specification, Performance, Production and Compliance - Additional specifications for the application of EN 206*, paragraph 5.3, contains a prospectus in which the maximum percentages of substitution of large aggregates with recycled aggregates are distinct according to the environmental exposure class and also the resistance class (more explicitly than EN 206).

In both cases reference is made to large recycled aggregates designated as belonging to the categories named Type A and Type B. This distinction is based on the different percentage limits of the constituents of large aggregates, evidently with a significant prevalence of Type A concrete. UNI 11104 also provides guidance with respect to prefabrication plants where concrete internal reuse is permitted as a large aggregate up to a maximum value of 10% in the case of concrete of the same resistance class and up to 15% in the case of lower strength class concrete.

References to **UNI 8520-1: 2015** *Aggregates for concrete - Additional provisions for the application of EN 12620 - Part 1: Designation and conformity criteria* and **UNI 8520-2: 2016** *Aggregates for concrete - Additional provisions for the application of EN 12620 - Part 2: Requirements* guidelines may be used in the project prescriptions in order to identify the physio-chemical requirements that are additional to those set for natural aggregates, and that recycled aggregates must meet, depending on the final destination of the concrete and its performance properties (mechanical, durability and environmental hazards, etc.), as well as maximum percentage of recycle aggregates or concrete strength classes that are lower than those defined in the Technical Standards for Construction. [20]
Regarding any acceptance checks to be carried out by the Works Director, these are aimed at least to the determination of the following technical characteristics:

- Simplified petrographic description
- Size of the aggregate (granulometric analysis and end content)
- Flattening index
- Filler dimension
- Shape of big aggregate (for aggregate from recycled material)
- Resistance to fragmentation / crushing (for concrete Rck ≥ C50 / 60).

The test methods to be used are those indicated in the cited harmonised European Standards, in relation to each characteristic. [20]

In **Lithuania**, the **Construction Technical Regulations (CTR) 2.06.03:2001 "Roadways"** defines common requirements (characteristics, granular structure, etc.) to apply for aggregates. These requirements do not differentiate between recycled CDW and raw material. Recommendations were published (**R 34-01 "Roadways basics"**) to meet the mentioned regulations. The recommendations describe requirements for crushed concrete and for its mixtures with new material. The existing recommendations facilitate conformance evaluation, although there are no particular standards for recycled CDW. [21]

In **Luxembourg**, there are two important documents which have to be consulted and followed while using recycled aggregates for concrete production:

- Combined document 'concrete', EN 206-1: Concrete - Specification, performance, production and conformity, completed by the national application **DNA EN 206-1:2000**;
- **Specification sheet: Aggregates** (Original title: *Ponts et chaussees, cahier des charges: 'Granulats'* (**CDC-GRA08**)). [21]

In the **Netherlands**, the set of standards which regulates the use of recycled aggregates for concrete production is given by the existing European ones, and additionally by the standard **NEN 5905:2010** *Dutch supplement to NEN-EN 12620+A1 Aggregates for concrete*, where the requirements that recycled aggregates should satisfy are reported. Two types of recycled aggregates are defined, depending on their composition. Current regulation allows the use of recycled concrete aggregates (RCA), characterized by at least 95 % of concrete-originated material, for concrete manufacturing for pre-stressed and reinforced structures, but it is limited to the coarse fraction (CRCA). RCA should not contain more than 5 % of masonry, 0.1 % of organic materials, and 1 % of impurities (asphalt is not included in this definition).
It should satisfy three minimum requirements in terms of minimum OD density, maximum chloride and sulphate content. [22]

Since February 2015, according to **Branch organisation breaking and sorting (BRBS)**, recycled aggregates have to respect the following criteria:

- Requirements of the stony waste to be recycled into aggregates
- Production control
- Product quality
- Declaration of Conformity
- Quality assurance.

The requirements of the **stony waste** contains:

- Quality
  - No hazardous waste
  - No asbestos, tar, residential waste, gypsum, ground, carbon black and timber
- Registration
  - Date of receipt, quantity, name and address of the supplier, and whether the offered stony waste is accepted or rejected
- A check on the presence of tar and polycyclic aromatic hydrocarbons
- A visual observation for asbestos. [22]

In **Portugal**, the national **Decree-law 46/2008**, concerning the management of CDW, includes, among others, the possibility of reusing CDW aggregates in construction if Portuguese or European specifications are verified and, in the absence of such standards, the requirements established by the LNEC (National Laboratory of Civil Engineering):

- **E 471: Guide for the use of thick recycled aggregates in hydraulic binder concretes.**
- E 472: Guide for the recycling of hot bituminous mixtures in the plant.
- E 473: Guide for the use of recycled aggregates in uncontaminated layers of floorings.
- E 474: Guide for the use of construction and demolition waste in landfill and bed layer of transport infrastructures.
- E 483: Guide for the use of recycled aggregates from recovered bituminous mixtures for uncontaminated layers of road pavements.
- E 484: Guide for the use of materials from construction and demolition waste in rural and forestry roads.
- E 485: Guide for the use of materials from construction and demolition waste in ditch filling.

In LNEC - E 471 three types of recycled aggregates are defined with respect to their composition, e.g. concrete, masonry, asphalt, floating, matter and other materials content, as reported in Table 6. Only classes ARB1 and ARB2, which are made principally of concrete-origin aggregates, are allowed to be applied into structural concrete. Class ARC is excluded from structural applications: coarse ARC aggregate can be only used for non-structural applications, i.e. levelling and filling concrete, in non-aggressive exposure classes. It is worth noting that, for these applications, no limits to the maximum replacement level exist for ARB1 and ARB2 types. The replacement ratio for structural application is defined in accordance with the exposure and strength class of the structures were they will be placed: ARB1 aggregates can be used in structures with a maximum strength class of C40/50, up to 25 % replacement of natural aggregates. ARB2 aggregates can instead be used in structures with maximum strength class of C35/45, up to 20 % replacement of natural aggregates. In both the cases, the exposure classes of the structure where they will be placed are limited in certain ranges, and it should fall within the followings: X0, XC1, XC2, XC3, XC4, XS1 and XA1. The use of fine recycled aggregates for concrete production is not allowed. In addition, concrete produced with recycled aggregate could not be used in structures in contact with water for human consumption.[12]

The application rules are summarised below:

- Recycled aggregates cannot be used in concrete in contact with water for human consumption.
- Recycled concrete cannot be used in aggressive environments.
- Up to 20% recycled aggregate can be included without express notification.

In **Spain**, there are specific technical regulations for the use of CDW aggregates for each kind of civil engineering work:

- **General Technical Specifications for Road Works and Bridges of the General Direction of Roads and Highways (PG3)**, specifies that "*the preceding material of the milling of hot bituminous mixtures may be used as aggregates for base and intermediate layers, including those of high modulus, in proportions less than 10% of the total mass of the mixture*";
- **General Technical Specifications for Road Maintenance Works (PG4)**, Article 22 states that a recycled bituminous mixture shall contain a mass proportion of the bituminous material to be recycled between 10% and 50% of the total mass of the mixture. On the other hand, all recovered asphalt material available (RAP-Reclaimed Asphalt Pavement) in Spain is used from average percentages of recycling of 10-20%, which means that there is no demand for new methods that allow recycling with high rates;
- **Code on Structural Concrete EHE-08**, approved under the Royal Decree 1247/2008 on 10 July:
    - Annex 13 ("Structure's contribution to sustainability index") takes a positive view of the use of recycled aggregates in concrete structures;
    - Annex 15 ("Recommendations for using recycled concrete"). This Annex recommends limiting the content of coarse recycled aggregate up to 20% by weight out of the total weight of coarse aggregate. With this limitation, the final properties of recycled concrete are hardly affected compared to results obtained for conventional concrete. For higher percentages, special studies and complementary experiments are required for each

application. Recycled aggregate may be used for mass concrete and reinforced concrete with characteristic strength no greater than 40 N/mm^2 while its use in prestressed concrete is excluded;
- Annex 18 ("Concretes for non-structural use") states that up to 100% of recycled coarse aggregate may be used for the manufacture of non-structural cement.

In **Slovakia**, the following technical regulations and standards are in force:

- **Act 264/1999 on Technical Requirements of Products** – CE marking, technical requirements on products which could threaten health, safety or possessions of individuals or endanger the environment;
- **Act 102/2014 on Consumer Protection**;
- § 19 of the **Regulation no. 283/200139** as amended by 310/201340, on the removal of materials with asbestos;
- **Regulation 133/2013** on construction products requires the recycled construction material to have a declaration of conformity with the relevant standards for construction products and prove harmless for the environment and human health.

In **Sweden**, rules for the application of CDW aggregates in concrete, are given in detail in the Swedish application standard to EN 206:2013, **SS137003:2015** *Concrete - Application of EN 206 in Sweden*. The rules are based on the recommendations given in EN 206 with this regard, but slightly adapted to conditions in Sweden. These requirements are valid for both precast concrete and in-situ concrete.

In **Switzerland**, the **UFAM 31-06** *Directive on the Recycling of Mineral Construction Waste* states that six recycled building materials are produced during the preparation of the four mineral construction waste categories (cfr. § 4.1):
– Asphalt granules
– Recycling gravel sand P
– Recycling gravel sand A
– Recycling gravel sand B
– Concrete granules
– Mixed demolition granules. [8]

Details about the quality standards for recycled construction materials, are reported in the Annex of Switzerland.

The excavation, dismantling and recycling organisation Switzerland (ARV) provides appropriately qualified recycled construction materials which fulfill structural requirements similar to those of the primary building materials. To this end, there is a Swiss-wide guideline of the ARV for recycling building materials. Since July 1997, ARV quality assurance has been aiming at a consistent approach to the production of recycled building materials and creating uniform designations in order to guarantee high quality standards for recycled building materials.

Swiss specific standards are:

– **SN 670 071** *Basic standard for recycling* regulates general recycling of mineral CDW into RC construction materials**.**
– **SN 670 102b-NA** *granulates for concrete* regulates aggregates for concrete production and has integrated the use of recycled aggregates according to EN 933 under compliance with the BAFU guideline.
– **SN 670 119-NA** *Integration of recycled granules* regulates aggregates for use in hydraulically-bonded and loose applications, e.g. construction of roads, train tracks etc. It is part of the Swiss version of EN 13285.
– **SN 670 902-11-NA** *Tests to determine the geometric characteristics of the granules* regulates geometrical properties of mineral aggregates and is part of the Swiss version of EN 933-11.

In **United Kingdom** the regulation distinguishes two types of recycled aggregates, RCA and RA, the former coming just from concrete-based material, characterized by a limitation of about 5 % in masonry content (in weight), and the second from mixed waste. The complementary UK Standard to EN 206-1, **BS 8500-2 2015+A1:2016** *Concrete-Complementary British Standard to BS EN 206. Part 2: Specification for constituent materials and concrete*, limited the use of RA to the production of road surfaces or underpinning works. The use of recycled aggregates is limited until C16/20 strength class, and only in the mildest structure exposure conditions. This choice is governed by the absence of a specific regulation about recycled aggregates use, which is reflected in a great variability of their properties, composition and origin.
Concerning the RCA, they are admitted to partially substitute natural aggregates, until 20 % in weight, up to concrete strength class C40/50, and within prescribed exposure classes: X0, XC1, XC2, XC3, XC4, XF1, DC-1. Exposure to salt (XS, XD) and severe freeze-thaw (XF2–XF4) are excluded. Higher replacement ratios are allowed only with documented experimental results, hence if the prescriber takes his own responsibility for the results. [12]

In **Taiwan** (extra-EU country), to implement the goal of sustainable development of green construction projects, and to promote the recycling of limited sand and gravel resources, the Government promotes the use of asphalt concrete recycling [13]. In the standard specification for **National Standard and Construction** [23], the standards regulating the use of alternative aggregates in construction materials are:

- **CNS 12549** granulated ground blast furnace slag (GGBFS) for using in concrete and cement mortar;
- **CNS 11824** Blast furnace slag for using as coarse aggregate in Concrete;
- **CNS 11890** granulated ground blast furnace slag (GGBFS) as fine aggregate in concrete**;**
- **CNS 12223** Granulated ground blast furnace slag (GGBFS);
- **CNS 11827** Blast furnace slag for road;
- **CNS 15305** gradation base, bottom and surface layer;
- **CNS 15358** Road or airport slab, gravel grading with grass;
- **CNS 15310** steel ballast for asphalt pavement mixes, allow construction use furnace ballast.

The **Code of Practice for Water Resources** Department, Ministry of Economic Affairs, No. 02722 [24] also mentioned that the material used in the grading of the aggregate shall be a rock, a gravel-grade,

a natural grade ingredient or a recycled aggregate grade. Recycled aggregate grade refers to waste concrete and brick-like materials removed from buildings or other concrete structures, suitably processed.
In Taiwan, government wants to promote "green building blocks system" since 2004 [25], introducing several categories of green building materials assessment benchmark, based on "health", ecological" and performance" parameters.

Wood
The European Panel Federation (EPF), which has members in 25 European Countries, has developed two recommendations on the use of recycled wood. Most European wood manufacturers apply these standards for the use of recycled wood for the production of wood-based panels. The first EPF standard aims at ensuring that wood-based panels are as safe as toys and are environmentally friendly. It is based on European standards on safety of toys that lay down limit values for the presence of potential contaminants. The second EPF standard describes the conditions under which recycled wood can be accepted for the manufacturing of wood-based panels. This standard comprises general requirements on quality and chemical contamination, classes of unacceptable materials as well as reference methods for sampling and testing. [5]

4.3 Prefabricated elements (with or without CDW materials)

The rules regarding the scope of prefabricated elements are very wide since there are many products.

4.3.1 Prefabricated concrete elements

At European level there are many technical regulations for structural and non-structural precast concrete elements, as for each type there is a specific product standard. All these product standards are harmonised and the complete list is given in Annex 1.

The design of prefabricated concrete elements follows the **EUROCODE 2 - EN 1992:2004 Part 1-3**: *Precast Concrete Elements and Structures,* which has been transposed by all the European countries.

The European standards **EN 13369:2013 - *General rules for prefabricate concrete elements*** identifies the requirements (with reference to the material clauses in EN 206), the basic performance criteria and evaluation of conformity for unreinforced, reinforced and prestressed precast products made of compact light-, normal- and heavyweight concrete. This standard is of general use for all types of precast products and it may be used as a common reference in specific product standards, but it no harmonised standard. If a specific product standard exists it takes precedence over this standard, even if it postpones to EN 13369 for concrete requirements and conformity control testes. The precast products dealt with in EN 13369 are factory produced for building and civil engineering works, in series or individually. This standard may also be applied to products manufactured in temporary plants on site if the production is protected against adverse weather conditions and controlled following specific provisions. Therefore, as evident form the list of European Standards, almost every type of prefabricated element has its own specific product standard, and all of them are harmonised.

Regarding the use of recycled aggregates in prefabricated elements, the European Standard **EN 13369:2013 - *General rules for prefabricate concrete elements***, at **§ 4.1.2.2**, provides information about the use of reclaimed crushed and recycled coarse aggregates, which can be used mixed in concrete with other aggregates. In detail, it states the limit for the use of crushed recycled aggregates obtained from precast concrete products manufactured in the same factory, which is up to 10% in weight of the total content of aggregates in the concrete mix, with no more further testing of the mechanical strength of the product of hardened concrete properties. For further prevision, and in particular for the use of coarse recycled aggregates, the standard remands to the new version of EN 206, which at the time was under development. Therefore, nowadays it is possible to apply to prefabricated elements the same indications given by the EN 206 for concrete with recycled aggregates.
The standard EN 206 limits the use of recycled aggregates for concrete production to the coarse recycled concrete aggregate fraction (CRCA) and, in Annex E.3, it gives limits for the replacement of natural normal-weight coarse aggregates by coarse recycled aggregates in relation to exposure classes. As reported in the previous paragraph, each country has adapted the European standard according to its needs (see § 4.2).

In **Croatia**, there are the following regulation deals with prefabricated concrete elements:

- The **Building Law** (Official Gazette No. 52/99) and the L**aw on Revisions and Additions to the Building Law** (Official Gazette No. 75/99, 117/01) are fundamental laws regulating the design, construction and maintenance of structures;
- the *Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements and Reinforced Cellular Concrete* **6/81***, **14/89***;
- the *Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements Formed of Unreinforced and Reinforced Cellular Concrete*, **14/89***;
- the *Order on Obligatory Certification of Prefabricated Elements Made of Cellular Concrete,* 34/85*, 14/89*;
- **HRN U.E3.050**, *Prefabricated concrete elements*. [27]

In **France**, two new technical documents were published end 2016, which mark a step forward for suspended pre-slabs in seismic zones and pre-walls (prefabricated walls).
The French national organisation for standardisation published a documentation leaflet (known as an FD for "*Fascicule de Documentation*") on suspended pre-slabs with continuity systems, magnetic rulers or equivalent (LPPVE). It covers design, dimensioning, and implementation according to Eurocode 2 for non-seismic zones and Eurocode 8 for seismic areas. The FDs are conceived as precursor tools to ISO 9000 norms and they include guidelines and good practices. This guide secures the process towards insurers and enables a wider acceptance by control offices.
The Pre-wall process was developed 25 years ago and has known a strong development in the past decade. The *pre-wall good practice guide Qualiprémur* was published in September 2016 (available online at: http://www.egfbtp.com/sites/default/files/7-brochure_qualipremur_bat_web_01-09-16.pdf). It targets structural engineering companies and defines the respective role of various actors

(company, supplier, engineering consultant) and how they should communicate amongst themselves. It also highlights both safety rules, which must be respected on site, and implementation rules to guarantee the quality of the works.

In **Germany** prefabricated elements are governed by the standard **DIN 1055-4** *Concrete, reinforced and prestressed concrete structures – Part.4 Additional rules for the production and conformity control of prefabricated elements*. Other specific national regulations are:

- **DIN 4223** *Prefabricated reinforced components of autoclavated aerated concrete*;
- **DIN 4223-2** *Prefabricated reinforced components of autoclavated aerated concrete – Part.2: Design and calculation of structural components*;
- **DIN 4223-4** *Prefabricated reinforced components of autoclavated aerated concrete – Part.4: Design and calculation of structural components; Application of components in structures.*

In **Hungary**, there are some technical regulations for construction elements made by recycled materials, such as:

- **JM2/01** *Main wall slabs made from crushed brick*. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete for making solid wood flooring elements from the demolition of buildings using brick dough additives
- **JM2/02** *Pre-made light concrete slabs for basements made with addition of crushed brick*. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete hollow cellar wall elements from the demolition of buildings using brick dough additives
- **JM2/03** *Indoor floor tiles made from crushed bricks*. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete for interior tiles from the demolition of buildings using brick dough additives. [26]

In **Italy**, there are the following national standards for concrete precast element:

- **Ministerial Decree**: *Technical Standards for Construction,* of **14 January 2008**;
- **UNI 9053-1:1987**. *Building. Structural elements prefabricated or made on site. Measurements for the dimensional geometric control of the single element*;
- **UNI 9053-2:1987**. *Building. Structural elements prefabricated or made on site. Measures for dimensional geometric control of elements in operation*.

In **Poland**, there are the following national standards:

- Norm **C367/C367M-16**: *Standard Test Methods for Strength Properties of Prefabricated Architectural Acoustical Tile or Lay-In Ceiling Panels*
- Norm **E477-13e1**: *Standard Test for Laboratory Measurements of Acoustical and Airflow Performance of Duck Liner Material and Prefabricated Silencers.*

In **Portugal**, in additional to the European legislation, precast concrete products are regulated by the Standard **REBAP** *Regulation of Reinforced Concrete Structures*.

In **Spain**, the Spanish *Code on Structural Concrete* **EHE-08**, in force since December 2008, is the Spanish regulatory framework that establishes the requirements that concrete structures must fulfill to meet structural and fire safety requirements, as well as environmental protection, by providing procedures that demonstrate compliance with sufficient technical guarantees. The following precast concrete products are specifically mentioned through dedicated articles in the Code:

- Chapter 6. Materials. Article 36. Infill elements in floor slabs
- Chapter 12. Structural members. Article 59. Structures comprising precast elements
- Chapter 13. Construction. Article 76. Precast elements
- Chapter 16. Control of the conformity of the product. Article 85. Specific criteria for checking the conformity of the component materials of the concrete; Article 86.9. Control of the concrete; Article 91. Control of precast elements
- Chapter 17. Control of the construction. Article 99. Control of the assembly and joints of precast elements.
- Annex 12. Specific construction and calculation aspects of one-way floor slabs with precast beams and hollow-core slabs.

4.3.2 Prefabricated timber elements

At European level, **prefabricated timber elements** are regulated by specific technical product European Standards, which define product requirements in terms of geometry, mechanical properties, test methods, etc.
The design of timber structures follows the international **EUROCODE 5 - EN 1995-1-1 (2004)**: *Design of timber structures - Part 1-1: General - Common rules and rules for buildings*. The European Standards for prefabricated timber elements are listed in Annex 1.

According to the Construction Product Regulation (EU 305/2011), structural timber products/elements and wood based panels and elements are under CE marking, as the specific products European Standards are harmonised.

Timber Building Kits (including timber frame kits) are also considered as construction products. Consequently, the manufacturers have to mark their products with CE marking and issue a Declaration of Performance (DOP), based on European Technical Assessment (ETA). Currently, ETA (e.g. ETA, 2010) are prepared on the basis of the Guideline for European Technical Approval ETAG 007 used as European Assessment Document (EAD).

In **Croatia**, wood prefabricated elements are regulated by the following standards:

- Design and realization of wooden structures **HRN U.C9.200, 200/1, 300, 400, 500 U.D0.001, 001/1**;
- Sawn timber **HRN D.C1.040, 041, 042**;
- Order on obligatory certification of chipboard used for general purposes and in construction industry **61/83***;
- Wood glue **HRN H.K1.041, 042, 045, H.K2.023, 024, 025 H.K8.020, 021, 022, 023, 024, 025, 026**. [27]

In **Germany**, wood structure are designed according to the standard **DIN 1052** *Design timber structures – General rules and rules for buildings*. The "**wood panel directive** (Holztafelbaurichtlinie-HoTaRi) for the monitoring of wall, ceiling and roof panels for wooden houses in panel type according to DIN 1052 part 1 to 3 "for the production of both sides closed elements in wooden frame and wooden panel construction was introduced as a technical rule, in order to ensure a proper execution of the wooden panel elements which are no longer visible on the construction site. [28]
The Federal Association of German Prefabricated Buildings (BDF) has developed a leaflet for direct planking with plasterboard and gypsum fibre boards on wooden panels for wall, ceiling and roof elements in wood panel construction, which are connected to each other by brackets at the factory and on the construction site. This leaflet applies to the industrialized prefabricated timber construction of BDF companies. It applies to companies which are subject to the building control regulations as well as the additional RAL and QDF quality assurance at the plant. In addition, the construction sites are supervised externally by the companies in accordance with the guidelines of the "Quality association Deutscher Fertigbau (QDF)". [29]

In **United Kingdom** there are the following specific standards:

- **PAS 104:2004** *Wood recycling in the panelboard manufacturing industry. Specification for quality and guidance for good practice for the supply of post consumer wood for consumption in the manufacture of panelboard products*;
- **BS 5268-2:2002** *Structural use of timber. Code of practice for permissible stress design, materials and workmanship*. [30]

4.3.3 Prefabricated masonry elements

Only in **Germany**, there are standards regulating prefabricated masonry elementys: **DIN 1053-4: 2013-04** *Masonry - Part 4: Prefabricated masonry compound units*, which applies to mainly prefabricated and predominantly high-volume prefabricated building elements made of masonry and buildings constructed therefrom. The standard contains constructive notes and information on the provision of the stability verification for the individual prefabricated components, including transport and assembly as well as for the building. A current draft is available for this standard (DIN 1053-4: 2017-02 - Entwurf).

4.4 Prefabricated construction

At European level the design of prefabricated constructions follows the European Standards EUROCODES, which specifies how structural design should be conducted within the European Union.
Particularly, **Eurocode 1. Part 1.3 - EN 1992-1-3** *Precast Concrete Elements and Structures* gives a general basis for the design and detailing of concrete structures in buildings made partly or entirely of precast elements; **Eurocode 5 – EN 1995** *Design of timber structures* describes how to design buildings and civil engineering works in timber, using the limit state design philosophy.

At national level, in most European countries, there are several building regulation, setting general provisions for building, regarding construction, health, safety and aesthetics, but none of them refer specifically to prefabricated constructions.
Consequently, the normal technical regulations and legislation in place for construction as a whole should also hold for anything concerning prefabricated construction.

In **Austria**, the **ÖNORM B 2310: 2009 05 01** *Prefabricated structures - Definitions and Minimum Scope of Services* defines the vocabulary and the minimum scope of benefits of prefabricated structures made of storey-high, prefabricated construction elements, regardless of the building materials used .
The **ÖNORM B 2320: 2010 07 15** *Wooden houses - technical requirements* contains technical requirements for the production and erection of wooden houses whose wall, ceiling and roof structures consist essentially of wood and/or wood materials. It applies to residential buildings which are made of wood frame construction (for example bar, stand and panel construction), wooden skeleton construction and / or wooden construction (for example plywood, plank stacking and block construction). If individual parts are built in timber construction for buildings, the provisions contained therein apply only to these parts.

In **Croatia**, the **Building Law (Official Gazette No. 52/99)** and the **Law on Revisions and Additions to the Building Law (Official Gazette No. 75/99, 117/01)** are fundamental laws regulating the design, construction and maintenance of structures.
In the field of prefabricated construction, the following subordinate acts, based on the Building Law and previous laws, were amended:

- Bylaw on *Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements and Reinforced Cellular Concrete* **6/81*, 14/89***
- Bylaw on *Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements Formed of Unreinforced and Reinforced Cellular Concrete* **14/89***. [31]

In the **Czech Republic**, the following national standards regulate prefabricated construction:

- **Norm 13369** – *Common regulation for concrete prefabricates*
- **Act 22/1997** on *Technical Requirements of Products* (it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials)
- **Government Regulation No. 299/2001**. It contains a list of standardised structural systems of panel houses. This list defines 53 main standardized structural systems which have different specific regional variations. A panel building is an object constructed by utilization of the standardized structural wall system from prefabricated panels.

In **Germany**, The **Building Regulations List** (Bauregelliste A, B and C) is an instrument developed by the authorities responsible for construction supervision in the federal states (stipulated in § 17 of the model building regulations, abbr. MBO), which determines which construction products may be considered controlled and used. This includes a list of prefabricated components made of concrete and reinforced concrete, of bricks and prefabricated components for timber construction.

Prefabricated buildings made of building materials and components are considered to be prefabricated systems according to the Land Building Regulations (LBOs) of the federal states. The building list is managed by the German Institute for Structural Engineering (abbr. DIBt) and is constantly updated.

In **Italy**, in 1987, the first binding rules specifically dedicated to prefabricated structures were issued and, after that, their explanatory circular:

- Ministerial Decree of 3 December 1987 *Technical standards for the design, execution and testing of prefabricated buildings*
- Circular of the Ministry of Public Works March 16, 1989 n. 31104 *instructions on technical standards for the design, execution and testing of prefabricated buildings*.

These rules were valid until the entry into force of the **Ministerial Decree of 14 January 2008**.

In **Sweden**, the national **Board of Housing Building and Planning** (Boverket) 1999 issued a handbook for the recycling of construction materials comprising chapters on Recycled concrete for the use as concrete aggregate, Reuse of structural timber elements, Reuse of steel products and Reuse of masonry units. Since this handbook was issued the earlier national design regulations has been replaced by the Eurocodes but this handbook has not been updated on this regard.
Some general recommendations for use in load-bearing structures are:

- Structural timber elements that by evaluation have be proven to fulfil the valid regulations may be used
- Structural timber elements not fulfilling the valid regulations but assumed to be possible to use, may be used in the lowest reliability classes, under condition that they have not been damaged by rot, insects or fungi.
- Used structural and glued laminated timber can be classified according to the same rules as new timber.
- Used masonry units may be used in non-reinforced structures when properly sorted and classified according to the same rules as for new units. The units shall not be damaged by frost or erosion or contaminated by pollution, as for instance units used in chimneys.
- These rules are valid for timber elements, steel products and masonry units under condition that they are not damaged during the demolition, storage and installation processes. The structural and environmental actions in the new structure must not be more severe than in the former position.

Currently in **the United Kingdom**, approved documents for England, Wales, Scotland and Northern Ireland set the minimum standards for the construction of all types of buildings including alternative forms of residential building construction (such as prefabricated buildings made of precast concrete, prefabricated timber, light steel framing or prefabricated aluminium) in accordance with **The Building Regulations 2010**. More specifically, the above-mentioned approved documents provide practical guidance (including examples and solutions for some of the more common building situations) on the expected performance of materials and workmanship in order to comply with all requirements set by The Building Regulations 2010.

A complete overview of the technical regulations and legislations collected in this chapter is reported in Annex 1. It also contains information on any drivers and barriers to the development of prefabricated elements with recycled materials form CDW.

5. POLICY MEASURES

At European level the main policy measures (direct and indirect), which encourages the use of CDW and prefabricated elements are:

- Waste Framework Directive (2008/98/EC)
- EU Green Public Procurement (GPP) instrument
- Directive 2010/31/EU (Energy Performance of Buildings Directive – EPBD).

Details about the above-mentioned instruments are described in the following sub-paragraph.

5.1 Materials from CDW

One of the objectives of the ***Waste Framework Directive*** (2008/98/EC) is to provide a framework for moving towards a European recycling society with a high level of resource efficiency. In particular, Article 11.2 stipulates that "Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery" (including backfilling operations using waste to substitute other materials).

On average, Europe generates around 890 million tonnes of construction and demolition waste (CDW) per year and only 50% of this CDW is recycled. This is far from the objectives determined in the European Directive for 2020. Fully aware of this situation, European Countries are implementing national policies to prevent avoidable waste and to promote measures to increase recycling and recovery.

Among the **EU Green Public Procurement** (GPP) instrument, the most recent criteria regard "*Office Building Design, Construction and Management*" [32]. This criteria state that the production of construction products is responsible for one of the most significant environmental impacts. This highlights the importance of designing and specifying for resource efficiency, with the most significant building elements to address being the floors, roof, structure and external walls. In this respect the recycling and re-use of construction materials and products, as well as whole building elements, can contribute to reducing environmental impacts and the development of a circular economy. Particularly, the use of recycled materials such as aggregates from construction and demolition waste can help develop a market for such materials, in line with EU Circular Economy objectives, and provide associated resource efficiency benefits. Therefore the criterion B 10.2 *Incorporation of recycled content in concrete and masonry*, defines the minimum value of 15% of recycled content and/or by-products for the main building elements.
The recycled content shall be calculated on the basis of an average mass balance of recycled materials and/or by-products according to how they are produced and delivered to site (as applicable):
- For each ready-mixed batch from which deliveries are dispatched to the construction site, in accordance with EN 12620 (aggregates for concrete) and EN 206 (concrete) or equivalent;

- On an annual basis for factory-made panels, columns, blocks and elements with claimed content levels, in accordance with EN 12620 (aggregates for concrete) and EN 206 (concrete) or equivalent. [32]
The incorporation of the recycled content criterion has to be applied during the detailed design and performance requirements procurement phase. Moreover, recycled content has to be verified during construction of the building or major renovation works procurement phase by means of a contract performance clause. With this aim, the criterion *Monitoring the recycled content* has been introduced in the procurement phase of *Construction of the building or major renovation works*. [12]
Therefore, this prevision in optional just because GPP is a voluntary instrument.

Most of the initiatives at national level concern the management of CDW, as detailed in the deliverables D1.1 and 1.2. Only in some countries are there technical innovations, as reported below.

In **Estonia**, in order to address the current situation and in an effort to overcome the apparent barriers in improving (a) the quality of recycling and (b) the market of CDW recycled products (e.g. recycled aggregates), the waste management sector in Estonia, through its Waste Management Association, has created the **Waste Recycling Cluster** (eventually becoming the **Recycling Competence Centre**). [33]

In **Italy**, two major regulatory innovations have been introduced recently: the so-called **Environmental Link (Law No. 221 of December 28, 2015)** and the new **Code of Practices (Legislative Decree of 18 April 2016, n.50**). Specifically, the Decree describes the technical specifications of building components such as concrete, brick, wood products, for example, the quantity to be recycled. In the technical specifications, the criteria to be followed in the demolition, for the materials used in the construction site and excavations are explained. Concrete and prefabricated concrete products on site are pre-packaged and pre-fabricated with a minimum content of recycled material of at least 5% by weight, as a sum of recycled material percentages contained in individual components (cement, additives, aggregates, additives), compatible with the limits imposed by the specific technical standards. [34]

The **Slovenian** National Building and Civil Engineering Institute, which is a member of a number of national European institutes working in the fields of buildings and infrastructure, co-operates actively in numerous joint research projects. These include, among others, "**InnoWEE** *Innovative pre-fabricated components including different waste construction materials reducing building energy and minimizing environmental impacts*" H2020 (§6.4), which runs from October 2016 up to September 2020, and "**REBIRTH** *Promotion of the Recycling of Industrial Waste and Building Rubble for the Construction Industry*", a project founded by the EU's LIFE programme to date. The aim of REBIRTH is to increase and improve the recycling of industrial and construction and demolition waste for re-use as new regenerated construction material [35]. The project highlighted some inconsistencies in the application of waste legislation and several legislation developments are expected as a consequence, including:

- A proposal for an amendment to green public procurement legislation;
- A proposal for legislation regarding the concentrations of dangerous substances in the leachates of construction materials;
- A proposal for legislation on CDW – harmonization with decree on waste and defining end-of-waste criteria for CDW; and
- Guidelines for the classification of CDW. [35]

In **Spain**, one of these measures has been the development of a CDW recycling guide for the manufacture of mortar, concrete, brick and lightweight aggregates. However, there is still insufficient information on the possibility of incorporating different CDW materials in the manufacture of other products.
The Spanish **Guide of recycled aggregates** (GEAR) has prepared technical recommendations and operation instructions applicable to all aggregates from CDW, which will be used as materials for construction. The technical recommendations of the Spanish Guide are the following:

- GEAR-RT-01: Technical recommendations for aggregates from CDW for bituminous mixtures and surface treatments for roads.
- GEAR-RT-02: Technical recommendations for aggregates from CDW for backfills.
- GEAR-RT-03: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in civil engineering work and road construction
- GEAR-RT-04: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in prefabricated elements.
- GEAR-RT-05: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in concrete.
- GEAR-RT-06: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in roller-compacted concrete layers.

5.2 Prefabricated elements (with or without CDW materials)

At European level there are no policy measures for promoting the use of prefabricated elements in building construction, even if the use of prefabricated elements can offer significant advantages, such as shortened construction time, improved quality, enhanced occupational health and safety, less construction site waste, less environmental emissions, and reduction of energy and water consumption. According to the **Energy Performance of Buildings Directive** – EPBD (DIRECTIVE 2010/31/EU), the EU has agreed on ambitious Energy and Climate targets for 2020 and beyond to reduce greenhouse gas emissions, increase the share of renewable energies and improve energy efficiency, setting the target of 20%. Therefore, with regard to these targets, in several analysed cases, States or Municipalities support the housing and development of industry subjects, with the participation in research projects funded by the EU. These programs encourage building under several conditions:

- Use of material with minimal energy use and minimal CO_2 emissions
- Use of lightweight materials
- Use of renewable sources and recycled materials to a large extent
- Use of constructions allowing easy separation of materials and their removal.

One of the main topics of these research projects is precisely the development of prefabricated elements (better if with recycled materials) for energy-efficient constructions, as detailed in the following.

In **Croatia**, with respect to innovation in construction, the government also supports participation of local research institutions and companies in EU-funded projects. Instances include **ECO-SANDWICH**, supported by the *Ministry of Environment and Nature Protection and the Ministry of Construction and Physical Planning*, among others, and led by the Faculty of Civil Engineering of the University of Zagreb. The project developed an innovative prefabricated wall panel using recycled construction and demolition waste and mineral wool produced with an innovative sustainable technology, achieving a reduction of primary energy consumption in the building stock due to its enhanced insulation and ventilation properties. [38]

In **Greece**, the *Varis-Voulas-Vouliagmenis Municipality* and the industrial partner AM Solutions are involved in the afore-mentioned **InnoWEE** research project. In this project, one of the main results, among others, is the development of ventilated façade claddings based on the geopolymer technology.[39]

In **Taiwan** (extra EU country), the government wants to promote "green building blocks system" since 2004 [25]. In 2015 the Ministry of the Interior defined the "**Green Building Label**" certification, following the international development trend. One of the nine-indicator green building evaluation is "Construction Waste reduction", to promote the use of recycling CDW in "green concrete" building materials including pre-cast element, requiring at least 40% of the recycled material to replace the concrete aggregate.

5.3 Prefabricated construction

Even if there are no EU policies which have the specific intent to promote prefabricated construction, however, a number of other EU policies may indirectly support this construction approach. For example, the energy efficiency requirements, fixed by the EPBD (§ 5.2), have driven every European country to implement their energy codes for newly constructed or renovated buildings, creating sometimes a new building code for sustainable housing, as is the case of the UK, and others had to add a whole chapter to their existing building codes – as is the case of Germany and the Netherlands.

Inspired by the principles of thermal insulation, energy efficiency, and life-cycle construction, prefabricated construction should be widely regarded as a sustainable construction method in terms of its impact on environmental protection. One important aspect of this perspective is the influence of prefabrication on construction waste reduction and the subsequent waste handling activities, including waste sorting, reuse, recycle, and disposal.

Nevertheless, it would appear that existing research with regard to this topic has failed to take into account its innate dynamic character of the process of construction waste minimization; integrating all essential waste handling activities has never been achieved thus far.

Only in Bulgaria, Italy, Lithuania and Slovenia, are there specific policy measures for the refurbishment of existing prefabricated buildings.

In **Bulgaria**, since 2004, the housing policy has focused on energy efficiency with the launch of a number of policy measures, such as the National Programme for Energy Efficiency of Residential Buildings and, specifically, with **Measure N. 511: Development of a national programme for refurbishment of the existing prefabricated panel buildings in Bulgaria**.

In **Italy**, thanks to the **Financial Law of 2017**, there is the possibility to obtain tax breaks for seismic improvements as well as energy efficiency, also for interventions for the adaptation of prefabricated structures, up to 2021.

In **Lithuania**, in order to reduce the energy consumption of the residential building stock, the State has adopted a **Programme for the Refurbishment of Multi-Apartment Buildings**. Its target group is the multi-apartment buildings that had been constructed before 1993 [40]. The programme was initially enforced in 2005, offering state grants of up to 50% of the costs of the renovation works, with the balance provided by commercial banking loans [40].

In 2015, **Slovenia** launched its **National Energy Efficiency Action Plan 2014-2020**, which defines measures to be implemented in order to reach the energy efficiency target set in the Energy Efficiency Directive 2012/27/EU. The **ECO Fund**, the Slovenian environmental public fund, provides soft loans for environmental investments, as well as subsidies for residential and multi-residential/apartment buildings. [41]

Other indirect instruments which can encourage the use and the diffusion of prefabricated construction with recycled materials from CDW are the "**Certification Protocols**" in the context of sustainable building design. The majority of the certification systems have, among the evaluation criteria, the environmental compatibility of buildings. Therefore, there is no internationally recognized system to rate buildings according to the definitions applied by the trading industry (Class A) or, at least, a system that takes into account shared parameters and standards. Many of the methods are inevitably linked to the context for which they were developed.

The main international certification protocols are:

BREEM - Building Research Establishment Environmental Assessment Method. It is one of the first instruments for the assessment the sustainability of buildings and it has become one of the most comprehensive and widely recognised measures of a building's environmental performance. The UK system was developed in 1990 by the BRE (Building Research Establishment) and represented a reference point for the elaboration of the methods later. The BREEAM assessment process evaluates the procurement, design, construction and operation of a development against targets that are based on performance benchmarks. It measures sustainable value in a series of categories, ranging from energy to ecology. Each of these categories addresses the most influential factors, including low impact design and carbon emissions reduction; design durability and resilience; adaption to climate change; and ecological value and biodiversity protection. Within every category, developments score points – called credits – for achieving targets, and their final total determines their rating. According to the BREEAM scoring and rating system, the Re[4] products may demonstrate potential in relationship with different categories, but mostly with "***Resource and energy***", in which the following topics are dealt with:

- "**materials**": it encourages steps taken to reduce the impact of construction materials through design, construction, maintenance and repair. Issues in this section focus on the procurement of materials that are sourced in a responsible way and have a low embodied impact over their life including extraction, processing and manufacture and recycling;
- "**waste**": this category encourages the sustainable management (and reuse where feasible) of construction, operational waste and waste through future maintenance and repairs associated with the building structures. By encouraging good design and construction practices, issues in this category aim to reduce the waste arising from the construction and operation of the building, encouraging its diversion from landfill. It includes recognition of measures to reduce future waste as a result of the need to after the building in the light of future changes to climate. [42]

LEED - Leadership in Energy and Environmental Design. This is the certification system certainly more widespread globally. Defined and promoted by the U.S. Green Building Council (USGBC) in 1993, this is in more than 110 countries. LEED certification is a voluntary standard and it is suitable for all buildings, at all phases of development. Projects pursuing LEED certification earn points across several areas that address sustainability issues. Based on the number of points achieved, a project then receives one of four LEED rating levels.
There are five rating systems that address multiple project types:

- LEED BD+C Building Design and Construction
- LEED ID+C Interior Design and Construction
- LEED O+M Building Operations and Maintenance
- LEED ND Neighborhood Development
- LEED HOMES Homes.

The basic areas that address key aspects of green buildings are:

1. Integrative process
2. Location and transportation
3. Sustainable sites
4. Water efficiency
5. Energy and atmosphere
6. Materials and resources
7. Indoor environmental quality
8. Innovation
9. Regional priority.

Particular interesting are the key aspects 1, 6 and 7, to the development of Re[4] products, as:

- **Integrative process** is a comprehensive approach to building systems and equipment, by identifying synergies between them, as to help achieve high levels of building performance, human comfort, and environmental. By identifying synergies between systems, it will save time and money in both the short and the long term while optimizing resource use. Finally, the integrative process can avoid the delays and costs resulting from design changes during the construction documents phase and can reduce change orders during construction;

- **Materials and Resources** aspects focuses on minimizing the embodied energy and other impacts associated with the extraction, processing, transport, maintenance, and disposal of building materials;
- **Indoor Environmental Quality** category rewards decisions made by project teams about indoor air quality and thermal, visual, and acoustic comfort. Green buildings with good indoor environmental quality protect the health and comfort of building occupants. [43]

6. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

Prefabrication can be applied in a wide variety of project types, ranging from residential housing to large-scale industrial plants. Sector is characterized by a large number of small, domestic, country-specific vendors in the market as of 2015 who are also providing prefabricated building components. These vendors are offering affordable solutions to SMEs and small construction companies and developers that engage mainly in small-scale residential development projects [44]. The prefabricated construction market in Europe is the second largest prefabricated construction market in the world. In 2015, the prefabricated construction market in Europe was valued at close to € 26.5 billion [45]. The growth of the prefabricated construction market in Europe is attributed to the steady recovery of the construction markets in the leading countries of the region, such as the UK and Germany.

How widely and to what degree prefabrication is accepted in the construction industry depends on the segment and country. Prefabrication is very common in residential projects in Scandinavia, whereas it has made little headway in the residential market in Germany. It is used very widely in the construction of prisons, and is becoming more important in transportation infrastructure, such as bridges and elevated highways [46].

Productivity in construction could receive a substantial boost from standardization, modularization and prefabrication. The standardization of components brings many benefits, including a reduction in construction costs, fewer interface and tolerance problems, greater certainty over outcomes, reduced maintenance costs for end-users, and more scope for recycling. Modularization adds to the advantages of standardization, by increasing the possibilities for customization and flexibility, and helping to realize the potential of prefabrication in a factory-like environment [47].

Prefabrication would increase construction efficiency, enable better sequencing in the construction process and reduce weather-related holdups; by such means, it becomes possible to reduce a project's delivery times and construction costs relative to traditional construction methods, and also to create safer working environments.

6.1 Exports / imports of prefabricated elements

According to the PRODCOM Eurostat database [45], in EU 28 value of production sold of **prefabricated buildings** - whether or not complete or already assembled - amounted to € 26.5 billion in 2015. Reporting the volume of production sold of prefabricated structures to revenue generated by the segment of residential and non-residential buildings (€ 580 Billion, 2015), production sold is equivalent to about 4/5% of the total turnover generated by the segment of residential and non-residential buildings [48].

More than half of the production sold (57%) is for prefabricated iron or steel structures. Nearly 1/3 of the market is for prefabricated wooden structures, while concrete prefabricated structures account for 7% of the market. The overall growth rate of production volume sold in the period 2009-2015 is about 3%.

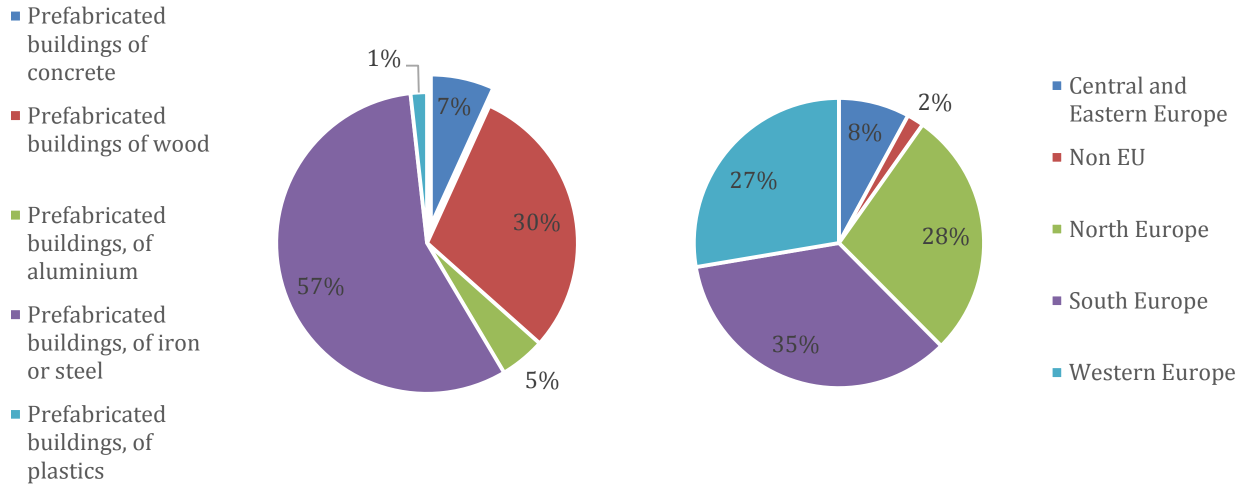


Figure 2- Prefabricate buildings by type - production value sold (as %) and geographical distribution – 2015

Italy accountings the largest share with 28.6%, followed by Germany (12.4%), UK (12.5%) and Frence (9.4%). The 2009 financial crisis and subsequent European debt crisis were detrimental to the European construction industry, and caused the prefabricated buildings market to record a Compound Annual Growth Rate (CAGR) review-period of 3.5%. With the increasing adoption of green building practices, the market for prefabricated construction is expected to have a positive outlook in the coming years. Market Analysts foresee for the next period (2016/2020) that the global prefabricated construction market will grow progressively at a CAGR of more than 6% over the forecast period.

In terms of growth of the volume of production of prefabricated, countries such a United Kingdom, Hungary, Denmark, Croatia, Lithuania, Estonia, Latvia, show a strongest growth in production volume over the observed period, between 9% and 32% more high than the overall EU 28 (3.5%). Important growth rates of the industry are also observed for countries like Romania, Czech Republic, Netherlands, Slovenia, Slovakia, Sweden, that show a growth rate between 3% and 9%. However, countries such as Italy, Belgium and France show a slightly lower trend than the overall trend of the European market, their growth rate is between 1% and 4%. Finally, there are countries that have reduced their production volume and have negative market performance, Greece, Norway, Bulgaria, Portugal, Finland, Ireland, and Spain. Their growth rate is between -13% and -1%.

Table 11 - Prefabricated Buildings - value of production sold, market share and growth rate by countries

PRODVAL _ prefabricated buildings[5] (Value in euro)	2009	2015	Share on Value of Production (2015)	Growth in value of production (CAGR)
Austria	875.509.100	1.032.325.300	3,96%	2,78%
Belgium	563.368.334	611.466.111	2,35%	1,37%
Bulgaria	116.863.177	73.017.937	0,28%	-7,54%
Croatia	44.737.869	108.197.394	0,42%	15,86%
Cyprus	-	-		
Czech Republic	447.192.888	630.488.067	2,42%	5,89%
Denmark	88.892.590	165.214.582	0,63%	10,88%
Estonia	116.750.221	349.719.262	1,34%	20,06%
Finland	582.946.026	467.923.516	1,80%	-3,60%
France	2.264.531.594	2.459.022.103	9,43%	1,38%
Germany	2.634.716.911	3.244.658.852	12,45%	3,53%
Greece	127.717.209	54.953.040	0,21%	-13,11%
Hungary	70.009.711	127.794.716	0,49%	10,55%
Ireland	130.432.000	119.372.000	0,46%	-1,47%
Italy	6.776.454.000	7.460.831.000	28,62%	1,62%
Latvia	23.581.577	126.040.613	0,48%	32,23%
Lithuania	59.457.976	147.638.164	0,57%	16,37%
Luxemburg	-	-		
Malta	-	-		
Netherlands	822.492.000	1.264.871.000	4,85%	7,44%
Norway	822.492.000	432.422.343	1,66%	-10,16%
Poland	238.185.923	257.076.049	0,99%	1,28%
Portugal	445.930.449	354.361.326	1,36%	-3,76%
Romania	338.471.272	474.900.178	1,82%	5,81%
Slovakia	73.888.703	122.070.018	0,47%	8,73%
Slovenia	100.144.424	159.982.372	0,61%	8,12%
Spain	1.466.525.801	1.374.216.487	5,27%	-1,08%
Sweden	961.944.703	1.612.815.523	6,19%	8,99%
United Kingdom	1.850.042.651	3.268.064.587	12,54%	9,95%
EU 28 Total	**21.462.327.470**	**26.513.054.096**	**100,00%**	**3,59%**

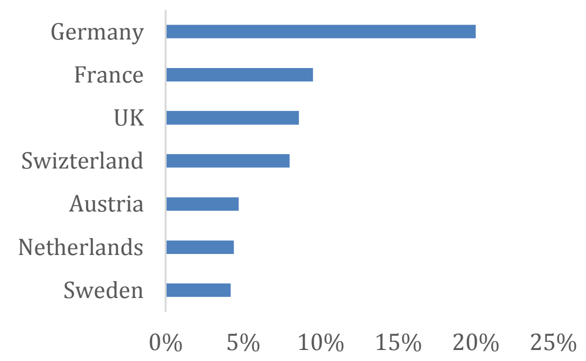
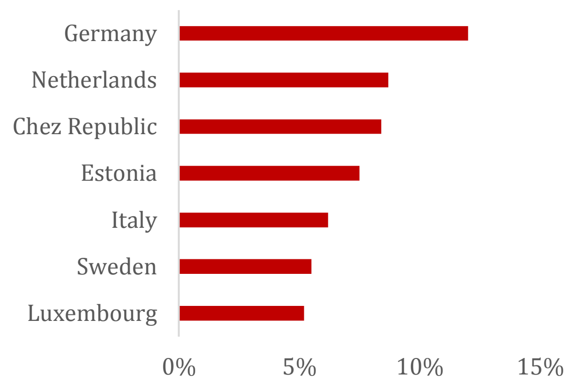
Source: PRODCOM, Eurostat 2017

Overall, in terms of imports and exports, the value of trading on the market is 7.33 billion, of which € 3.95 billion are generated from export activities, while € 3.37 billion relates to import activities.

[5] Data for Cyprus, Luxembourg and Malta are not shown. According to the terms of the PRODCOM Regulation, these countries are exempted from reporting PRODCOM data to Eurostat and zero production is recorded for them for all products. The regulation stipulates that zero can be reported for any NACE class where the reporting country has less than 1 % of Community total and this is true for all NACE classes of these three countries.

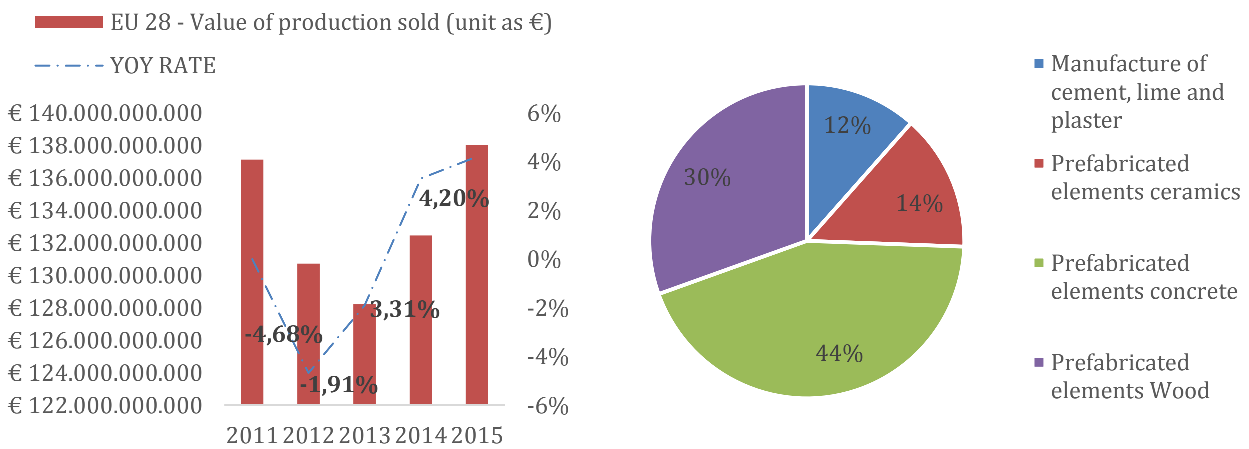
According to the Product Complexity Index (PCI) [49] prefabricated Buildings are the 363rd most traded product and the 652nd most complex product. The top importer European countries of Prefabricated Buildings are Germany, France and UK, while top exporter are Germany, Netherlands, and Checz Republic.

Table 12- Import-export of prefabricated buildings by countries

TOP IMPORTER OF PREFABRICATED BUILDINGS	TOP EXPORTER OF PREFABRICATED BUILDINGS
	

Source: Observatory of economic complexity

Focusing on the segment of prefabricated elements in terms of import and export, in 2015, the volume of production sold amounts to € 138 billion. After a period of decline, the production sold of segment of prefabricated returned to growth with a rate year over year (yoy) at around 4.2% observed between the last two years. More than half of the production consists of precast concrete elements (44%), followed by wood (30%) and ceramic (14%). These segment of prefabricate elements are those that showed higher growth in the observed period.



Source: PRODCOM, Eurostat 2017

Figure 3. Historical trend and share of prefabricated building elements (value of sold production)

As can be seen from the trend in the sector shown in Figure 3, the production of prefabricated elements has grown steadily over the past 2 years. Between 2013 and 2014, it grew at a yoy rate of 3.3%, while between 2014 and 2015 it grew at a rate of 4.2%. In 2015, the sector reached and exceeded the production volumes observed in 2011. The construction sector is confirmed as the main reference market for all sub-contractors of building materials. In fact, observing the trend in the volume of production of prefabricated elements have a similar trend to the construction market. In the construction market resumption signals are observed in last three years (2014-16), at the same time the sector of prefabricated elements probably continues to grow due to the recovery in demand for construction market in Europe [50].

Not all segments considered were the same trend. In the observer period, there is a contraction of production sold for group of manufactures of cement, ready mix concrete and mortar, non-structural element of concrete, plaster and cement, fiber cement group, marble, travertine and alabaster, and bricks, tiles and constructive clay-based products. Overall, these segments represent 43% of the sample considered and have a negative growth trend of between -6% and 0%. The worst performances are obtained, in particular, by two segments such as non-structural elements of concrete, plaster and cement (-4%); and of other prefabricated products such as fiber cement group (-6%).

On the other side, Concrete for constructional purpose have the largest market share (17.15%) and must keep evolving to satisfy the increasing demands of all of its users. In fact, there is an increase in volumes produced and sold of concrete for construction purposes (5.15%), followed by an increase of production of plaster products for constructional purposes (1.42%), ceramic tiles and flags, and parquet floor assembly (2.5%) and veneer sheets and wood-based panels (1.27%). Overall, these segments represent 57 % of the sample considered and have a growth trend of between 0% and 5%.

Table 13 -Trend in share in value of production sold of the main constructional prefabricate elements (CAGR 2015/11)

EU 28 – Value of production sold of prefabricated elements	2011	2015	Share 2015	Growth (CAGR)
Bricks, blocks, tiles and other ceramic goods (Group /2320)	4.314.320.069	4.293.070.408	3,11%	-0,1%
Cutting, shaping and finishing of stone (Marble, travertine, alabaster, worked, and articles thereof) (Group /2370)	6.338.161.969	6.057.900.336	4,39%	-1,1%
Manufacture of assembled parquet floors (Group /1622)	1.636.194.971	1.807.814.046	1,31%	2,5%
Manufacture of bricks, tiles and construction products, in baked clay (Group /2332)	5.969.978.881	5.503.885.969	3,99%	-2,0%
Manufacture of cement (Group /2351)	14.631.583.819	12.789.740.079	9,27%	-3,3%

Manufacture of ceramic tiles and flags (Group /2331)	8.545.537.011	9.609.455.929	6,96%	3,0%
Manufacture of concrete products for construction purposes (Group /2361)	19.359.098.048	23.666.653.342	17,15%	5,2%
Manufacture of fibre cement (Group /2365)	1.288.581.597	1.025.127.696	0,74%	-5,6%
Manufacture of lime and plaster (Group /2352)	3.198.719.645	3.121.283.804	2,26%	-0,6%
Manufacture of other articles of concrete, plaster and cement (Group /2369)	5.942.870.254	4.962.518.994	3,60%	-4,4%
Manufacture of other builders' carpentry and joinery (Group /1623)	21.188.377.962	21.186.691.104	15,35%	0,0%
Manufacture of plaster products for construction purposes (Group /2362)	2.855.053.922	3.020.184.071	2,19%	1,4%
Manufacture of ready-mixed concrete and Mortars (Group /2363_64)	23.715.850.434	21.897.368.679	15,87%	-2,0%
Manufacture of veneer sheets and wood-based panels (Group /1621)	18.140.126.559	19.081.289.970	13,82%	1,3%
Total value of production sold	**137.124.455.141**	**138.022.984.427**	**100,00%**	**0,16%**

Source: PRODCOM, Eurostat 2017

The production plus imports minus exports (apparent consumption), is equal to 129 Billion to EU 28. Much of the production of prefabricated constructional elements is destined for domestic consumption, mainly because most of the building and construction materials required by the industry are manufactured locally.

Table 14- Import and export (Value in €) of prefabricated elements by EU 28/RE4 Member State

2015	VALUE OF PRODUCTION (PRODCOM)	EXPORT (Int. Trade COMEXT)	IMPORT (Int. Trade COMEXT)
EU 28	138.022.984.427	32.708.860.698	23.728.106.548

Source: PRODCOM and International Trade, Eurostat 2017

Overall, the value of imports and exports is about € 56.4 billion for EU 28, the export account € 32.7 billion while import € 23.7 billion. During the observed period, exports grew by 3% CAGR, while import grew by 1.1% for EU 28 countries. The trade balance is in active, the value of exports exceeds that of imports.

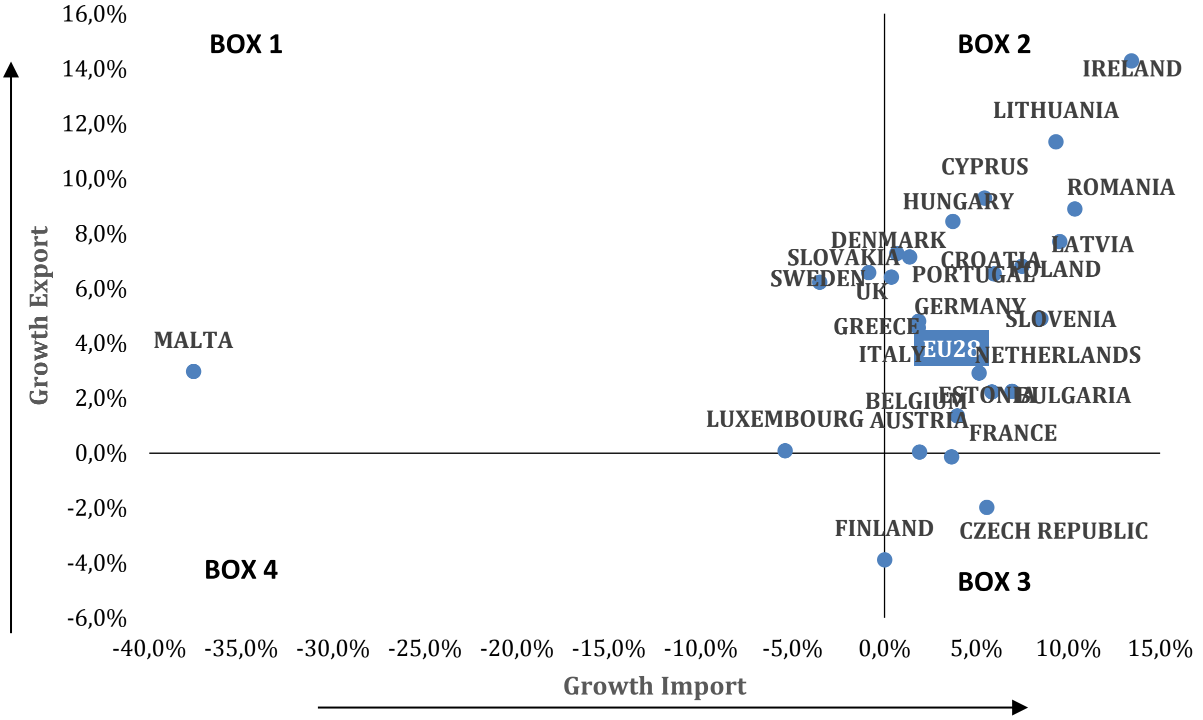
Table 15 - Import and export (Value in €) - prefabricated buildings elements (CAGR 2015/2011)

EU 28	2011	2015	CAGR
EXPORT	28.976.724.652	32.708.860.698	3,08%
IMPORT	22.661.905.044	23.728.106.548	1,16%
EU 28 Total	**51.638.629.696**	**56.436.967.246**	**2,25%**

Source: International Trade (COMEXT), 2017

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

Base on the last three years (2016/2013), Figure 4 shows the market trend in terms of exports and imports of prefabricated elements for buildings. At the top left of the chart, **in box 1**, there are countries that have seen increasing their export quota but declining import activities. **In box 2** are all countries that have seen both import and export increases. **In box 4**, that have contracted in both in export and import activities. **In box 3** are countries that have seen increasing their import quota, but they have reduced the export quota.



Source: International Trade (COMEXT), 2017

Figure 4 -Growth in import and export of prefabricated elements (CAGR 2013-2016)

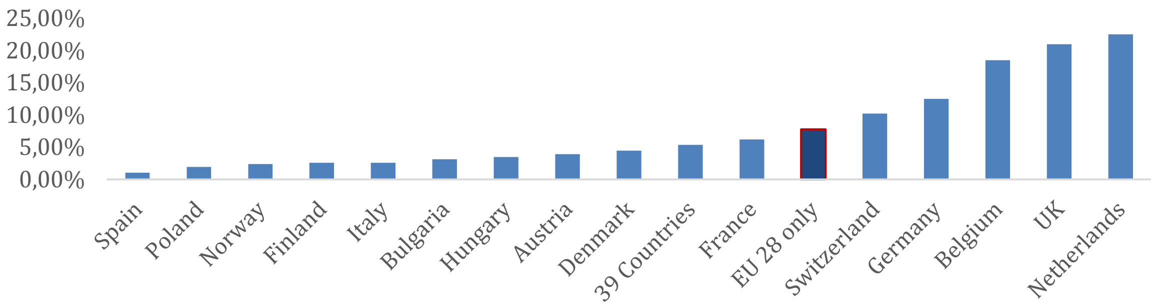
About 70% of the sector's trade flows are concentrated in the EU 28, the remaining 30% relates to import and export activities carried out outside the European borders. Most of the observed countries have increased their import and export activities over the years (box 2). First, probably that is a signal of the recovery that is going through the construction market in Europe [50]. Second, as a saw previously, most of construction materials required by the industry are manufactured locally, and this explain the large concentration of import and export activities mainly in EU 28 inside borders.

In the case of prefabricated building elements, for some countries import means gives access to important resources and products otherwise unavailable or at a cheaper cost, while for the other countries exports mean more production, labor, and income. In this context, engaging in a culture of sustainable development means refocusing productive processes through the creation of a virtuous supply chain characterized by the greater efficiency and effectiveness of partnerships that could lead to a recovery in competitiveness in European markets, supporting growth and Import and Export activities.

To increase the possibility of exporting and importing, it needed to must know the similarities and differences in the matter. Europe can benefit from the development of a common approach and a common vision that facilitates joint innovation and export, making prefabrication easier. The repeatability and reuse of the pre-fabrication technology are prerequisites for increasing the attractiveness of residential blocks, reviewing energy efficiency, and coordinating the renovation of homes so that facades and buildings can be restored to a large extent by more homes.

6.2 Market conditions / costs and benefits

Natural aggregates are simple and cheaper to process than recycled aggregates, since natural raw material is more homogeneous and have much lower contamination than recycled one. The low cost of natural aggregates has been certainly a limitation factor for a decisive factor for any material, even for sustainable construction. However, in many regions the economic factors are changing. Production of recycled and reused aggregates increased to 228mt in 2014, representing 8.6% of the total output of 2.65 billion tonnes, this also representing around 40% of total demolition materials available. Germany led with 73mt of recycled materials, followed by UK, the Netherlands, France, Belgium, Poland and Switzerland, the leaders supplying over 20% of national demand through recycling [51]. Production of recycled materials in other countries is slowly increasing, though may not be as technically or commercially viable in countries of lower population density. It is likely that recycling is in many cases not fully reported, so that actual progress maybe greater [52][51].



Source: European Aggregates Association UEPG

Figure 5 - Recycled aggregate on total aggregates productions (as %) - 2015

In order to make recycled aggregate competitive to natural aggregate and to close the building materials cycle by recycling CDW in high-grade applications, it is necessary to increase its market value through properties, application possibilities and price. Recycling CDW must be necessarily cheaper than raw material or than disposal [53]. Generally, costs and benefits of the market are related to:

- Reliability of supply, quality and quantity of CDW (availability of materials and capacity of recycling facility),
- Public perceptions regarding the quality of recycled products,
- Government procurement incentives,
- Standards and regulations requiring treatment for recycled,
- Taxes and levies on natural aggregates and on landfill.

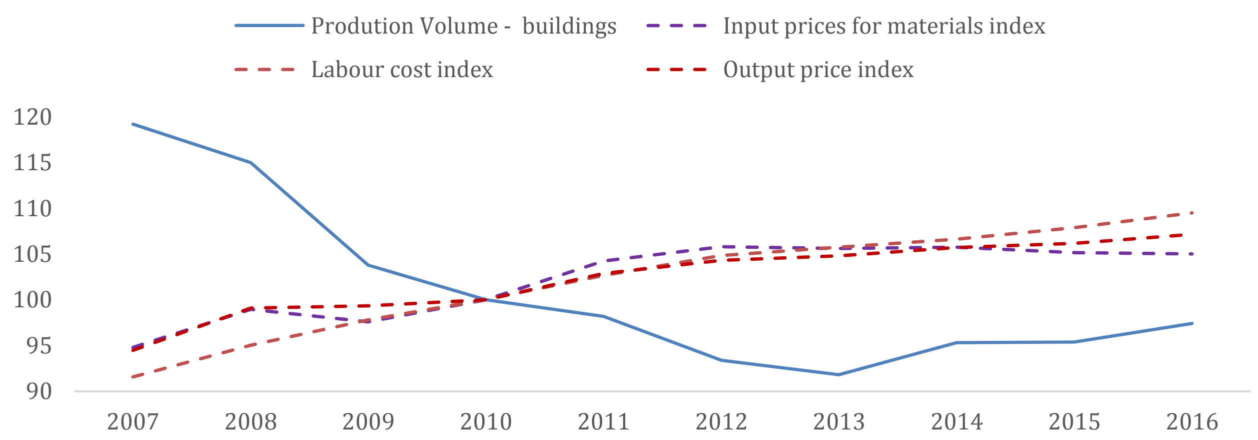
In the high countries CDW recovery rates (like Germany, Holland and Denmark) government takes various measures to make waste incineration or landfilling particularly expensive. Measures such as landfill taxes and charges for unsorted CDW favor selective collection and recycling of CDW. In these countries generally landfill costs are higher, and have generally a high recycling rate. The result is that CDW is often cheaper than new materials. Moreover, Construction materials producers are benevolent to sell recycled materials, because they recognize the large future market.
The existence of quality standards and norms apply to recycled CDW (and related legal obligations, including sufficiently high sanctions in case of non-conformity), ensure both the circulation and marketing of a high-quality product, and fulfil requirements and quality standards equal to the primary raw. These are most important to undermine the market circulation of recycled materials which usually bear higher costs due to improper treatment and recycling processes. These factors can making secondary building materials derived from recycled material particularly attractive to the market with respect to the primary virgin building material and could justify the creation of a large supply chain and a large market for the collection and sale of waste materials (Deloitte).
By contrast, the absence of a clear and strong regulatory framework, as shown for countries with low recycling and CDW reuse, leads to persistence of lack of sufficient sanctions in case of illegal disposal. For example, many Eastern European countries (Bulgarian or Romanian) does not have a clear and strong regulatory framework, sanctions are defined, but according to experts, it does not appear to be an important constraint. On the economic side, the recycling market is really new, the costs and benefits are unclear for CDW management players. CDW deactivation is more expensive to dispose of in alternative ways. In fact, CDW producers do not have financial leverage to send CDW for recycling [54].
Another factor limiting market expansion is the higher cost of secondary material than the primary one. In Romania, buy the secondary raw materials it is currently more expensive than primary ones. One of the main reasons is that the large number of pits in Romania leads to an abundance of supply of natural aggregates, and to low prices. For this reason, using recycled CDW for new constructions is not very well perceived in as the actors in the construction sector tend to prefer the use of primary raw material, which they perceive as having higher quality than secondary (recycled CDW) materials [55].

6.3 Construction sector make up

6.3.1 Potential of prefabricated constructions

The construction sector plays an important role in the European economy. It generates almost 10 % of GDP and provides more than 20 million jobs, mainly in micro and small enterprises. The markets of the EU construction sector and the sector itself are highly fragmented, with many micro-enterprises. The competitiveness of construction companies is therefore an important issue not only for the Growth, but also for the sustainability of the sector [56].

Construction sector is a major consumer of intermediate products (raw materials, chemicals, electrical and electronic equipment, etc.) and related services. The construction and use of buildings in the EU account for about 1/3 of our water consumption, about half of all our extracted materials and energy consumption. In the six years between 2007 and 2013 the volume of production in the industry has drastically reduced. Altogether, the index has lost near 30 percentage points. Resumption signals are observed in last three years (2014-16), when it is noted that construction production has returned to grow by about 6/7%. However, the current production volume is far from the pre-crisis level. The financial crisis has particularly affected the construction sector; there have been severe drops in demand especially in the private residential market but also in other markets (e.g. infrastructure market). As a show the graph below, the use of traditional manufacturing methods for the construction of new buildings, it would require a significant effort, for a sector that is already facing considerable decrease of production volume [57], correlated at the growth of production costs such as materials and labor [58], and the availability of skilled labor.



Source: Eurostat, 2017

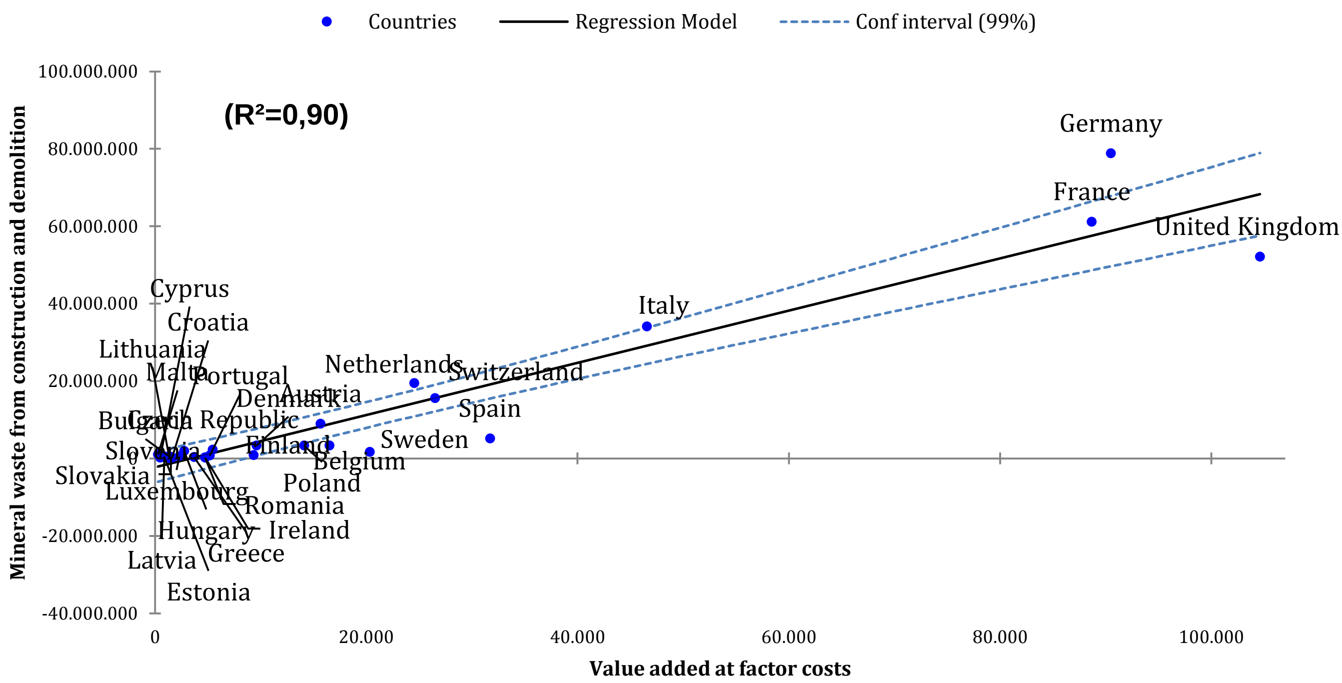
Figure 6. EU 28 Member state - Construction cost (or producer prices) and Volume of Production INDEX (2010=100) - new residential buildings

The crisis in the construction sector has affected all EU-28 countries, although to varying degrees. All countries have experienced a decline in construction production, which may vary from a remarkable reduction observed, for example, in Latvia, Slovenia or Portugal to stable and / or growing activity levels registered in the Netherlands, Belgium or Sweden. For the sector, competitiveness depends on new technologies and production techniques able to increase the degree of innovation in the sector and to be able to adequately support it in to the transition to a resource-efficient and low-carbon economy.

In a context characterized by a sharp contraction in production volumes and continuous divestments in the sector, the creation of new value chains by expanding the size and attractiveness of CDW recycling and reuse for energy-efficient buildings construction and refurbishment, could lead to a recovery in competitiveness in the national and international markets.

As suggest the model elaborated by ISPRA In the report on special waste 2016 [1], the regression analysis shows how the amount of secondary raw material [59] to be reused in the production cycle, increases proportionally with the added value [60]. **Coefficient R2 is 0.90** (90% of the variance explained), and confirms a significant relationship between the quantity of waste produced and the added value of the construction. The gross value added of the Construction industry is a valid one Regressor, which should be used with caution, because exist other factors involved in significant way to determine the quantities of waste produced, such as the political, economic and social factors described in section 6.2 on the benefits and costs of the market. Model it only shows that there is a significant relationship between the added value of the construction sector and the amount of waste generated by construction demolitions.

In the EU, CDW accounts for approximately 25% - 30% of all waste generated and consists of numerous materials [61], of this 97% of the waste produced is not dangerous, and can be easily recycled. Given the size of the buildings, every demolition produces a huge amount of waste. Only to demolish a single-family house of 130 m2 produces 400 t of building waste, made up of 70-90% of bricks, cement and plaster and 10% by wood, plaster-based materials, metals and plastics [62]. Value added at factor cost is the gross income from operating activities after adjusting for operating subsidies and indirect taxes. It is an indicator of the value increase that occurs in the production and distribution of end-products (such as prefabricated building materials), thanks to the intervention of the productive factors (capital and labor) starting from the purchase and use of initial primary goods and resources (such as aggregates from CDW). Especially in countries where the market price of recycled aggregates is lower than that of virgin aggregates, the major availability can impact positively on purchase of initial primary materials. Assuming optimal use of productive factor, the major availability of CDW can generate gross income from operating activities to the industry, and is it is correlated to value added of construction sector.



Source: Structural business statistics (SBS), Eurostat 2017 and ISPRA

Figure 7. Regression of Value added at factor cost by Mineral waste from construction and demolition

The deployment of enabling technologies and the use of flexible work-organization (off-site production) is a possible solution to the production crisis that hit the industry. As a European

Commission study shown, "*the sector will probably intensify its efforts in research and innovation to cope with the high consumption of inputs (such as metallic and non-metallic minerals, chemicals and wood) and the production of large quantities of waste. Moreover, the industry is developing more and more materials that are easier to collect and reuse and systems or 'building solutions' that facilitate the 'deconstruction' of the works and the re-use of materials*" [56].

Here are the main market trends, so according to industry analysts, the prefabricated construction market could have a greater penetration in the segment of residential and non-residential construction [63].
Growth in urbanization and industrialization, and a grown demand for low cost residential units are among some of the key factors that drive the precast construction market. Precast solutions offer attractive alternative solutions for architects and structural engineers to meet the demand for affordable housing with more demanding building criteria, especially in terms of total cost efficiency, construction speed, high quality of works, reduced weight of the upper structure, and more environmental friendly projects.
The rapid growth and development of urban housing demand causes for shorter construction timelines and reduced cost. Speed in construction can be attained as precast products are quickly erected on site, providing the opportunity to rapidly construct a building and speed up construction. Precast construction is considered to produce better productivity and reduce completion time, cost and dependency on work force which drives the market. Due to this, construction companies are adoptive for cost effective, proven technologies of precast to ensure the highest standards and uniform quality, which can be met by precast technology.

6.3.2 Prefabrication typology

Prefabrication is the practice of assembling components of a structure in a factory or other manufacturing site, and afterward transporting complete assemblies or sub-assemblies to the construction site where the structure is to be located.
Prefabricated units may include doors, stairs, window, walls, wall panels, floor panels, roof trusses, room-sized components and even entire buildings.

The components of prefabricated structures are constructed with different materials, for instance, those listed below:

- Concrete
- Steel
- Treated wood
- Aluminum
- Cellular concrete
- Light weight concrete elements
- Ceramic products
- Plastics
- Etc.

The system of prefabricated construction depends on the extent of the use of prefabricated components, their materials sizes and the technique adopted for their manufacture and use in building.

Prefabricated structural systems can be divided according of the used of materials, methods, structural configuration or dimensions. According to the conceptual dimension, prefabricated systems can be categorized as:

- Open prefab systems: this system is based on the use of the basic structural elements to form whole or part of a building. The standard prefab concrete components which can be used are:
  - Reinforced concrete channel units
  - Hollow core slabs
  - Hollow blocks and battens
  - Precast planks and battens
  - Precast joist and tiles
  - Cellular concrete slabs
  - Prestressed/reinforced concrete slabs
  - Prestressed/reinforced concrete beams
  - Prestressed/reinforced concrete columns
  - Precast lintels
  - Reinforced concrete waffle slabs/shells
  - Room size reinforced/prestressed concrete panels
  - Reinforced/prestressed concrete walling elements
  - Reinforced/prestressed concrete trusses.
- Mekano systems: the components are not interchangeable with the components of another system. The components are produced as the certain parts of a package and cannot be replaced.

In practical dimension, prefabricated systems can be categorized as:

- **Frame systems**: prefabricated systems that comprise structural, load-bearing elements such as walls and slab elements. One of the dimensions of these elements is greater than the other dimensions. The basic framework exchanges stacks through interconnected auxiliary parts or individuals [40]. The ground floor is surrounded with joists. Mastic cement is connected to the upper edges of the joists, and the board is set down and attached to the upper heavenly attendants of the joists with screws. Steel studs are laid at on the floor and joined to make divider edges. The divider edges are sheathed for non-combustible construction; the divider edges are tilted up, screwed down to the edge, and propped. The upper stage is surrounded, then the upper dividers. At last, the roof and rooftop are encircled similarly as in a confined house. Prefabricated assembled trusses of edge frameworks which are screwed or welded together are regularly used to casing roofs and rooftops (Figure 8). Since the prefabricated frame system is a fundamental structure, the thickness of the boards is 15-20 cm which is thicker than the average block divider. The tallness is between 3-3.5 m which is the tallness of one story. This framework can lessen development time on location for average size buildings (pretty nearly 150-200 square meters) from 12 months to as few as 4-5 months (excluding the creation time of every board in the processing plant). Today, most vast private creating organisations have utilized the prefabrication concrete structure as opposed to the skeleton structure [65]. The boards are planned by planners or basic designers to match the building rises. The span of the board is equivalent to the stature of a floor to floor (3-4 m) and the width is equivalent to the compass of the building (5-6 m). The thickness of this board is usually 15-18 cm.

Figure 8. Installing roof trusses

Figure 9. Precast concrete beams and columns [66]

- **Panel systems**: prefabricated systems that comprise structural, load-bearing elements such as walls and slab elements. Two dimensions are greater than the third one. Panel System is one of the prefabrication systems ideal for straight, curved or angled facade applications and has an elegant and light appearance with smooth rounded edges. Prefabricated panel is set in position and layer of cement or mortar are connected to both sides (Figure 10, Figure 11). Boards are utilized as a part of the development of outside and inside bearing and non-load bearing dividers and floors in a wide range of construction. The board gets its quality and unbending nature from the inclining cross wires welded to the welded-wire fabric on each side [67]. Panel System rushes to introduce with not very many devices needed. At the point when the steel divider sections are fitted to the façade, the bearer profiles with (pre-settled) sections and spacers or stringers slide over the divider sections and are effortlessly altered with a jolt through association. The C-molded boards (in full length) are bolted on to the sections.

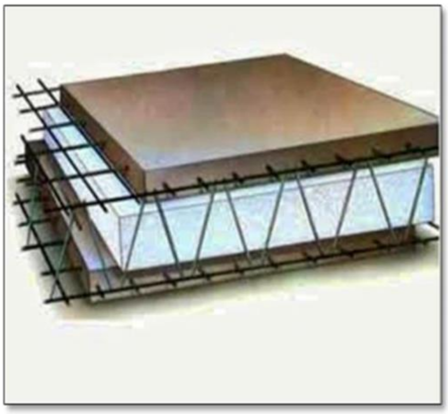


Figure 10. Prefabricated panel

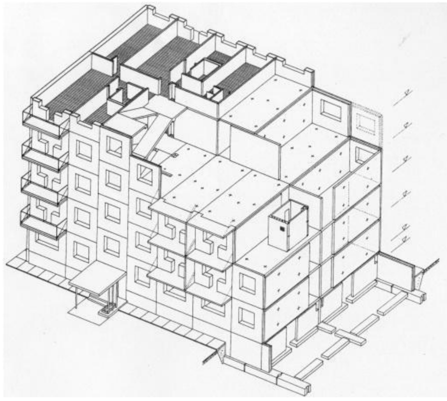


Figure 11. Panel building [75]

Large-panel systems are used typically in socialist countries (such as Bulgaria, Hungary, Lithuania, Romania) and they are characterized by multi-floor buildings.

- **Cells systems**: systems that comprise three-dimensional (3D) cellular units. Cells system is a modern system where burden bearing dividers give the essential vertical backing and horizontal solidness for floors. Outside divider boards, lift centres or staircases are utilized to give the obliged longitudinal dependability. Connecting parts, for example, floors, rooftops and pillars are bolstered by the heap bearing dividers or facade divider. In cells system, components are conveyed to site 'in the nick of time. Concealed joints and ties, both on a level plane and vertically are grouted set up as the work creates, avoiding dynamic breakdown. Different works, for example, establishment of mechanical and electrical administrations and completed that are needed can begin preceding the culmination of cells structure [69]. In this system, concrete is a standout amongst the most usually utilized bits of materials for cells construction around the world. Previously, concrete was utilized just by a cast set up strategy. The cast set up solid arrives in a fluid manifestation of blended concrete which makes it simple to cast into a fancied shape. To help expand its quality, the fluid bond is regularly blended with sand and pulverized stone before it is filled a formwork at a development site. Due to its quality and adaptability, concrete is regularly utilized as essential material for building structures, for example, pillars, sections, and floor pieces (Figure 12, Figure 13).

Figure 12. Cells system in a building

Figure 13. Construction of 20 m high modular stair and lift core

- **Combined systems**: prefabricated systems that use different types of elements stated above together. (Figure 14)

Figure 14. Hybrid Concrete Construction (Precast twin wall and lattice girder slab with in-situ concrete), Hilton Hotel, Tower Bridge, London [68]

Table 16 summarises the main prefab techniques and used materials, found among the EU countries and Taiwan. Frame system and panel system are the most popular; particularly, in northern countries, timber prefab are more diffused. Panel system is used in many countries, and it is characterized mainly by multi-floor building, constructed among 1950-1960 years. Modular system diffusion is under development in several countries, as manufacturers have understood the usefulness of this technique, in terms of construction time, product quality, installation easiness, energy efficiency and sustainability.

Table 16 – Main prefab techniques among EU countries and Taiwan

	Frame system	Panel system	Cell-system	Combined system
Austria				
Belgium		Concrete		
Bulgaria	Concrete	Concrete		

Croatia	Timber			Concrete/timber
Cyprus	Timber/steel		Light metal	
Czech Republic		Concrete		
Denmark		Concrete		
Estonia		Timber	Timber	
Finland	Timber			
France	Timber	Concrete		
Germany	Timber	Concrete	Concrete	Concrete
Greece		Concrete		
Hungary	Concrete	Concrete		
Ireland	Timber/light steel		Concrete	
Italy		Concrete	Concrete/timber	
Latvia	Timber	Concrete	Timber	Concrete/timber
Lithuania	Concrete/timber	Concrete	Concrete	Concrete/timber
Luxembourg	Steel			
Malta				
Netherlands	Timber	Concrete	Concrete	Concrete/timber
Poland			Concrete	
Portugal	Steel		Concrete	Concrete/steel
Romania	Timber	Concrete		
Slovakia	Concrete			
Slovenia	Timber			
Spain	Timber		Concrete	
Sweden	Timber	Timber	Concrete/timber	
Switzerland	Timber	Timber		
United Kingdom	Concrete/steel	Concrete/timber	Concrete/light metal	
Taiwan	Concrete	Concrete		

As result of the market and technical analysis done in the present work, Table 17 shows the level of diffusion of prefabricated construction among the EU countries and in Taiwan.

Table 17 – Diffusion level of prefabricated constructions among EU countries and Taiwan

	Low	Medium	High
Austria		X	
Belgium	X		
Bulgaria	X		
Croatia	X		
Cyprus			
Czech Republic		X	
Denmark	X		
Estonia			X
Finland	X		
France			X

Germany			X
Greece	X		
Hungary	X		
Ireland			
Italy			X
Latvia		X	
Lithuania		X	
Luxembourg			
Malta			
Netherlands		X	
Poland	X		
Portugal	X		
Romania	X		
Slovakia	X		
Slovenia			X
Spain		X	
Sweden		X	
Switzerland			
United Kingdom			X
Taiwan			

Data for Ireland is confidential, while data for Cyprus, Luxembourg and Malta are not shown. According to the terms of the PRODCOM Regulation, these countries are exempted from reporting PRODCOM data to Eurostat and zero production is recorded for them for all products. The regulation stipulates that zero can be reported for any NACE class where the reporting country has less than 1 % of Community total and this is true for all NACE classes of these three countries.

Below, details about each country are summarized.

The most applied systems for prefabricated buildings in **Bulgaria** are:

- large-panel systems;
- frame systems;
- lift-slab system with walls.

The designation "large-panel system" refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure. The "precast frame system" can be constructed using either linear elements or spatial beam-column sub-assemblages. [70]

Modern prefabrication methods used in **Cyprus** include:

- Modular Construction (light metal frame)
- Timber Prefabricated Systems (SIPS or Open Panel Frames)
- Light-Gauge Steel Construction.

Timber Prefabricated Systems in Cyprus are either SIPS or Open Panel Timber Frames. Light-Gauge Steel Construction is very similar to Timber Frame Construction but they offers a number of advantages when compared to traditional Timber Frame Construction, such as: light weight, higher strength compared to timber allows, adaptability to any kind of shape or form, easily to be changed or modified during its design life, non-combustible. However, it should be noted that steel experiences a rapid loss of strength when exposed to elevated temperatures (fire). Consequently, adequate fire protection must be provided. In addition, light-gauge steel structures do not offer the same level of sound insulation compared to Timber Frame Construction. [70]

In **Croatia**, low-energy prefabricated houses are spreading: they are an example of sustainable construction, from the construction material which doesn't harm the environment with its production to their energy efficiency and rational use of energy, which is more and more expensive every day. Prefabricated houses have a load-bearing wooden construction filled with mineral wool with a vapour membrane, closed on both sides with panel sheathing, over which a thermal façade is installed on the exterior, and on the interior, another panel is placed, which ensures better sound insulation. [72]

Estonians have long-term traditions in producing homes from round logs. Manufacturing of wooden houses started to develop in Estonia in the 1950s when prefab homes from milled log and panels were produced in forest industries. On the 20th of May in 1999, Estonian Woodhouse Association was established by 17 companies, which were manufacturing wooden houses. The various products produced by members of Estonian Woodhouse Association are the following: modular houses, element houses, garden houses, log houses from planed and round timber. These are divided as the producers of handmade log homes and machined log homes. All manufacturers have a long term traditions in producing and are competitive in foreign markets. [73]
Modular housing is a very modern and advanced building system and it's slowly replacing the traditional building technologies. The modular system is based on the technology of timber frame, where fully finished modules are produced in the factory. [74]

In **Hungary**, the mass housing policy utilizing prefabricated technology was initiated with the help of the first fifteen-year housing policy 1961–75. Several large companies experimented (relying on their experience with the application of block technology) with the production and construction of buildings of large prefabricated concrete blocks based on (mainly Soviet) examples abroad. Panel buildings consist of sheet-like frameworks, which are normally a storey high and the size of a room. These modules may be turned into a supporting frame by pouring concrete into them along the edges at the construction site. [75]

During 1960s, **Ireland** gained significant experience of prefabricated residential building construction mainly in the form of Industrialised Building Construction based on precast concrete. Most notable examples were 36 tower blocks of flats (7 fifteen-storey, 19 eight-storey and 10 four-storey blocks) built in Ballymun area of Dublin during 1960s. Eventually, all tower blocks were demolished during a period of 12 years (2004-2015) as part of a major regeneration programme of the area. Modern prefabrication methods used in Ireland include a number of prefabricated systems for a wide variety of applications. The main types of prefabrication systems used are:

- Frame and Deck Construction (precast concrete)
- Cross-wall Construction (precast concrete)
- Mixed Construction (combination of precast concrete and in-situ concrete, steel or glass)
- Volumetric (modular) Construction (timber or light steel frame)
- Timber Prefabricated Systems.

Precast concrete manufacturers are represented by the Irish Precast Concrete Association (IPCA), whereas the work and activities of prefabricated timber frame manufacturers are represented by the Irish Timber Frame Manufacturers' Association (ITFMA). Despite the really difficult situation in which the housing sector is currently in, light steel frame modular construction and prefabricated timber frame construction are becoming more popular in Ireland.

In **Italy**, on the market, the types of prefabricated dwellings are divided into:

- Container prefabricated, easily transportable;
- prefabricated in woods such as chalets, made especially in alpine areas;
- Prefabricated in Canadian, made of plasterboard and wood with plastic tiles.

In the Italian building market, wooden prefabricated houses are increasingly present, which have the great value of being built with natural materials and guarantee a high energy saving. Wood, in fact, is a great natural insulator that avoids heat dispersion in the winter and keeps the environment cool during the summer. The most commonly used construction techniques are: the "frame system" (55% of the buildings) and the "X-lam" (38% of the buildings), ie the system consisting of crossed and glued wooden panels; They follow the blockhouse technique (which uses solid or laminated wood beams vertically spaced between them to form the walls, carriers or partitions) and, at 3%, the MHM technique - acronym Massiv-Holz-Mauer, consisting of untreated wood panels, which are connected with aluminum plugs, without needing to use glues for garaging the binding. [76][77]

Latvia is a very suitable place for the manufacturing of wooden houses. The main wood prefab products are:

- timber frame houses,
- modular houses.

The first examples of prefabricated houses in **Lithuania** were **concrete panel structures** enabled a faster and more reliable construction and was clearly advantageous against the typical masonry construction. The prefab timber construction in the local market is not very popular, so prefab timber constructions manufacturers export almost the whole productions. The main wood prefab products are:

- timber frame houses,
- panel house;
- modular house.

Prefab timber elements are becoming key elements of the retrofit system. The Timber Element System (TES) has been developed since 2006 and it consist in **prefabricated insulated timber frame façade panels** (TES Energyfacade).

Prefabrication in **Luxembourg** is diffused among **steel constructions**. Steel prefabricated buildings give the customer a great deal of freedom in the design.

In the **Netherlands**, prefabricated elements are used in over half of all projects. The type of prefab mostly used is panelized system, 3D prefab is used least [78]. Residential design is increasingly moving closer to the domain of industrial design due to mass customization. Catalogue homes have become a well-known phenomenon in the countryside and many building companies are focusing on supply chain integration and mass customization. Prefab construction method, named "assembling construction" is characterized by prefabricated construction elements that are delivered at the site, as in timber frame building with prefab wall elements, prefab wooden or concrete floor elements, and an outer surface of wood or brick.
Timber frame is also used to construct houses, apartment buildings up to five stories, and commercial and industrial buildings.

In **Poland**, the method of constructing buildings using prefabrication technology in the field of multi-family residential construction is not popular [79]. In consequence, companies offering the construction of residential buildings using systems based on prefabricated technology should focus more on individual private clients interested in building a home.
The Polish market is rapidly following European trends. There are a number of small and medium-sized companies that offer timber frame construction with open and closed elements as well as block houses. Many manufacturers offer their houses with different energy standards, including the passive house standard.

Timber-framed buildings with infill masonry wall can be observed in many European countries, among with **Romania** too. Timber-framed buildings were already documented during the High Middle Ages but it is between the 17th and 18th centuries that these buildings gained (more or less explicitly) their anti-seismic function, especially in high-risk countries. [80]
Nowadays there are several manufactures of timber-framed buildings, and they offer two different solutions:

- To provide timber-frames kit with all necessary components for installation;
- To provide timber frame houses turnkey solutions.

Precast concrete panel apartment buildings were built in Romania form 1960s through the 1990s. Buildings of this type are typically high-rises (10 or 11 stories), although there are also low-to medium-rise buildings (4 to 8 stories) with different structural details.
Nowadays, precast concrete structures mainly consist of long precast concrete columns and precast concrete panels. An innovative precast concrete dual flat-slab structure has been developed during 2012, and it consists in long precast columns and precast concrete flat-slab panels, limiting the number of structural inner walls, leading to a dual structural system of the frame-wall type, suitable in seismic areas, such as the Romania. [81]

In **Slovakia**, the most common prefabricated elements mounted into the building are prefabricated column structures, wall construction and floor construction. Construction companies are aware that the difficult part is still to convince investors of the benefits of prefabricated technology. They are particularly interested in the effectiveness of the implementation more prefabricated elements into the project and achieved energy savings.

Prefabricated timber frame building is a typical single-family house commonly found in all **Slovenian** regions. They are usually low-rise with 1-2 stories. The basic building block is a prefabricated composite wall element - panel which may be of different size (large-panels were used in the past; nowadays only small-panels are produced). Walls and floors are prefabricated while roof structure in built on site. This structural typology is suitable in area affected by earthquakes, so, following the Friuli earthquake (1976) around 500 prefabricated timber frame buildings were constructed in the north-western region of Slovenia. [82]

The **United Kingdom** has significant experience of prefabricated residential building construction with approximately 1 million dwellings constructed using a large number of prefabrication techniques.

The prefabricated construction sector is dominated by:

- precast concrete,
- light steel frame modular construction
- prefabricated timber structures.

Precast concrete manufacturers are represented by the British Precast Concrete Federation (BPCF), whereas the work and activities of light steel frame modular construction manufacturers are promoted by the Steel Construction Institute (SCI) and the Modular and Portable Building Association (MPBA). Finally, prefabricated timber frame manufacturers are represented by the Timber Research and Development Association (TRADA) and the Structural Timber Association (STA).

6.4 Use of CDW materials for prefabricated elements

In Europe, there is no developed market for the use of CDW recycled materials in prefabricated elements.

Concerning the use of recycled aggregates in the prefabrication sector, there are only experimental researches that prove the possibility to realize prefabricated elements with recycled aggregates.

Based on the observations made during the production phases of some manufactured articles and the results obtained from the tests, it can be stated that the use of aggregates from recycling of the establishment waste does not induce statistically significant variations in behavior between the ordinary conglomerate and the one packaged with a large recycled aggregate in percentages up to 30%. However, real-world applications have only been made for search purposes. [83]

The use of CDW materials for prefabricated elements is a strategy that affects the whole project of construction sector from its start, rather than being just a selection of products or technologies applied later on. International reports have extolled its virtues as a valuable part of the built environment. Prefabricated elements from CDW promote a successful industry in construction sector producing high quality, well designed, affordable, functional and inspiring residential and commercial infrastructures for satisfied customers.

Prefabricated elements in construction sector span from small components to big volumes of materials, that origin infrastructures, with mixtures from different types of materials including (concrete, bricks, tiles and ceramic, asphalt, wood, gypsum).

Prefabricated elements containing recycled CDW are perceived as a new technological concept for sustainable development in construction sector. It dramatically reduces costs in spheres where it is necessary and needed and reduce overall financial costs. It substantially protects environment and reserve raw materials. Due to recyclability of this materials, the source of material is inexhaustible and principles of circular process of materials are employed.

First example about the use of CDW materials for prefabricate elements is the prototype developed during the project **ECO-SANDWICH** (as mentioned in chapter 0). The product is an innovative ventilated prefabricated concrete wall panel with integrated mineral wool insulation; particularly, it consists of two precast concrete layers; recycled concrete aggregate and recycled brick aggregate is used in production of concrete for the inner and outer layer respectively (around 50% of total aggregates needed in production of concrete is obtained from recycled CDW, and the exact quantities were entered in the model). [84]

Figure 15. ECO-SANDWICH Panel [84]

Another research project is developing with the aim to develop ventilated façade claddings based on the geopolymer technology and incorporating selected CDW. It is **InnoWEE** project "*Innovative pre-fabricated components including different construction and demolition Waste materials reducing building Energy consumption and minimising Environmental impacts*", which is funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 723916. The panels that will developed during the project, will be composed out of an outer High Density Geopolymer (HDG) layer (6-8 mm thick) incorporating at least 40-50% of selected CDW and an inner layer (10-15mm thick) Wood-Geopolymer Panel (WGP) incorporating at least 50-60% (by weight) of CDW wood. The weight will be ca 20-30 kg/m^2 and have an average density of 1,2-1,4 Kg/dm^3 compared to 2,2-2,5 Kg/dm3 for concrete and 2,4-3 kg/dm3 for natural stone (basalt, marble, porphyry, granite). [39]

Among the research project on the use of CDW materials for prefab elements, funding from the European Union's H2020 framework program for research and innovation under grant agreement, there is also **MORE-CONNECT**. Objective is to develop and to demonstrate technologies and components for prefabricated modular renovation elements in five geo-clusters in Europe. This includes prefabricated durable, innovative, modular composed building envelope elements for the total building envelop for the renovation market, including the prefab integration of multifunctional components for climate control, energy saving, building physics and aesthetics, with advanced easy to use plug&play connections (mechanical, hydraulic, air, electric, prefab airtight joints). Particularly, product innovation includes the selection of sustainable materials and sustainable detailing based on LCA, including recycling of materials, bio-based materials, flexible, disassemble, and the use of secondary materials. The technologies and components, necessary to come to a NZEB renovation will be combined and integrated as much as possible in multifunctional elements. Low embodied energy will be a criterion in the design and development. [85][86]

In **UK**, all steel used in modular construction can be recycled. In addition, up to 50% of new steel used in modular construction comes from old steel scrap. [87]

7. CONCLUSION - BARRIERS/DRIVERS

TECHNICAL REGULATION AND LEGISLATION

- The **recycled materials** obtained **from CDW** and regulated by European legislation are **recycled aggregates**. The use of recycled aggregate in construction industry is also quite low with most of it used for backfilling operations.
  Their use in structural concrete production has been widely explored in literature, principally, at the lab-scale level, often reporting good results. However, the international codes, guidelines and recommendations vary greatly from country to country, with respect to the maximum allowable quantity and quality allowed in structural concrete mixtures.
- The use of recycled aggregates in **prefabricated elements** is regulated by the European standard **EN 13369:2013 - *General rules for prefabricated concrete elements***. Among the main technical changes introduced by the new version of this standard, there is the new clauses to use recycled coarse aggregates, which have to conform to the requirements of standards **EN 12620:2013 – *Aggregates for concrete*** and **EN 206-1:2013 *Concrete - Specification, performance, production and conformity***; the latter was under development during the publication of the standard.
- The CE marking, introduced by the European: Construction Products Regulation **CPR 305/2011/EU**, enables to compare recycled aggregates to natural ones and to replace them with each other without distinction. Recycled aggregate with the CE marking are, to all intents and purposes, construction materials. [9]
  The Construction Product Regulation lays down harmonised rules for the marketing of construction products and provides tools to assess the performance of construction products. Construction products that are covered by harmonised European Standards (hENs) need a Declaration of Performance (DoP) and have to be CE-marked to increase transparency. Products that are not (fully) covered by hENs can still be CE-marked with the use of Europeans Technical Assessments (ETA) issued according to European Assessment Documents (EAD). [5]
- Starting from this consideration, and referring to prefabricated concrete elements with recycled CDW materials (aggregates), it follows that:

- Most prefabricated elements are regulated by harmonized product standards, so they are subjected to CE marking for commercialization;
- EN 13369:2013 and EN 206:2013 are not harmonised standards, so they may not be used on their own for the purpose of CE marking of precast concrete products. The product/material requirements are given in the provisions valid in the place of use, which differ from country to country;
- EN 12620:2013 is a harmonised standard; therefore, recycled aggregates are subject to CE marking in order to be marketed.

- In several Member States there are **Quality Assurance schemes** in place for specific products, like recycled aggregates. Such schemes often contain requirements concerning waste acceptance and environmental issues. When working with such national or regional schemes it is important to ensure that:
  - There is no conflict with the European harmonised approach;
  - No technical barriers to trade are invoked. [5]

- At national level only one good example of standards regarding specifically the use of CDW recycled materials in prefabricated elements was found and it refers to Hungary.

- At European level the design of **prefabricated constructions** follows the European Standards EUROCODES, which specifies how structural design should be conducted within the European Union.

- At national level, in most European countries, there are several building regulation, setting general provisions for building, regarding construction, health, safety and aesthetics, but none of them refer specifically to prefabricated construction.

Technical regulation and legislation	
Barriers	**Drivers**
There are no standards regulating the use of fine recycled aggregates in prefabricated elements	EN 12620 which regulates recycled aggregates, among others, is a harmonised standard and thus recycled aggregates need CE marking for their commercialization
European standards on concrete are not harmonised and therefore all type of concrete may not follow CE marking	The recent version of EN 206 defines technical requirements and limits of recycled aggregates
European and national standards do not regulate the use of other types of CDW recycled materials, a part from recycled aggregates	Among the main technical changes of the new version of EN 13369 there is a new clause for recycled coarse aggregates
There is no European standard which deals with the use of CDW-recycled materials in timber products/elements and wood-based panels/elements	Most prefabricated elements are regulated by specific harmonized product standards, and for the properties of the composite materials refer to EN 13369

Recommendations on the use of recycled wood in the production of wood panels are not official standards because amended by the European Panel Federation	Structural timber products/elements and wood-based panels and elements are under CE marking

ABOUT POLICY MEASURES

- At European level the main policy measures (direct and indirect), which encourages the use of CDW and prefabricated elements are:
  - Waste Framework Directive (2008/98/EC)
  - EU Green Public Procurement (GPP) instrument
  - Directive 2010/31/EU (Energy Performance of Buildings Directive – EPBD).
- One of the objectives of the Waste Framework Directive is to provide a framework for moving towards a reduction of 70% (by weight) of non-hazardous CDW by 2020. The numbers, today, are far from the objectives determined in the European Directive for 2020 and aware of this situation, European Countries have implemented national policies to prevent the avoidable waste and to promote measures to increase recycling and recovery. Therefore, a communitarian sharable policy is needed, to control the quality of primary and secondary raw materials and to fix equitable prices.
- The new GPP (green Public Procurement) criteria regard "*Office Building Design, Construction and Management*" highlights the use of **recycled materials** such as aggregates **from construction and demolition waste** can help develop a market for such materials, in line with EU Circular Economy objectives, and provide associated resource efficiency benefits. Therefore the criterion B 10.2 *Incorporation of recycled content in concrete and masonry*, regulates recycled content and/or by-products for the main building elements.
- There is an important interrelation between housing and sustainable development especially in terms of urban development, energy saving and the reduction of CO_2. Despite the increased need for housing policies in Europe, the EU has no specific legislation on housing. This is handled only at national or municipal level.
- One of the strategies to reach the target foreseen in the **Energy Performance of Buildings Directive** – EPBD (DIRECTIVE 2010/31/EU), is the use of constructions made by prefabricated elements with recycled materials, allowing the use of recycled materials, easy separation and reuse of materials/elements, and production of nearly zero waste.
- Inspired by the principles of thermal insulation, energy efficiency, and life-cycle construction, **prefabricated construction** should be widely regarded as a sustainable construction method in terms of its impact on environmental protection, but the innate dynamic character of this topic is not yet taken into account in terms of national and international policy.
- Virtuous examples are present at the level of participation and involvement of national and municipal institutions in research projects funded by the EU, on CDW recycling topics and the development of prefabricated elements with CDW materials.

Policy measures	
Barriers	**Drivers**
Lack of integrated policy on raw materials	GPP criteria *Office Building Design, Construction and Management* support the use of CDW materials in public buildings construction and refurbishment
Lack of coherent EU level housing policy	Interrelation between housing and sustainable development
GPP criteria are voluntary instrument	States and Municipalities are involved in EU-funded research projects developing innovative prefabricated elements (even with CDW materials) for sustainable construction applications
No policy measures favouring dynamic character of prefabricated constructions	EPB Directive objectives encourage indirectly the development and use of prefabricated elements
Low policy measures specific on prefabricated construction refurbishment	Voluntary international certification protocols (such as BREEM and LEED) are indirect instrument favouring the use of recycled construction materials and prefabricated constructions.

ABOUT PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

- Sustainable construction criteria may constitute a significant turning point and support for the development of new prefabricated housing construction technologies. Entrepreneurs are slowly perceiving an opportunity for the development of prefabrication in the **construction market**. The implementation and popularisation of ready-made homes will undoubtedly constitute a favourable change in the Polish construction market; however, this will require a modification of habits.
- Houses built using prefab elements typically require less energy to heat because of increased levels of insulation fitted in the walls and roof, and also less air leakage from the building.
- What is presently characterized by the actor of the market is the price sensitivity of secondary raw materials, which, in the absence of certain macroeconomic factors (incentives, regulatory framework, technical standards for the standardization of secondary material processing, etc.), may be higher than that of the raw materials.
- To build an **efficient and effective supply chain**, economic incentives such as landfill taxes and charges for unsorted CDW favour selective collection and recycling of CDW play a crucial role in driving CDW management performance (in many countries such as the UK, the Netherlands, or Denmark, taxes on waste disposal have encouraged recycling and therefore favour lowering the final price of recycled material).
- **A clear Legislative framework and the presence of quality standards and norms** are most important to undermine the market circulation of recycled materials which usually bear higher costs due to the treatment and recycling processes, and ensure they fulfil requirements and quality standards equal to the primary raw materials. These are most important to undermine the market circulation of recycled materials, which usually bear higher costs due to improper treatment and recycling processes. In addition to the strong legal framework, the effective and strong enforcement of the implementation of legal obligations (including sufficiently high sanctions in case of non-conformity) is necessary.
- Initiatives facilitating resource efficiency in the construction sector improve the knowledge and recycling efforts of actors engaged in CDW management.
- The low cost of natural aggregates has been certainly a limiting or decisive factor for any material, even for sustainable construction. That is why economic incentives are important.
- There is a general lack of knowledge, experience and coordination of setting up CDW management and recovery systems – avoiding the costs of CDW management chain and the output price of recycled aggregates, making them less competitive than virgin materials.
- In countries where there is a deficiency in the road network it is very difficult to transport precast construction components over very long distances. Precast method can create added shipping costs, depending on the shipper, the location of the job, and the location of the precast plant

Prefabricated Construction sector characteristics	
Barriers	**Drivers**
Lack in supply/demand systems	Economic incentives
Sanctions and prescriptions not clearly defined	Clear Legislative Framework
Lack of experience, labour and infrastructure,	Infrastructure and macroeconomic

Environmental concerns	Social framework
Limited application of prefab elements in today's construction sector	Energy savings of prefabricated constructions are stimulating entrepreneurs
Relatively enough primary material sources – slow down demand for products using CDW	Passive-house construction is diffusing among private owners
Unstable quality of final product from CDW, breaking rules for sorting and separating	Social housing in socialist countries needs to be refurbished
Week support from public sector	Building constructions in factories may reduce the total number of trips to a building site.
Prefabrication technologies require additional planning efforts and accurate measuring of existing building structure	Precast technologies ensure the highest standards and uniform quality

As final recommendation, there are three actions to be done in the short term at European level, to promote the use of prefabricated elements with CDW materials in constructions:

- **Codes and Enforcement**: Establish and effectively enforce standards related to waste reuse targets, and codes to increase the efficient use of prefabricated elements and provide standard definitions about these in construction sector.
- **Disclosure and Transparency**: Transparently disclose information and data to support informed decision making, help build market demand for prefabricated elements in construction sector.
- **Market Forces**: Support construction sector about materials recycling and promote innovation that increases their reuse, significantly reduces costs, and increases utilization of prefabricated elements in the construction sector. [37]

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ANNEX 1 – TECHNICAL REGULATIONS AND LEGISLATIONS – POLICY MEASURES

Technical standard and regulation			
CDW			
Country	Title	Barriers	Drivers
EUROPE	Waste Framework Directive 2008/98/EC		Target of 70% do CDW recycled by 2020
GERMANY	Ordinance on Requirements for the Recycling and Elimination of Waste Wood		Definition of waste wood categories and their potential applications
AUSTRIA	Recycled Construction Materials Regulation		Link to technical regulations about recycled aggregates
ITALY	Ministerial Decree 05/02/98 and s.m.i.		CDW can be started to produce secondary building materials by mechanical and technologically interconnected steps
EUROPE	EN 12457-2:2002 Characterisation of waste - Leaching - Compliance test for leaching of granular waste materials and sludges - Part 2: One stage batch test at a liquid to solid ratio of 10 l/kg for materials with particle size below 4 mm (without or with size reduction)	Different test methodologies among the EU countries	Definition of leaching test on granulate wastes
ITALY	UNI 10802:2013 Waste. Liquid, granular, pasty and sludge wastes. Manual sampling, preparation and analysis of eluates		Definition of preparation and test procedures, according to EN 12457-2
SWITZERLAND	Directive for the recycling of mineral construction waste	Applied only to mineral construction wastes	Establishes the ecological requirements for the recycling of mineral construction
SWITZERLAND	Guideline for the use of mineral construction waste		Regulates how mineral construction waste is to be sorted, labelled, treated and quality controlled before it is used to create new RC materials
SWITZERLAND	SN 640 740a General information		Technical specifications for the recycling and recovery of a specific type of CDW
SWITZERLAND	SN 640 741a Recovery of asphalt		Technical specifications for the recycling and recovery of a specific type of CDW
SWITZERLAND	SN 640 742a Recovery of roadbreak		Technical specifications for the recycling and recovery of a specific type of CDW

Technical standard and regulation			
CDW			
Country	Title	Barriers	Drivers
SWITZERLAND	SN 640 743a Recovery of concrete demolition		Technical specifications for the recycling and recovery of a specific type of CDW
SWITZERLAND	SN 640 744a Recovery of mixed demolition		Technical specifications for the recycling and recovery of a specific type of CDW
	Construction Products Regulation CPR 305/2011/EU		

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
EUROPE	Construction Products Regulation CPR 305/2011/EU		Recycled aggregates are subjected to CE marking
EUROPE	EN 12620:2002+A1:2008 Aggregates for concrete	Filler recycle aggregates are not regulated but they are not prohibited.	Specifies the properties of recycled materials and mixtures with other aggregates for use in concrete. It also covers recycled aggregate with densities between 1,50 Mg/m3 (1 500 kg/m3) and 2,00 Mg/m3 (2 000 kg/m3) with appropriate caveats and recycled fine aggregate (4 mm) with appropriate caveats."
EUROPE	EN 13043:2002 Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas		Specifies the properties of recycled aggregates and recycled filler aggregates for use in bituminous mixtures and surface treatments for roads, airfields and other trafficked areas.
EUROPE	EN 13055:2016 Light aggregates		It refers to specific aggregate technical standards for recycled aggregates
EUROPE	EN13139:2013 Aggregates for mortar		Specifies the properties of recycled aggregates and recycled filler aggregates for mortar.
EUROPE	EN 13242:2008 Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction		Specifies the properties of recycled aggregates and recycled filler aggregates for use in civil engineering work and road construction.
EUROPE	EN 13285:2010 Unbound mixtures - Specifications		Specifies the properties of recycled aggregates and recycled filler aggregates for unbound mixtures.
EUROPE	EN 13383:2013 Armourstone - Part 1: Specification		Specifies the properties of recycled aggregates and recycled filler aggregates for use as armourstone.

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
EUROPE	EN 13450:2013 Aggregates for railway ballasts	No specific reference to recycled aggregates	
EUROPE	EN 993-11 Tests for geometrical properties of aggregates – Part 11: Classification test for the constituents of coarse recycled aggregate		Specific test method for recycled aggregates
EUROPE	EN 1744-6 Tests for chemical properties of aggregates – part 6: Determination of the influence of recycled aggregate extract on the initial setting time of cement		Specific test method for recycled aggregates
EUROPE	EN 206-1:2013 Concrete - Specification, performance, production and conformity	No harmonised standard. It refers to additional provisions in force in the country in which the concrete is produced and used. It does not contain information for the use of recycled fine aggregates, but they are not prohibited.	It applies to concrete and precast concrete made with recycled aggregates. It gives recommendations in an informative annex (E) regarding requirements for these properties for recycled coarse aggregates to be used in concrete.
EUROPE	EN 13369:2016 Common rules for precast concrete products	No harmonised standard. It does not contain information for the use of recycled fine aggregates, but they are not prohibited.	It allows the use of recycled coarse aggregates. For precast concrete elements
AUSTRIA	ÖNORM B 3140: 2016 06 01 Recycled aggregates for unbound and hydraulically bound applications as well as for concrete		Is refers specifically to recycled aggregates
BELGIUM	'eenheidsreglement' (23/11/2011)		It establishes a management system for recycled granulates.
BELGIUM	16/03/1995 Arrêté du Gouvernement de la Région de Bruxelles-Capitale		It establishes a mandatory recycling system for the stony and sandy fraction.
BELGIUM	PTV 406 Technical Prescription Recycled aggregates from construction and demolition waste		It regulates the composition of the recycled aggregate that could be used in concrete production, based on EN 206
CZECH REPUBLIC	Act 22/1997 on Technical Requirements of Products		It regulates the use specific of CDW as aggregates for railway construction

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
DENMARK	DS 2426 - EN 206-1:2011 Beton - Materialer - Regler for anvendelse af EN 206-1 i Danmark		It is the national application of EN 206
ESTONIA	Building product standard 2325-CPD-0038		Following the EN 13242:2006 it contains specific requirements for recycled aggregates.
FINLAND	SFS 7022 Betoni. Standardin SFS-EN 206:2014 käyttö Suomessa		It is the national application of EN 206, providing the use of recycled materials
GERMANY	DAfStb guideline " Concrete in accordance with DIN EN 206-1 and DIN 1045-2 with recycled aggregates in accordance with DIN EN 12620"		It classifies recycled aggregates
GERMANY	DIN 4226-100 Aggregates for concrete and mortar - Part 100: Recycled aggregates		It defines requirement for recycled aggregates for concrete and mortar
HUNGARY	General geotechnical rules of Roads and Motorways of E - 06:02:11 UT (2007 ROAD 2-1222)		It is the national application of EN 13043
HUNGARY	JM2/01 Main wall slabs made from crushed brick: 2002		It's a guidance for pre-made rigid, lightweight concrete production in accordance with MSZ EN 206-1:2002
HUNGARY	JM2/02 Pre-made light concrete slabs for basements made with addition of crushed brick		It's a guidance for pre-made light concrete slabs for basements production in accordance with MSZ EN 206-1:2002
HUNGARY	JM2/03 Indoor floor tiles made from crushed bricks		It's a guidance for indoor tiles made from crushed bricks in accordance with MSZ EN 206-1:2002.
HUNGARY	JM3/01 Guidance on CDW re-use		It applies to construction materials containing hydraulic or bituminous binders and mineral wastes not containing binders
HUNGARY	JM3/02 Guidance		It's applies for re-use of CDW from structural engineering and materials without binders
HUNGARY	JM3/03 Guidance		It's applies for re-use of CDW from structural engineering and materials with cement binders
ITALY	UNI 11531-1: 2014 Standard for recycled aggregates used for civil engineering works and road construction		It's the application of EN 13242

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
ITALY	Ministerial Decree of January 14, 2008 Technical Standards for Construction		It regulates, among the others, the use of recycled aggregates conforming to hEN 12620 and hEN 13055-1, defining different application limits depending on the origin of recycled aggregates and the concrete class
ITALY	UNI 11104 Concrete - Specification, Performance, Production and Compliance - Additional specifications for the application of EN 206		It contains a prospectus in which the maximum percentages of substitution of large aggregates with recycled aggregates are distinct according to the environmental exposure class and also the resistance class. It also provides guidance with respect to prefabrication plants where concrete internal reuse is permitted as a large aggregate up to a maximum value of 10% in the case of concrete of the same resistance class and up to 15% in the case of lower strength class concrete.
ITALY	UNI 8520-1: 2015 Aggregates for concrete - Additional provisions for the application of EN 12620 - Part 1: Designation and conformity criteria		It is the national application of EN 12620
ITALY	UNI 8520-2 Aggregates for concrete - Additional provisions for the application of EN 12620 - Part 2: Requirements		It contains additional prevision of the application of EN 1620
LITHUANIA	Construction Technical Regulations (CTR) 2.06.03:2001 "Roadways"	No particular specification for recycled aggregates	Defines common requirements for aggregates in roadways applications
LUXEMBOURG	CDC-GRA08 Ponts et Chaussees, Cahier des Charges: 'Granulats'	No specific requirement for recycled aggregates	It specifies requirements for aggregates
NETHERLANDS	NEN 5905:2010 Dutch supplement to NEN-EN 12620+A1 Aggregates for concrete		It is the national application of EN 12620. It defines two classes of recycled aggregates depending on their composition.
NETHERLANDS	Branch organisation breaking and sorting (BRBS)		It defines criteria for recycled aggregates and stony waste.
PORTUGAL	Decree-law 46/2008		It includes the possibility to use CDW aggregates in constructions

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
PORTUGAL	LNEC - E 471: Guide for the use of thick recycled aggregates in hydraulic binder concretes		It regulates the use of thick recycled aggregates in hydraulic binder concretes. It defines three types of recycled aggregates with respect to their composition and for each of them it defines the possible application in different concrete exposition classes.
PORTUGAL	LNEC - E 472: Guide for the recycling of hot bituminous mixtures in the plant		It regulates the recycling of hot bituminous mixtures in the plant
PORTUGAL	LNEC - E 473: Guide for the use of recycled aggregates in uncontaminated layers of floorings.		It regulates the use of recycled aggregates in uncontaminated layers of floorings
PORTUGAL	LNEC - E 474: Guide for the use of construction and demolition waste in landfill and bed layer of transport infrastructures		It regulates the use of construction and demolition waste in landfill and bed layer of transport infrastructures
PORTUGAL	LNEC - E 483: Guide for the use of recycled aggregates from recovered bituminous mixtures for uncontaminated layers of road pavements		It regulates for the use of recycled aggregates from recovered bituminous mixtures for uncontaminated layers of road pavements
PORTUGAL	LNEC - E 484: Guide for the use of materials from construction and demolition waste in rural and forestry roads		It regulates the use of materials from construction and demolition waste in rural and forestry roads
PORTUGAL	LNEC – E 485: Guide for the use of materials from construction and demolition waste in ditch filling		It regulates the use of materials from construction and demolition waste in ditch filling
SPAIN	PG3 General Technical Specifications for Road Works and Bridges of the General Direction of Roads and Highways		It covers the possibility to use the milling of hot bituminous mixtures as aggregates for base and intermediate layers
SPAIN	PG 4 General Technical Specifications for Road Maintenance Works		It covers the possibility to use recycled bituminous
SPAIN	EHE-08 Code on Structural Concrete		It contains recommendations for using recycled concrete in which it regulates the use of coarse recycled aggregates in concrete mixture, for structural and non-structural applications.

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
SLOVAKIA	Regulation no. 283/200139		It regulates the removal of materials with asbestos
SLOVAKIA	Regulation 133/2013		
SWEDEN	SS 137003:2015 Concrete - Application of EN 206 in Sweden		It's the national application of EN 206:2013
SWITZERLAND	UFAM 31-06 Directive on the Recycling of Mineral Construction Waste		It regulates six classes of recycled building materials depending on their composition
SWITZERLAND	SN 670 071 Basic standard for recycling		It regulates general recycling of mineral CDW into RC construction materials and defines four classes for CDW
SWITZERLAND	SN 670 102b-NA granulates for concrete		It regulates aggregates for concrete production and has integrated the use of recycled aggregates according to EN 933 under compliance with the BAFU guideline
SWITZERLAND	SN 670 119-NA Integration of recycled granules		It regulates aggregates for use in hydraulically bonded and loose applications, e.g. construction of roads, train tracks etc. It is part of the Swiss version of EN 13285
SWITZERLAND	SN 670 902-11-NA Tests to determine the geometric characteristics of the granules		It regulates geometrical properties of mineral aggregates and is part of the Swiss version of EN 933-11
UNITED KINGDOM	BS 8500-2 2015+A1:2016 Concrete-Complementary British Standard to BS EN 206. Part 2: Specification for constituent materials and concrete		It's the national complementary standards to EN 206:2013
TAIWAN	CNS 12549 granulated ground blast furnace slag (GGBFS) for using in concrete and cement mortar		It regulates the use of GGBFS for using in concrete and cement mortar
TAIWAN	CNS 11824 Blast furnace slag for using as coarse aggregate in Concrete		It regulates the use of Blast furnace slag for using as coarse aggregate in Concrete
TAIWAN	CNS 11890 granulated ground blast furnace slag (GGBFS) as fine aggregate in concrete		It regulates the use of GGBFS as fine aggregate in concrete
TAIWAN	CNS 12223 Granulated ground blast furnace slag (GGBFS)		It regulates the properties and applications of GGBFS
TAIWAN	CNS 11827 Blast furnace slag for road		It regulates the use of Blast furnace slag for road

Technical standard and regulation			
Materials from CDW			
Country	Title	Barriers	Drivers
TAIWAN	CNS 15305 gradation base, bottom and surface layer		It regulates the properties of gradation base, bottom and surface layer
TAIWAN	CNS 15358 Road or airport slab, gravel grading with grass		It regulates definitions and materials for Road or airport slab, gravel grading with grass
TAIWAN	CNS 15310 steel ballast for asphalt pavement mixes, allow construction use furnace ballast		It regulates the use of steel ballast for asphalt pavement mixes, allow construction use furnace ballast
TAIWAN	Code of Practice for Water Resources n. 02722		It provides the possibility to use recycled aggregates for construction applications

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
EUROPE	EN 1168:2006 + A3:2011 Precast concrete products - Hollow core slabs	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12602:2016 Prefabricated reinforced components of autoclaved aerated concrete	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12794:2005 +A1:2007/AC:2008 Precast concrete products - Foundation piles	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12737:2004 + A1:2007 Precast concrete products – Floor slats for livestock	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12794:2005 A1:2007/AC:2008 Precast concrete products – Foundation piles	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12839:2012 Precast concrete products – Elements for fences	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12843:2004 Precast concrete products - Masts and poles	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
EUROPE	EN 13224:2011 Precast concrete products - Ribbed floor elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13225:2013 Precast concrete products - Linear structural elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13369:2013 Common rules for precast concrete products	No harmonised standard. It does not contain information for the use of recycled fine aggregates, but they are not prohibited.	It provide specific requirement for the use of recycled coarse aggregates
EUROPE	EN 13693:2004 +A1:2009 Precast concrete products - Special roof elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13747:2005 +A2:2010 Precast concrete products - Floor plates for floor systems	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13978-1:2005 Precast concrete products - Precast concrete garages - Part 1: Requirements for reinforced garages monolithic or consisting of single sections with room dimensions	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 14843:2007 Precast concrete products – Stairs	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 14844:2006 +A2:2011 Precast concrete products - Precast concrete products - Box culverts	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 14991:2007 Precast concrete products - Foundation elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 14992:2007 +A1:2012 Precast concrete products - Wall elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15037-1:2008 Precast concrete products. Beam-	No specific reference to recycled aggregates	Harmonised standard.

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
	and-block floor systems. Part 1: Beams		It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15037-2:2009 + A1:2011 Precast concrete products - Beam-and-block floor systems - Part 2: Concrete blocks	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15037-3:2011 Precast concrete products - Beam-and-block floor systems - Part 3: Clay blocks	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15037-4:2010 + A1:2013 Precast concrete products - Beam-and-block floor systems - Part 4: Expanded polystyrene blocks	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15037-5:2013 Precast concrete products - Beam-and-block floor systems - Part 5: Lightweight blocks for simple formwork	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15050:2007 + A1:2012 Precast concrete products – Bridge elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1520:2011 Prefabricated reinforced components of light aggregate concrete with open structure with structural or non-structural reinforcement	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15258:2008 Precast concrete products – Retaining wall elements	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15435:2008 Precast concrete products – Normal weight and lightweight concrete shuttering blocks – Product properties and performance	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15498:2008 Precast concrete products – Wood-chip concrete shuttering blocks – Product properties and performance	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
EUROPE	EN 1992:2004 Part 1-3: Precast Concrete Elements and Structures – EUROCODE 2		It provides general rule to design precast concrete elements and structures.
EUROPE	EN 490:2012 Concrete roofing tiles and fittings for roof covering and wall cladding - Product specifications	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 771-3:2011 Specification for masonry units - Part 3: Aggregate concrete masonry units (Dense and lightweight aggregates)	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 771-4:2011 Specification for masonry units - Part 4: Autoclaved aerated concrete masonry units	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 845-2:2014 Specification for ancillary components for masonry - Part 2: Lintels	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1338:2004 Concrete paving blocks - Requirements and test methods	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1339:2004 Concrete paving flags - Requirements and test methods	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1340:2004 Concrete kerb units - Requirements and test methods	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1520:2011 Prefabricated reinforced components of lightweight aggregate concrete with open structure with structural or non-structural reinforcement	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1916:2008 Concrete pipes and fittings, unreinforced, steel fibre and reinforced	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 1917:2008 Concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
EUROPE	EN 12602:2011 Prefabricated reinforced components of autoclaved aerated concrete	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12737:2006 Precast concrete products - Floor slats for livestock	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 12839:2012 Precast concrete products - Elements for fences:	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13748-1:2005 Terrazzo tiles - Part 1: Terrazzo tiles for internal use	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 13748-2:2005 Terrazzo tiles - Part 2: Terrazzo tiles for external use	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15285:2009 Agglomerated stone - Modular tiles for flooring and stairs (internal and external)	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15286:2013 Agglomerated stone - Slabs and tiles for wall finishes (internal and external)	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15435:2009 Precast concrete products - Normal weight and lightweight concrete shuttering blocks - Product properties and performance	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
EUROPE	EN 15498:2009 Precast concrete products - Wood-chip concrete shuttering blocks - Product properties and performance.	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
CROATIA	Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements and Reinforced Cellular Concrete 6/81*, 14/89*		It's a specific technical regulation on prefabricated concrete structures
CROATIA	the Bylaw on Technical Standards for the Design,		It's a specific technical regulation on prefabricated concrete structures

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
	Production and Realization of Structures Made of Prefabricated Elements Formed of Unreinforced and Reinforced Cellular Concrete, 14/89*		
CROATIA	the Order on Obligatory Certification of Prefabricated Elements Made of Cellular Concrete, 34/85*, 14/89*		It's a specific technical regulation on prefabricated concrete structures
CROATIA	HRN U.E3.050, Prefabricated concrete elements		It's a specific technical regulation on prefabricated concrete elements
GERMANY	DIN 1055-4 Concrete, reinforced and prestressed concrete structures – Part.4 Additional rules for the production and conformity control of prefabricated elements		It contains specific rules for prefabricated concrete elements
GERMANY	DIN 4223 Prefabricated reinforced components of autoclavated aerated concrete		It contains specific rules for prefabricated concrete elements
GERMANY	DIN 4223-2 Prefabricated reinforced components of autoclavated aerated concrete – Part.2: Design and calculation of structural components		It contains specific rules for prefabricated concrete elements
GERMANY	DIN 4223-4 Prefabricated reinforced components of autoclavated aerated concrete – Part.4: Design and calculation of structural components; Application of components in structures		It contains specific rules for prefabricated concrete elements
HUNGARY	JM2/01 Main wall slabs made from crushed brick: 2002		It's a guidance for pre-made rigid, lightweight concrete production in accordance with MSZ EN 206-1:2002
HUNGARY	JM2/02 Pre-made light concrete slabs for basements made with addition of crushed brick		It's a guidance for pre-made light concrete slabs for basements production in accordance with MSZ EN 206-1:2002
HUNGARY	JM2/03 Indoor floor tiles made from crushed bricks		It's a guidance for indoor tiles made from crushed bricks in accordance with MSZ EN 206-1:2002.

Technical standard and regulation			
Prefabricated elements - concrete			
Country	Title	Barriers	Drivers
ITALY	Ministerial Decree of January 14, 2008 Technical Standards for Construction		It regulates, among the others, the use of recycled aggregates conforming to hEN 12620 and hEN 13055-1, defining different application limits depending on the origin of recycled aggregates and the concrete class and de design of prefabricated elements
ITALY	UNI 9053-1:1987. Building. Structural elements prefabricated or made on site. Measurements for the dimensional geometric control of the single element	No specific reference to recycled aggrgates	Recycled aggregates are not prohibited.
ITALY	UNI 9053-2:1987. Building. Structural elements prefabricated or made on site. Measures for dimensional geometric control of elements in operation	No specific reference to recycled materials	Recycled aggregates are not prohibited.
POLAND	C367/C367M-16: Standard Test Methods for Strength Properties of Prefabricated Architectural Acoustical Tile or Lay-In Ceiling Panels		It regulates specific tests for acoustic characterization of reinforced elements
POLAND	E477-13e1: Standard Test for Laboratory Measurements of Acoustical and Airflow Performance of Duck Liner Material and Prefabricated Silencers		It regulates specific tests for acoustic characterization of reinforced elements
PORTUGAL	REBAP Regulation of Reinforced Concrete Structures		It contains specific requirement for prefabricated concrete structures
SPAIN	EHE-08 Code on Structural Concrete		It contains recommendations for using recycled concrete and specific construction aspects on prefabricate elements.

Technical standard and regulation			
Prefabricated elements - wood			
Country	Title	Barriers	Drivers
EUROPE	EN 336:2013 Structural timber - Sizes, permitted deviations	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 338:2016 Structural timber - Strength classes	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.

Technical standard and regulation			
Prefabricated elements - wood			
Country	Title	Barriers	Drivers
EUROPE	EN 384:2016 Structural timber - Determination of characteristic values of mechanical properties and density	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 14081-1:2016 Timber structures - Strength graded structural timber with rectangular cross section - Part 1: General requirements	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 14081-2:2010+A1:2012 Timber structures - Strength graded structural timber with rectangular cross section - Part 2: Machine grading; additional requirements for initial type testing3	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 14081-3:2012 Timber structures - Strength graded structural timber with rectangular cross section - Part 3: Machine grading; additional requirements for factory production control.	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 14250:2010 Timber structures - Product requirements for prefabricated structural members assembled with punched metal plate fasteners.	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 15644:2008 Traditionally designed prefabricated stairs made of solid wood - Specifications and requirements	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 15736:2009 Timber Structures - Test methods - Withdrawal capacity of punched metal plate fasteners in handling and erection of prefabricated trusses	No specific reference to recycled materials	Harmonised standard. Recycled materials are not prohibited.
EUROPE	EN 1995-1-1 (2004) (English): Eurocode 5: Design of timber structures - Part 1-1: General - Common rules and rules for buildings	It does not contain information for the use of recycled fine aggregates, but they are not prohibited.	It provides general rule to design precast concrete elements and structures.

Technical standard and regulation			
Prefabricated elements - wood			
Country	Title	Barriers	Drivers
EUROPE	CEN/TS 15680:2007 Prefabricated timber stairs - Mechanical test methods	No specific reference to recycled aggregates	Harmonised standard. It refers to EN 13369 for concrete properties so it indirectly allows the use of recycled aggregates.
CROATIA	Design and realization of wooden structures HRN U.C9.200, 200/1, 300, 400, 500 U.D0.001, 001/1		It contains recommendation for the design of wooden structures
CROATIA	Sawn timber HRN D.C1.040, 041, 042		It contains recommendation for the design of timber structures
CROATIA	Order on obligatory certification of chipboard used for general purposes and in construction industry 61/83*		It contains recommendation for prefabricated wood structures
CROATIA	Wood glue HRN H.K1.041, 042, 045, H.K2.023, 024, 025 H.K8.020, 021, 022, 023, 024, 025, 026		It contains recommendation for wood glue elements
GERMANY	DIN 1052 Design timber structures – General rules and rules for buildings		It contains recommendation for the design of timber structures
UNITED KINGDOM	PAS 104:2004 Wood recycling in the panelboard manufacturing industry. Specification for quality and guidance for good practice for the supply of post consumer wood for consumption in the manufacture of panelboard products		It contains recommendations for wood recycling in panelboard industry.
UNITED KINGDOM	BS 5268-2:2002 Structural use of timber. Code of practice for permissible stress design, materials and workmanship.		It regulates the design of timber structures

Technical standard and regulation			
Prefabricated elements - masonry			
Country	Title	Barriers	Drivers
GERMANY	DIN 1053-4: 2013-04 Masonry - Part 4: Prefabricated masonry compound units		It contains constructive notes and information on the provision of the stability verification for the individual prefabricated components.

Technical standard and regulation			
Prefabricated constructions			
Country	Title	Barriers	Drivers
EUROPE	Eurocode 1. Part 1.3 - EN 1992-1-3 Precast Concrete Elements and Structures		It contains rules for design of prefabricated concrete structures.
EUROPE	Eurocode 5 – EN 1995 Design of timber structures		It contains rules for design of timber structures.
AUSTRIA	ÖNORM B 2310: 2009 05 01 Prefabricated structures - Definitions and Minimum Scope of Services		It defines the minimum scope of benefits of prefabricated structures made of storey-high, prefabricated construction elements, regardless of the building materials used
AUSTRIA	ÖNORM B 2320: 2010 07 15 Wooden houses - technical requirements		It contains technical requirements for the production and erection of wooden houses whose wall, ceiling and roof structures consist essentially of wood and / or wood materials
CROATIA	Building Law (Official Gazette No. 52/99) and the Law on Revisions and Additions to the Building Law (Official Gazette No. 75/99, 117/01)		They are fundamental laws regulating the design, construction and maintenance of structures, among which prefabricated constructions
CROATIA	Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements and Reinforced Cellular Concrete 6/81*, 14/89*		It contains rules for design, production and realization of structural prefabricated concrete elements.
CROATIA	Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements Formed of Unreinforced and Reinforced Cellular Concrete 14/89*.		It contains rules for design, production and realization of structural prefabricated concrete elements.
CZECH REPUBLIC	Norm 13369 – Common regulation for concrete prefabricates		It contains rules for prefabricated concrete elements.
CZECH REPUBLIC	Act 22/1997 on Technical Requirements of Products		it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials
CZECH REPUBLIC	Government Regulation No. 299/2001		It contains a list of standardized structural systems of panel houses.
GERMANY	Building Regulations List (Bauregelliste A, B and C)		It includes a list of prefabricated components made of concrete and reinforced concrete, of bricks and

Technical standard and regulation			
Prefabricated constructions			
Country	Title	Barriers	Drivers
			prefabricated components for timber construction, to be controlled
ITALY	Ministerial Decree of January 14, 2008 Technical Standards for Construction		It regulates, among the others, the design of prefabricated constructions
UNITED KINGDOM	The Building Regulations 2010		It is the minimum standards for the construction of all types of buildings (also prefabricated buildings made of precast concrete, prefabricated timber, light steel framing or prefabricated aluminium)

Policy measure			
Material form CDW – prefabricated elements and constructions			
Country	Title	Barriers	Drivers
EUROPE	Waste Framework Directive (2008/98/EC)	Each European has implemented national policies but the results are not everywhere cheering.	It indirectly encourages the use of CDW and prefabricated elements to pursue the target of 70% in recycling CDW up 2020.
EUROPE	EU Green Public Procurement (GPP) instrument	This instrument is voluntary and not all the European Countries have transpose it	Among the criteria regard "Office Building Design, Construction and Management" there is "Incorporation of recycled content in concrete and masonry", which defines the minimum value of 15% of recycled content and/or by-products for the main building elements
EUROPE	Directive 2010/31/EU (Energy Performance of Buildings Directive – EPBD)		The target of 20% in reducing greenhouse gas emissions and improving energy efficiency, encourages the use of recycled materials and prefabricated constructions, and the participation of national and local institutions into founded research projects.
BULGARIA	Measure N. 511: Development of a national program for refurbishment of the existing prefabricated panel buildings in Bulgaria		It encourage the refurbishment of the existing prefabricated panel buildings
CROATIA	ECO-SANDWICH project		the Ministry of Environment and Nature Protection and the Ministry of Construction and Physical Planning supports the development of

Policy measure			
Material form CDW – prefabricated elements and constructions			
Country	Title	Barriers	Drivers
			innovative prefabricated wall panel using recycled CDW
ESTONIA	Recycling Competence Centre		It encourages recycling and the market of recycled materials.
GREECE	InnoWEE project		Municipality Varis-Voulas-Vouliagmenis is partner in the research project aimed at developing innovative prefabricated components made with different waste construction materials
ITALY	Environmental Link (Law No. 221 of December 28, 2015) Code of Practices (Legislative Decree of 18 April 2016, n.50)		It describes the quantity of building components to be recycled and the recycled materials to use for new constructions.
ITALY	Financial Law of 2017		It provides tax breaks for seismic improvement as well as energy efficiency, also for interventions for the adaptation of prefabricated structures, up to 2021
LITHUANIA	Program for the Refurbishment of Multi-Apartment Buildings		It encourage the refurbishment of prefabricated buildings
SLOVENIA	InnoWEE project		National Institutions co-operates as partners in the development of the research project on innovative prefabricated components made with different waste construction materials
SLOVENIA	National Energy Efficiency Action Plan 2014-2020 - ECOFOUND		It provides soft loans for environmental investments, as well as subsidies for residential and multi-residential/apartment buildings
SPAIN	Guide of recycled aggregates (GEAR)		It contains technical recommendations about the use of aggregates form CDW for different construction applications
TAIWAN	Green Building Label		It's a certification program promoting the use of recycled CDW in "green concrete", with at least 40% of the recycled material to replace the concrete aggregate

ANNEX 2 – STATISTICAL DATABASES

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - WOOD			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
16211100	Plywood, veneered panels and similar laminated wood, of bamboo	m^3	4412 10
16211211	Plywood consisting solely of sheets of wood (excluding of bamboo), each ply not exceeding 6 mm thickness, with at least one outer ply of tropical wood	m^3	4412[.31(.10 + .90)]
16211214	Plywood consisting solely of sheets of wood (excluding of bamboo), each ply not exceeding 6 mm thickness, with at least one outer ply of non-coniferous wood (excluding tropical wood)	m^3	4412[.32(.10 + .90)]
16211217	Plywood consisting solely of sheets of wood (excluding of bamboo), each ply not exceeding 6 mm thickness (excluding products with at least one outer ply of tropical wood or non-coniferous wood)	m^3	4412 39
16211221	Veneered panels and similar laminated wood with blockboard, laminboard or battenboard	m^3	4412[.94(.10 + .90)]
16211224	Veneered panels and similar laminated wood (excluding with blockboard, laminboard or battenboard)	m^3	4412[.99(.30 + .40 + .50 + .85)]
16211313	Particle board, of wood	m^3	4410[.11(.10 + .30 + .50 + .90)]
16211316	Oriented strand board (OSB), of wood	m^3	4410[.12(.10 + .90)]
16211319	Waferboard and similar board, of wood (excluding particle board and oriented strand board [OSB])	m^3	4410 19
16211350	Particle board and similar board of ligneous materials (excluding wood)	m^3	4410 90
16211423	Medium density fibreboard (MDF), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a thickness not exceeding 5 mm	m^2	4411[.12(.10 + .90)]
16211426	Medium density fibreboard (MDF), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a thickness exceeding 5 mm but not exceeding 9 mm	m^2	4411[.13(.10 + .90)]
16211429	Medium density fibreboard (MDF), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a thickness exceeding 9 mm	m^2	4411[.14(.10 + .90)]
16211443	Fibreboard (excluding medium density fibreboard [MDF]), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a density exceeding 0,8 g/cm^3	m^2	4411[.92(.10 + .90)]
16211446	Fibreboard (excluding medium density fibreboard [MDF]), of wood or other ligneous materials, whether or not bonded with resins or other organic substances, of a density exceeding 0,5 g/cm^3 but not exceeding 0,8 g/cm^3	m^2	4411[.93(.10 + .90)]
16211449	Fibreboard of wood or other ligneous materials (excluding medium density fibreboard [MDF]), whether or not bonded with resins or other organic substances, of a density not exceeding 0,5 g/cm^3	m^2	4411[.94(.10 + .90)]

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - WOOD			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
16212113	Veneer sheets, sheets for plywood and other wood sawn lengthwise, sliced/peeled, thickness ≤ 6 mm and end-jointed, planed/sanded/small boards for the manufacture of pencils	m^3	4408[.10(.15 + .91) + .31(.11 + .21 + .25) + .39(.15 + .21 + .55 + .70) + .90(.15 + .35)]
16212118	Wood veneer sheets and sheets for plywood, sawn lengthwise, sliced or peeled, of a thickness ≤ 6 mm excluding end-jointed, planed or sanded	m^3	4408[.10(.98) + .31(.30) + .39(.30 + .85 + .95) + .90(.85 + .95)]
16212200	Densified wood, in blocks, plates, strips or profile shapes	m^3	4413
16221030	Assembled parquet panels of wood for mosaic floors	m^2	4418 71
16221060	Assembled parquet panels of wood (excluding those for mosaic floors)	m^2	4418[.72 + .79]
16231110	Windows, french windows and their frames, of wood	p/st	4418[.10(.10 + .50 + .90)]
16231150	Doors and their frames and thresholds, of wood	p/st	4418[.20(.10 + .50 + .80)]
16231200	Shuttering for concrete constructional work, shingles and shakes, of wood	kg	4418[.40 + .50]
16231900	Builders' joinery and carpentry of wood (excluding windows, french windows and doors, their frames and thresholds, parquet panels, shuttering for concrete constructional work, shingles and shakes)	kg	4418[.60 + .90(.10 + .80)]
16232000	Prefabricated buildings of wood		9406[.00(.11 + .20)]

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - CONCRETE, CEMENT AND PLASTER			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23611130	Building blocks and bricks of cement, concrete or artificial stone	kg	6810[.11(.10 + .90)]
23611150	Tiles, flagstones and similar articles of cement, concrete or artificial stone (excluding building blocks and bricks)	kg	6810 19
23611200	Prefabricated structural components for building or civil engineering, of cement, concrete or artificial stone	kg	6810 91
23612000	Prefabricated buildings of concrete		9406 00 80b
23621050	Boards, sheets, panels, tiles and similar articles of plaster or of compositions based on plaster, faced or reinforced with paper or paperboard only (excluding articles agglomerated with plaster, ornamented)	m^2	6809 11

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - CONCRETE, CEMENT AND PLASTER			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23621090	Boards, sheets, panels, tiles and similar articles of plaster or of compositions based on plaster, not faced or reinforced with paper or paperboard only (excluding articles agglomerated with plaster, ornamented)	m^2	6809 19
23631000	Ready-mixed concrete	kg	3824 50 10
23641000	Factory made mortars	kg	3824 50 90
23651100	Panels, boards, tiles, blocks and similar articles of vegetable fibre, of straw or of shavings, chips, particles, sawdust or other waste of wood, agglomerated with cement, plaster or other mineral binders	m^2	6808
23651220	Articles of asbestos-cement, of cellulose fibre-cement or similar mixtures of fibres (asbestos, cellulose or other vegetable fibres, synthetic polymer, glass or metallic fibres, etc.) and cement or other hydraulic binders, containing asbestos	kg	6811 40
23651240	Sheets, panels, tiles and similar articles, of cellulose fibre-cement or similar mixtures of fibres (cellulose or other vegetable fibres, synthetic polymer, glass or metallic fibres, etc.) and cement or other hydraulic binders, not containing asbestos	m^2	6811[.81 + .82]
23651270	Articles of cellulose fibre-cement or the like, not containing asbestos (excluding corrugated and other sheets, panels, paving, tiles and similar articles)	kg	6811 89
23691100	Articles of plaster or compositions based on plaster, n.e.c.	kg	6809 90
23691930	Pipes of cement, concrete or artificial stone	kg	6810 99 00a
23691980	Articles of cement, concrete or artificial stone for non-constructional purposes (including vases, flower pots, architectural or garden ornaments, statues and ornamental goods)	kg	6810 99 00b
236919Z0	Pipes and other articles of cement, concrete or artificial stone, and accessories	kg	6810 99
23701100	Worked monumental/building stone and articles thereof, in marble, travertine and alabaster excluding tiles, cubes/similar articles, largest surface < 7 cm^2, setts, kerbstones, flagstones	kg	6802[.21 + .91]
23701210	Natural stone setts, kerbstones and flagstones (excluding of slate)	kg	6801
23701230	Tiles, cubes and similar articles of natural stone, whether or not rectangular (including square), the largest surface area of which is capable of being enclosed in a square the side of which is < 7 cm; artificially coloured granules, chippings and powder of natural stone	kg	6802 10

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - CONCRETE, CEMENT AND PLASTER			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23701260	Worked monumental or building stone and articles thereof, of granite (excluding tiles, cubes and similar articles, of which the largest surface area is capable of being enclosed in a square the side of which is < 7 cm, setts, kerbstones and flagstones)	kg	6802[.23 + .93(.10 + .90)]
23701270	Worked monumental or building stone and articles thereof (excluding of granite or slate, tiles; cubes and similar articles; of which the largest surface area is < 7 cm²)	kg	6802[.29 + .92 + .99(.10 + .90)]
23701280	Worked slate and articles of slate or of agglomerated slate	kg	6803[.00(.10 + .90)]

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - CERAMIC CONSTRUCTIONS			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23201100	Ceramic goods of siliceous fossil meals or earths including bricks, blocks, slabs, panels, tiles, hollow bricks, cylinder shells and pipes excluding filter plates containing kieselguhr and quartz	kg	6901
23201210	Refractory ceramic constructional goods containing >50 % of MgO, CaO or Cr2O3 including bricks, blocks and tiles excluding goods of siliceous fossil meals or earths, tubing and piping	kg	6902 10
23201233	Refractory bricks, blocks..., weight > 50 % Al2O3 and/or SiO2: ≥ 93 % silica (SiO2)	kg	6902 20 10
23201235	Refractory bricks, blocks, tiles and similar refractory ceramic constructional goods containing, by weight, > 7 % but < 45 % alumina, but > 50 % by weight combined with silica	kg	6902 20 91
23201237	Refractory bricks, blocks..., weight > 50 % Al2O3 and/or SiO2: others	kg	6902 20 99
23201290	Refractory bricks, blocks, tiles, etc., n.e.c.	kg	6902 90
23201300	Refractory cements, mortars, concretes and similar compositions (including refractory plastics, ramming mixes, gunning mixes) (excluding carbonaceous pastes)	kg	3816
23201410	Articles of stone or other mineral substances, n.e.s. containing magnesite, dolomite or chromite	kg	6815 91
23201430	Refractory ceramic goods, n.e.c., by weight > 25 % graphite or other forms of carbon	kg	6903[.10 + .90(.10)]
23201455	Refractory ceramic goods, n.e.c., alumina or silica or mixture > 50 % : alumina < 45 %	kg	6903 20 10
23201459	Refractory ceramic goods, n.e.c., alumina or silica or mixture > 50 % : alumina ≥ 45 %	kg	6903 20 90
23201490	Refractory ceramic goods, n.e.c.	kg	6903 90 90
23311010	Unglazed ceramic mosaic tiles, cubes and similar articles, with a surface area < 49 cm²	m²	6907 10
23311020	Glazed ceramic mosaic tiles, cubes and similar articles, with a surface area < 49 cm²	m²	6908 10

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - CERAMIC CONSTRUCTIONS			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23311050	Unglazed ceramic and stoneware flags and paving, hearth or wall tiles; unglazed ceramic and stoneware mosaic cubes and the like, whether or not on a backing	m^2	6907[.90(.20 + .80)]
23311071	Glazed ceramic double tiles of the spaltplatten type	m^2	6908[.90(.11 + .31)]
23311073	Glazed stoneware flags and paving, hearth or wall tiles, with a face of > 90 cm^2	m^2	6908 90 91
23311075	Glazed earthenware or fine pottery ceramic flags and paving, hearth or wall tiles, with a face of > 90 cm^2	m^2	6908 90 93
23311079	Glazed ceramic flags and paving, hearth or wall tiles excluding double tiles of the spaltplatten type, stoneware, earthenware or fine pottery flags, paving or tiles with a face of not > 90 cm^2	m^2	6908[.90(.20 + .51 + .99)]
23321110	Non-refractory clay building bricks (excluding of siliceous fossil meals or earths)	m^3	6904 10
23321130	Non-refractory clay flooring blocks, support or filler tiles and the like (excluding of siliceous fossil meals or earths)	kg	6904 90
23321250	Non-refractory clay roofing tiles	p/st	6905 10
23321270	Non-refractory clay constructional products (including chimneypots, cowls, chimney liners and flue-blocks, architectural ornaments, ventilator grills, clay-lath; excluding pipes, guttering and the like)	kg	6905 90
23321300	Ceramic pipes, conduits, guttering and pipe fittings: drain pipes and guttering with fittings	kg	6906

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - IRON, STEEL AND ALUMINUM			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
25111030	Prefabricated buildings, of iron or steel		9406[.00(.31 + .38)]
25111050	Prefabricated buildings, of aluminium		9406 00 80c
25112100	Iron or steel bridges and bridge-sections	kg	7308 10
25112200	Iron or steel towers and lattice masts	kg	7308 20
25112310	Iron or steel equipment for scaffolding, shuttering, propping/pit-propping including pit head frames and superstructures, extensible coffering beams, tubular scaffolding and similar equipment	kg	7308 40
25112350	Other structures principally of sheet: other	kg	7308 90 59
25112355	Weirs, sluices, lock-gates, landing stages, fixed docks and other maritime and waterway structures, of iron or steel, Structures and parts of structures of iron or steel, n.e.s. (excluding bridges and bridge-sections; towers; lattice masts; gates; doors, windows and their frames and thresholds; equipment for scaffolding, shuttering, propping or pit-propping, and structures and parts of structures not manufactured exclusively or mainly from plate)	kg	7308 90 98

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - IRON, STEEL AND ALUMINUM			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
25112370	Aluminium structure and parts of structures..., n.e.c.	kg	7610[.90(.10 + .90)]
25121030	Iron or steel doors, thresholds for doors, windows and their frames	p/st	7308 30
25121050	Aluminium doors, thresholds for doors, windows and their frames	p/st	7610 10

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - MORTAR, CEMENT AND LIME			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
23511100	Cement clinker	kg	2523 10
23511210	Portland cement	kg	2523[.21 + .29]
23511290	Other hydraulic cements	kg	2523[.30 + .90]
23521033	Quicklime	kg	2522 10
23521035	Slaked lime	kg	2522 20
23521050	Hydraulic lime	kg	2522 30
23522000	Plasters consisting of calcined gypsum or calcium sulphate (including for use in building, for use in dressing woven fabrics or surfacing paper, for use in dentistry)	kg	2520 20
23523030	Calcined and sintered dolomite, crude, roughly trimmed or merely cut into rectangular or square blocks or slabs	kg	2518 20
23523050	Agglomerated dolomite (including tarred dolomite)	kg	2518 30

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - PLASTIC			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
22231155	Floor coverings in rolls or in tiles and wall or ceiling coverings consisting of a support impregnated, coated or covered with polyvinyl chloride	M^2	3918 10 10
22231159	Other floor, wall, ceiling... Coverings of polymers of vinyl chloride	M^2	3918 10 90
22231190	Floor coverings in rolls or in tiles; and wall or ceiling coverings of plastics (excluding of polymers of vinyl chloride)	M^2	3918 90
22231250	Plastic baths, shower-baths, sinks and wash-basins	P/st	3922 10
22231270	Plastic lavatory seats and covers	P/st	3922 20
22231290	Plastic bidets, lavatory pans, flushing cisterns and similar sanitary ware (excluding baths, showers-baths, sinks and wash-basins, lavatory seats and covers)	P/st	3922 90
22231300	Plastic reservoirs, tanks, vats, intermediate bulk and similar containers, of a capacity > 300 litres	Kg	3925 10
22231450	Plastic doors, windows and their frames and thresholds for doors	P/st	3925 20
22231470	Plastic shutters, blinds and similar articles and parts thereof	Kg	3925 30

PRODCOM HARMONIZATION TO INTERNATIONAL TRADE COMEXT - PLASTIC			
PRCCODE	**DESCRIPTION**	**Unit**	**HS/CN (1)**
22231500	Linoleum, floor coverings consisting of a coating or covering applied on a textile backing (excluding sheets and plates of linoleum compounds)	M^2	5904[.10 + .90]
22231950	Builder's fittings and mountings intended for permanent installation of plastics	Kg	3925 90 10
22231990	Builders' ware for the manufacture of flooring, walls, partition walls, ceilings, roofing, etc., guttering and accessories, banisters, fences and the like, fitted shelving for shops, factories, warehouses, storerooms, etc., architectural ornaments such as fluting, vaulting and friezes, of plastics, n.e.c.	Kg	3925 90 80
22232000	Prefabricated buildings, of plastics		9406 00 80a

PREFABRICATED ELEMENTS ON PRODCOM DATABASE		
Database	**Description**	**Link to database PRODCOM**
PRODCOM	• Manufacture of veneer sheets and wood-based panels **(Group 1621)** • Manufacture of assembled parquet floors **(Group 1622)** • Manufacture of other builders' carpentry and joinery **(Group 1623)**	Prefabricated elements of wood
PRODCOM	• Manufacture of builders' ware of plastic **(Group 2223)**	Prefabricated elements of plastic
PRODCOM	• Manufacture of refractory products **(Group 2320)** • Manufacture of ceramic brick, tiles and flags **(Group 2331)** • Manufacture of bricks, tiles and construction products **(Group 2332)**	Prefabricated elements of ceramic
PRODCOM	• Manufacture of cement, lime and plaster **(Group 2351_2352)**	Manufacture of cement, lime and plaster
PRODCOM	• Manufacture of concrete products for construction purposes **(Group 2361)** • Manufacture of plaster products for construction purposes **(Group 2362)** • Manufacture of ready-mixed concrete and mortars **(Group 2363_2364)** • Manufacture of fibre cement **(Group 2365)** • Manufacture of other articles of concrete, plaster and cement **(Group 2369)** • Cutting, shaping and finishing of stone (Marble, travertine, alabaster, worked, and articles thereof) **(Group 2370)**	Prefabricated element of concrete, plaster, fiber cement. Cutting, shaping and finish stone

Prodcom	• Manufacture of metal structures and parts of structures; Manufacture of doors and windows of metal (Group 2511_2512)	Prefabricated element in iron, steel and aluminum

Link_ International trade harmonized with Prodcom

IMPORT-EXPORT OF PREFABRICATED ELEMENTS ON INTERNATIONAL TRADE ELEMENTS		
Database	**Description**	**Link to database COMEXT International Trade**
International Trade COMEXT	• Manufacture of veneer sheets and wood-based panels **(Group 1621)** • Manufacture of assembled parquet floors **(Group 1622)** • Manufacture of other builders' carpentry and joinery **(Group 1623)**	**GROUP 44** International Trade (wood elements)
International Trade COMEXT	• Manufacture of concrete products for construction purposes **(Group 2361)** • Manufacture of plaster products for construction purposes **(Group 2362)** • Manufacture of ready-mixed concrete and mortars **(Group 2363_2364)** • Manufacture of fibre cement **(Group 2365)** • Manufacture of other articles of concrete, plaster and cement **(Group 2369)** • Cutting, shaping and finishing of stone (Marble, travertine, alabaster, worked, and articles thereof) **(Group 2370)**	**GROUP 68** International Trade (Concrete, cement and plaster)
International Trade COMEXT	• Manufacture of refractory products **(Group 2320)** • Manufacture of ceramic brick, tiles and flags **(Group 2331)** • Manufacture of bricks, tiles and construction products **(Group 2332)**	**GROUP 69** International Trade (Ceramics elements)
International Trade COMEXT	• Manufacture of metal structures and parts of structures; Manufacture of doors and windows of metal (Group 2511_2512)	**GROUP 73_76** International Trade (Structure iron, steel & aluminum)
International Trade COMEXT	• Manufacture of builders' ware of plastic **(Group 2223)**	**GROUP 39** International Trade (Plastic elements)

ANNEX 3 – COUNTRIES FRAMEWORK

DISCLAIMER

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AUSTRIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TILES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Austria has replaced its multitude of regulations concerning handling and treatment of CDW recently with the **Recycled Construction Materials Regulation**, which came into force on 1st January 2016 and was last changed on 28th October 2016.

The main aim of this regulation is to guarantee environmentally compatible RC building materials and legal certainty for their users and producers.

Specific requirements for recycling-oriented demolition and separation as well as manufacture and construction with recycled construction materials are determined.
This ensures that the European Waste Framework Directives obligations are met. Furthermore, a link to a new Austrian standard on the use of recycled aggregates (ÖNORM B 3140) is established. This standard covers a wider range of end uses than EN 12620. [1]

The scope of the Waste Incineration Ordinance (Abfallverbrennungsverordnung) includes, among other things, wood waste which may contain halogen-organic compounds or heavy metals as a result of treatment with wood preservatives or coating (§ 2 (2)). This applies in particular to wood waste from construction and demolition activities. The thermal utilization of waste wood from the construction industry therefore falls within the scope of the Incineration Ordinance. [2]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The recycling ordinance regulation, which entered into force on 1 January 2016, aims to ensure a consistently high quality of construction waste in order to increase its recycling rate. Included are requirements for dismantling and the detection of harmful substances and impurities. In addition, provisions for the further treatment of construction and demolition waste, quality specifications for recycling building materials and fields of application for recycled building materials are listed. The focus is on the production and use of recycled materials as a natural, recycled or industrially produced aggregate.

For the various quality classes of mineral, recycled building waste, for example, permissible fields of application, such as the unbound application and the production of concrete as well as asphalt mix, but also prohibitions of use are mentioned.

In addition, there are specifications for the separation of construction waste depending on the size of the construction project in m^3. [3]

The ÖNORM B 3140: 2016 06 01 "Recycled aggregates for unbound and hydraulically bound applications as well as for concrete" is setting specific requirements on recycled aggregates for asphalt and surface treatments for roads, airfields and other traffic areas according to the categories of ÖNORM EN 13043 due to the specific geographical, topographical and climatic conditions prevailing in Austria. There is currently no regulation on the use of recycled aggregates in building construction.

1.3 Prefabricated elements (with or without CDW materials)

Requirements for the performance criteria for and the conformity assessment of a large number of prefabricated concrete products produced under factory conditions are listed in EN 13369: 2013-08 "General rules for concrete prefabricated parts". This is used in Austria as ÖNORM EN 13369: 2013-06-01.

In Austria, the harmonized European standards for precast concrete parts are also applicable.

1.4 Prefabricated construction

The ÖNORM B 2310: 2009 05 01 "Prefabricated structures - Definitions and Minimum Scope of Services" defines definitions and the minimum scope of benefits of prefabricated structures made of storey-high, prefabricated construction elements, regardless of the building materials used .

The ÖNORM B 2320: 2010 07 15 "Wooden houses - technical requirements" contains technical requirements for the production and erection of wooden houses whose wall, ceiling and roof structures consist essentially of wood and / or wood materials. It applies to residential buildings which are made of wood frame construction (for example, bar, stand and panel construction), wooden skeleton construction and / or wooden construction (for example, plywood, plank stacking and block construction). If individual parts are built in timber construction for buildings, the provisions contained therein apply only to these parts.

2. POLICY MEASURES

2.1 Materials from CDW

In 2012, around 5.8 million tonnes of building material were recycled. According to an evaluation by the Austrian Building Materials Recycling Association, an annual total capacity of at least 8 million tonnes of building material processing plants is to be expected. This clearly exceeds the volume of waste, which is why an increase in the processing ratio appears to be possible from a plant engineering standpoint.

2.2 Prefabricated elements (with or without CDW materials)

Political measures for the use of prefabricated elements could not be researched for Austria.

2.3 Prefabricated construction

With his approx. 880,000 housing, social housing in Austria accounted for 24% of the total housing stock (60% of the rental housing sector) and thus ranked second in the EU.

The new building in the socially tied rental housing sector is entirely managed by the non-profit housing sector. It builds approx. 15,000 apartments annually. This represents a share of the total new construction output of 30%. In comparison to the EU, the social housing new construction in Austria is undisputedly the first place. [4]

The promotion of new residential buildings in Austria is a matter for the country or the individual municipalities and is available to both developers and private individuals. Depending on the state, and sometimes from one municipality to another, there are different types of funding, subsidies and conditions which must be fulfilled. On a flat-rate basis, it can be noted that above all those construction projects have a right to a housing promotion which also meets ecological and economic requirements and requirements. Prefabricated buildings meeting these requirements can therefore also be funded. There is no special support for prefabricated buildings.

Just as there are differences in the amount of subsidies across Austria, there are different types of funding or possibilities. There are, for example, favorable subsidy loans, which are usually based on the number of persons and the square meters of living space. Promoted apartments are on average about half cheaper than free-lanced. [5]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Some specialized concrete products are exported globally, e.g. "Koch-Beton" exports a specialized prefab concrete tube globally. [6]

Austria is a significant exporter of timber products. Thus 70% of wood products are exported. [7]. Around 75% of the exports go to EU-25, most of them to Italy [8]. Its imports in this regard are low. Some raw wood is imported for conversion into refined wood products [9].

No reliable data on prefab timber element export could be found; however, it can be assumed that a significant percentage of Austria's tremendous timber export comes in form of elements that are prefabricated to some extent.

3.2 Market conditions / costs and benefits

Between 2012 and 2015, the prefabricated construction sector suffered sales losses of around 10%. With the general upturn in the construction industry and rising average prices, sales in the prefabricated construction sector increased by 7.0%. Overall, the market volume rose from 726 to 777 million EUR. Also 2017 is expected with an increasing turnover. In addition to sales, the number of prefabricated residential buildings sold increased by 4.6% in 2016. The prefabricated rate rose marginally in 2016 and now stands at 34.6%.

Within Austria there are strong regional differences. In general, the east of Austria is of greater importance for the prefabricated residential building market. The highest regional prefabricated building rate in 2016 had Vienna with 43.6%. Lower and Upper Austria together represent 54% of the entire Austrian prefabricated construction market.

At the other end is Tyrol, with the lowest regional prefabricated rate of 17.7%. The worst regional market development occurred in Carinthia. In 2016, the only state of Austria was able to cope with a market decline: sales fell by 7.7%.

As a result of the 2015 market adjustment, the market concentration in 2016 continued to grow. Austria's top three companies cover more than a quarter of the finished market at 28.8%. [10]

3.3 Construction sector make up

In 2014, the construction sector in Austria listed around 34,000 companies with 288,000 employees. 82% of the companies employed less than 10 people, making around 25% of the total sector’s turnover. There existed 68 companies with more than 250 employees that were responsible for 23% of the overall turnover (43bn EUR in 2014). More details are provided in below graphs. [11]

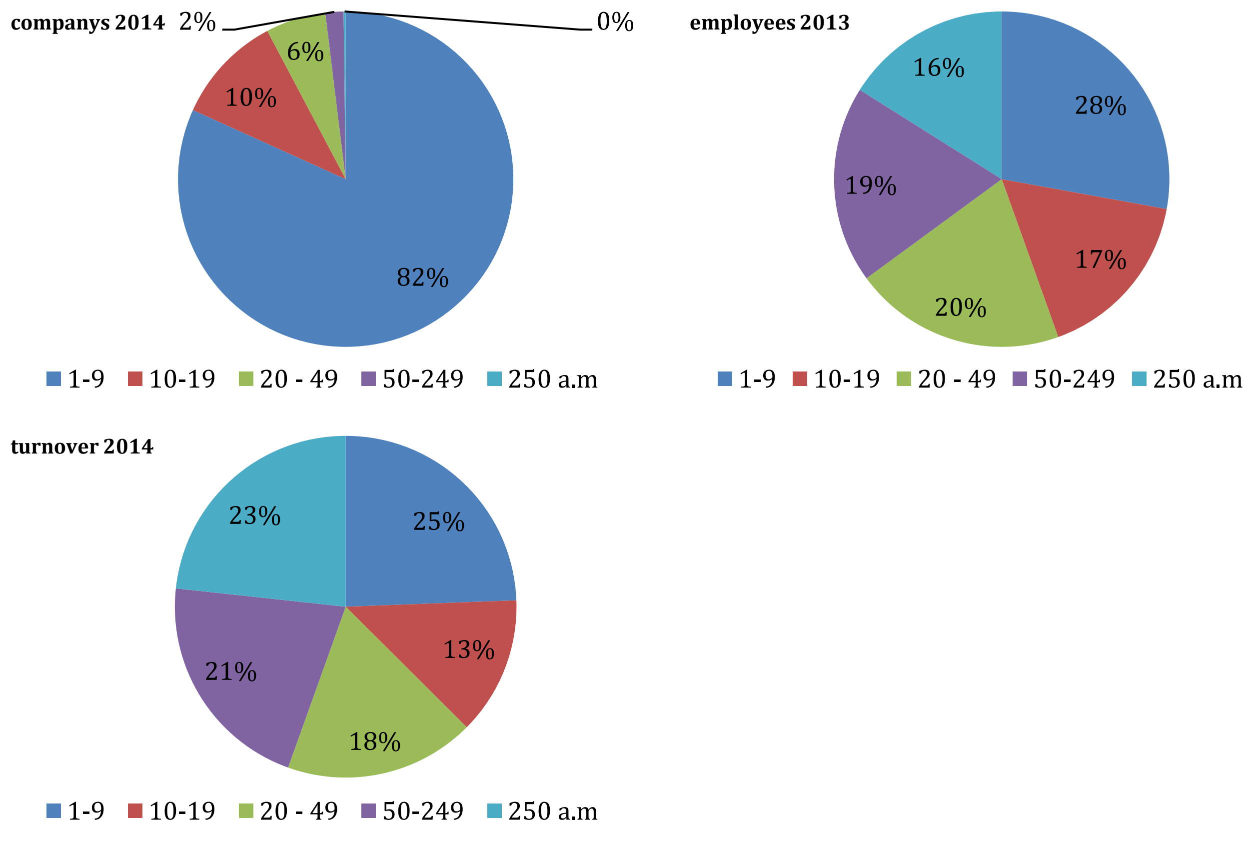

Figure 1. Structure of companies, employees and the turnover by company size in the building sector in Austria [11]

3.4 Use of CDW materials for prefabricated elements

There are no figures for the use of recycled aggregates in the precast concrete industry in Austria available.

Austria's abundant timber resources suggest that the use of recycled timber products might be of secondary importance for its local market.

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BELGIUM

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TILES AND CERAMIC, ASPHALT, WOOD, GYPSUM

1.2 Materials from CDW (aggregates, binders, reinforcement…)

In Flanders, 'eenheidsreglement' (23/11/2011) established a management system for recycled granulates, including a demolition management system that aims to guarantee quality and a system for the certification of the recycled aggregates [2].
In Brussels, 16/03/1995 Arrêté du Gouvernement de la Région de Bruxelles-Capitale established a mandatory recycling system for the stony and sandy fraction. Additionally, there is a requirement to use this material for use as a secondary raw material on different projects [2].

1.3 Prefabricated elements (with or without CDW materials)

There seems to be very little information on this, however the information that has been found comes from the Flanders region of Belgium. Certain prefabricated elements seem to be more widely used in Flanders, including [6]:

- BW24_hollow brick concrete prefab panel (uses gypsum plaster)
- Prefabricated wall full panels (gypsum blocks)
- Prefabricated wall 100% glazed (timber frame plasterboard)
- Prefabricated wall glass
- Prefabricated panels filled with PUR + laths [6]

Furthermore, there seems to be a market for prefabricated elements for electrical circuits [1].

1.4 Prefabricated construction

There does not seem to be specific legislation for prefabricated construction in Belgium. Consequently, the normal technical regulations and legislation in place for construction as a whole should also hold for anything concerning prefabricated construction.

2. POLICY MEASURES

2.1 Materials from CDW

Belgium is trying to move toward more use of secondary material, although this market is not increasing at the rate needed. Recycling plants are attempting to promote selective demolition by using different delivery tariffs for mixed and clean material [5]. The prices for this in 2000 can be seen in Table 1:

Table 1. Average prices for delivery of CDW in recycling plants [5]

Average prices for delivery at recycling plants	
Concrete	Free of charge
Reinforced concrete	1.25-2.5 ECU/ton
Heavily reinforced concrete	6.25-12.5 ECU/ton
Masonry	2.5-6.25 ECU/ton
Mixed rubble containing plastics, wood	2.5-12.5 ECU/ton

The majority of CDW is process into secondary aggregates that are then used for construction, including prefabricated construction.

2.2 Prefabricated construction

The prefabricated construction market seems to have been established in Belgium for some time, including the prefabrication of walls [4]. By 1969, 2% of houses in Belgium were being constructed using prefabricated methods [7]. Instead of the heavy prefabrication that was popular in the rest of Europe, Belgium focused on partial prefabrication such as hollow core slabs and lightweight concrete. It should be noted that there were several heavy prefabricated systems in Brussels that became popular, including the Barets system (La Magnanerie and La Cité Modèle are famous examples of this).

Unfortunately, there does not seem to be a lot of information on this market, although there are bigger companies involved, such as Willy Naessens.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Market conditions / costs and benefits

There seems to be a reasonably sized market for prefabricated construction in Belgium, with numerous operators and types. There is no data available and it is therefore difficult to understand the scope of the market, however there does seem to be competition.
Unlike other EU member however, there is something resembling a secondary materials market in Belgium, including for construction materials. It is still the case that this material is not less expensive than raw material (legislation would have to add a subsidy or add a tax), however depending on the building requirements it is possible that there is opportunity.

3.2 Construction sector make up

The majority of the information concerning the use of CDW or prefabricated construction is coming from Flanders. There seems to be less information on this sector coming from the Brussels Region or the Walloon Region. Consequently, the following information holds true for Flanders.
The construction industry seems to be the largest consumer of materials within Flanders. Sustainable materials management has become more of a concern in this sector as a result. A new standard is being considered for "sustainable buildings and infrastructure that require less energy and materials, that are easily modified and the components of which can eventually be readily

reused or recycled" [3]. This is in order to incentivize the industry to start choosing sustainable construction.

Currently, there are pilot project in place on flexible construction and on the creation of a materials measurement tool in order to assist practitioners. The Flanders government is also planning to add this in their public procurement requirements.

The Walloon Region and Brussels Capital Region, according to the EEA, were "probably inspired by the German 'employment-environment alliance' strategy on building renovation" [3]. The Brussels Capital Region released its own version of this plan, with an action plan that was released in 2012.

3.3 Use of CDW materials for prefabricated elements

There does not seem to be any information on this, although the slight emphasis on secondary material usage in construction would point to this being in the introductory stages in the market.

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BULGARIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Waste Management Act of July 13th 2012 transposes Directive 2008/98 / EC and, about CDW it requires, before starting construction works and / or removal of construction contracting, to prepare a management plan for construction waste.
The main national instruments for sustainable management of CDW in Bulgaria are:

- the Ordinance on construction and demolition waste management and use of recycled building materials of Ministry of Environment and Water (2012);
- the Regulation for management of construction waste and incorporation of recycled construction materials of Council of Ministers' Order 277 (2012) 89 SG;
- the National Construction and demolition Waste Management plan for the territory of the Republic of Bulgaria for the period 2011-2020 of Ministry of Environment and Water (2011). [1] [2]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Aggregates
CDW are largely recycled in the form of aggregates because of the broad range of possibilities for their implementation.
The introduction of the CE marking for building materials and the publication of harmonized standards for aggregates have officially ruled out traditional distinction of the aggregates according to their nature, requiring materials to be evaluated only for their performance characteristics.
The CE marking therefore enables to compare recycled aggregates to natural ones and to replace them with each other without distinction (for the uses set by the designer).
Recycled aggregates with the CE marking are, to all intents and purposes, construction materials.
Harmonized norms for the EC marking of natural, recycled and manufactured aggregates are:

EN 13055-1 "Light aggregates – Part I: Light aggregates for concrete, mortar and grout"
EN13139 "Aggregates for mortar"
EN 13383 "Aggregates for protection works (armourstone)"
EN 12620 "Aggregates for concrete"
EN 13242 "Aggregates for unbound and bound materials with hydraulic binders to be used in civil engineering works and in road construction"
EN 13450 "Aggregates for railway ballasts". [3]

1.3 Prefabricated elements (with or without CDW materials)

The technical requirements for construction works and products are set out in Ordinances, Norms and Standards for:

- actions on structures including seismic ones;
- design of all types of structures;
- foundation of all types of structures;
- technical systems and installations;
- design of all types of buildings – residential, public, administrative, industrial.

From January 6, 2014 the design or the construction engineer (design and construction) of new construction contracts awarded under the terms and conditions of the Public Procurement Act shall be made in the Eurocodes.
The design of buildings outside the scope of above text is determined year transition period from the date of enforcement of the regulation, in which the structures of buildings can be designed as the national regulations for the design of building structures and in the Eurocodes, without mixing national and Eurocodes systems.
So for prefabricated elements, the European legislation to be followed is EN 13369 Precast concrete products.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

Bulgarian legislation requires before starting construction works and / or removal of construction contracting to prepare a management plan for construction waste.
With specific text, the legislature prohibits illegal dumping, incineration, and any other form of unauthorized treatment of construction waste, including disposal in containers for collection of household waste and packaging waste.
Among the requirements contained in the Ordinance on CDW management there is the "implementation of CDW recycling products in infrastructure projects", as below:

- for construction of buildings - 2 % from total amount of construction products;
- road construction - 10 %;
- renovation works – 3%. [2]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

Since 2004, housing policy has focused on energy efficiency with the launch of a number of policy measures, such as the National Programme for Energy Efficiency of Residential Buildings and, specifically, with the **Measure N. 511: Development of a national program for refurbishment of the existing prefabricated panel buildings in Bulgaria**. In Bulgaria, indeed, the number of prefabricated panel residential buildings is prevailing, more than 18,900 blocks of flats, located in 120 housing estates, constructed in the sixties and eighties, of which 96.5% private property. So, one of the National Priority is the Refurbishment of Panel Buildings, even if the Program will not cover all panel buildings in this country, or the most damages ones, but provide financing to those who file their application first. [1] [4]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [5], the value of trade of prefabricated elements is € 359 Million. Export activities account 194 € Millions, while import account 165 € Million. The sold construction products in Bulgaria between 2012 and 2016 has growth at a rate (CAGR) of 1.98% for export and 1.14% on import. For Bulgaria export of prefabricated elements are higher than imports. The only category of products for which imports are higher than exports are for the production of prefabricated wooden items.

On the export side, precast elements (26.6%) and ceramic elements (37.8%) hold more than half of the exports. In the observed period, their growth rate in exports is between 1 and 3%. Significant growth in cement, mortars and plaster ready mix exports (+ 7.8% CAGR)

On the import side, the wood elements and the ceramic structural elements are the most imported ones. Their share on import is 45.5% for wood structural elements, and 34.2% for ceramic constructional goods. Concrete goods elements is the 3rd largest export goods, it account 16.2% of export. In the observed period, the quantity (expressed in euro) of cement and mortar ready mix (-8.9%) and prefabricated ceramic items (-3.3%) decreases. On the other hand, imports of prefabricated wood (+5.5%) and concrete items (+3.9%) increase.

Approximately 66 % of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders

BULGARIA TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on export**
Cement, lime and plaster (ready mix)	15.970.884	21.625.648	7,87%	11,10%
Ceramic constructional goods	66.419.182	73.612.361	2,60%	37,80%
Concrete, plaster structural elements	49.263.740	51.828.100	1,28%	26,61%
Wood Structural elements	48.377.659	47.677.676	-0,36%	24,48%
TOTAL EXPORT	**180.031.465**	**194.743.785**	**1,98%**	**100,00%**

IMPORT	2012	2016	CAGR	Share on Import
Cement, lime and plaster (ready mix)	9.673.040	6.657.424	-8,92%	4,03%
Ceramic constructional goods	64.617.911	56.483.828	-3,31%	34,22%
Concrete, plaster structural elements	22.960.997	26.769.667	3,91%	16,22%
Wood Structural elements	60.511.533	75.167.349	5,57%	45,53%
TOTAL IMPORT	**157.763.481**	**165.078.268**	**1,14%**	**100,00%**

3.2 Market conditions / costs and benefits

As a show Deloitte research, Bulgaria does not have a clear and strong regulatory framework, sanctions are defined, but according to experts, it does not appear to be an important constraint. On the economic side, the recycling market is really new, the costs and benefits are unclear for CDW management players. CDW deactivation is more expensive to dispose of in alternative ways. In fact, CDW producers do not have financial leverage to send CDW for recycling [8].
As demonstrated by UEPG (European aggregates Association) in Bulgaria, on a total of 32 million tons of aggregate products, the majority were from Crushed Rock (59%) and Sand & Grave (34%). Overall, the volume of natural aggregates production increased between 2009 and 2015 by 4% (CAGR), even if far from the production volumes reached in 2008. The increase of production is driven mainly by Crushed Rock (+5%). Over the years, the number of companies in the industry has increased (as well as the number of Extraction Sites, the aggregate production volume of aggregates has increased, while the production of recycled aggregates has recently touched 3% of the total volume of production [12].

BULGARIA– Estimates of Aggregates Production	2015	2014	2013	2012	2011	2010	2009	2008
Total Number of Producers (companies)	217	217	217	217	190	190	190	200
Total Number of Extraction Sites (Quarries and Pits)	295	295	295	295	295	280	280	100
Sand & Gravel (millions tonnes)	11	11	11	10	10	11	11	18
Crushed Rock (millions tonnes)	19	19	19	18	18	14	14	22
Marine Aggregates (millions tonnes)	0	0	0	0	0	0	0	0
Recycled Aggregates (millions tonnes)	1	1	1	1	0	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0	0	0	0	0
Total Production (millions tonnes)	**32**	**32**	**32**	**29**	**28**	**24**	**25**	**40**

Source: EUROPEAN AGGREGATES ASSOCIATION (UEPG)

In addition, from the perception and awareness point of view, stakeholders in Bulgaria are not sufficiently aware of the environmental / economic / social benefits associated with the recycling of waste. In this context, Bulgarian companies are much more sensitive to economic (cost and price) than environmental concerns. Moreover, there are no economic levers for recycled material, making it less attractive to the market than the final price of primary building material. Industry studies have shown that in Europe recycled concrete aggregate can sell for 3 to 12 € per tonne with a production cost of 2.5 to 10 € per tonne. The higher selling price is obtained on sites where all C&DW is reclaimed and maximum sorting is achieved, there is strong consumer demand, lack of natural alternatives and supportive regulatory regimes [6]. In fact, Bulgaria, along with countries like Hungary and Romania, is a country were the highest prices for recycling aggregates, made from C&DW or waste concrete that are about USD 16/t (~12 Euro) [7]. In this context, the market of waste management cannot take off and the incentives for recycling are lacking in Bulgaria.

3.3 Construction sector make up

The building sector represents an important economic activity in Bulgaria: 10.5% of Bulgarian GDP in 2015. As a show Deloitte research, "in the early 2000's the market was growing with projects related mostly to housing, tourism infrastructure, offices and road construction. The majority of ongoing construction projects are public procurements, financed by EU funds. Lately the general construction market is rather stagnant"[8].

According to European commission studies "the economic crisis had negative repercussions on the Bulgarian construction sector, particularly with regard to employment, production and profitability. This was accompanied by a significant drop in production in parallel to rising construction costs"[9] .

Like many cities in Eastern Europe, Bulgaria is surrounded by several cities have a large share of prefabricated housing estates, built during the socialist period. For example, in Sofia more than 60% of the population lives in buildings like this [10]. Historically, low energy prices meant little or no attention was paid to energy efficiency. Many of the buildings are now in a bad state of repair and often use 30% more energy compared to housing in Western European countries. Recently government have stablished several measure, such as direct subsidy of up to 20% of total costs is provided for the renovation of prefabricated panel buildings [11]

The most applied systems for prefabricated buildings in Bulgaria are:
- large-panel systems;
- frame systems;
- lift-slab system with walls.

The designation "large-panel system" refers to multistory structures composed of large wall and floor concrete panels connected in the vertical and horizontal directions so that the wall panels enclose appropriate spaces for the rooms within a building. These panels form a box-like structure.
The "precast frame system" can be constructed using either linear elements or spatial beam-column sub-assemblages. [13]

The "large-panel system" is very popular in the Bulgarian construction practice in the recent past. It is one of the symbols of socialism and the migration of rural population to the cities. The peak in the construction of panel buildings was between the 1960's and the 1980's. The construction of

panel buildings in Bulgaria was brought from France. However, Western Europe did not witness such a large-scale construction of panels buildings, as it happened in Bulgaria. [4]
In the cities-regional centers are located 82.3% of the total fund of panel buildings. The largest share belongs to Sofia (28.5% - 200579 residential), followed by Plovdiv (8.2% -57468 residential), Varna (8.1% - 56821 residential), Burgas (4.9% - 34714 residential) and Rousse (4.2% -29378 residential). In these five cities are concentrated 53.8% (378960 residential) of all prefabricated housing (707441 residential). (Figure 1) [13]

Figure 1. Experience of "large-panel system" residential buildings in Bulgarian cities [13]

The panel flats are cheap: their price corresponds to the budget of an average Bulgaria family. Despite their unattractive look, they left a permanent mark on the architecture typical of the socialist period. Several decades later they remain part of the urban environment and social phenomenon.
Theoretically, the life of the prefabricated buildings is around 50-60 years. Fortunately, in most cases the estimates do not correspond to reality. The critical point in this case is the solidity of the welding connecting the panels. If the welding becomes weak, the panels may separate from each other and cause serious damage to the building construction. However, investigation is expensive, as the competent experts need to reach to the welding, which is quite inconvenient for the home

owners, too. That is why, people rely in most cases on wrong calculations regarding the life cycle of this type of building. The new program of the Belgian cabinet which enables people to insulate their panel buildings could bring new life to them. [4]

3.4 Use of CDW materials for prefabricated elements

First example about the use of CDW materials for prefabricate elements is the prototype developed during the project ECO-SANDWICH. The product is an innovative ventilated prefabricated concrete wall panel with integrated mineral wool insulation; particularly, it consists of two precast concrete layers; recycled concrete aggregate and recycled brick aggregate is used in production of concrete for the inner and outer layer respectively (around 50% of total aggregates needed in production of concrete is obtained from recycled CDW, and the exact quantities were entered in the model). [14]

Figure 2. ECO-SANDWICH Panel [14]

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DISCLAIMER

CROATIA

1. TECHNICAL REGULATION AND LEGISLATION

In construction industry, the expression "technical regulations" denotes a portion of construction-related regulations which deal with technical issues relating to the design, construction, production of building products, as well as with the maintenance and demolition of structures. These regulations include technical regulations, standards and special regulations of technical character. Many technical issues are solved in construction industry through autonomous regulations. In this case, such regulations are, for instance, General Technical Requirements (GTR) and Special Technical Requirements (STR) for construction contracts, General Requirements for Construction Contracts (OUG), Special Requirements for Construction Contracts (PUG), etc. [1]

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

The **Croatian Waste Management Strategy for the period 2005–2025** tackles, among the other, the area of CDW in two separate sections (2.3.2. and 4.2.2) and provides an overview of the current state of CDW in Croatia as well as guidelines for the CDW management system improvement.
Also the recently published NWMP (**National Waste Management Plan**) includes specific measures aimed at increasing waste prevention activity, about CDW.
The "**Ordinance on by-products and end-of-waste status (OG No. 117/14)**" establishes special EoW status requirements for seven CDW types by reference to recovery activities for the manufacture of building products.
Within the project LIFE05 TCY/CRO/00014 CONWAS "Development of sustainable construction and demolition waste management system for Croatia", the document "**Construction and demolition waste management plan**" has been published. The document is an integral part of the Waste Management Plan for Croatia and as such presupposes the inclusion of its basic guidelines and measures into waste management plans of counties, i.e. the City of Zagreb, as well as into waste management plans of towns and municipalities and waste management plans of waste producers. [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The Croatian Waste Act allows contractors to reuse their own waste as building materials on the building sites where it was generated, but only if it complies with the Technical Regulations on construction products and the given norms. [3]

Recycled asphalt aggregates
Recycled asphalt aggregate, that is a product of milling of asphalt courses or crushing of asphalt slabs, is allowed to be used as part of different bituminous mixes prepared by both hot and cold methods. New regulations also define requirements for recycled asphalt aggregate to be used in new asphalt mixtures in terms of grading, proportion of bitumen and softening point of bitumen

separated from the recycled aggregate. Before application, recycled aggregate has to go through testing defined by norms:

- sampling to assess homogeneity (HRN EN 932-1),
- bitumen extraction (HRN EN 12697-3 or HRN EN 12697-4),
- determination of bitumen softening point (HRN EN 1427),
- proportion of bitumen in reclaimed asphalt aggregate (HRN EN 12697-1),
- granulation of recycled asphalt aggregates (HRN EN 12697-2).

Beyond recycled asphalt aggregate, the possibility of application of fly ash from coal combustion as a filler and different types of slag (steelmaking, other metals) as an aggregate is mentioned for bituminous mixes. [3]

1.3 Prefabricated elements (with or without CDW materials)

The Ministry of Construction and Physical Planning acts as the main **Product Contact Point for Construction (PCPC)**, according to Regulation EU 305/2011 on construction products. The PCPC gives access to national technical rules related to construction products in Croatia and provides free information and advice on provisions aimed at fulfilling basic requirements for construction works applicable for the intended use of construction products. For instance, it provides information on the application of the principle of mutual recognition, the contact data of the competent authorities in Croatia, including the details of the bodies responsible for overseeing the implementation of national regulations, as well as information on construction products in the harmonized and non-harmonized areas (i.e. areas where the CE mark is affixed on products or not, respectively).

Finally, with respect to the implementation of Eurocodes, all EN Parts are published as National Standards in Croatia. National Annexes are published to all Eurocode Parts, except EN 1997-2 and are available in English (with the exception of those to EN 1991, EN 1992 and EN 1993). The use of Eurocodes is not compulsory, but since there is no other national scheme available, they are the only means for structural design. No other National Standards are used in parallel with Eurocodes. [6]

Order on Obligatory Certification of Prefabricated Elements Made of Cellular Concrete 34/85*, 14/89*

1.4 Prefabricated construction

The Building Law (Official Gazette No. 52/99) and the Law on Revisions and Additions to the Building Law (Official Gazette No. 75/99, 117/01) are fundamental laws regulating the design, construction and maintenance of structures.

In the field of prefabricated construction, the followed subordinate acts, based on the BL and previous laws, was amended:

- Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements and Reinforced Cellular Concrete 6/81*, 14/89*

- Bylaw on Technical Standards for the Design, Production and Realization of Structures Made of Prefabricated Elements Formed of Unreinforced and Reinforced Cellular Concrete 14/89*. [1]

There is also the National Standard: Prefabricated concrete elements HRN U.E3.050.

2. POLICY MEASURES

2.1 Materials from CDW

The legal framework for CDW is defined by the Act on Sustainable Waste Management (OG 94/13) and the Rules on construction waste management (OG 38/08) as well as the Rules on the method and procedures for managing waste containing asbestos (OG 42/07) and Instructions on handling waste containing asbestos (OG 89/08). Furthermore, the Croatian Waste Management Strategy introduced in 2005 covering the period until 2025 provides guides for strengthening CDW management. In addition to the Waste Management Strategy, a Waste Management Plan was devised for the period 2007-2015 aimed at implementing the goals of the overall Strategy, namely establishing waste management systems at regional level, increasing the separate collection of waste, pre-treating waste and fostering re-use and recycling. [6]

2.2 Prefabricated elements (with or without CDW materials)

With respect to innovation in construction, the government also supports participation of local research institutions and companies in EU-funded projects. Instances include ECO-SANDWICH, supported by the Ministry of Environment and Nature Protection and the Ministry of Construction and Physical Planning, among others, and led by the Faculty of Civil Engineering of the University of Zagreb. The project developed an innovative prefabricated wall panel using recycled construction and demolition waste and mineral wool produced with an innovative sustainable technology, achieving a reduction of primary energy consumption in the building stock due to its enhanced insulation and ventilation properties. [6]

2.3 Prefabricated construction

Housing policy in Croatia aims to boost the availability of dwellings, but also to ensure a good quality and affordable housing stock for all population groups. To this end, the government introduced a number of policy schemes.

The **Programme of State-subsidised Housing Construction** (Poticana stanogradnja - POS) was launched to offer housing at more favourable terms compared to market conditions, and boost the construction sector at the same time. The programme provides state funding for the construction of residential properties, with the local governments providing plots and covering the costs of connection to municipal infrastructure.

In 2013, the Ministry of the Economy also launched the **Strategic Guidelines for the Development of the Construction Sector** in order to strengthen its competitiveness and tackle some of the industry's main challenges. The five priority axes of the Guidelines are to strengthen the institutional and infrastructural support, provision to support research, development of human resources, improve access to finance, and strengthening the societal contribution of the construction sector.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT, the value of trade of prefabricated elements is € 347 Million in 2016. Export activities account 160 € Millions, while import account 186 € Million. The sold construction products in Croatia between 2012 and 2016 has growth at a rate (CAGR) of 7.9% for export and 3.7% on import [4].

On the export side, wood elements (47.1%) and concrete constructional goods (20.7%) hold the largest part of the exports. In the observed period, their growth rate in exports is 10% of prefabricated elements in wood, and 9% for prefabricated constructional concrete. Ceramics goods elements is the 3rd largest export goods, it account 17.6% of export and it's export trade growth with a rate of 1.2%.

On the import side, the ceramic and wood structural elements are the most imported ones. Their share on import is 35% for ceramic constructional goods, and 36.3% for wood structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramic items (+3%) and wood elements (+5.9%) are in growth. Concrete goods elements are the 3rd largest import goods, it account 25.8% of export and its export trade growth with a rate of 1.5%.

Approximately 72% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

CROAZIA TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	16.676.204	23.219.872	8,63%	14,48%
Ceramic constructional goods	26.987.455	28.314.017	1,21%	17,65%
Concrete, plaster structural elements	23.045.457	33.199.106	9,56%	20,70%
Wood Structural elements	51.332.530	75.662.427	10,18%	47,17%
TOTAL EXPORT	**118.041.646**	**160.395.422**	**7,97%**	**100,00%**
IMPORT	2012	2016		Share on Import
Cement, lime and plaster (ready mix)	3.817.236	5.248.367	8,29%	2,81%
Ceramic constructional goods	57.927.258	65.359.429	3,06%	35,00%
Concrete, plaster structural elements	45.505.437	48.298.259	1,50%	25,87%
Wood Structural elements	53.932.713	67.820.917	5,90%	36,32%
TOTAL IMPORT	**161.182.644**	**186.726.972**	**3,75%**	**100,00%**

3.2 Market conditions / costs and benefits

CROATIA- AGGREGATE PRODUCTION	2015	2014	2013	2012
Total Number of Producers (companies)	170	170	170	170
Total Number of Extraction Sites (Quarries and Pits)	250	250	250	250
Sand & Gravel (millions tonnes)	4	3	4	3
Crushed Rock (millions tonnes)	15	14	12	9
Marine Aggregates (millions tonnes)	0	0	0	0
Recycled Aggregates (millions tonnes)	0	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0
Total Production (millions tonnes)	**20**	**17**	**16**	**13**

Source: EUROPEAN AGGREGATES ASSOCIATION (UEPG)

The competitiveness of C&DW recycling could be improved with several operations, i.e. raising the price of raw materials, through taxation, and setting End-of-Waste criteria for certain C&DW fractions. Especially from a legislative point of view, Croatia is implementing its regulatory framework to foster the growth and sustainability of the chain. New CDW Rules to be introduced soon and National strategic programmes and EU funding priorities promote the establishment of treatment facilities. Another, there is a strong engagement of the Croatian Environment Agency in improving the system, accomplished by changes to the data management system announced [5] .

However factor such as Need for more (organized) places for CDW collection, insufficient selective separation facilities, and high costs of transportation and depositing can cause sharp increase in costs of C&D water recycled. According to Deloitte Market prices and operating costs of CDW sorting, recovery and recycling are still considered too high. In addition, Higher engagement of all stakeholders is needed [5].

3.3 Construction sector make up

The Croatian construction industry remained weak following the global and European financial crises. This decline was strongest for buildings, where production decreased by 53.4%, while production of civil engineering dropped by 39.4%. Furthermore, the number of firms operating in the broad construction sector decreased by 22.4% compared to 2008 reaching 31,048 in 2014. The total turnover of the broad construction industry also experienced a 44.9% decline compared to 2008 levels amounting to EUR 8.4 billion in 2013. Similarly, the gross operating surplus of the broad construction sector decreased by 49.7% since 2008, totaling EU 1.2 billion in 2013 [6].

In today's day and age, when we are faced with a large lack of energy sources, and a limited amount of fossil fuels, along with an increased price of energy, the demand for low-energy houses has grown.

Low-energy prefabricated houses are energy efficient houses. They are an example of sustainable construction, from the construction material which doesn't harm the environment with its production to their energy efficiency and rational use of energy, which is more and more expensive every day.

In Croatia, a low-energy house is defined as a house that uses a maximum of 40 kWh/m² of energy for heating. Such energy use can be clearly expressed with the equivalent use of 2.7 liters of fuel oil per m², so a low-energy house is also called a "three-liter house".

Prefabricated houses have a load-bearing wooden construction filled with mineral wool with a vapor membrane, closed on both sides with panel sheathing, over which a thermal façade is installed on the exterior, and on the interior, another panel is placed, which ensures better sound insulation. The width of the wooden construction, mineral wool, and type of panel depend on the construction system. More thermal insulation - ensures a greater energy efficiency and a lower coefficient of heat transferal. [7]

Figure 1. Example of Prefabricated house in Croatia [7]

3.4 Use of CDW materials for prefabricated elements

First example about the use of CDW materials for prefabricate elements is the prototype developed during the project ECO-SANDWICH. The product is an innovative ventilated prefabricated concrete wall panel with integrated mineral wool insulation; particularly, it consists of two precast concrete layers; recycled concrete aggregate and recycled brick aggregate is used in production of concrete for the inner and outer layer respectively (around 50% of total aggregates needed in production of concrete is obtained from recycled CDW, and the exact quantities were entered in the model). [8]

Figure 2. ECO-SANDWICH Panel [8]

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CYPRUS

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Please refer to Deliverable D1.1 (Cyprus).

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Please refer to Deliverable D1.1 (Cyprus).

1.3 Prefabricated elements (with or without CDW materials)

The following Cypriot Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of precast concrete elements:

CYS EN 12602:2016 [1CY] sets the requirements for the use of Autoclaved Aerated Concrete (AAC) (including AAC made from recycled AAC) in structural (such as load bearing walls, retaining walls, roofs, floors, beams and piers) and non-structural (such as non-load bearing walls, cladding without fixtures for external facades of buildings, small box culverts and noise barriers) prefabricated elements.

CYS EN 13369:2013 [2CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for unreinforced, reinforced and pre-stressed precast concrete products made of compact lightweight, normal-weight or heavy-weight concrete. It allows the use of crushed recycled aggregate (up to 10% in weight of the total content of aggregates in the concrete mix) obtained from precast concrete products manufactured in the same factory. The above replacement level can be increased up to 20% provided certain conditions are met. Recycled coarse aggregates from external sources which are composed of pure concrete debris can be used under the same conditions described above provided the source and mix properties of the crushed concrete are known by the manufacturer. It should be noted that CYS EN 13369:2013 [2CY] does not allow the use of recycled aggregates in concrete for which durability requirements are higher than those for the concrete from which they originate (This does not apply for exposure classes X0, XC1 and XC2 as defined by CYS EN 206:2013+A1:2016 [3CY]).

CYS EN 1168:2005+A3:2011 [4CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast hollow core slabs made of reinforced or pre-stressed normal-weight concrete.

CYS EN 12794:2005+A1:2007 [5CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete foundation piles manufactured and stored in a factory, transported and finally installed on a construction site.

CYS EN 12839:2012 [6CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete products (reinforced or pre-stressed with or without fibres) to be used together or in combination with other elements in order to erect fences such as boundary fences.

CYS EN 12843:2004 [7CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete poles and masts (reinforced or pre-stressed) to be used for overhead electrical lines, telecommunication lines, overhead electrical lines (railways and trams), supports for lighting, supports for loudspeaker installations, antenna and telecommunication poles, supports for wind turbines and similar installations.

CYS EN 13224:2011 [8CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast ribbed floors or roofs made of reinforced or pre-stressed normal-weight concrete.

CYS EN 13225:2013 [9CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast linear elements such as beams, columns and frames made of reinforced or pre-stressed lightweight or normal-weight concrete to be used in the construction of buildings and other structures (except bridges).

CYS EN 13693:2004+A1:2009 [10CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for special precast roof elements made of reinforced or pre-stressed normal-weight concrete to be used in the construction of buildings.

CYS EN 13747:2005+A2:2010 [11CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast floor plates made of reinforced or pre-stressed normal-weight concrete to be used together with cast-in-situ concrete in the construction of composite floor slabs.

CYS EN 13978-1:2005 [12CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast reinforced concrete garages built as monolithic units or as kits of single sections with room dimensions in precast concrete factories.

CYS EN 14843:2007 [13CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast (reinforced or pre-stressed) concrete monolithic stairs as well as precast concrete elements such as individual steps used to make reinforced or pre-stressed concrete stairs. It is applicable to structural stairs for indoor or outdoor use.

CYS EN 14844:2006+A2:2011 [14CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for large (structural) and small (non-structural or light structural) box culverts of monolithic construction and rectangular cross-section designed as continuous elements with a joint detail shaped to allow the possible incorporation of sealing materials.

CYS EN 14991:2007 [15CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast foundation elements (such as columns with integrated foundation elements, pocket foundation elements or sockets) made of reinforced normal-weight concrete to be used in the construction of buildings.

CYS EN 14992:2007+A1:2012 [16CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for prefabricated walls made of lightweight, normal-weight or fibre (steel, polymer or other fibres) reinforced concrete.

CYS EN 15037-1:2008 [17CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast beams made of reinforced or pre-stressed normal-weight concrete to be used together with blocks with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

CYS EN 15037-2:2009+A1:2011 [18CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of lightweight or normal-weight concrete to be used together with precast concrete beams conforming to CYS EN 15037-1:2008 [17CY] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

CYS EN 15037-3:2009+A1:2011 [19CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of clay to be used together with precast concrete beams conforming to CYS EN 15037-1:2008 [17CY] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

CYS EN 15037-4:2010+A1:2013 [20CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of expanded polystyrene (EPS) to be used together with precast concrete beams conforming to CYS EN 15037-1:2008 [17CY] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

CYS EN 15037-5:2013 [21CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for lightweight blocks to be used together with precast concrete beams conforming to CYS EN 15037-1:2008 [17CY] with or without cast-in-situ concrete as formwork during the construction of a beam-and-block floor systems.

CYS EN 15050:2007+A1:2012 [22CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast structural elements made of reinforced or pre-stressed normal-weight concrete and produced in a factory to be used as deck elements in bridge construction (footbridges as well as road and railway bridges). Deck elements can either be single elements from which the deck is composed (beams, slabs, ribbed or cellular elements) or elements which form a segment of the entire deck.

CYS EN 15258:2008 [23CY] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast elements made of plain, reinforced or pre-stressed normal-weight concrete to be used for the construction of retaining walls.

The following Cypriot Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated timber elements:

CYS EN 336:2013 [24CY] specifies two classes of permitted cross-sectional deviations from target sizes for structural timber of softwood or hardwood species. In addition, it specifies the moisture content to be used as a reference point for measuring sizes and provides average values for changes in size as a result of changes in moisture content.

CYS EN 338:2016 [25CY] specifies a system of strength classes to be used in design codes. It provides characteristic strength, stiffness and density values for each class. It is applicable to all softwood and hardwood species of timber used for structural applications.

CYS EN 14081-1:2016 [26CY] states the requirements (mechanical resistance, fire resistance, reaction to fire release of dangerous substances, biological durability and geometrical data) for structural timber with rectangular cross-sections (either visual or machine graded) and shaped by sawing, planning or other methods.

CYS EN 14081-2:2010+A1:2012 [27CY] states additional requirements to those in CYS EN 14081-1:2016 [26CY] for initial type of testing of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in CYS EN 336:2013 [24CY].

CYS EN 14081-3:2012 [28CY] states additional requirements to those in CYS EN 14081-1:2016 [26CY] for factory production control of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in CYS EN 336:2013 [24CY].

CYS EN 14250:2010 [29CY] states the requirements (material, product and documentation), testing methods and evaluation of conformity for prefabricated structural members (such as trusses for roofs, walls and floors, frames, composite beams and girders) to be used in construction of buildings made from solid structural timber with or without finger joints assembled with punched metal plate fasteners.

CYS EN 15644:2008 [30CY] states the specifications and requirements for prefabricated stairs in which the components contributing to the fulfilment of mechanical resistance and stability are made of solid wood (traditionally designed stairs).

CYS EN 15736:2009 [31CY] describes a test method for determining the withdrawal behaviour of punched metal plate fasteners.

CYS CEN/TS 15680:2007 [32CY] provides test methods for evaluating the mechanical performance of prefabricated timber stairs.

The following Cypriot Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated aluminium elements:

CYS EN 507:2000 [33CY] states the requirements (general, materials and products), testing methods and designation (sheet, coil, slit coil, cut length, roof panel, clip or tile) for all discontinuously laid and fully supported aluminium sheets with or without additional organic coatings to be used for pitched roofs. Products can be pre-formed (prefabricated), semi-formed or as strip, coil and sheet for on-sit-formed applications.

CYS EN 508-2:2008 [34CY] states the requirements (general, materials and products), testing methods and designation for all discontinuously laid self-supporting external profiled aluminium sheets with or without additional organic coatings to be used for roofing.

CYS EN 14782:2006 [35CY] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made self-supporting metal (copper, zinc, steel, stainless steel and aluminium) sheets and tiles with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining. It also covers ceiling and soffit applications and cassettes.

CYS EN 14783: 2013 [36CY] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made fully-supported metal (copper, zinc, lead, steel, stainless steel and aluminium) coil, strip and flat sheets with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining.

CYS EN 13830:2015 [37CY] states the product characteristics, testing methods and assessment and verification of constancy of performance of curtain walling systems to be used as part of the building envelope.

1.4 Prefabricated construction

Cyprus has adopted the following Cypriot Standards/European Norms and National Documents (Annexes) for structural design of housing buildings which also cover the design of prefabricated structures:

Basis of structural design and loading

CYS EN 1990:2002 [38CY]

National Annex to CYS EN 1990:2010 [39CY]

CYS EN 1991-1-1:2002 [40CY]

National Annex to CYS EN 1991-1-1:2002 [41CY]

CYS EN 1991-1-2:2002 [42CY]

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CYS EN 1991-1-6:2005 [50CY]

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CYS EN 1991-1-7:2006 [52CY]

National Annex to CYS EN 1991-1-7:2006 [53CY]

CYS EN 1991-3:2006 [54CY]

National Annex to CYS EN 1991-3:2006 [55CY]

Structural work of reinforced, pre-stressed or plain concrete

CYS EN 1992-1-1:2004 [56CY]

National Annex to CYS EN 1992-1-1:2004 [57CY]

CYS EN 1992-1-2:2004 [58CY]

National Annex to CYS EN 1992-1-2:2004 [59CY]

Structural work of steel

CYS EN 1993-1-1:2005 [60CY]

National Annex to CYS EN 1993-1-1:2005 [61CY]

CYS EN 1993-1-2:2005 [62CY]

National Annex to CYS EN 1993-1-2:2005 [63CY]

CYS EN 1993-1-3:2006 [64CY]

National Annex to CYS EN 1993-1-3:2006 [65CY]

CYS EN 1993-1-4:2006 [66CY]

National Annex to CYS EN 1993-1-4:2006 [67CY]

CYS EN 1993-1-5:2006 [68CY]

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CYS EN 1993-1-12:2007 [82CY]

National Annex to CYS EN 1993-1-12:2007 [83CY]

CYS EN 1993-5:2007 [84CY]

National Annex to CYS EN 1993-5:2007 [85CY]

CYS EN 1993-6:2007 [86CY]

National Annex to CYS EN 1993-6:2007 [87CY]

Structural work of composite steel and concrete

CYS EN 1994-1-1:2004 [88CY]

National Annex to CYS EN 1994-1-1:2004 [89CY]

CYS EN 1994-1-2:2005 [90CY]

National Annex to CYS EN 1994-1-2:2005 [91CY]

Structural work of timber

CYS EN 1995-1-1:2004 [92CY]

National Annex to CYS EN 1995-1-1:2004 [93CY]

CYS EN 1995-1-2:2005 [94CY]

National Annex to CYS EN 1995-1-2:2005 [95CY]

Structural work of masonry

CYS EN 1996-1-1:2005 [96CY]

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Geotechnical work and foundations

CYS EN 1997-1:2005 [104CY]

National Annex to CYS EN 1997-1:2005 [105CY]

CYS EN 1997-2:2007 [106CY]

National Annex to CYS EN 1997-2:2007 [107CY]

Seismic aspects

CYS EN 1998-1:2004 [108CY]

National Annex to CYS EN 1998-1:200 [109CY]

CYS EN 1998-3:2005 [110CY]

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CYS EN 1998-5:2004 [112CY]

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Structural work of aluminium

CYS EN 1999-1-1:2007 [114CY]

National Annex to CYS EN 1999-1-1:2007 [115CY]

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National Annex to CYS EN 1999-1-3:2007 [119CY]

CYS EN 1999-1-4:2007 [120CY]

National Annex to CYS EN 1999-1-4:2007 [121CY]

CYS EN 1999-1-5:2007 [122CY]

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2. POLICY MEASURES

2.1 Materials from CDW

Please refer to Deliverable D1.1 (Cyprus).

2.2 Prefabricated elements (with or without CDW materials)

Please refer to Paragraph 2.2.3 below.

2.3 Prefabricated construction

Cyprus lies in a very active earthquake zone. Consequently, cast-in-situ reinforced concrete frames are the norm for all types of buildings including low-rise residential ones. Resistance to lateral earthquake loads is achieved by the use of shear walls and lift/staircase cores. Despite this, over the last 20 years a number of prefabricated construction companies were established which offer both temporary accommodation (such as construction site office huts) and permanent low-rise housing solutions which comply with the current provisions of EN 1998 Eurocode 8.

Modern prefabrication methods used in Cyprus include:

- Modular Construction (light metal frame)
- Timber Prefabricated Systems (SIPS or Open Panel Frames)
- Light-Gauge Steel Construction

Modular Construction transfers most of the construction site activities into the factory premises of the prefabrication company. The technique consists of building large modules that are designed to include all services (electrical, mechanical and water/sewage systems) and external/internal finishes. Available modular construction units in Cyprus cover a large spectrum of applications such as: security/guard booths, construction site office huts, shops, temporary and permanent accommodation, schools and medical facilities as shown in Fig. 1 (a-f) [124CY].

a) Security booth

b) Construction site office hut

c) Bookshop

d) Temporary (holiday) accommodation

e) Permanent accommodation

f) Permanent accommodation

g) School

h) Medical facility

Fig. 1 (a-h): Examples of modular construction (light metal) in Cyprus [124CY]

Timber Prefabricated Systems in Cyprus are either SIPS or Open Panel Timber Frames as shown in Fig. 2 (a-d).

a)

b)

c)

d)

Fig. 2 (a-d): Examples of prefabricated timber houses in Cyprus.

Light-Gauge Steel Construction is very similar to Timber Frame Construction as shown in Fig. 3 (a-b) [125CY]. Essentially, the timber frame members are replaced by cold formed thin steel sections (i.e. sections which are formed or shaped at room temperature). Cold formed steel is shaped by passing thin sheets of steel through a series of rollers. The shape of the sheet is slightly changed by each roller. As a result of this process, the original flat sheet of steel is converted into an I or C cross-section. The steel used is coated with zinc (known as galvanized steel) or a mixture of zinc and aluminium (known as zincalume or galvalume steel) to protect it from corrosion. The thickness of coating can be varied depending on the environment. Typically, marine environments require the most protection, whereas dry and arid regions the least. The thicknesses of steel used ranges from 1 to 3 mm for structural elements and 1 to 2 mm for non-structural elements. Like Timber Frame Construction, a light-gauge steel frame is first constructed and then clad with dry sheeting on both sides to form a load bearing wall [126CY].

Light-Gauge Steel Construction offers a number of advantages when compared to traditional Timber Frame Construction. These are summarised below [126CY]:

- Its light weight allows for fast construction without the need for heavy tools or equipment.
- Its higher strength compared to timber allows for larger spacing between members resulting in faster completion times.
- It is able to take almost any kind of shape or form.
- It can be clad and insulated using a large variety of materials
- It can be easily changed or modified during its design life.
- It is non-combustible.

However, it should be noted that steel experiences a rapid loss of strength when exposed to elevated temperatures (fire). Consequently, adequate fire protection must be provided. In addition, light-gauge steel structures do not offer the same level of sound insulation compared to Timber Frame Construction [126CY]. Typical examples of completed light-gauge steel houses in Cyprus are shown in Fig. 4 (a-d) [127CY].

a) b)

Fig. 3 (a-b): Examples of Light-Gauge Steel Frame in Cyprus [125CY]

a) b)

c) d)

Fig. 4 (a-d): Examples of Light-Gauge Steel houses in Cyprus [127CY]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

The Statistical Service of Cyprus (CYSTAT) [128CY] does not seem to provide any specific information when it comes to exports/imports of prefabricated elements or raw materials for making prefabricated elements. However, it should be reasonable to assume that most raw materials (galvanized steel and timber) are imported and manufactured prefabricated elements are largely destined for the domestic market.

3.2 Market conditions / costs and benefits

During a period of 10 years (2000-2010) modern prefabrication techniques for low-rise buildings were introduced in Cyprus. This was mainly due to high demand for new homes as a result of strong and sustained economic growth. Despite the 2012-2013 economic crisis and its negative effect on the construction industry, modern prefabrication techniques are still used today and slowly becoming more and more popular. This is because they are viewed by a number of architects, engineers and developers as the best option for achieving consistently high standards, shorter completion times and lower construction costs compared to traditional on site methods of construction.

3.3 Construction sector make up

The prefabricated construction sector is made of Light Steel Modular, Light-Gauge Steel and Prefabricated Timber (SIPS or Open Frame) Construction manufacturers. A number of precast concrete companies exist, however these are not involved in the production of load bearing elements for prefabricated houses (cast in-situ reinforced concrete frames are the norm for all types of low and medium-rise buildings). Instead, they produce a variety of products such as bricks & blocks, pipes and drainage systems, water storage & treatment tanks, box culverts, paving blocks, sea & river defence units, pontoons, sub-sea bases, transmission poles, vehicle safety barriers and street furniture & bollards.

3.4 Use of CDW materials for prefabricated elements

There is no developed market for the use of CDW recycled materials in prefabricated elements (or in any other applications) in Cyprus. In addition, recycling of CDW is considered by most construction contractors, which are struggling to keep their businesses afloat (due to the financial crisis between 2008 and 2014) as an extra cost they have to avoid paying. However, the establishment of two collective and three-single member CDW management systems has acted as a driver for increasing CDW recycling [129CY]. Currently, CDW material which is recycled in accordance with the requirements set by the above management systems is used for "low-value" applications such as backfilling operations [130CY].

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CZECH REPUBLIC

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

- Waste Act 185/2001 and Waste Act 185/2011
- City Planning and Building Code Act 183/2006 (demolitions only their permissions, must undertake pre-demolition audit and CDW management plan)
- Act 100/2001 on Assessment of Impacts on Environment (examination of impacts on health, environment, ecosystem, land, water, climate, natural resources, etc.)
- Act 360/1992 on performance of architects, engineers and technicians in construction industry
- Decree 381/2001 (establishment of waste catalogue, the list of hazardous wastes, lists of waste used for export and import, details regarding waste management)
- Decree 432/2003 (requirement to announce work with asbestos and biological elements)
- Decree 499/2006 (documentation of buildings and other construction activities)
- Decree 294/2005 (requirements on landfilling and using waste for backfilling)
- Decree 137/1998 (general technical requirements for construction)
- Government Decision 197/2003 on Waste Management Plan of Czech Republic
- Government Decision 163/2002 on technical requirements of particular construction products.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

- Act 22/1997 on Technical Requirements of Products (it is possible to use specific CDW as aggregates for railway construction, as backfilling material for disposal of mines, construction fill, rehabilitation of mine dumps and as railway ballast and service roads for mining operations; it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials)
- Act 634/1992 on Consumer Protection (seller is obliged to sell products in required quality)
- Act 258/2000 on Public Health Protection (a producer or importer of a product, which will come in contact with water directly, is obliged to provide accreditation according to specific rules)
- Government Decision 591/2006 on minimum requirement regarding the safety and health protection during the construction activities

1.3 Prefabricated elements (with or without CDW materials)

- Norm 12620 – aggregate for concrete
- Norm 13043 – aggregate for asphalt mixtures

- Norm 1355-1 – Porous aggregate for concrete and mortar
- Norm 13055-2 – Porous aggregate for asphalt mixtures
- Norm 13130 – aggregate for mortar
- Norm 13450 – Aggregates for railroads
- Act 22/1997 on Technical Requirements of Products (it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials).

1.4 Prefabricated construction

- Norm 13369 – Common regulation for concrete prefabricates
- Act 22/1997 on Technical Requirements of Products (it is allowed to use recycled materials in construction under the condition that the material meets the requirements of primary materials)
- Act 102/2001 on general safety of products
- A panel building is an object constructed by utilization of the standardized structural wall system from prefabricated panels. List of standardized structural systems of panel houses is stated in Government Regulation No. 299/2001. This list defines 53 main standardized structural systems which have different specific regional variations.

2. POLICY MEASURES

2.1 Materials from CDW

- Implementation program for CDW – the aim of it is to improve CDW management according to CDW management hierarchy (prevention, re-use, material recovery, energy recovery and disposal
- The previous targets set for the Czech Republic revolved around the rate of recycling. The first target was set to recover/recycle 50% of CWD produced by December 31, 2005. The next target raised the percentage to 75% for waste produced by December 31, 2012. Both targets were met. Current targets revolve around the percentage given by the Waste Framework Directive – 70% of CDW by weight should be recovered, re-used, recycled, or utilized otherwise.
- Methodological guideline No.6 regarding sampling of waste, bulletin of MoE No.4/2008
- Methodological guideline for evaluation of infusibility of waste, bulletin of MoE No.12/2002
- Methodological guideline for description of waste, bulletin of MoE No.2/2007
- Methodological guideline No.9 regarding the CDW management, bulletin of MoE No.9/2003
- Methodological guideline No.4 regarding the CDW generation and its management, bulletin of MoE No.3/2008
- Raw material policy – agreed by the Decree 1311/1999

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

State support of housing and development of industry subjects. These programs encourage building under several conditions:

- Use of material with minimal energy use and minimal CO_2 emissions
- Use of lightweight materials
- Use of renewable sources and recycled materials in large extent
- Use of constructions allowing easy separation of materials and their removal.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Due to a lack of raw materials in the Czech Republic, secondary materials (including CDW) constitute a significant part of material base for all sectors in industrial production. The Czech market of secondary materials is in terms of international trade fully integrated, often resulting in significant changes in prices. This is the primary reason that the domestic manufacturing industry is not able to absorb all the offers of domestic recyclers. The ferrous scrap market is very much export related. The domestic generation of scrap metal is almost 3.5 million tonnes, with 2 million of this being exported. Overall, the ratio of exports and imports is 3:1.

Czech export-oriented trade of secondary materials is an effective solution to the surpluses in the domestic market, but it also means exposing the market to foreign trade conditions, which often follows a boom sales slump with all the economic consequences.

Within Czech Republic Secondary materials are considered materials, products, wastes that after treatment have qualities of materials used for production and together with the raw materials enter the production process

The particular data about export/import of prefabricated elements made from CDW are not available. CDW waste in the Czech Republic is processed mainly into recyclates, which can be later on used in production of new construction elements. But, numbers of final prefabricated elements are not available, less so data about import/export of these elements. Regarding the fact the production of prefabricated elements from CDW is not much developed in the Czech Republic, we can assume that the foreign trade rate of prefab elements is negligible in the Czech Republic.

3.2 Market conditions / costs and benefits

The recycling of CDW is financially beneficial if there is a recycling facility near the place of waste arising. If this is not the case, it is more than likely that the waste will end up at a landfill. One of the causes of inefficiencies of the secondary materials (including CDW) is the lack of information regarding the supply and demand in the market. The aim of the Raw Materials Policy Action plan is to create a catalogue of entities that come into contact with secondary materials and help to provide information about the availability within the market. The catalogue should contain information about entities (including brokers), secondary material prices and quantities traded and specification of the market. [1]

Landfill charge for CDW (market price + tax)

The charge for disposal in landfills consists of a compensation to the municipality in which territory the landfill is based. The charge is collected by the landfill operator who transfers the basic component to the municipality. The amount of charge is laid down in the Act on Waste. At the time of writing, the charge for landfilling mixed CDW is 19 EUR/tonne and EUR 225/tonne (in 2015) for hazardous waste.

The main goal of the charge is to encourage the use of more environmentally friendly ways of waste disposal. The amount of charge should economically disadvantage the waste landfilling and promote the waste reuse and recycling. For this reason, until all landfills are closed, charges for landfilling will be continuously increased. The typical landfill prices for certain CDW materials (per tonne) are shown in Table 1.

Table 1. Prices for various waste materials at Rožany Landfill, prices are excluding VAT, and are converted using the current conversion rate of 1 CZK = 0,037 euro (08/04/2015) [2]

Catalogue number	Waste material	Total (Eur/tonne)
170101	Concrete fraction of up to 10 cm	**5.92**
170101	Concrete fractions 10-50 cm	**14.8**
170102	Bricks fraction of up to 10 cm	**5.92**
170102	Bricks fractions above 10 cm	**18.5**
170103	Tiles and ceramics	**18.5**
170107	Rubble fraction up to 10 cm	**5.92**
170107	Rubble fractions 10-50 cm	**14.8**
170504	Soil and stones up to 10 cm	**5.92**
170504	Soil and stones over 10 cm	**7.4**
170904	Mixed construction and demolition wastes up to 50 cm	29.6

Construction from CDW

While from the buildings built before 1900 can be reused over 80% of components, the situation with newer constructions is more complicated. There are much more glued and firmly connected parts that cannot be separated without being damaged. Therefore, the next step how to reduce the quantity of demolition waste in future, is to employ easily dismantled buildings. Another way are constructions of buildings directly from secondary raw materials. In Europe, there are already several such projects. However, in the Czech Republic no similar project like this does occur. According to a recently published waste prevention programs, in the Czech Republic almost all construction and demolition waste is re-used, but it is mainly reuse of excavated soil and debris during backfill or other construction work.

One of the basic conditions for successful recycling of CDW is also competitiveness of recycled materials, which is based primarily on strict adherence to their quality especially in accordance with the relevant CSN EN (Czech technical norms) applicable to the aggregate.

Prefabricated elements potential

In order to make recycled aggregate competitive to natural aggregate and to close the building materials cycle by recycling CDW in high-grade applications, it is necessary to increase its market value through properties, application possibilities and price.

Prefabricated elements containing recycled CDW are perceived as a new technological concept for sustainable development in construction sector. It dramatically reduces costs in spheres where it is necessary and needed and reduce overall financial costs. It substantially protects environment and reserve raw materials. Due to recyclability of this materials, the source of material is inexhaustible and principles of circular process of materials are employed.

Benefits:

- energy savings – houses built using prefab elements typically require less energy to heat because of increased levels of insulation fitted in the walls and roof, and also less air leakage from the building.
- construction waste – the amount of waste produced is likely to be reduced because factory materials can be ordered to exact specifications, and there is a lower risk of on-site spoilage, e.g. through wet weather. However, there is little research confirming such reductions.
- transport – building constructions in factories may reduce the total number of trips to a building site. This is of growing importance as more house building takes place on 'brownfield' sites in inner-city areas. Little detailed analysis has been conducted to date on transport benefits, but they are likely to vary considerably depending on the distance between the building site and the factory.

Obstacles:

- limited application of prefab elements in today's construction sector
- relatively enough primary material sources – slow down demand for products using CDW
- unstable quality of final product from CDW, breaking rules for sorting and separating
- week support from public sector.

3.3 Construction sector make up

The Czech Republic's construction industry is expected to recover between 2016 and 2020 due to investment in road, rail and energy infrastructure expansion projects [3]. The industry's performance struggle in previous years, undergoing only slow growth from 2011 to 2015. A weak economy undermined by inadequate demand, low-business confidence and an uncertain political scenario led to a flat out-turn, with the industry registering a compound annual growth rate (CAGR) of just 1.18% during the period.

According to the Czech Statistical Office, the country witnessed a slump in its construction industry as evident by the fall in the number of building permits issued. A decrease of 6.5% was registered in 2015 including both residential and non-residential buildings.

The sector is, however, expected to register higher growth starting this year, on strong economic cues such as an increase in export demand and better employment opportunities, with investments anticipated in the industrial and residential segments. It is also anticipated to receive a boost through the government's National Development Strategy 2011-2016, National Tourism Development Strategy 2014-2020 and the European Union (EU) Cohesion Policy 2014-2020 (CZK 594.8 billion (EUR 21,716 billion) support from EU structural funds program). All these schemes are expected to attract investments in the public and private sector. The industry is expected to record a forecast-period nominal CAGR of 2.12%.

Prefabricated construction products

In the Czech Republic, the following prefabricated products are being produced:

- Floors & roofs
- Walls
- Columns & beams
- Staircase
- Girders
- Lintels
- Paving slabs
- Others (door & window components, manholes, and water & sewer system products)

3.4 Use of CDW materials for prefabricated elements

Recyclates

In the Czech Republic, the principle of construction materials recovery from waste consists of mechanical treatment, which means crushing and screening and classification of materials according to their technical, quality and market requirements between products or waste. Recyclates adequately represent natural materials, moreover, are comparably priced. Association for recycling of building materials distinguish various recycled materials for concrete, asphalt and brick.

In the Czech Republic, as specified products (materials) for conformity assessment under the Act no. 22/1997 it is possible to use:

- Aggregates for railway construction (according to Government Regulation163/2002) Appendix 2 group of construction products no. 9, the sequence number 16);
- Construction product used as backfilling material for disposal of major and historical mine works (according to Government Regulation 163/2002, Annex no. 2 group of construction products, no. 9, serial number 13);
- Granules used as railway ballast and service roads for mining operations, granulate in hoppers of quarries for construction fill, granules for the rehabilitation of mine dumps (according to Government Regulation 163/2002) [4]

The regulations allow the use of recycled materials in some phases of construction, but only under conditions that meet the criteria for primary materials.

Recycled brick

This recyclate occupies the first place in terms of the amount of recycled building materials in recycling lines. The resulting recycled material is generally obtained in three fractions: 0-16 mm, 16-32 mm and 32-80 mm. Various fractions of the resulting recycled material allow its use for the manufacture brick-concrete which has a wide range of uses: as filling masonry monolithic structures, for the production of precast elements for preparing vibration-pressed blocks, as fillers in masonry mortar using a small fraction, and air or hydraulic lime, manufacturing unfired bricks molded from a blend of recycled brick having a fraction of 0-16 mm or clay with 10% admixture of cement or without cement admixture. This recycled material offers significantly greater possibility of use than so far is implemented in Czech Republic.

Recycled concrete aggregates

The use of recycled concrete for bituminous mixtures for construction and repair of bituminous pavement can be performed if the requirements and working procedures prescribed in the relevant standards are met, for example Czech norm CSN 73 6121 – Compaction of the asphalt layer.

The use of recycled concrete is relatively widespread, such as in the sub-base layers of cemented roads, protective layers of roads and track bed (as mechanically reinforced soil), and mainly as a substitute for natural aggregates in structural concrete lower classes.

Recyclate from asphalt

Consumed mainly for the production of bituminous mixtures used for construction and surface treatment of roads or other structures.

Standards for the quality of recycled materials

Unlike in some other EU countries, the Czech Republic does not apply any technical standards for the quality of recyclates.

There are currently no requirements for public and private projects for construction products regarding recycled contents and recyclability applied in Czech Republic.

Prerequisite for meaningful functioning recycling is an existing demand for recycled materials. Currently, the majority of sales of products consists of easy processed waste: crushed brick and concrete aggregate used to backfill and subbase construction engineering and technical networks. Using products with a high percentage of recycled materials it is possible to support more demanding forms of recycling.

Recycled construction materials - are the material outputs of non-hazardous CDW and wastes similar to CDW from facilities used for the CDW treatments based on shredding and separation of different fractions.

- *Recycled concrete* - recycled aggregate obtained by crushing and sorting concrete and concrete products, the volume is determined according to EN 933-11.
- *Recycled road material* - recycled aggregates obtained by crushing and sorting concrete, asphalt or cemented layers of hydraulic binder possibly unbound layers and coarse-grained soils.
- *Recycled masonry* - recycled aggregates obtained by crushing and sorting of burnt and unburnt bricks elements (e.g. Bricks, tiles, lime elements, aerated concrete blocks) and concrete.
- *Mixed Recycled CDW* - recycled, obtained by crushing and sorting CDW, which is not considered aggregate according to EN 12620 + A1, EN 13043 or EN 13242 + A1. Recycled composite is used mainly as a substitute earth for the construction of embankments and subgrade treatment of roads according to CSN 73 6133, backfilling trenches, landscaping and so on.
- *R-material* - asphalt mix, reclaimed asphalt layers by milling or grinding parts of asphalt. This material is designed mainly for use in the hot asphalt mixture, which is considered with great use in the future.
- *Recycled asphalt* - recycled from the roads. The material of the pavement, which is used in Czech Republic for unbound base courses of roads with a low traffic load, and similar [5].

The MoE is planning to increase the level of CDW recovery/recycling with the new Environmental Operational Programme 2014 –2020 [6].

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DENMARK

1. TECHNICAL REGULATION AND LEGISLATION

Information included in the main document D1.4.

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Information included in the main document D1.4.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Denmark has not implemented EN 206:2013 where the recommendations for the use of recycled aggregate was introduced and specified any national implementation to this. In the Danish application standard to EN 206-1, DS 2426:2011 with an amendment from 2013 it is specified that "Crushed concrete and masonry shall be sorted according to the requirements for fine and coarse aggregate according to EN 12620. " The same requirements as for normal aggregate apply. For exposure classes other than X0 and XC1, special Danish requirements on with regard to alkali silica reactivity and frost-resistance (where relevant) also has to be fulfilled. No guidance on maximum amount of recycled aggregate is given.

1.3 Prefabricated elements (with or without CDW materials)

For precast concrete products covered by harmonized standards the rules according to EN 13369 described in Deliverable D.2.1 – section 3.2 are applied.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

Information included in the main document D1.4.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

No specific information has been found.

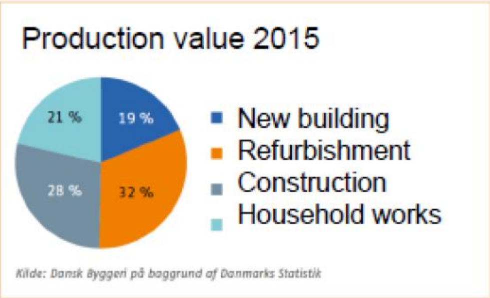
3.2 Market conditions / costs and benefits

No specific information has been found.

3.3 Construction sector make up

The total production value of the Danish construction sector is estimated to be DKK 163.8 billion (EUR 22 billion) in 2016. This is a significant decrease since year 2000 with a production value of DKK 176.2 billion (EUR 23.6 billion).
Weak growth in the new building sector is expected for 2015 and the production value is estimated for the following year to be on the level of DKK 39.5 billion (EUR 5.3 billion).

The number of construction enterprises in 2013 was 15 837 (Eurostat, 2015). The construction sector represents 5 % of the economy and employs about 150 000 people and it has great potential for growth.



3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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ESTONIA

1. TECHNICAL REGULATION AND LEGISLATION

The European Regulation (EU) No 305/2011 on Construction Materials, has been transposed at national level by the Regulation "**Requirements to the building materials and construction products, and procedure for attestation of conformity**" of the Minister of Economic Affairs and Communications in force since 2013. The regulation establishes the requirements for the list of mandatory declared characteristics and conformity assessment procedure for building materials and construction products. [1]

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

There is no specific technical regulation and legislation in place for the CDW, while the management of CDW is well articulated in the local waste management rules which are issued at municipality level. CDW therefore, is regulated at municipality level with the obligatory rules laid down in the local government waste management rules (Waste Act, Art.71). The local waste management rules are governed by the provisions of the National Waste Management Plan as well as the Regional Waste Management Plans. [2]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The Estonian building product standard **2325-CPD-0038**, following the specification of EU standard **EVS-EN 13242:2006+A1:2008**, is applied for recycled aggregates. However, this standard applies to all natural, artificial or recycled materials for construction purposes. This means that the requirements set by this standard are high for recycled aggregates, compared to the natural material.
The Waste Recycling Competence Centre is putting forward a plan to establish certification criteria for crushed concrete for the production of recycled aggregates. This endeavor is still at the planning stage but the Competence Centre would like to speed up the process. [2]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

Construction activities in Estonia are governed by two main pieces of legislation, namely the new Building Act and the Planning Act, revised and adopted in 2015.
The Building Act (Ehitusseadustik) covers aspects related to the design construction, operation and maintenance of buildings, and is structured into two main parts, namely a general section and a special one detailing provisions for major special construction works. The general section details the basic requirements for buildings and construction works (e.g. mechanical resistance, fire resistance, accessibility for disabled users, etc.), the obligations of persons operating in the field of construction, design requirements, procedure of construction notice and building/use and

occupancy permit. The 'special' section governs aspects related to energy efficiency requirements, the set-up of protection zones, electrical installations and provisions regarding the construction of roads, railways, public water bodies and pipes, among others.
Moreover, the **Planning Act** (Planeerimisseadus) sets out the principles and requirements for planning, so as to achieve long-term sustainable and balanced spatial development, land use, and built environment. Namely, planning principles are defined at the national, regional and local government levels. [3]

Estonian Woodhouse Association in association with Estonian University of Life Sciences and the Tallinn University of Technology Standards, have prepared Standards for log houses. The standards are recommended minimum requirements for heated log houses produced in Estonia.
The standards include requirements for the quality of materials and the construction process in conformity with general building requirements.
The standards are applicable to both solid log and glue-laminated log buildings made as handcrafted as well as manufactured by machines, and they are valid at the moment of the delivery of the building. [4]

2. POLICY MEASURES

2.1 Materials from CDW

In order to address the current situation and in an effort to overcome the apparent barriers in improving (a) the quality of recycling and (b) the market of CDW recycled products (e.g. recycled aggregates), the waste management sector in Estonia through its Waste Management Association initiated the creation of a **Waste Recycling Cluster** (eventually becoming the **Recycling Competence Centre**). [5]
The activities of the Recycling Competence Centre are mainly focused on the development of different waste recycling projects (incl. international projects), trainings for all stakeholders in waste management/recycling and sharing internationally the experiences of Estonian companies in waste recycling. Further areas of focus include the development of standards and a certification scheme for recycled aggregates.
The Recycling Competence Centre has been successful in establishing partnerships with other cluster networks and recycling associations in the EU (e.g. the Austrian Association for the Recycling of Building Materials - BRV) as well as an extensive network of partners in the Nordic countries, especially Norway, Finland and Sweden. The wide partner network has facilitated knowledge sharing and dissemination, among the international and national partners and the Recycling Competence Centre, and has led to increased uptake of the latest developments and technologies in the sector.
The academic partners in the Recycling Competence Centre, namely the 3 Universities taking part in the initiative, are mainly responsible for the dissemination of research results and demonstration of innovative practices in CDW management and especially the utilization of recycled aggregates in different construction projects (e.g. the construction of a test road with recycled materials). [6] [8]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

Housing policy in Estonia is under the responsibility of the construction and housing sector of the Ministry of Economic Affairs and Communications, which offers several support schemes (loans, grants, guarantees, etc.) for the purchase, reconstruction/renovation and demolition of dwellings, in cooperation with KredEx, the national financing institution.
Estonia has implemented a large number of fiscal measures to incentivise home ownership. These include, among others, deductible mortgages, non-taxation of gains from selling residential properties and low property taxes, which remain one of the lowest in the EU (0.3% of GDP). As a result, the rental market remains very limited (only 3% of the total household market), compared to 19% in the EU on average. [3]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT, the value of trade of prefabricated elements is € 569 Million in 2016. Export activities account 430 € Millions, while import account 139 € Million. The sold construction products in Estonia between 2012 and 2016 has growth at a rate (CAGR) of 5.9% for export and 4.5% on import [7].
On the export side Estonia is the largest exporter of wooden houses in EU (84.5% of total export). According to Eurostat, Estonia's wooden houses export increased by 6.4% in 2015, growing from 283 million euros in 2012 to 363 million euros in 2016. The second largest exporter goods are concrete structural elements, it accounts 14.4% of export, and increased on export by 16.2% in the observed period.
On the import side, Wood and concrete are confirmed by the main components imported on the market. Their share on import is 56.9% for wood constructional goods, and 24.2% for concrete and plaster structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated concrete items (+9.2%) and for wood elements (+4.08%) increase.
Approximately 75% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders

ESTONIA TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	14.269.056	143.139	-68,35%	0,03%
Ceramic constructional goods	9.040.830	4.179.762	-17,54%	0,97%
Concrete, plaster structural elements	34.000.404	62.131.943	16,27%	14,44%
Wood Structural elements	283.700.146	363.736.666	6,41%	84,55%
TOTAL EXPORT	**341.010.436**	**430.191.510**	**5,98%**	**100,00%**
IMPORT	2012	2016	CAGR	Share on Import
Cement, lime and plaster (ready mix)	2.617.203	6.696.818	26,48%	4,80%

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

Ceramic constructional goods	24.871.601	19.453.289	-5,96%	13,94%
Concrete, plaster structural elements	23.797.668	33.882.349	9,23%	24,27%
Wood Structural elements	67.794.890	79.559.396	4,08%	56,99%
TOTAL IMPORT	**119.081.362**	**139.591.852**	**4,05%**	**100,00%**

Estonia is the largest exporter of wooden houses in EU. Estonian wooden houses Cluster Manager Lauri Kivil brings forth that among 10 biggest wooden houses exporters only three countries – Estonia, Lithuania and Poland – were able to increase export. Strong growth of Lithuanian and Polish wooden houses producers has also been felt by the Estonian producers. "Our main markets have little procurements where our producers do not have to compete with producers from those countries," Kivil describes the situation [9].

3.2 Market conditions / costs and benefits

Actually the recycling plants have had much difficulty in putting on the market their recycled materials. Barriers to their use are mainly dictated by economic aspects, lack of experience, assurance of quality of recycled materials, existence of regular supply/demand systems and environmental concerns.

There are strong financial incentives in place in Estonia for encouraging recycling and recovery of CDW over landfilling. As landfilling is considered to be rather an expensive option, waste recovery services and infrastructure have developed considerably over the last years.

In Estonia, on a total of 13 million tons of aggregate products, the majority were from Crushed Rock (47%) and Sand & Grave (53 %). The growth in production volume is not linear, it has a cyclical trend ranging between 11 million and 13 million tones. At present, the weight of recycled aggregates on total production volume is close to zero [11]. The market for recycled CDW materials in Estonia is not very developed yet. So far, the major part of mineral CDW is used for backfilling operations (reclamation of old quarries, use on construction works, etc.) and is not recycled to new products [2].

ESTONIA – Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	190	190	190	190
Total Number of Extraction Sites (Quarries and Pits)	290	280	280	280
Sand & Gravel (millions tonnes)	7	7	9	7
Crushed Rock (millions tonnes)	5	5	4	4
Marine Aggregates (millions tonnes)	0	0	0	0
Recycled Aggregates (millions tonnes)	0	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0

Total Production (millions tonnes)	**13**	**11**	**13**	**11**

Currently the resource tax is considered to be at very low level and do not represent the actual situation of prospective resource scarcity of natural materials for construction (e.g. aggregates). It is estimated that the quarries in Tallinn and in its surrounding area have a life expectancy of approximately 5-6 years, while at the same time there are significant difficulties in opening new quarries. This means that resource constraints will arise in the short-medium term which will affect the construction industry in the capital city of Estonia[2]. Alternative options would be to transport aggregates for longer distances within Estonia or even import aggregates from abroad. However, it is considered more beneficial to recycle and use again material from CDW which can be found in abundance from construction works around Tallinn metropolitan region [2].

3.3 Construction sector make up

The Estonian construction sector suffered from the boom and bust cycle linked to the global economic crisis and gradually recovering since. Indeed, production in construction dropped by 45.2% over 2008-2010 but recovered over 2010-2014, with production being again close to pre-crisis levels. Similarly, turnover of the broad construction sector declined sharply over 2008-2009 (-31.9%) but in 2013 stood 4.6% above 2008 levels. In parallel, construction costs went up steadily until 2008, then decreased by 10.8% over 2008-2010, and climbed up again by 14.6% over 2010-2015[3].

Estonians have long-term traditions in producing homes from round logs – for centuries they have built Estonian farmhouses from local pine or fir. In Estonia there are log homes that are more than 300 years old. In Nordic countries there are also wooden houses that are even 800-1000 years old.

Manufacturing of wooden houses started to develop in Estonia in the 1950s when prefab homes from milled log and panels were produced in forest industries. Nowadays the manufacturing of wooden houses has developed to one of the key industries in Estonia with 140 enterprises. The sector's turnover is approximately 128 million EUR per year and apx. 85-90% of wooden houses produced in Estonia are exported. Estonia is the 1th exporter of wooden houses in EU based on total turnover of wooden houses exported in a year.

Therefore, on the 20th of May in 1999, **Estonian Woodhouse Association** was established by 17 companies, which were manufacturing wooden houses.

The main goal of Estonian Woodhouse Association is to increase the competitiveness and export capabilities of it's member companies through different supporting joint ventures. The complex of joint ventures include general development, marketing, vocational training activities, political lobbying and information exchange.

The various products produced by members of Estonian Woodhouse Association are the following: modular houses, element houses, garden houses, log houses from planed and round timber. These are divided as the producers of handmade log homes and machined log homes. All manufacturers have a long term traditions in producing and are competitive in foreign markets. [9]


Figure 1. Example of Prefabricated elements and house in Estonia

Modular housing is a very modern and advanced building system and it's slowly replacing the traditional building technologies. The modular system is based on the technology of timber frame, where fully finished modules are produced in the factory. The prefab modules are produced such that it is possible to combine them into a so-called multi-module building- modular house. Modular houses can be built in different sizes – one module can serve as a small apartment or as a part of a larger house. [10]

In order to improve the international competitiveness of Estonian Prefab Wood products, **Estonian Wooden Houses Cluster** was created, so to add value and export turnover of cluster companies through international cooperation between companies, R&D and educational institutions in the fields of joint marketing, product development and competence building.
The specific goals of Estonian Wooden Houses Cluster for the year 2017 are:

- the increase of turnover;
- the increase of export turnover;
- the increase of profitability;
- the increase of productivity;
- the increase of added value;
- the increase of the number of cluster organizations.

The leader organization of the Estonian Wooden Houses Cluster is Estonian Woodhouse Association. The cluster was created by 20 organizations (including 12 companies producing wooden houses). At the moment, there are 44 organizations in the cluster (including 27 companies producing wooden houses). [9]

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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FINLAND

1. TECHNICAL REGULATION AND LEGISLATION

Information included in the main document D1.4.

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Information included in the main document D1.4.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Use of CDW as aggregates in concrete

In the Finnish application standard for EN 206, **SFS 7022**, the recommendations regarding recycled aggregate for use in concrete given in EN-206 are accepted without any modifications, both as regards the requirements on quality and properties of the recycled aggregate and how much can be used under different conditions. The recommendations regarding quality are described in detail in Deliverable D.2.1 – section 3.2.

Rules for the use of the recycled CDW as aggregate in concrete (precast or in-situ)

The recommendation sin EN 206 regarding how much recycled aggregate can be used in concrete in different exposure classes is given in Table 1,

Table 1. Highest mass fraction of the coarse aggregate[c] which may consist of recycled aggregate

		Exposure classes			
	Type of material	XO	XC1, XC2	XC3, XC4; XF1, XA1, XD1	All other exposure classes
01	Recycled aggregate Type A	50 %	30 %	30 %	0 % [a]
02	Recycled aggregate Type B [b]	50 %	20 %	0 %	0 %

[a] Type A recycled aggregates from a known source may be used in exposure classes to which the original concrete was designed with a maximum percentage of replacement of 30 %.
[b] Recycled aggregate Type B may not be used in compressive strength classes above C30/37.
[c] Coarse aggregate is defined in SS-EN 12620+A1:2008 as follows: "designation given to the larger aggregate sizes with D greater than or equal to 4 mm and d greater than or equal to 2 mm"

1.3 Prefabricated elements (with or without CDW materials)

For precast concrete products covered by harmonized standards the rules according to EN 13369 described in Deliverable D.2.1 – section 3.2 are applied.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

Information included in the main document D1.4.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

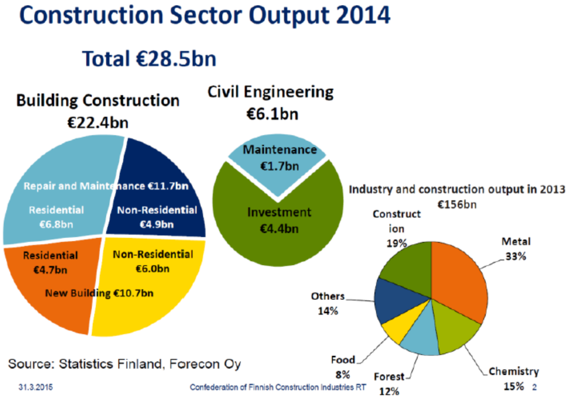
No specific information has been found.

3.2 Market conditions / costs and benefits

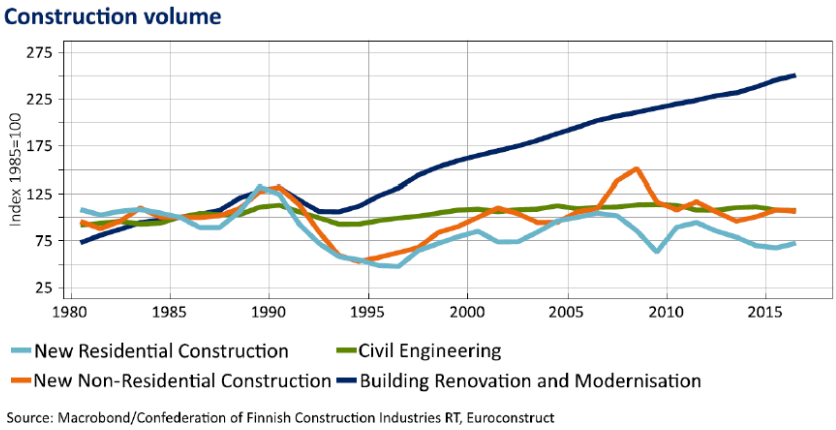
No specific information has been found.

3.3 Construction sector make up

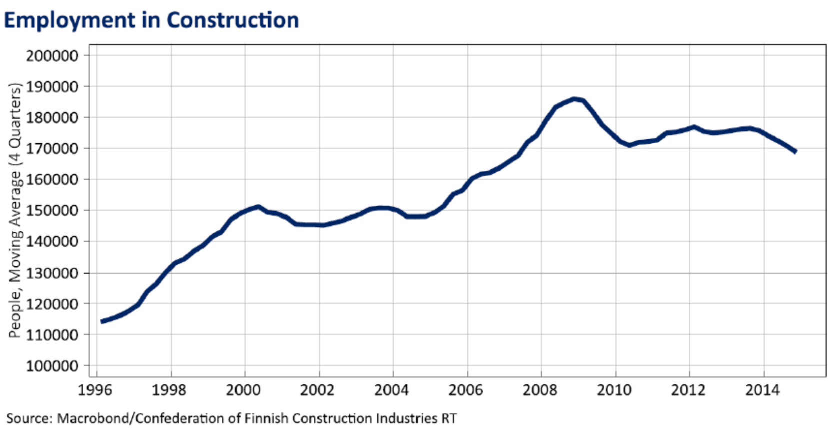
The total value of the Finnish construction sector in 2014 was altogether EUR 28.5 billion of which 79 % is accounted for by housing construction and 21 % by infra construction (Confederation of Finnish Construction Industries RT, 2015). In 2013, the number of construction companies was about 42 500. The total volume of construction is estimated to decrease in 2015. However, a slight increase is expected for 2016. In 2015 the estimated number of dwellings started is 23 500. The value of refurbishments (total EUR 11.9 billion in 2014) exceeds the volume of new construction. Employment in the construction sector in Finland is about 165 000. The following graphs extracted from the latest economic outlook report of the construction sector give further insight into the key economic figures and recent trends within Finnish construction sector.



Source: Confederation of Finnish Construction Industries RT, 2015

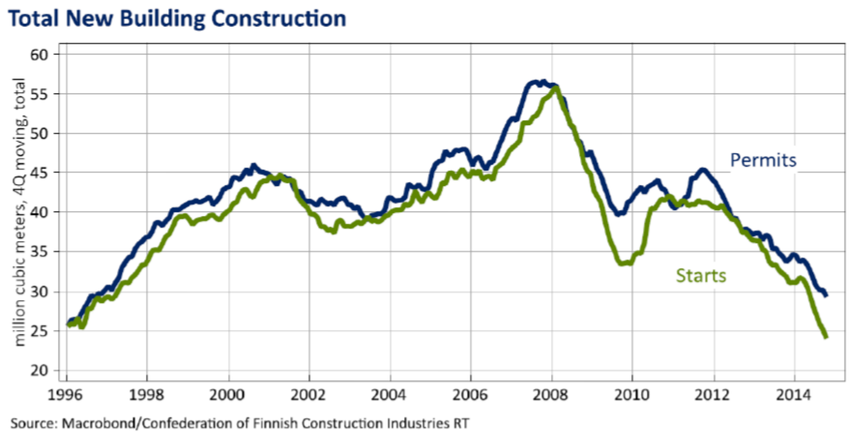


Source: Confederation of Finnish Construction Industries RT, 2015

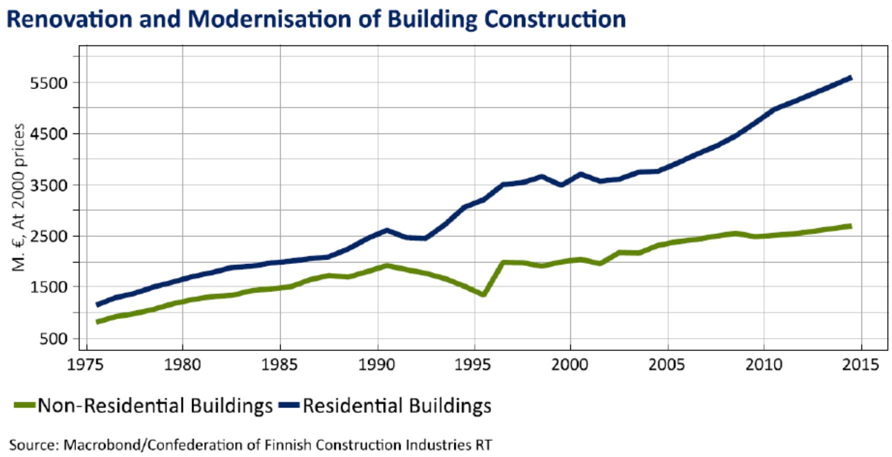


Source: Confederation of Finnish Construction Industries RT, 2015

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583



Source: Confederation of Finnish Construction Industries RT, 2015



Source: Confederation of Finnish Construction Industries RT, 2015

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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The sole responsibility of this publication lies with the author. The European Union is not responsible for any use that may be made of the information contained therein.

FRANCE

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

An overview of French regulation and legislation is available in RE[4] Deliverable 1.1. French regulation on CDW generally covers all types of construction and demolition waste, without distinguishing between materials. A waste audit prior to demolition or deconstruction is required by Law 2010-788 of 12 July 2010 for buildings of over 1000 m² or which have housed hazardous waste.

Reuse is near the top of the waste hierarchy, therefore waste prevention and management regulation highly encourages it. Yet lack of understanding of material status (waste or product) by the different actors has been identified as an issue. There is also a lack of incentive for eco-design of products and buildings and for the use of reused products. Both points were highlighted in a recent study on drivers and barriers to reuse of construction products and materials carried out for the French Environment and Energy Management Agency, **ADEME** [5]. This study aimed to analyse the situation in order to propose an action plan to activate drivers identified to counter barriers to reuse. In total, 23 key barriers to reuse of construction materials were identified. Article 79 of the **bill on energy transition for a green growth** also takes action on this topic, reiterated in the Waste reduction and recovery plan 2016-2025. Indeed, public authorities will have to ensure that **50% of materials used in road works** originate **from reuse or recycling of CDW in 2017**, 60% in 2020.

There is a General Tax on Polluting Activities (TGAP) in France, which must be paid by companies whose activities or products are considered polluting: waste, pollutant emission, oils, detergents, extracted materials, etc. The tax is based on the weight in tonnes of waste received in an installation to which it applies. The amount of the tax is higher for more polluting activities – therefore sending waste to better performing landfills is cheaper than sending it to regular ones, and much cheaper than sending it to unauthorised ones. The rate is also slightly higher in continental France and Corsica than it is in Guadeloupe, Martinique, and Reunion Island. The 2017 rates for continental France are listed in Deliverable 1.1 [4]. The mere existence of the TGAP penalises landfill and incineration, therefore encouraging recycling of CDW materials.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Although the TGAP encourages recycling, there is still a long way to go to encourage the use of recycled materials, according to the national project RECYBETON.

Technical documents such as Product Norms which explicitly cover recycled materials, Execution Norms, and technical guides can cover aspects of suitability for use and implementation of certain reused materials for public works.

In the building sector, however, the majority of technical documents are dedicated to manufactured products and not applicable for reused products, except for example for the implementation norm of steel structures (currently under discussion). Although it is possible to modify these texts to include performance target definition and circular economy during their revision, the process is long and requires a consensus of various actors with diverging interests.

In the building sector, the use of recycled material to make concrete has been authorised since 2012, but not in every type of work. For example, norm NF EN 206-1/CN, published in December 2014, allows for 20% substitution of natural gravel by recycled gravel in concrete subjected to common exposure classes. For road works, standardisation is more advanced, and 60% of concrete is currently recovered in road underlay [6].

1.3 Prefabricated elements (with or without CDW materials)

Voluntary product certification, governed by the French Consumer Code, exists for over 25 types of concrete products – the main marks are "NF" and "CSTBat" [2].

Two new technical documents were published end 2016, which mark a step forward for suspended pre-slabs in seismic zones and pre-walls (prefabricated walls).

Two-thirds of the French territory is classified as seismic zones. The Decree of 22 October 2010 and the related application Order targeting "normal risk" buildings require the use of Eurocode 8 for the design and dimensioning of earthquake-resistant buildings. Control bodies have long considered suspended pre-slabs to be unsuitable in seismic zones, a fact which has haltered their progress. However, a group of professionals and experts have adjusted suspended pre-slabs with a process called LPPVE (French abbreviation for flooring to pre-slab liaisons and wall notches). A magnetic ruler stabilises and ensures adequate continuity systems and creates supporting notches in the wall. This process guarantees maintain of the floor level and reinforces the reliability of suspended pre-slabs.

The French national organisation for standardisation published a documentation leaflet (known as an FD for "*Fascicule de Documentation*") on suspended pre-slabs with continuity systems, magnetic rulers or equivalent (LPPVE). It covers design, dimensioning, and implementation according to Eurocode 2 for non-seismic zones and Eurocode 8 for seismic areas. The FDs are conceived as precursor tools to ISO 9000 norms and they include guidelines and good practices. This guide secures the process towards insurers and enables a wider acceptance by control offices.

The Pre-wall process was developed 25 years ago and has known a strong development in the past decade. Current annual production of pre-walls is around 2.5 million m^2/year [3]. The pre-wall good practice guide *Qualiprémur* was published in September 2016 (available online at: http://www.egfbtp.com/sites/default/files/7-brochure_qualipremur_bat_web_01-09-16.pdf). It targets structural engineering companies and defines the respective role of various actors (company, supplier, engineering consultant) and how they should communicate amongst themselves. It also highlights both safety rules, which must be respected on site, and implementation rules to guarantee the quality of the works.

1.4 Prefabricated construction

Prefabricated construction is governed by the same rules as traditional construction, regarding the need for architects, insurance, building permits (compulsory for any construction of over 20 m²), to name just a few. Prefabricated construction has so far rarely been considered by legislators.
There is one key difference which should be noted. When a building is sold to a buyer, it is generally covered by a 10-year insurance, if it is solidly anchored to its foundation. As this is not always the case for prefabricated construction, insurers can occasionally refuse this type of insurance on prefabricated construction.

2. POLICY MEASURES

2.1 Materials from CDW

No specific information has been found.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

National data on the prefabricated sector is not readily available for official government bodies. Professional organisations, however, have some information on the sector.

With regards to **prefabricated construction**, The Association of Industrialised and Modular Construction, ACIM, gathers the main 23 actors in the sector, representing around 90% of the profession in terms of sales revenues. In 2015, ACIM members represented a total of 3310 employees and 718 M€ revenues, with 43% in distribution and 57% in rentals. Public authorities accounted for 31% of distribution, the building and public works sector 19%, and industry, services, events, and others accounted for the remaining 50%. Rentals have a slightly different distribution per sector, as 15% were for public authorities, 41% for building and public works, and 44% for industry, services, events, and others [1].

About two-thirds of **prefabricated elements** made of concrete in France are destined towards building works (64%), with the remaining third used in public works (36%) [2].

3.1 Exports / imports of prefabricated elements

No specific information has been found.

3.2 Market conditions / costs and benefits

No specific information has been found.

3.3 Construction sector make up

No specific information has been found.

4. REFERENCES

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DISCLAIMER

GERMANY

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TILES AND CERAMIC, ASPHALT, WOOD, GYPSUM

General:

The European Waste Management Directive (Directive 2008/98 / EC, AbfRRL) has been implemented into German law, modernizing the existing German waste legislation through the new Circular Economy Act (KrWG), which is currently Germany's main waste disposal statute. This Act replaces the first uniform National Waste Disposal Act (AbfG), adopted in 1972. The objective of the new Act is to achieve a sustainable improvement in environmental and climate protection as well as resource efficiency in waste management by strengthening waste prevention and recycling of waste. At the same time, the adoption of EU legal concepts and definitions as well as the clarification of central regulations are intended to facilitate the practical and legal application of the law.

As Germany consists of 16 federal states, certain aspects of the CDW disposal, which are not regulated centrally, are governed by the states themselves, such as the determination of entities, which are subject to waste disposal obligations, authorizing bodies for waste disposal matters and municipal waste disposal ordinances.

Prior to dismantling a building, it is important to determine the age of construction and the buildings use to identify typical pollutants or polluted building materials of that time or contamination in relation to the operation of the building. In case of relevant findings, a technical investigation with sampling has to be carried out.

Although not mandatory, a dismantling and disposal concept is recommended. Building materials containing pollutants must be removed prior to dismantling or demolition. In case those fractions of the CDW are classified as hazardous waste, the Waste Register Ordinance (AVV) in connection with instructions set out by the Federal Ministry for Environment must be taken into account.

For the recycling or dismantling of commercial CDW the Ordinance on the Management of Municipal Waste (Gewerbeabfallverordnung) applies. In case of hazardous waste, evidence (proof of disposal and accompanying documents) according to the Proof Ordinance (Nachweisverordnung) must be provided to the Central Body for Waste Supervision (Zentrale Stelle Abfallüberwachung (ZSA)) at the State Office for Environment (LfU). In case of transport of commercial waste, the notification and permit regulation (AbfAEV) must be applied. The respective county administration authority (County Council or Environment Agency) is responsible for granting the transport license.
Other regulations (Abfallverzeichnisverordnung, AVV) regulate the types of wastes, classified into hazardous and non-hazardous wastes.

For the transport of CDW, the transport licence ordinance (Transportgenehmigungsverordnung (TgV)) needs to be considered. [1]

Wood:
The "Ordinance on Requirements for the Recycling and Elimination of Waste Wood (Altholzverordnung – AltholzV)" specifies four categories of waste wood:

Wast wood category A I: untreated or merely mechanically treated waste wood which, when used, was not impregnated with wood-impregnated substances,

Waste wood category A II: glued, painted, coated, varnished or otherwise treated old wood without halogenated organic compounds in the coating and without wood preservatives,

Waste wood category A III: waste wood with organo-halogen compounds in the coating without wood preservatives,

Waste wood category A IV: waste wood treated with wood preservatives, such as railway thresholds, piping masts, hop bars, piles, and other waste wood which can not be attributed to waste wood categories A I, A II or A III due to its pollution, except PCB waste wood (limit value is not defined)

In the case of a mixture of different types of waste wood, the requirements for recycling are determined by the highest category of waste wood. The sorting of waste wood has to be carried out in waste wood treatment plants by visual inspection of knowledgeable persons. [2]

Table 1. Procedure for the recycling of waste wood, Annex I (to § 3 Abs.1) Altholzverordnung – AltholzV [2]

	Approved waste wood categories				
Recovery process	**A I**	**A II**	**A III**	**A IV**	**Special requirements**
Treatment of waste wood to wood chips and shavings for the production of wood materials	yes	yes	(yes)		The processing of waste wood of the waste wood category A III is only permitted if varnishes and coatings have been largely removed by a pretreatment or are removed during the process.
Extraction of synthesis gas for further chemical use	yes	yes	yes	yes	Recycling is permitted only in plants approved for this purpose under § 4 of the Federal Pollution Control Act (Bundesimmissionsschutzgesetz)
Production of activated charcoal / industrial charcoal	yes	yes	yes	yes	Recycling is permitted only in plants approved for this purpose under § 4 of the Federal Pollution Control Act (Bundesimmissionsschutzgesetz)

Gypsum:
The recycling rate of gypsum building waste was around 52% in 2015, while the recycling rate tumbled towards zero. Only about half of the approximately 0.6 million tonnes of gypsum construction waste generated annually was recyclable gypsum board waste. The rest was e.g. contained in form of adherent plasters in the construction demolition waste.

With the construction of several pilot recycling plants for gypsum construction materials in Germany gypsum-based building waste should to be used as a source of raw materials in the near future, which corresponds to the requirements of § 23 KrWG for the primary use of recyclable waste or secondary raw materials for the production of products.

Moreover, by the exit from nuclear and fossil-fuel energy in Germany, REA gypsum from flue gas desulphurization plants, which until now covers 55% of Germany's gypsum demand, will no longer be available in sufficient quantities. However, since recycled plaster will not be able to close the gap in REA-gypsum in the near future, the mining of natural gypsum will increase in the medium term. [3]

According to a decision of the EU Commission, gypsum waste for reclamation measures by the various potash deposits in Thuringia and Lower Saxony has to be rejected for reasons of environmental law contrary to the previous practice, so that only the landfilling remains as the main path of disposal.

The storage of gypsum waste on landfill sites is regulated by EU law (Council Decision of 19 December 2002 laying down criteria and procedures for the acceptance of waste on landfill sites pursuant to Article 16 and Annex II of Directive 1999/31 / EC) on shipments Of waste only if the landfill has a monocell. Since the total organic carbon (abbr. TOC) value of gypsum waste is too high to be stored together with other waste, the storage is quickly cost-intensive and recycling a more economical solution. [4]

Asphalt:
According to the Ordinance on the Implementation of the European Waste List (Abfallverzeichnis-Verordnung-AVV), tar containing and bituminous road construction waste is classified as hazardous waste.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The required physical or chemical properties of recycled building materials result from the intended use. The application-specific requirements for recycled building materials are formulated in accordance with standards and other regulations, whereby the same standards are generally applied to recycled building materials, as for primary raw materials. In addition, however, RC materials must also demonstrate the safety of potential impacts on the environment. These are the responsibility of the federal states in Germany. [5]
There are no national legislative instruments governing the requirements for the recycling of mineral wastes or for the use of recycled building materials or spare building materials so far.

RC-aggregates:

For example, the quality requirements (properties, quality proof) of RC concrete are subject to the same standards and regulations as conventionally produced concrete, but the use of RC aggregates for the production of concrete is bound to additional specifications.

In 2002 the national standard DIN 4226-100: 2002-02 entered into force. It has been developed under the responsibility of the NABau Working Committee 35 "Aggregates for concrete and mortar" and specifies special structural and environmentally compatible requirements for recycled aggregates for use in concrete and mortar.

With the publication of the DAfStb guideline "Concrete according to DIN EN 206-1 and DIN 1045-2 with recycled aggregate grains according to DIN 4226-100", edition 2004-12, another basic set of rules entered into force. This DafStb guidline regulates and clearly defines the structural requirements as well as the restrictions for the use of RC aggregates in concrete.

Recycled aggregates are classified into four types: concrete rubble (Type 1), demolition debris (Type 2), masonry rubble (Type 3) and mixed rubble (Type 4).

Table 2. Recycled aggregate composition and property requirements for use in the production of concrete

Type	Concrete content (%)	Masonry content (%)	Max. contaminants content[1] (%)	Max. chloride content (%)	Max. sulfate content (%)	Min. density (kg/m^3)	Max. water absorption (%)
1	> 90	< 10	1	0.04	0.8	2000	10
2	> 70	< 30	1	0.04	0.8	2000	15
3	< 20	> 80	1	0.04	0.8	1800	20
4	Concrete + Masonry content > 80		n/a	0.15	n/a	1500	n/a

1-Bituminous materials are not included.

In the course of the harmonization of technical standards by the elaboration of European standards, DIN 4226-100: 2002-02 has been transferred to DIN EN 12620: 2008-08 in large parts (structural parameters). The DAfStb guideline has been adapted accordingly. The updated version from 2010 is "Concrete according to DIN EN 206-1 and DIN 1045-2 with recycled aggregates according to DIN EN 12620".

Concrete rubble or demolition debris can be used in the production of structural concrete (Exposure classes X0, XC1-XC4, XF1-XF3 and XA1 in accordance with EN 206:2013+A1:2016), whereas masonry rubble or mixed rubble can only be used in non-structural concrete. The maximum replacement levels of virgin aggregate by concrete rubble (Type 1) or demolition debris (Type 2) are set at 35% and 25 % for manufacturing C25/30 and C30/37 concrete, respectively.

Because the requirements for the contents of recycled aggregates from Annex G of the DIN 4226-100: 2002-02 (Environmental Impact Assessment) were not taken over, in the DAfStb-guideline, edition 09/2010, is determined that recycled aggregates according to DIN EN 12620 do not have environmental impact, in particular on soil and ground water.

However, it is currently not clear which limit values should be used to assess the environmental compatibility of recycled aggregates. Neither the currently valid standardization, nor the DAfStb-guideline or the German Institute for Structural Engineering (abbr. DIBt), which is the publisher of the building catalogs (Bauregellisten), comment on this. [6]

Reinfocement:
Iron and non-ferrous metals from demolition work are completely recycled into the metal and steel sector due to the good raw material situation after the separation into the individual metal grades and preparation, which comprises the removal of extraneous matter and impurities. Processes as well as application areas of the reused metals have become established, so that an almost complete recycling rate exists. About 5 million tonnes of metal waste were exported from Germany in 2010. [7]

1.3 Prefabricated elements (with or without CDW materials)

Prefabricated concrete parts:
Requirements for the performance criteria for and the conformity assessment of a large number of prefabricated concrete products produced under factory conditions are listed in EN 13369: 2013-08 "General rules for concrete prefabricated parts". This is used in Germany as DIN EN 13369: 2013-08. A current draft (DIN EN 13369:2017-05 - Entwurf) is available for this standard.

Examples, of the precast concrete standards harmonized at European level, are listed below:

– EN 1168: 2005 + A3: 2011 Prefabricated concrete slabs - hollow slabs
– EN 1520: 2011 2 Prefabricated structural elements made of light-weight concrete and with statically credible or non-chargeable reinforcement
– EN 12794: 2005 + A 1: 2007 Prefabricated concrete parts - foundation piles
– EN 13224: 2011 Precast concrete slabs - ceiling slabs with bars
– EN 13225: 2013 Prefabricated concrete parts - rod-shaped structural elements
– EN 13693: 2004 + A 1: 2009 Prefabricated concrete parts - Special prefabricated parts for roofs
– EN 14843: 2007 Prefabricated concrete parts - Stairs
– EN 14844: 2006 + A2: 2011 Precast concrete parts - hollow box elements
– EN 14991: 2007 Prefabricated concrete parts - Foundation elements
– EN 14992: 2007 + A1: 2012 Precast concrete parts - wall elements
– EN 15037-1: 2008 Prefabricated concrete parts - beam ceilings with intermediate components - Part 1: beams
– EN 15037 -2: 2009 + A 1: 2011 Prefabricated concrete parts - Beam ceilings with intermediate components - Part 2: Intermediate components made of concrete

Reconstituted concrete elements can either be reworked as a component in whole or recycled in RC plants as secondary raw material or recycled material. Both cycle variants correspond to the overarching goal of sustainability policy to conserve natural resources. Component recycling takes account of the avoidance of building waste according to §4 (1) sentence 1 KrW- / AbfG (highest priority). The development of building waste is promoted and energy and material flows are reduced.

In accordance with the KrW- / AbfG (Recycling and Waste Management Act, Germany), reconstructed concrete parts are then products and therefore economic goods and no waste if they can be reused as components because they correspond to the quality of their components.
Since the use of the components must primarily meet the requirements for building safety, the building regulations of the individual federal states are primarily decisive.
As there are currently no universally accepted rules for the use of second- RC concrete elements, they still require the following in accordance with the building regulations:

- a general building inspection certificate,
- a general building appraisal certificate or
- consent in individual cases.

In Germany, this means that the approval expenditure for reuse may be very time-intensive. A test standard, which provides a uniform procedure for the inspection of dismantled concrete parts and thus a certification of the elements for the secondary use (conformity, use proof) does not exist so far. [8]

Prefabricated timber parts:
The "wood panel directive“ (Holztafelbaurichtlinie-HoTaRi) for the monitoring of wall, ceiling and roof panels for wooden houses in panel type according to DIN 1052 part 1 to 3 "for the production of both sides closed elements in wooden frame and wooden panel construction was introduced as a technical rule, in order to ensure a proper execution of the wooden panel elements which are no longer visible on the construction site.

Timber construction companies, which produce wooden panel elements, which are planked on both sides and thus closed, must be able to carry out self-monitoring, ie a factory production control, except in Baden-Wuerttemberg as well as regular external monitoring. Both self-monitoring and external monitoring are carried out according to the respectively valid version of the HoTaRi (DIN 1052 parts 1 to 3). [9]

The Federal Association of German Prefabricated Buildings (abbr.: BDF) has developed a leaflet for direct planking with plasterboard and gypsum fiber boards on wooden panels for wall, ceiling and roof elements in wood panel construction, which are connected to each other by brackets at the factory and on the construction site.

This leaflet applies to the industrialized prefabricated timber construction of BDF companies. It applies to companies which are subject to the building control regulations as well as the additional RAL and QDF quality assurance at the plant. In addition, the construction sites are supervised externally by the companies in accordance with the guidelines of the "Quality association Deutscher Fertigbau (QDF)". [10]

Prefabricated masonry elements:
DIN 1053-4: 2013-04 "Masonry - Part 4: Prefabricated masonry compound units" applies to mainly prefabricated and predominantly high-volume prefabricated building elements made of masonry and buildings constructed therefrom. The standard contains constructive notes and information on the provision of the stability verification for the individual prefabricated components, including transport and assembly as well as for the building. A current draft is available for this standard (DIN 1053-4: 2017-02 - Entwurf).

1.4 Prefabricated construction

The Building Regulations List (Bauregelliste A, B and C) is an instrument developed by the authorities responsible for construction supervision in the federal states (stipulated in § 17 of the model building regulations, abbr. MBO), which determines which construction products may be considered controlled and used. This includes a list of prefabricated components made of concrete and reinforced concrete, of bricks and prefabricated components for timber construction.

Prefabricated buildings made of building materials and components are considered to be prefabricated systems according to the Land Building Regulations (LBOs) of the federal states. The building list is managed by the German Institute for Structural Engineering (abbr. DIBt) and is constantly updated.

2. POLICY MEASURES

2.1 Materials from CDW

Some federal states want to promote the use of quality-controlled recycling building materials and thus the cycle management of construction. In October 2012, the state government in Rhineland-Palatinate was the first to establish an alliance for a non-discriminatory tender for quality-controlled recycling building materials. This alliance economy on construction promotes resource conservation and reuse in the construction sector. The regional associations of municipal associations, the Chamber of Architects, the Chamber of Engineers, the Federation of Building Industries, the Construction Industry Association, the Stones and Earthworks Association, and the Building Materials Monitoring Association are also participating in the initiative. [11]

2.2 Prefabricated elements (with or without CDW materials)

Political measures for the use of prefabricated elements could not be researched for Germany.

The interests of manufacturers of prefabricated parts are represented both at the state level as well as at the federal level by various associations, which also take care of the public relations work of the respective represented sector. Examples include the "Verband Beton- und Fertigteilindustrie Nord e.V" and the "Fachvereinigung Deutscher Betonfertteilteilbau" (FDB)

2.3 Prefabricated construction

In Germany, the "Alliance for Affordable Housing and Building" was set up in July 2014 by the Federal Ministry for the Environment, Nature Conservation, Construction and Nuclear Safety (abbr.: BMUB), in which federal, state, municipalities and associations jointly took measures to create more affordable Living space. The final report, presented on 27 November 2015, contains recommendations for action to the Confederation, the federal states, local authorities and private housing market actors. On the basis of this report, the BMUB has submitted a ten-point program for a housing construction project.

In this context, the increase in compensatory funds for social housing has been implemented by the Asylum Procedure Acceleration Act, which entered into force on 24 October 2015. In addition, EUR 500 million will be made available to the federal states by 2016 through 2019. This corresponds roughly to a doubling of the previous approach. The federal states have agreed to use the compensatory funds for social housing.

Central points for the reduction of construction costs in social housing are, among other things, the serial construction and the uniform adoption of the model building regulations (abbr. MBO) in all federal states. The support of serial construction is an important element of the housing construction offensive, due to the cost saving potential through modularization, standardization and industrial, serial prefabrication especially with regard to optimized construction processes. For this reason, serial building is to be strengthened taking into account aspects of sustainability and building culture.

As part of the development of measures for the promotion of affordable housing (20 January 2016), companies in the prefabricated and timber construction sector have submitted proposals for the construction of refugee housing, which can also be used for social housing. According to the industry, sufficient production capacity is available to almost double the current production. [12]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

There are no statistical surveys on the export and import of prefabricated elements in Germany. Individual companies in the German prefabricated concrete industry, according to their own data, are exporting part of their production to neighboring countries.
Examples are the companies “Elsässer Beton”, which is located in south west Germany and exports more than 40% of its volume, mostly to Switzerland [13] and “Betonwerk Fehrbellin

GmbH", which is located in north eastern Germany and exports its precast concrete products to Scandinavian countries.

It can be assumed that in general prefabricating companies export their products into adjacent countries with a high purchasing power.

3.2 Market conditions / costs and benefits

In 2015, a total of 15,854 residential buildings were built in Germany in prefabricated construction, in which roughly 86% predominantly wood and approximately 9% predominantly reinforced concrete were used. [15]

In absolute terms, prefabricated timber construction predominates the conventional timber construction. In 2012, 14,931 homes were built in prefabricated construction, but 16,285 homes were built in timber construction. Of this total, 82.1% were produced in prefabricated construction and 17.9% in conventional construction. [16]

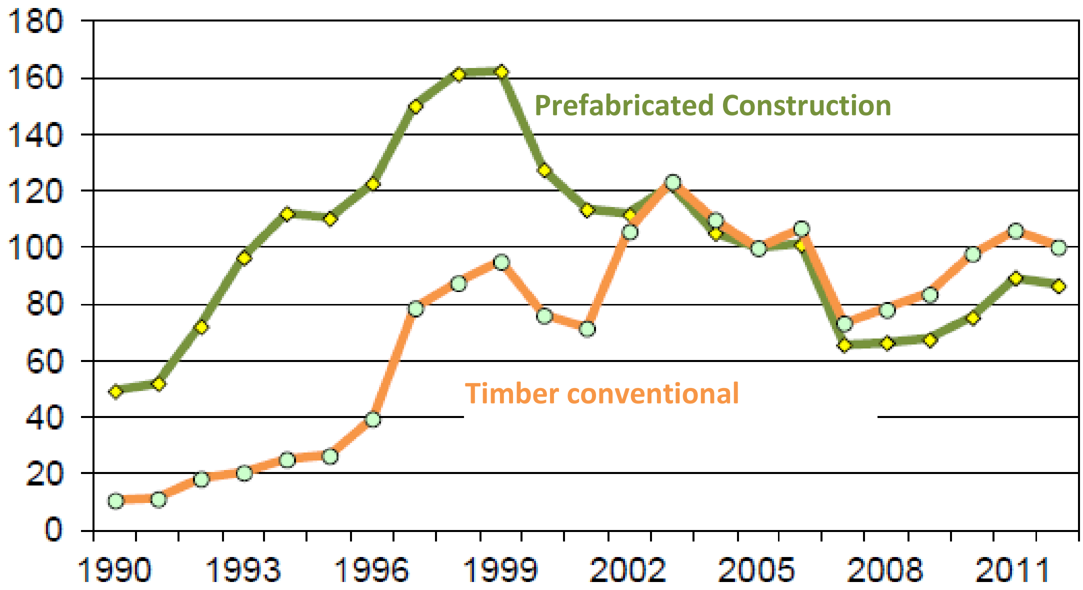


Figure 1: Index comparison of wooden houses by construction (index 2005=100) [16]

In Germany, turnover for prefabricated buildings rose by 15.7% in 2016. Compared to the overall market, the demand for prefabricated houses rose disproportionately and led to a prefabricated rate of over 20% (20.4%). The number of prefabricated buildings rose by 9.4% in 2016.

The share of the prefabricated buildings in the entire new building in 2015 varies greatly between the different federal states. While around 33% of all new buildings were erected in Bremen as prefabricated buildings, the figure for Berlin is only 10%, while in Lower Saxony it is only around 7%. [17]

Overall, the average price of the industry in 2016 rose by 5.8%, which made the competition with solid construction manufacturers somewhat more difficult. With a share of 83%, the single-family housing segment accounts for the largest share of prefabricated houses.

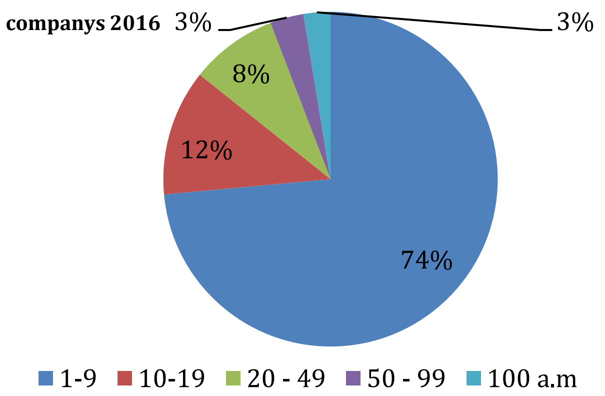
After a market adjustment and restructuring in the years 2002 to 2009, the larger manufacturers in Germany were able to prevail. The market concentration of the 10 largest manufacturers continued to grow in 2016, reaching a level of 37.8%. However, many companies were able to record sales growth, which is also reflected in an increase in the completion of the construction work for 2017. [18]

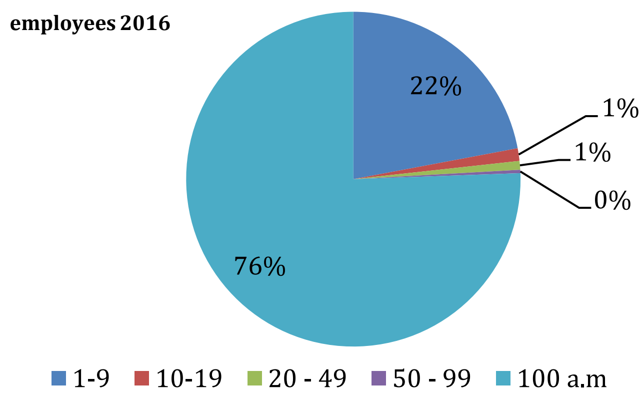
3.3 Construction sector make up

According to the latest figures of the Federal Statistical Office, at the end of June 2016, out of a total of 19,456 companies are involved in the construction of buildings, 616 companies and thus only 3% are specialized in the construction of prefabricated structures from self-made or externally-related components.

The number of employees in the construction of prefabricated buildings amounted to around 9990 persons at the time of the survey. While 74% of the companies in the prefabricated construction sector are small companies with less than 10 employees, 76% of the employees work in the few large factories with more than 100 employees, as the following graph illustrates.

The total turnover of the construction of the prefabricated buildings amounted to 2067.7 million EUR in 2015, which corresponds to 5% of the turnover of the enterprises of the building construction as a whole. Companies with more than 100 employees account for 59%. [19]





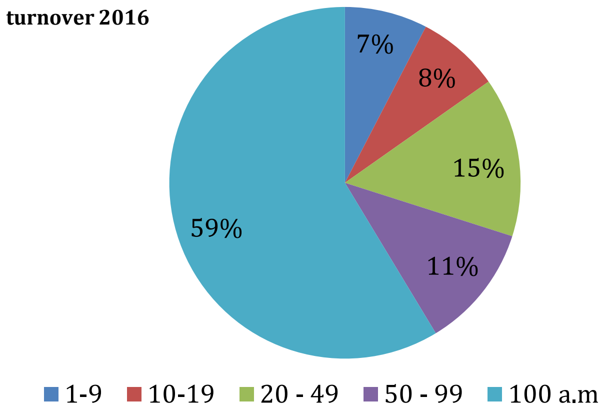


Figure 2. Structure of companies, employees and the turnover by company size in the building sector in Germany [19]

3.4 Use of CDW materials for prefabricated elements

In Germany, the material use mainly takes place in the woodworking industry for the production of chipboards and fibre boards. Since 2010/11 an uptake of approx. 13 % has been recognised in comparison to former stable rates of 20 %.

However, it has to be noted that overall the rate for material recycling in Europe is relatively low and the majority of wood waste is incinerated in an unsorted way. In Germany the main reason for this situation relates to the relatively strict requirements set out in the waste wood ordinance, which are unique in Europe and stipulate a fairly restricted use for treated, coated or laminated timber containing halogen organic compounds or wood preservation. As the determination of such compounds requires technical equipment, most often a worst case will be assumed and the waste material will be incinerated. Therefore, 50% - 75% of materials for a potential cascade use are lost.

There are no figures for the use of recycled materials in the prefabricated concrete industry.

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GREECE

1. Technical regulation and legislation

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

CDW is regulated by the following legislation: **Law 4042** of 2012 "**Penal protection of the environment - Compliance with Directive 2008/99/EC - Framework for waste generation and management - Compliance with Directive 2008/98/EC - Regulating issues of the Ministry of Environment, Energy and Climate Change**" which transposes the EU Waste Framework Directive (2008/98/EC) into Greek law. All provisions in the WFD related to CDW are valid for Greece and form the legal basis for the management of CDW in the country.
Further legislation, regulations and guidelines concerning CDW in Greece includes:

- **Joint Ministerial Decision 36259/1757/E103 of 2010** stipulating measures, conditions and programmes for the alternative management of excavation, construction and demolition waste (ECDW). Here, the obligations of all actors involved in the management of CDW is presented with emphasis on increasing the re-use and recovery of CDW following the waste hierarchy.
- **Law 2939 of 2001** for the alternative management of packaging and other products, as amended by Law 3854/201010. This piece of legislation lays down the principles of alternative waste management of the CDW waste stream, among others, and stipulates the organization systems for the management of CDW. Also, fines and other administrative and legal sanctions are prescribed in the case of non-compliance with the regulation.
- **Law 4030 of 2011** '**New way of issuing building permits, control of construction and other provisions**'. Article 40 describes permit issuing provisions for CDW treatment facilities in inactive quarries and the rules for accepting and managing CDW in these treatment facilities.
- **Law 4067 of 2012** '**New Building Regulation**', where Article 17 stipulates that for the construction of any building and the landscaping of the building surroundings, the provisions of the relevant legislation for alternative management of waste from excavation, construction and demolition waste should be applied.
- Circular of the Ministry of Environment, Energy and Climate Change no. 4834 of 25 January 2013 with subject the '**Management of excess excavation materials from Public Works - Clarifications on the requirements of the JMD 36259/1757/E103/2010'**, exempting the management of excess materials from excavation activities during public works through the certified systems of alternative CDW management, as long as the excess material is handled in sound environmental manner.
- Commission Decision 2011/753/EU establishing rules and calculation methods for verifying compliance with the targets set in Article 11(2) of Directive 2008/98/EC of the European Parliament and of the Council.
- Law 4280 of 2014 '**Environmental upgrading and private urbanization - Sustainable development of settlements. Forest law regulations and other provision**s', Article 52

stipulates the possibility of deposition and processing of CDW in inactive mines and quarries by the certified systems of alternative CDW management. [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

According to CDW treatment operators, the recycled CDW at the output of the recycling process should comply with technical criteria similar to that of the natural products in order to be used for construction activities. There is a plurality of standards concerning aggregates for construction purposes, which the recycled aggregates must fulfil in order to be returned back to the market. The standardization body in Greece, responsible for setting technical standards, is called ELOT (Greek Organization for Standardization). The following standards have been established according to **Joint Ministerial Decision 5328/122/200748**:

- Aggregates for concrete (ELOT EN12620-2002)
- Aggregates for bituminous mixtures (ELOT EN 13043-2002)
- Aggregates for mortar (ELOT EN 13193-2002)
- Aggregates for road construction (ELOT EN 13242-2002)
- Aggregates for railway ballast (ELOT EN 13450-2002)
- Natural boulders (ELOT EN 13383-1-2002)
- Lightweight Aggregates (ELOT EN 13055-1-2002 and ELOT EN 13055-2-2004)

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

The legal framework governing construction activities in Greece is constituted by the **General Building Regulation** (Γενικό Οικοδομικό Κανονισμό - Γ.Ο.Κ.), with subsequent amendments, which establishes the terms and conditions for the proper development of construction projects within or outside urban settlements, with the aim of protecting the physical, natural and cultural environment. A series of buildings regulations complementing the General Building Regulation contain provisions related to the classification of buildings, safety and durability of structures, various structural elements (walls, openings, windows, etc.), basic facilities (plumbing, heating, elevators, etc.). Moreover, spatial planning is regulated by Law 2742 on 'Spatial Planning and Sustainable Development', whereas urban planning is governed by Law 2508/97 on 'Sustainable Residential Development'. As for the execution of public works, this is defined by the Code of Construction and Public Works, which details the requirements for carrying out the works, the procedure for selecting contractors and award criteria, among others. [2]

As for the implementation of Eurocodes, Greece published National Annexes to all 58 Eurocode Parts, which are all published as National Standards. Eurocodes are not mandatory for structural design in Greece, and can be used in parallel to national standards and regulations. Indeed, contracting authorities can choose which regulatory framework to use in tender documents for the structural design of construction works. However, Eurocodes are typically the chosen option by public authorities in the case of public procurement contracts. [2]

2. Policy measures

2.1 Materials from CDW

Currently, there is no market for recycled CDW in Greece. No financial incentives enable the creation of such a market since the prices or raw materials for construction are still cheaper and are easier to access than recycled materials from the treatment of CDW. Also, there is no obligations for recycled materials or recycled content in construction materials, which renders the recycling product unfavourable for use in new construction activities. [1]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. Prefabricated Construction Sector characteristics

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [5], the value of trade of prefabricated elements is € 485 Million in 2016. Export activities account 300 € Millions, while import account 185 € Million. The sold construction products in Greece between 2012 and 2016 has increase at a rate (CAGR) of -2.5% for export, while import increase by rate of +0.9%.

On the export side, Greece is a largest exporter of Concrete structural elements in EU (61.4% of total export), and the export of this elements increase by 6.5% in 2016, passing from 143 million euros in 2012 to 184 million euros in 2016. The second largest exporter goods are cement, lime and plaster, it accounts 17.8% of export, however this group show a decline by -7.4% rate

On the import side, Wood and ceramics structural elements are confirmed by the main components imported on the market. Their share on import is 36% for wood constructional goods, and 41% for ceramic structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramics items (+0.1%) and for wood elements (+3.2%) increase.

Approximately 42% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

GREECE TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	73.073.176	53.641.931	-7,44%	17,88%
Ceramic constructional goods	24.580.013	28.818.324	4,06%	9,61%
Concrete, plaster structural elements	143.215.387	184.405.299	6,52%	61,46%

Wood Structural elements	30.991.551	33.160.707	1,71%	11,05%
TOTAL EXPORT	**271.860.127**	**300.026.261**	**2,50%**	**100,00%**
IMPORT	**2012**	**2016**		**Share on Import**
Cement, lime and plaster (ready mix)	9.709.685	5.834.006	-11,96%	3,15%
Ceramic constructional goods	75.604.127	76.016.773	0,14%	41,09%
Concrete, plaster structural elements	34.073.350	36.411.281	1,67%	19,68%
Wood Structural elements	58.651.651	66.745.117	3,28%	36,08%
TOTAL IMPORT	**178.038.813**	**185.007.177**	**0,96%**	**100,00%**

3.2 Market conditions / costs and benefits

The total aggregate production estimated for Greece is 21 million tonnes in 2015. Mostly these are crushed rock. Over the years the production volume has increased from 25 million tonnes in 2012, to a peak of 38 million tons in 2014, which in comparison with the 2015 production volume, meaning a decrease in total production - 45% (yoy). At present, the weight of recycled aggregates on total production volume is close to zero [3].

GREECE– Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	105	140	138	137
Total Number of Extraction Sites (Quarries and Pits)	196	192	190	189
Sand & Gravel (millions tonnes)	0	0	0	0
Crushed Rock (millions tonnes)	20	38	30	25
Marine Aggregates (millions tonnes)	0	0	0	0
Recycled Aggregates (millions tonnes)	0	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0
Total Production (millions tonnes)	**21**	**38**	**30**	**25**

There are no significant financial incentives for CDW recycling while at the same time the, apart from the landfill tax, there are no other taxes or financial instruments targeting the use of natural resources. The prices or raw materials for construction are still cheaper and are easier to access than recycled materials from the treatment of CDW. Another, uncontrolled dumping of CDW and the breaching of legislation by many actors in the CDW management chain, especially the waste holders and the collection services not affiliated to any CDW management system as laid down in legislation, hampers any efforts towards the direction of increasing CDW recycling. The recycling of CDW is perceived as a cost to pay, since alternatives are not well developed in Greece and the market for recycled CDW is not developed [1].

3.3 Construction sector make up

The **cutting-edge technology** is a revolution in the Greek building industry, having the ability to construct not only underground and ground-floor buildings but also multi-storey buildings. It consist in double walls and pre-slabs made from high-strength [4]

Figure 1. Example of Prefabricated elements and house in Greece

3.4 Use of CDW materials for prefabricated elements

Municipality Varis-Voulas-Vouliagmenis and the industrial partner AM Solutions, are involved in a research project named InnoWEE "Innovative pre-fabricated components including different construction and demolition Waste materials reducing building Energy consumption and minimising Environmental impacts", funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723916. In this project, among the others, one of the main result is the development of ventilated façade claddings based on the geopolymer technology. The panels will be composed out of an outer High Density Geopolymer (HDG) layer (6-8 mm thick) incorporating at least 40-50% of selected CDW and an inner layer (10-15mm thick) Wood-Geopolymer Panel (WGP) incorporating at least 50-60% (by weight) of CDW wood. The weight will be ca 20-30 kg/m2 and have an average density of 1,2-1,4 Kg/dm3 compared to 2,2-2,5 Kg/dm3 for concrete and 2,4-3 kg/dm3 for natural stone (basalt, marble, porphyry, granite). [6]

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HUNGARY

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

National Regulatory concerning CDW in Hungary are listed in Deliverable D1.1.
Particularly, **Ministerial decree 45/2004** details rules for CDW management. Requires the waste producer to complete a waste registration form after the construction or demolition work is completed. According to the Government, the Regulation is lacking guidance on where and how recycled construction materials can be used, or prohibition of their use. It is planned to address these issues in an amendment of this Regulation.
The waste type has to be summarized and exceeding quantities to limits in Regulation 45/2004 (VII. 26) have to be separated for recovery/recycling and treatment method has to be described in the **Demolition Waste Registration Card**.
In the same way, after completing the construction activity a **Construction Waste Registration Card** has to be completed showing the types and quantities of generated waste. Waste transfer notes have to confirm the validity of the data. These two documents have to be submitted to the building authorities together with a request for the occupancy permit. [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

<u>CDW used in road construction</u>

- General geotechnical rules of Roads and Motorways of E - 06:02:11 UT (2007 ROAD 2-1222)
- Road Course structures for unbound and hydraulically bound base layer design E- 06:03:52 UT (2-3207 ROAD : 2007)

<u>Bricks and tiles</u>

- MSZ EN 771 series (and masonry panels)
- MSZ EN 1304 (ceramic tiles)
- MSZ EN 490 (concrete roof tiles)

<u>Construction materials with CDW</u>

- JM3/01 Guidance on CDW re-use. For construction materials containing hydraulic or bituminous binders and mineral wastes not containing binders;
- JM3/02 Guidance. For re-use of CDW from structural engineering and materials without binders
- JM3/03 Guidance. For re-use of CDW from structural engineering and materials with cement binders.

Construction products sold or used in construction have to have a CERTIFICATE OF CONFORMITY.

The **Government Decree 191/2009 (IX.15)** about construction activities requires arranging for an expert examination of natural building materials from construction work and demolished building products to assess their adequacy of utilization, re-usability or treatment options.
The technical manager should decide on handling of these materials and record the decision in the log book.

§ 7 (1) of Decree 3/2003 on technical requirements for construction products, compliance certification, and detailed rules for the marketing and use states that, if a construction product is unique, made at the construction site or in-built/demolished from a historical monument, and there is no declaration of performance available from the manufacturer, this construction product can be used in construction, if the responsible technical manager makes a statement in the construction log, confirming that the proposed incorporation of the construction product is in compliance with the § 41 of Built Environment and Conservation Regulation LXXVIII from 1997.

§ 41 of Built Environment and Conservation Regulation LXXVIII from 1997 states that:

- Only construction products complying with basic requirements listed below can be used for construction:
  - Regulation on harmonized conditions for the marketing of construction products established in the Council Directive 89/106/EEC and 305/2011/EU of the European Parliament, or
  - Specific Technical Documentation defined in Articles 37 and 38 of the Regulation 305/2011/EU is available to demonstrate that the required performance specifications are met, or
  - The construction product complies with the requirements set out in separate legislation.
- For evaluation and verification of suitability of construction products and for suitability of organizations performing the verification, evaluation and registering of these products applies the CXXXIII Regulation on the activities of conformity assessment bodies and requirements in Directive 305/2011/EU

89/106 / EEC Construction Products Directive (Construction Product Directive - CPD), is established in **Decree 3/2003** (I.25) on the technical requirements for construction products, compliance certification, and detailed rules for the marketing and use.

305/2011/EU Construction Products Regulation (Construction Product Regulation - CPR) from 2011 has been adopted since July 2013 regarding the marketing of products. [1]

1.3 Prefabricated elements (with or without CDW materials)

Public civil engineering and hydraulic engineering projects do not have to require a minimum level of recycled CDW materials used in their construction.
There are, therefore, some technical for construction elements made by recycled materials, such as:

- JM2/01 Main wall slabs made from crushed brick. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete for making solid wood flooring elements from the demolition of buildings using brick dough additives
- JM2/02 Pre-made light concrete slabs for basements made with addition of crushed brick. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete hollow cellar wall elements from the demolition of buildings using brick dough additives
- JM2/03 Indoor floor tiles made from crushed bricks. TECHNICAL DIRECTIVE DRAFT - Prefabricated lightweight concrete for interior tiles from the demolition of buildings using brick dough additives. [1]

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

The Ministry of Environment and Water has supported the Independent Ecological Centre NGO to develop the online portal "**Nemsitt.hu**", aiming to facilitate the brokerage of used construction materials (especially bricks and tiles) and building components, thus promoting their reuse and reducing the amount of CDW going to landfill. 80% of the database implementation cost was supported by the Ministry. [2]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

Since the home building VAT rate was reduced to 5% from 27%, at the start of the year 2016 and until the end of the year 2019, prefab home companies have received at least a hundred orders. [3]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [7], the value of trade of prefabricated elements is € 742 Million in 2016. Export activities account 444 € Millions, while import account 298 € Million. The sold construction products in Hungary between 2012 and 2016 has increase at a rate (CAGR) of -3.7% for export, while import increase by rate of +9.9%.
On the export side, Hungary is a largest exporter of wood structural elements in EU (58.7% of total export), and the export of this elements increase by 6.9% in 2016, passing from 200 million euros

in 2012 to 261 million euros in 2016. The second largest exporter goods are ceramics constructional goods, it accounts 23.6% of export, however this group show a decline by 1.8% rate Concrete structural elements is the 3rd largest export goods, it account 16.8% of export and it's export trade growth with a rate of 4.6%

On the import side, Wood and ceramics structural elements are confirmed by the main components imported on the market. Their share on import is 53.9% for wood constructional goods, and 23.4% for ceramic structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramics items (+2.6%) and for wood elements (+16.3%) increase. Concrete structural elements are the 3rd largest import goods, it account 16.8% of export and its export trade growth with a rate of 7.6%

Approximately 87% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

HUNGARY TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on export**
Cement, lime and plaster (ready mix)	10.949.541	2.966.809	-27,85%	0,67%
Ceramic constructional goods	110.012.710	105.357.289	-1,08%	23,68%
Concrete, plaster structural elements	62.581.679	75.099.503	4,66%	16,88%
Wood Structural elements	200.148.622	261.505.693	6,91%	58,77%
TOTAL EXPORT	**383.692.552**	**444.929.294**	**3,77%**	**100,00%**
IMPORT	**2012**	**2016**		**Share on Import**
Cement, lime and plaster (ready mix)	13.519.143	14.668.769	2,06%	4,92%
Ceramic constructional goods	62.883.207	69.916.517	2,69%	23,46%
Concrete, plaster structural elements	39.205.470	52.616.613	7,63%	17,65%
Wood Structural elements	88.746.509	160.868.723	16,03%	53,97%
TOTAL IMPORT	**204.354.329**	**298.070.622**	**9,90%**	**100,00%**

3.2 Market conditions / costs and benefits

The total production volume of aggregates is 58 million tonnes. Although not perfectly linear, production volume grew in the past few years from 36 million in 2012 to 58 million tonnes in 2015. Compared with the previous year, however, there is a contraction of -7.9% (yoy). The weight of aggregates recycled on total production volume is 3.4%, equivalent to about 2 million tonnes [6]

HUNGARY– Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	461	461	461	473
Total Number of Extraction Sites (Quarries and Pits)	760	760	760	788
Sand & Gravel (millions tonnes)	40	49	30	24
Crushed Rock (millions tonnes)	16	14	15	13
Marine Aggregates (millions tonnes)	0	0	0	0

Recycled Aggregates (millions tonnes)	2	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0
Total Production (millions tonnes)	**58**	**63**	**44**	**36**

CDW collection, pre-treatment and recycling is currently costly and therefore more expensive than the primary building materials Construction companies are not familiar with the use of recycled construction materials. Nearly the half of these products are construction products. The prices of recycled CDW products are often not competitive with virgin materials. However, The number of eco-friendly products on the Hungarian market has increased from 2000 to 2009 by 80% [1].

3.3 Construction sector make up

In Hungary, the mass housing policy utilizing prefabricated technology was initiated with the help of the first fifteen-year housing policy 1961–75 and the second five-year-plan development project 1961–65, so that in Budapest, one third of the population lives in large prefabricated housing estates. New units of city organization were developed everywhere, called *lakótelep* (large prefabricated housing estate). Nevertheless, it is evident that this common product of 20th-century urbanism was modified by local urban potential and socio-economic backgrounds. Budapest's first Soviet housing factories began to produce in 1965, when planning and design were directed by new norms, panel-house technology and national economic requirements. [4]
Several large companies experimented (relying on their experience with the application of block technology) with the production and construction of buildings of large prefabricated concrete blocks based on (mainly Soviet) examples abroad. The first house factory in Hungary started production in 1965, while the last one, the tenth, in Kecskemét, started in 1976. [5]
As a result of this centrally-coordinated process, the first large prefabricated housing estate within the city was realized in Kelenföld, creating modern homes for human beings of the future. [4]

Figure 1. Typical soviet prefab building in Obuda, Budapest, 2014 [4]

Panel buildings consist of sheet-like frameworks, which are normally a storey high and the size of a room. These modules may be turned into a supporting frame by pouring concrete into them along the edges at the construction site.

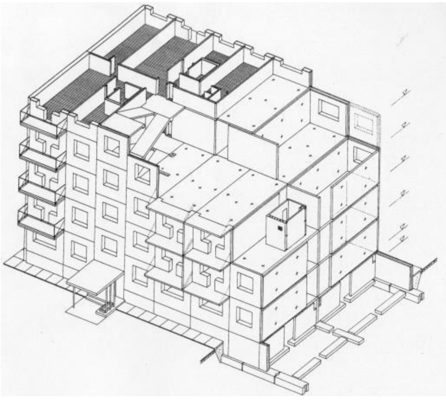

Figure 2. Panel building [5]

Further characteristics of the panel structure are:
1) modules generally weigh 1-7 tonnes;
2) gaps between the joints are filled with concrete; the joining of modules is done with the help of steel reinforcement and bracing along the edges;
3) the building is reinforced with two-way walls (the connection between the floorspace and walls does not provide enough firmness);
4) panels on the facade are sandwich-structured; panels on the inside are of concrete; while the floorspace is made of reinforced concrete. [5]

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

4. REFERENCES

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[7] http://epp.eurostat.ec.europa.eu/newxtweb/submitopensavedextraction.do?extractionId=13829578&datasetID=DS-045409&keepsessionkey=true

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IRELAND

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Please refer to Deliverable D1.1 (Ireland).

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Please refer to Deliverable D1.1 (Ireland).

1.3 Prefabricated elements (with or without CDW materials)

The following Irish Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of precast concrete elements:

I.S. EN 12602:2016 [1IRL] sets the requirements for the use of Autoclaved Aerated Concrete (AAC) (including AAC made from recycled AAC) in structural (such as load bearing walls, retaining walls, roofs, floors, beams and piers) and non-structural (such as non-load bearing walls, cladding without fixtures for external facades of buildings, small box culverts and noise barriers) prefabricated elements.

I.S. EN 13369:2013 [2IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for unreinforced, reinforced and pre-stressed precast concrete products made of compact lightweight, normal-weight or heavy-weight concrete. It allows the use of crushed recycled aggregate (up to 10% in weight of the total content of aggregates in the concrete mix) obtained from precast concrete products manufactured in the same factory. The above replacement level can be increased up to 20% provided certain conditions are met. Recycled coarse aggregates from external sources which are composed of pure concrete debris can be used under the same conditions described above provided the source and mix properties of the crushed concrete are known by the manufacturer. It should be noted that I.S. EN 13369:2013 [2IRL] does not allow the use of recycled aggregates in concrete for which durability requirements are higher than those for the concrete from which they originate (This does not apply for exposure classes X0, XC1 and XC2 as defined by I.S. EN 206:2013 [3IRL]).

I.S. EN 1168:2005 [4IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast hollow core slabs made of reinforced or pre-stressed normal-weight concrete.

I.S. EN 12794:2005 [5IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete foundation piles manufactured and stored in a factory, transported and finally installed on a construction site.

I.S. EN 12839:2012 [6IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete products (reinforced or pre-stressed with or without fibres) to be used together or in combination with other elements in order to erect fences such as boundary fences.

I.S. EN 12843:2004 [7IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete poles and masts (reinforced or pre-stressed) to be used for overhead electrical lines, telecommunication lines, overhead electrical lines (railways and trams), supports for lighting, supports for loudspeaker installations, antenna and telecommunication poles, supports for wind turbines and similar installations.

I.S. EN 13224:2011 [8IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast ribbed floors or roofs made of reinforced or pre-stressed normal-weight concrete.

I.S. EN 13225:2013 [9IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast linear elements such as beams, columns and frames made of reinforced or pre-stressed lightweight or normal-weight concrete to be used in the construction of buildings and other structures (except bridges).

I.S. EN 13693:2004 [10IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for special precast roof elements made of reinforced or pre-stressed normal-weight concrete to be used in the construction of buildings.

I.S. EN 13747:2005 [11IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast floor plates made of reinforced or pre-stressed normal-weight concrete to be used together with cast-in-situ concrete in the construction of composite floor slabs.

I.S. EN 13978-1:2005 [12IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast reinforced concrete garages built as monolithic units or as kits of single sections with room dimensions in precast concrete factories.

I.S. EN 14843:2007 [13IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast (reinforced or pre-stressed) concrete monolithic stairs as well as precast concrete elements such as individual steps used to make reinforced or pre-stressed concrete stairs. It is applicable to structural stairs for indoor or outdoor use.

I.S. EN 14844:2006 [14IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for large (structural) and small (non-structural or light structural) box culverts of monolithic construction and rectangular cross-section designed as continuous elements with a joint detail shaped to allow the possible incorporation of sealing materials.

I.S. EN 14991:2007 [15IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast foundation elements (such as columns with integrated foundation elements, pocket foundation elements or sockets) made of reinforced normal-weight concrete to be used in the construction of buildings.

I.S. EN 14992:2007 [16IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for prefabricated walls made of lightweight, normal-weight or fibre (steel, polymer or other fibres) reinforced concrete.

I.S. EN 15037-1:2008 [17IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast beams made of reinforced or pre-stressed normal-weight concrete to be used together with blocks with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

I.S. EN 15037-2:2009 [18IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of lightweight or normal-weight concrete to be used together with precast concrete beams conforming to I.S. EN 15037-1:2008 [17IRL] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

I.S. EN 15037-3:2009 [19IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of clay to be used together with precast concrete beams conforming to I.S. EN 15037-1:2008 [17IRL] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

I.S. EN 15037-4:2010 [20IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of expanded polystyrene (EPS) to be used together with precast concrete beams conforming to I.S. EN 15037-1:2008 [17IRL] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

I.S. EN 15037-5:2013 [21IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for lightweight blocks to be used together with precast concrete beams conforming to I.S. EN 15037-1:2008 [17IRL] with or without cast-in-situ concrete as formwork during the construction of a beam-and-block floor systems.

I.S. EN 15050:2007 [22IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast structural elements made of reinforced or pre-stressed normal-weight concrete and produced in a factory to be used as deck elements in bridge construction (footbridges as well as road and railway bridges). Deck elements can either be single elements from which the deck is composed (beams, slabs, ribbed or cellular elements) or elements which form a segment of the entire deck.

I.S. EN 15258:2008 [23IRL] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast elements made of plain, reinforced or pre-stressed normal-weight concrete to be used for the construction of retaining walls.

The following Irish Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated timber elements:

I.S. EN 336:2013 [24IRL] specifies two classes of permitted cross-sectional deviations from target sizes for structural timber of softwood or hardwood species. In addition, it specifies the moisture content to be used as a reference point for measuring sizes and provides average values for changes in size as a result of changes in moisture content.

I.S. EN 338:2016 [25IRL] specifies a system of strength classes to be used in design codes. It provides characteristic strength, stiffness and density values for each class. It is applicable to all softwood and hardwood species of timber used for structural applications.

I.S. EN 14081-1:2016 [26IRL] states the requirements (mechanical resistance, fire resistance, reaction to fire release of dangerous substances, biological durability and geometrical data) for structural timber with rectangular cross-sections (either visual or machine graded) and shaped by sawing, planning or other methods.

I.S. EN 14081-2:2010 [27IRL] states additional requirements to those in I.S. EN 14081-1:2016 [26IRL] for initial type of testing of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in I.S. EN 336:2013 [24IRL].

I.S. EN 14081-3:2012 [28IRL] states additional requirements to those in I.S. EN 14081-1:2016 [26IRL] for factory production control of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in I.S. EN 336:2013 [24IRL].

I.S. EN 14250:2010 [29IRL] states the requirements (material, product and documentation), testing methods and evaluation of conformity for prefabricated structural members (such as trusses for roofs, walls and floors, frames, composite beams and girders) to be used in construction of buildings made from solid structural timber with or without finger joints assembled with punched metal plate fasteners.

I.S. EN 15644:2009 [30IRL] states the specifications and requirements for prefabricated stairs in which the components contributing to the fulfilment of mechanical resistance and stability are made of solid wood (traditionally designed stairs).

I.S. EN 15736:2009 [31IRL] describes a test method for determining the withdrawal behaviour of punched metal plate fasteners.

SR CEN/TS 15680:2007 [32IRL] provides test methods for evaluating the mechanical performance of prefabricated timber stairs.

The following Irish Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated aluminium elements:

I.S. EN 507:2000 [33IRL] states the requirements (general, materials and products), testing methods and designation (sheet, coil, slit coil, cut length, roof panel, clip or tile) for all discontinuously laid and fully supported aluminium sheets with or without additional organic coatings to be used for pitched roofs. Products can be pre-formed (prefabricated), semi-formed or as strip, coil and sheet for on-sit-formed applications.

I.S. EN 508-2:2008 [34IRL] states the requirements (general, materials and products), testing methods and designation for all discontinuously laid self-supporting external profiled aluminium sheets with or without additional organic coatings to be used for roofing.

I.S. EN 14782:2006 [35IRL] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made self-supporting metal (copper, zinc, steel, stainless steel and aluminium) sheets and tiles with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining. It also covers ceiling and soffit applications and cassettes.

I.S. EN 14783: 2013 [36IRL] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made fully-supported metal (copper, zinc, lead, steel, stainless steel and aluminium) coil, strip and flat sheets with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining.

I.S. EN 13830:2015 [37IRL] states the product characteristics, testing methods and assessment and verification of constancy of performance of curtain walling systems to be used as part of the building envelope.

1.4 Prefabricated construction

Technical Guidance Document A-Structure [38IRL] sets the minimum standards for the construction of all types of buildings including alternative forms of residential building construction such as prefabricated buildings in accordance with Building Regulations (Part A Amendment) Regulations 2012 [39IRL]. More specifically, the above approved document provides practical guidance (including examples and solutions for some of the more common building situations) on the expected performance of materials and workmanship in order to comply with all requirements set by the Building Regulations (Part A Amendment) Regulations 2012 [39IRL]. It refers to the following Irish Standards/European Norms and National Documents for structural design purposes:

Basis of structural design and loading

I.S. EN 1990:2002 [40IRL]

I.S. EN 1990:2002 National Annex: 2010 [41IRL]

I.S. EN 1991-1-1:2002 [42IRL]

I.S. EN 1991-1-1:2002 National Annex: 2013 [43IRL]

I.S. EN 1991-1-2:2002 [44IRL]

I.S. EN 1991-1-2:2002 National Annex: 2007 [45IRL]

I.S. EN 1991-1-3:2003 [46IRL]

I.S. EN 1991-1-3:2003 National Annex: 2007 [47IRL]

I.S. EN 1991-1-4:2005 [48IRL]

I.S. EN 1991-1-4:2005 National Annex: 2013 [49IRL]

I.S. EN 1991-1-5:2003 [50IRL]

I.S. EN 1991-1-5:2003 National Annex: 2008 [51IRL]

I.S. EN 1991-1-6:2005 [52IRL]

I.S. EN 1991-1-6:2005 National Annex: 2007 [53IRL]

I.S. EN 1991-1-7:2006 [54IRL]

I.S. EN 1991-1-7:2006 National Annex: 2008 [55IRL]

I.S. EN 1991-3:2006 [56IRL]

Structural work of reinforced, pre-stressed or plain concrete

I.S. EN 1992-1-1:2005 [57IRL]

I.S. EN 1992-1-1:2005 National Annex: 2010 [58IRL]

I.S. EN 1992-1-2:2005 [59IRL]

I.S. EN 1992-1-2:2005 National Annex: 2010 [60IRL]

2.1.4.3 Structural work of steel

I.S. EN 1993-1-1:2005 [61IRL]

I.S. EN 1993-1-1:2005 National Annex: 2007 [62IRL]

I.S. EN 1993-1-2:2005 [63IRL]

I.S. EN 1993-1-2:2005 National Annex: 2010 [64IRL]

I.S. EN 1993-1-3:2006 [65IRL]

I.S. EN1993-1-3:2006 National Annex: 2010 [66IRL]

I.S. EN 1993-1-4:2006 [67IRL]

I. S. EN 1993-1-4:2006 National Annex: 2010 [68IRL]

I. S. EN 1993-1-5:2006 [69IRL]

I.S. EN 1993-1-5:2006 National Annex: 2010 [70IRL]

I.S. EN 1993-1-6:2007 [71IRL]

I.S. EN 1993-1-6:2007 National Annex: 2010 [72IRL]

I.S. EN 1993-1-7:2007 [73IRL]

I.S. EN 1993-1-7:2007 National Annex 2010 [74IRL]

I.S. EN 1993-1-8:2005 [75IRL]

I.S. EN 1993-1-8:2005 National Annex: 2010 [76IRL]

I.S. EN 1993-1-9:2005 [77IRL]

I.S. EN 1993-1-9:2005 National Annex: 2010 [78IRL]

I.S. EN 1993-1-10:2005 [79IRL]

I.S. EN 1993-1-10:2005 National Annex: 2010 [80IRL]

I.S. EN 1993-1-11:2006 [81IRL]

I.S. EN 1993-1-11:2006 National Annex: 2010 [82IRL]

I.S. EN 1993-1-12:2007 [83IRL]

I.S. EN 1993-1-12:2007 National Annex: 2010 [84IRL]

I.S. EN 1993-5:2007 [85IRL]

I.S. EN 1993-5:2007 National Annex: 2010 [86IRL]

I.S. EN 1993-6:2007 [87IRL]

I.S. EN 1993-6:2007 National Annex: 2010 [88IRL]

Structural work of composite steel and concrete

I.S. EN 1994-1-1:2004 [89IRL]

I.S. EN 1994-1-1:2004 National Annex: 2010 [90IRL]

I.S. EN 1994-1-2:2005 [91IRL]

I.S. EN 1994-1-2:2005 National Annex: 2010 [92IRL]

Structural work of timber

I.S. EN 1995-1-1:2004 [93IRL]

I.S. EN 1995-1-1:2004 National Annex: 2010 [94IRL]

I.S. EN 1995-1-2:2005 [95IRL]

I.S. EN 1995-1-2:2005 National Annex: 2010 [96IRL]

Structural work of masonry

I.S. EN 1996-1-1:2005 [97IRL]

I.S. EN 1996-1-1:2005 National Annex: 2010 [98IRL]

I.S. EN 1996-1-2:2005 [99IRL]

I.S. EN 1996-1-2:2005 National Annex: 2010 [100IRL]

I.S. EN 1996-2:2006 [101IRL]

I.S. EN 1996-2:2006 National Annex: 2010 [102IRL]

I.S. EN 1996-3:2006 [103IRL]

I.S. EN 1996-3:2006 National Annex: 2010 [104IRL]

Geotechnical work and foundations

I.S. EN 1997-1:2005 [105IRL]

I.S. EN 1997-1:2005 National Annex: 2007 [106IRL]

I.S. EN 1997-2:2007 [107IRL]

Structural work of aluminium

I.S. EN 1999-1-1:2007 [108IRL]

I.S. EN 1999-1-1:2007 National Annex 2010 [109IRL]

I.S. EN 1999-1-2:2007 [110IRL]

I.S. EN 1999-1-2:2007 National Annex: 2010 [111IRL]

I.S. EN 1999-1-3:2007 [112IRL]

I.S. EN 1999-1-3:2007 National Annex: 2010 [113IRL]

I.S. EN 1999-1-4:2007 [114IRL]

I.S. EN 1999-1-4:2007 National Annex: 2010 [115IRL]

I.S. EN 1999-1-5:2007 [116IRL]

I.S. EN 1999-1-5:2007 National Annex: 2010 [117IRL]

2. POLICY MEASURES

2.1 Materials from CDW

Please refer to Deliverable D1.1 (Ireland).

2.2 Prefabricated elements (with or without CDW materials)

Please refer to Paragraph 2.3 below.

2.3 Prefabricated construction

During 1960s, Ireland gained significant experience of prefabricated residential building construction mainly in the form of Industrialised Building Construction based on precast concrete. Most notable examples were 36 tower blocks of flats (7 fifteen-storey, 19 eight-storey and 10 four-storey blocks) built in Ballymun area of Dublin during 1960s. Like in the UK, this type of construction came to be associated with neglect as well as durability and structural integrity problems due to poor workmanship. In addition, social problems (such as high levels of unemployment, drug abuse and crime) in the area magnified the negative public perception regarding this type of prefabricated construction. Eventually, all tower blocks were demolished during a period of 12 years (2004-2015) as part of a major regeneration programme of the area.

Modern prefabrication methods used in Ireland include a number of prefabricated systems for a wide variety of applications. The main types of prefabrication systems used are:

- Frame and Deck Construction (precast concrete)
- Cross-wall Construction (precast concrete)
- Mixed Construction (combination of precast concrete and in-situ concrete, steel or glass)
- Volumetric (modular) Construction (timber or light steel frame)
- Timber Prefabricated Systems

Frame and Deck Construction is based on precast concrete decks supported by precast concrete beams and columns (Fig. 1 a-b). It is mainly used for building multi-storey industrial buildings or car parks with large spans which allow columns to be placed between car parking spaces.

a) b)

Fig. 1 (a-b): Frame and Deck construction (Nutgrove Retail Park in Rathfarnham, Dublin) [118IRL]

Cross-wall Construction is a modern and effective form of construction in which load bearing walls provide the main vertical support and lateral stability for precast floors. The required lateral stability is provided by lift cores, staircases or external wall panels (Figs. 2 a-b, 3 a-b and 4). The method is well suited for buildings with cellular and orthogonal grids such as private flats, hotels and student residences. It offers durable structures with good sound insulation which typically span up to ten storeys in height (due to restrictions imposed by Irish planning regulations).

a) Storage of cross-walls in precast factory yard

b) On-site Installation of cross-walls

Fig. 2 (a-b): Precast concrete cross-walls [119IRL]

a)

b)

Fig. 3 (a-b): Cross-wall Construction (Housing development in Cherry Orchard, Dublin) [120IRL]

a) Mount Saint Anne's apartments in Milltown, Dublin

a) Hanover Quay apartments in Dublin

Fig. 4 (a-b): Typical examples of apartments built using Cross-wall Construction [121-122IRL]

Mixed Construction is based on combining precast concrete and in-situ concrete, steel, masonry or glass. A typical example of mixed construction is steel frame and precast concrete elements such as wall and floor panels (Fig. 5). Consequently, it benefits from the speed, accuracy and high-quality finish of precast concrete and the robustness of structural steelwork. [119IRL].

Fig. 5: Mixed Construction (steel frame and precast concrete floor panels) of an industrial building in Ballina, County Mayo [119IRL]

Volumetric (modular) Construction transfers most of the construction site activities into the factory premises of the prefabrication company. The technique consists of building large modules that are designed to include services (electrical, mechanical and public health systems) and finishes (both exterior and interior). Modern volumetric construction covers a very broad spectrum of applications which include: private housing (including multi storey buildings), hotels (low and medium rise), schools, hospitals (operating theatres and rooms), office buildings (multi-storey as well as temporary), student residences, barracks and construction site office huts [123IRL].

The main forms of Volumetric (Modular) Construction in Ireland are:

- Shipping Container (steel)
- Modular Construction (light steel frame)
- 3D Volumetric Construction (precast concrete)

Shipping Container method is based on the strength and flexibility of the shipping container design. These blocks have dimensions of 2.5 m (width) by either 20 m or 40 m (length). Their interior is fully equipped with fixtures and fittings such as offices, kitchens, toilets and storage areas. They are mainly used in construction sites [123IRL]. However, since 2014, they have slowly started to find their way to the housing market (Fig. 6) [124IRL].

Fig. 6 (a-b): Example of Shipping Container house in Cork [124IRL]

The use of modular housing units based on timber or light steel frame is gathering pace in Ireland. A number of different internal layouts, external finishes and specifications are available. Modular units are mainly used as temporary accommodation for tackling homelessness in big Irish cities (Fig. 7 a-f) [125IRL]. However, latest information suggests that local authorities are considering the option of using them for permanent housing [126IRL]. Units come fully furnished with all services installed in the factory.

a) Modular house by Skyclad

b) Modular house by Mom Services Ltd

c) Modular house by Portakabin

d) Modular house by Spacebox

e) Modular house by Roankabin

f) Modular house by Modular Homes Ireland

Fig. 7 (a-f): Typical examples of modular housing units [125IRL]

Timber Prefabricated Systems in Ireland are similar to the ones used in the UK and include:

- Glued Laminated Timber (Glulam) Beams
- Cross Laminated Timber (CLT) Panels for walls, floors and roofs
- Structural Insulated Panels (SIPS)
- Open Panel or Closed Panel Timber Frames
- Roof Panels, Roof Trusses and Spandrel Panels
- Floor Panels/Cassettes, I-Joists and Open Web Joists

A detailed description of the above systems is provided by the Structural Timber Association (UK) [127-131IRL], Timber Research and Development Association (TRADA) (UK) [132IRL] and Timber Frame Housing Consortium) (TFHC) (Ireland) [133IRL] (Please refer to relevant List of Information for UK).

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Data of Irish Exports/imports of prefabricated buildings, plumbing and electrical fixtures and fittings for the period 2006-2016 is shown in Table 1 obtained from the Central Statistics Office [134IRL]. As it can be seen from Table 1 below, Ireland is a net importer of prefabricated buildings, plumping and electrical fixtures and fittings.

Table 1: Irish Exports/Imports of prefabricated buildings, plumbing & electrical fixtures & fittings [134IRL]

Year	Exports (€ Thousand)	Imports (€ Thousand)
2006	111,900	321,400
2007	125,700	351,900
2008	135,100	269,400
2009	102,700	199,400
2010	102,000	170,200
2011	98,700	152,100
2012	92,100	150,700
2013	111,000	157,600

2014	129,000	193,900
2015	157,200	236,100
2016	158,100	242,400

3.2 Market conditions / costs and benefits

During a period of 10 years (1998-2008) a significant shift towards prefabrication (both low and high-rise buildings) has been witnessed in Ireland. This was mainly due to high demand for new homes as a result of strong and sustained economic growth. Prefabricated construction (especially precast concrete) appeared to be the best option for achieving consistently high standards and shorter completion times compared to traditional on site methods of construction [119, 135IRL].

Many Irish prefabricated construction firms (either precast concrete, light steel frame modular construction or prefabricated timber frame manufacturers) use state of the art manufacturing techniques in modern and highly automated factories. As a result the following benefits can be achieved using prefabricated solutions (precast concrete or modular/panelised construction based on light steel or timber frame) [119, 135-137IRL]:

- Significant levels of recycling of raw materials
- Reduction in construction waste
- Controlled construction environment (better finishes and fewer defects)
- Shorter construction times
- Fewer operatives on site
- Cost savings (due to shorter construction times and fewer operatives on site)
- Creation of employment in areas away from construction sites
- Less noise and dust
- Reduction in accidents

However, the financial crisis of 2008 led to a severe reduction in construction activity which significantly affected the prefabrication sector. This is highlighted by the large number of unfinished, unoccupied or unsold housing developments all over the country that have been demolished or may have to be demolished in the near future (Fig. 8) [138IRL].

a)

b)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

c)

d)

e)

f)

Fig. 8 (a-f): Demolition of unfinished or unsold houses [138IRL].

3.3 Construction sector make up

The prefabricated construction sector is dominated by precast concrete, light steel frame modular construction and prefabricated timber manufacturers. Precast concrete manufacturers are represented by the Irish Precast Concrete Association (IPCA), whereas the work and activities of prefabricated timber frame manufacturers are represented by the Irish Timber Frame Manufacturers' Association (ITFMA).

Precast concrete companies produce a wide range of products which are not limited to residential buildings. These include: prefabricated buildings, architectural cladding, structural elements (for most types of structures), bricks & blocks, roof tiles, piles and foundations, pipes and drainage systems, box culverts, railway sleepers, tunnel linings, retaining walls, water storage & treatment tanks, paving blocks, sea & river defence units, lighting columns & transmission poles, vehicle safety barriers, garden products, fencing and street furniture & bollards.

Despite the really difficult situation in which the housing sector is currently in, light steel frame modular construction and prefabricated timber frame construction are becoming more popular in Ireland. They are viewed by some (local authorities) as the best solution (temporary accommodation) for tackling the growing problem of homelessness in big Irish cities.

3.4 Use of CDW materials for prefabricated elements

The use of recycled aggregate in concrete including precast concrete is quite low with most of it used for backfilling operations. This is mainly due to lack of confidence in its use and the large supply of low cost good quality virgin aggregate, for which demand has significantly dropped over the last years [139IRL]. The cost of recycled aggregate is estimated to be €1/tonne compared to €3.5/tonne for virgin aggregate [140IRL].

No figures for the reuse of timber in prefabricated construction could be obtained. However, available sources of data do not point towards significant quantities of recycled timber being used for such purpose.

Finally, up to 50% of new steel used in modular construction may come from old steel scrap [141IRL].

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ITALY

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Legislative Decree no. 152 transposes Directive 2008/98 / EC with the amendments introduced by **Legislative Decree 205/2010** and the principles of certain directives for specific types of waste or treatment; It sets, inter alia, specific preparation targets for the reuse and recycling of urban waste and waste from construction and demolition (70% by 2020); States that the Regions carry out waste planning through regional plans. So Regions, heard the Provinces, the Municipalities and, for the section on urban waste, the Area Authorities, prepare and adopt the regional plan for waste management.
Article 199 of Legislative Decree 152/2006 defines the essential contents of the plan. The same article also stipulates that the plan provides for "waste collection systems and existing disposal and recovery facilities".
The **National Waste Prevention Program**, approved by the Ministry of the Environment with a decree of directors of October 7, 2013, with the aim of dissociating economic growth from the environmental impacts associated with waste production, identifies specific prevention targets to be achieved in 2020, calculated from Values recorded in 2010.
Specifically, with regard to special waste, it provides:
- a 10% reduction in the production of special hazardous waste per unit of increasing GDP;
- a 5% reduction in non-hazardous non-hazardous waste production per unit of increasing GDP. [1]

Technical regulations about CDW can be found in DM 5/02/98 and s.m.i. In particular, it provides that only *"... waste consisting of bricks, plaster and conglomerates of reinforced concrete and not, including railway crossings and trams and reinforced concrete poles coming from railway lines, telematic and electrical, and fragments of road coatings, provided asbestos-free, can be started to produce secondary building materials by mechanical and technologically interconnected steps of grinding, screening, granulometric selection and separation of the metal fraction and of undesirable fractions for obtaining inert grafts of grain size with suitable and selected granulometry, with verification of the conformity of the disposal test elute."* In that sense, such waste from construction and demolition can be considered secondary building materials, which can be marketed and reused freely also for the formation of road signs and substrates.
As evidenced by the Decree cited, and in particular by the subsequent major changes made, a fundamental stage of verification and validation is represented by the "***assignment test***" (Article 9 of DM 5 February 1998), which must be carried out with the same standards as **UNI 10802**, "*Waste. Liquid, granular, pasty and sludge wastes. Manual sampling, preparation and analysis of eluates*", for which the analytical method prescribed by **UNI EN 12457-2**,"*Waste characterization. Leaching. Compliance test for granular and sludge waste disposal. Part 2*". [2]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

In the wide range of recycled materials, particularly interesting are the inerts treated by recovery plants whose use is more and more often a substitute for "natural" or "virgin" materials in the realization of infrastructure artifacts or civil engineering works.
CDW are largely made up of cement, bricks, tiles and other ceramic materials, lands and rocks, bituminous mixtures, metals, glass, wood and plastics, all (according to current legislation) cataloged as special waste belonging to Chapter 17 Of the CER Code. They originate from construction, maintenance, renovation, demolition, etc. of public and private buildings, civil and infrastructural works, industrial activities in the sectors including the prefabricated industry, ceramics, ornamental stones, manufacture and prefabrication of civilian building elements and components (bricks, tiles, structural elements In ca, etc.). Their composition can be extremely variable depending on the construction technology, the types of raw materials, the territorial conditions (in terms of climatic characteristics as well as economic and technological development).
Such waste of building activities and technological processes, through the workings carried out within recovery facilities, contribute to the formation of new materials, either individually or in aggregates (with or without bituminous or cementitious binders) classified as: milled found, screened, milled found, sands for substrates, stabilized screened. They are recycled aggregates with more or less mechanical properties of strength and bearing, produced by crushing, selecting and screening processes. [3]

Figure 1. Types of "second" raw materials (ground, found, screened, ground, ground, sand, stabilized Varied) © REM srl, Motta di Livenza. [3]

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The greater use of recycled aggregates concerns the field of road works and, as such they are subject to CE marking according to **EN 13242**: Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction. The suitability for specific use, however, is defined by **UNI 11531-1: 2014**, standard for recycled aggregates used for civil engineering works and road construction. More details about unbound mixtures of natural, artificial and recycled aggregates, for streets applications, are contained in the standard **UNI EN 13285**.

Less frequent is the production of recycled aggregates oriented to the use in concrete production, subject to the CE marking according to **EN 12620**. [4]

Recycled aggregates used **in concrete production** are divided into three types, depending on their origin: aggregates from construction and demolition waste, concrete aggregates and aggregated by excavation. CDW aggregates are those derived from construction and demolition waste, which represent a very wide range of materials. Their classification varies depending on the mode of waste generation.

The second type of recycled aggregates is that made from concrete or resulting concrete, that is, the cast concrete and therefore not used by the buyer and returned to the producer.

The third category of recycled aggregates is that of excavated land and rocks and is currently the least used in concrete production. Land and rock excavation means soil from excavation activities devoid of hazardous contaminants and / or ultrasonic material (plastic material, rubble, clay, metals, etc.). [5]

The current **Technical Standards for Construction**, issued by **D.M. January 14, 2008** (Suppl. Ord. N.30 GU 04-02-2008 n.29), Chapter 11 (MATERIALS AND PRODUCTS FOR STRUCTURAL USE), 11.2 (CONCRETE), PAR 11.2.9 (COMPONENTS OF THE CALCULATOR) , 11.2.9.2 (AGGREGATES), state that "Aggregates obtained from the processing of natural, artificial or recycled materials conforming to the European harmonized standard **UNI EN 12620** are suitable for the production of concrete for structural purposes and for aggregates lightweight, harmonized European standard **UNI EN 13055-1**". The system of attestation of conformity of such aggregates, pursuant to Presidential Decree No. 246/93, is 2+ for use in structural concrete.

The same rule states that: "The use of large recycled aggregates, subject to the limits set out in Table 1, provided that the mixture of concrete packed with recycled aggregates is preliminarily qualified and documented by appropriate tests of laboratory. For such aggregates, the factory production control tests specified in H1, H2 and H3 prospectuses of the Annex ZA of the Harmonized European Standard UNI EN 12620 for the relevant parts shall be carried out every 100 tonnes of aggregate product and, in recycling facilities, for each day of production. [6]

Table 1. Limits for the use of recycled aggregates of the Technical Standards for Buildings.

Origin of recycled material	Concrete class	% utilization
Building demolition (rubble)	= C8/10	Up to 100%
Demolition of only concrete and reinforced concrete	≤ C30/37	≤ 30%
	≤ C20/25	Up tp 60%
Re-use of internal concrete in qualified prefabricated	≤ C45/55	Up tp 15%

Origin of recycled material	Concrete class	% utilization
establishments - by any class		
Re-use of internal concrete in qualified prefabricated establishments - by concrete > C45/55	Same source concrete class	Up to 15%

It notes the case concerning the reuse of internal concrete in prefabrication plants.
References to **UNI 8520-1: 2015** and **UNI 8520-2: 2016** guidelines may be used in the project prescriptions in order to identify the physico-chemical requirements that are additional to those set for natural aggregates that recycled aggregates must meet, depending on the final destination of the concrete and its performance properties (mechanical, durability and environmental hazards, etc.), as well as maximum percentage percentages of recycle aggregates or concrete strength classes that are lower than expected in the Table 1. [6]
Regarding any acceptance checks to be carried out by the Works Director, these are aimed at least to the determination of the technical characteristics reported in Table 2. The test methods to be used are those indicated in the cited harmonized European Standards, in relation to each characteristic. [6]

Table 2. Acceptance test for aggregates for structural concrete.

Technical characteristics
Simplified petrographic description
Size of the aggregate (granulometric analysis and end content)
Flattening index
Filler dimension
Shape of big aggregate (for aggregate from recycle)
Resistance to fragmentation / crushing (for concrete Rck ≥ C50 / 60)

The proportion of constituent materials in large recycled aggregates must be determined in accordance with **UNI EN 933-11** and must be declared in accordance with the relevant category specified in Table 12 of **UNI EN 13242:2008**.
Even the Circular of Ministry of the Environment, N. 5205 of July 15, 2005, provides guidance to the definition of technical and performance criteria that recycled materials and articles have to possess for inclusion in the Recycling Directory. [7]
It is useful to recall that EU Regulation no**. 305/2011**, which lays down harmonized conditions for the marketing of construction products, sets out the basic requirements for construction works in Annex I, including the sustainable use of resources. In particular point no. 7 says: Construction works must be designed, constructed and demolished so that the use of natural resources is sustainable and in particular guarantees the following:
(A) the re-use or recyclability of construction works, their materials and parts after demolition;
(B) the durability of construction works;
(C) the use, in construction works, of environmentally compatible raw and secondary materials.

The said D.M. 14.01.2008 mentions several times as a useful reference to the requirement of the durability of concrete works in accordance with EN 206 and UNI 11104. In **Appendix E of EN 206**, Table E.2 indicates the maximum percentages of large aggregates replacement with recycled aggregates, depending on the environmental exposure class.
UNI 11104, paragraph 5.3, contains the prospectus 4 in which the maximum percentages of substitution of large aggregates with recycled aggregates are distinct according to the environmental exposure class and also the resistance class (more explicitly than EN 206).
In both cases reference is made to large recycled aggregates designated as belonging to the categories named Type A and Type B. This distinction is based on the different percentage limits of the constituents of large aggregates, evidently with a significant prevalence of Type A concrete.
UNI 11104 also provides guidance with respect to prefabrication plants where concrete internal reuse is permitted as a large aggregate up to a maximum value of 10% in the case of concrete of the same resistance class and up to 15% in the case of lower strength class concrete.
As far as prefabrication facilities are concerned, the standard **EN 13369**: Common rules for precast concrete products, which is the basis of the product standards in this sector, is set out in point 4.1.2.2 for a reuse limit at the same establishment as 10%, which can be lowered to 5% for specific applications. Further information is provided in Appendix Q of the Standard. In particular, it is stated that recycled aggregates or recycled concrete can be used up to the 5% limit without any other compression resistance.
In the case of recycled concrete from the same plant, the limit increases to 10%. [4]

1.3 Prefabricated elements (with or without CDW materials)

In addition to the harmonized European legislation (EN) which most of them are mandatory for the market commercialization (CE marking) of structural elements, the legislative and regulatory situation in precast concrete products in Italy is shown below:

CONCRETE PRECAST ELEMENT

- Ministerial Decree: Technical Standards for Construction, of 14 January 2008;
- UNI 9053-1:1987. Edilizia. Elementi strutturali prefabbricati o realizzati in sito. Misure per il controllo geometrico dimensionale del singolo elemento;
- UNI 9053-2:1987. Edilizia. Elementi strutturali prefabbricati o realizzati in sito. Misure per il controllo geometrico dimensionale di elementi in opera.

1.4 Prefabricated construction

In 1987, the first binding rules specifically dedicated to prefabricated structures were issued and, after that, their explanatory circular:

- DM 3 December 1987 Technical standards for the design, execution and testing of prefabricated buildings
- Circular Ministry of Public Works March 16, 1989 n. 31104 instructions on technical standards for the design, execution and testing of prefabricated buildings.

These rules were valid until the entry into force of the DM 14 January 2008.

2. POLICY MEASURES

2.1 Materials from CDW

From a regulatory point of view, the first step in Italian legislation towards a more conscious waste management, was carried out with the **Decree Ronchi** (DM 22 February 5, 1997 - Implementation of 91/156 / EEC Waste Conventions, 91/689 / EEC on Hazardous Waste and 94/62 / EC on Packaging And on packaging waste) which lay the foundations for reducing waste production and promoting their recovery.

The **Decree of the Ministry of the Environment of 5 February 1998**, Identifying non-hazardous waste under simplified recovery procedures pursuant to Articles 31 and 33 of Legislative Decree No 5 of February 5, 1997, affirms the privileged position of the construction sector, and in particular the concrete industry, in the potential absorption of inert waste and defines the activities, processes and methods for recovering them.

The **Decree of the Ministry of the Environment of May 8, 2003, No. 203**, for public bodies and for public capital companies, requires the obligation to use at least 30% of the annual requirement, manufactured goods and goods with recycled aggregates.

The following **Circular of the Ministry of Environment of July 15, 2005 No. 5205** provides indications for the operation of recycled aggregates in the construction, road and environmental sectors, according to D.M. 203/2003. However, recycled aggregates had to be registered with the National Recycling Information Center at the National Waste Observatory: for recruitment, recycler inertia producers must apply to the Observatory with relevant technical documentation attesting to compliance with the strict specifications for aggregates in Attached to the circular. Unfortunately, the list of licensed companies ("repertoire") has never been drawn up and in 2009 the National Environment Agency was also canceled, the National Observatory for Waste.

Legislative Decree 152/2006 on Environmental Matters is the main reference legislation for waste. In particular, it abrogated the Ronchi Decree and in its "Part Four" essentially confirmed the need to engage public administrations to take direct waste recovery measures through recycling, reuse, reuse or any other action aimed at obtaining secondary raw materials.

Here is Directive 2008/98 / EC, transposed at national level with Legislative **Decree 205/2010,** which has amended Legislative Decree 152/2006, bringing to 70% the minimum share of inert waste to be recycled. [8]

Two major regulatory innovations have been introduced recently, with reflections on the circular economy: the so-called **Environmental Link** (**Law No. 221 of December 28, 2015**) and the new **Code of Practices** (**D.Lgs. 18th April 2016, n.50**). The two main news in circular optics introduced by the Linked Environmental and with implications for the construction sector concern the introduction of incentives for the purchase of products derived from recovery materials and the obligation for Public Administrations (P.A.) to include in the tender dossier, the technical specifications contained in the CAMs (Minimum Environmental Criteria) in relation to certain categories of goods, including the assignment of design services and works for the new construction, renovation and maintenance of public administration buildings, providing in addition, the obligation for P.A. contracted construction works and works contractors, to provide for a waste management plan produced at the design stage, with **70% minimum start-up recovery of the materials**." [5]

The Decree describes the technical specifications of building components such as concrete, brick, wood products, for example, the quantity to be recycled. In the technical specifications of the yard, the criteria to be followed in the demolition, for the materials used in the construction site and excavations are explained. Concrete and prefabricated concrete products on site are pre-packaged and pre-fabricated with a minimum content of recycled material of at least 5% by weight, as a sum of recycled material percentages contained in individual components (cement, additives, aggregates, additives) , Compatible with the limits imposed by the specific technical standards. [8]

The **Environmental Associate,** in force since February 2, 2016 with the title "**Environmental provisions to promote green economy measures and to contain excessive use of natural resources**", Official Gazette (OJ No 13, 18 January 2016), provides in particular:

(A) the granting of incentives in favor of business activities of the production of goods resulting from recycled post-consumer goods or the recovery of waste and materials resulting from the disassembly of complex products,

(B) the provision of incentives for the marketing of CE registered recycled aggregates and defined in accordance with UNI EN 13242: 2013 and UNI EN 12620: 2013 standards, as well as products derived from waste electrical and electronic equipment and tires Out of use or made with plastic materials coming from the treatment of end-of-life products as defined by UNI 10667-13: 2013, post-consumer or recovery of production waste;

(C) the award of incentives to economic entities and public entities purchasing products deriving from the materials referred to in points (a) and (b). [9]

At the level of regulations and normative reference frameworks produced by local authorities on CDW products, the Autonomous Province of Trento has developed the Environmental Technical Standards for the production of recycled materials and poses in the construction and maintenance of construction works, roads and environmental recoveries (Provincial Council of June 24, 2011, No.1333 - Part B) and the Guidelines for the Proper Management of a Waste Recovery and Treatment Facility and for the production of recycled materials to be used in construction (Provincial Junta 24 June 2011 - A). The necessity of the provision of such instruments originated from the specific conditions of the driving forces of the Trentino economy, particularly characterized by mining activities. [3]

At the national level, Legambiente has promoted the Observatory Recycle, with the aim of telling and deepening the ongoing innovation in recycled aggregates production. In fact, there are no technical impediments or normative reasons that would prevent the use of recycled aggregates, but in reality, the spread of recovered materials faces strong obstacles. The first and the foremost problem concerns public and private construction sites, where the specifications are often an insurmountable barrier for recycled aggregates, although while requiring the use of certain categories of materials, the application is forbidden if coming from recycling.

Therefore, Legambiente published the document “Capitolati RECYCLE” with the aim to identify definitions that must enter into the Specific Contract Specifications (CSAs) and the Unit Price List (EPU) in order to simplify and give uniform readability to existing legislation on recovered materials and to prevent which can be excluded from use in all infrastructures, guaranteeing the direction of work and Authorizing Bodies the certainty of the possibility of use. [10]

2.2 Prefabricated elements (with or without CDW materials)

2.3 Prefabricated construction

In Italy, thanks to the Financial Law of 2017, there is the possibility to obtain tax breaks for seismic improvement as well as energy efficiency, also for interventions for the adaptation of prefabricated structures, up to 2021.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [18] , the value of trade of prefabricated elements is € 6.9 billion in 2016. Export activities account 5.2 € billions, while import account 1.6 € billion. The sold construction products in Italy between 2012 and 2016 has increase at a rate (CAGR) of 2.9% for export, while import decrease by rate of 1.5%.

On the export side, Italy is a largest exporter of Ceramics and Concrete structural elements in EU. Ceramics items account 46.3% of total export, and the export of this elements increase by 3.2% in 2016, passing from 1.8 billion euros in 2012 to 2 billion euros in 2016. The second largest exporter goods are concrete constructional goods, it accounts 38.8% of export, and growth by 2.9% rate Wood structural elements is the 3rd largest export goods, it accounts 13.5% of export, and its export trade growth with a rate of 1.6%

On the import side, Wood and ceramics structural elements are the main components imported on the market. Their share on import is 61.2% for wood constructional goods, and 20.9% for ceramics structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramics items increase by a rate of 4%, while wood elements increase by +2.7%. Concrete structural elements are the 3rd largest import goods, it accounts 15.1% of import and its import trade growth is relatively constat (-0.66%)

Approximately 53.5% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

ITALY TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on export**
Cement, lime and plaster (ready mix)	51.943.461	63.992.684	5,35%	1,21%
Ceramic constructional goods	2.163.800.552	2.457.334.951	3,23%	46,39%
Concrete, plaster structural elements	1.828.466.109	2.055.820.848	2,97%	38,81%
Wood Structural elements	674.907.782	719.679.959	1,62%	13,59%
TOTAL EXPORT	**4.719.117.904**	**5.296.828.442**	**2,93%**	**100,00%**

IMPORT	2012	2016		Share on Import
Cement, lime and plaster (ready mix)	60.399.133	44.673.638	-7,26%	2,72%
Ceramic constructional goods	294.071.466	344.366.992	4,03%	20,95%
Concrete, plaster structural elements	255.381.933	248.689.586	-0,66%	15,13%
Wood Structural elements	934.388.479	1.005.920.029	1,86%	61,20%
TOTAL IMPORT	**1.544.241.011**	**1.643.650.245**	**1,57%**	**100,00%**

3.2 Market conditions / costs and benefits

In 2015 the aggregate production volume is estimated at 155 million, largely comes from natural resources such as crushed rock (57%) and sand and gravel (41%). Compared to 2014, the volume of production increased by 2%, but compared to 2012, a sharp decline in production was recorded, accounting for 40 million tones produced less than aggregates. The use of recycled aggregates in concrete manufacturing have difficulties in increasing the share of recycled aggregates in this industry, their weight on production volume is less than 3% [15]. The main factor of the lack of market expansion is mainly derived from the absence of demand [17].

ITALY– Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	1120	1120	1120	1120
Total Number of Extraction Sites (Quarries and Pits)	2800	1800	1800	1800
Sand & Gravel (millions tonnes)	63	61	62	86
Crushed Rock (millions tonnes)	88	86	88	109
Marine Aggregates (millions tonnes)	0	0	0	0
Recycled Aggregates (millions tonnes)	4	5	5	0
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0
Total Production (millions tonnes)	**155**	**152**	**155**	**195**

Other factors, however, concern the low price both for landfill cost and raw material supply. Countries where landfill costs are higher have generally an high recycling rate, on the contrary the availability of raw materials and the low landfill costs, e.g. Italian situation, impede the knowledge's development about recycled aggregates performances and possible applications' fields. For example, concerning landfill cost, prices can be in a range from 5 € per ton in Italy to 50 € per ton in Denmark. Furthermore, no financial incentives have been found for recycling CDW.
Regarding the availability and the natural aggregate's cost, these factors depend on the Country, by the mines' availability in a specific area and by the transport's cost. Actually, in Europe the price per ton fluctuates between a minimum of 2.5 €/t and a maximum of 12 €/t. Countries like Italy that have a big availability of natural aggregates tend to sell them at the average price about 6 €/t [16][17].

3.3 Construction sector make up

Prefabricated construction characteristics

There are many types of prefabricated houses on the market that differ in functionality and features:

- implementation criteria, such as housing or industrial facilities;
- construction materials such as wood, concrete or masonry structures;
- size and size;
- delivery type.

Residential prefabricated construction: typologies

On the market, the types of prefabricated dwellings are divided into:

- Container prefabricated, easily transportable;
- prefabricated in woods such as chalets, made especially in alpine areas;
- Prefabricated in Canadian, made of plasterboard and wood with plastic tiles.

Residential prefabricated construction Canadian Wood

Canadian prefabricated woods do not really fit the name they bring because they are entirely made of plasterboard, built with wooden beams assembled with screws, bolts and nails that are then covered with plywood walls covered with plastic resin and plasterboard. Likewise, the roof is made of plastic tiles to lighten the supporting structure with a perfect visual impact.

Heavy Residential prefabricated construction: concrete realization

Heavy prefabricated concrete is the most pre-fabricated prefabricated house in Italy, including the full concrete, load-bearing, hydraulic and plumbing systems installed in the casting phase and the walls are entirely carriers; In this type of prefabricated, it is not possible to make subsequent editing works.

Industrial prefabricated construction: sheds and reinforced concrete structures

The two modes of delivery or rather, the two modes of construction, are also used for the construction of industrial warehouses and prefabricated buildings, which are distinguished by:

- industrial prefabricated, robust and sober external structure, but without finishing;
- Concrete prefabricated with either wooden or aluminum roofs with a wide range of customization options for each individual module, creating the most desired environments and premises, even with future modifications according to housing requirements;
- Prefabricated entirely made of concrete that does not allow for customization.

Ready-to-use prefabricated construction: Containers

Prefabricated ready-to-use or even better known as containers have many applications and especially in the emergency sector in which there is a need to realize housing quickly, such as earthquakes or floods.

This type of prefabricated is characterized by the lightness and transportability of the entire structure which is usually mounted on steel frames made of steel and made of sheet steel insulated with insulating foam or glass wool.
The prefabricated industrial housing modules are very sober and do not allow for special customization work, but the load-bearing structure is an optimal solution in the compartments for short-term housing and high performance endurance and durability.

Different typology of prefabricated construction delivery: turn-key or advanced raw
The prefabricated houses have different types of delivery and therefore it is established with the first owner of the housing:

- turnkey delivery that sets the complete construction of every part of the prefabricated, ready to be furnished;
- delivery of the prefabricated house to advanced raw with a complete external structure, but without flooring or sanitary ware, which are subsequently added by the owner owner according to their times and needs.

In the Italian building market, wooden prefabricated houses are increasingly present, which have the great value of being built with natural materials and guarantee a high energy saving. Wood, in fact, is a great natural insulator that avoids heat dispersion in the winter and keeps the environment cool during the summer.
In the 2014 in Italy, more than 3.000 buildings (90% residential) have been constructed in wood, so that Italy is fourth in Europe for the production of prefabricated buildings. In addition, wood construction records growth and is counterproductive with respect to the construction industry. Anti-seismic characteristics, fire resistance, but also durability of the structures are just some of the "secrets" of the success of wooden houses. The most commonly used construction techniques are: the "**frame system**" (55% of the buildings) and the "**X-lam**" (38% of the buildings), ie the system consisting of crossed and glued wooden panels; They follow the **blockhaus** technique (which uses solid or laminated wood beams vertically spaced between them to form the walls, carriers or partitions) and, at 3%, the **MHM technique** - acronym **Massiv-Holz-Mauer**, consisting of untreated wood panels, which are connected with aluminum plugs, without needing to use glues for garaging the binding. [11][12]

3.4 Use of CDW materials for prefabricated elements

Concerning the use of recycled aggregates in the prefabrication sector, there are only experimental researches that prove the possibility to realize prefabricated elements with recycled aggregates.
On the based of the observations made during the production phases of some manufactured articles and the results obtained from the tests, it can be stated that the use of aggregates from recycling of the establishment waste does not induce statistically significant variations in behaviour between the ordinary conglomerate and the one packaged with a large recycled aggregate in percentages up to 30%. However, real-world applications have only been made for search purposes. [13]

Figure 2. Prefabricated panels made of concretes made with recycled aggregate produced from mixed CDW [13]

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LATVIA

1. TECHNICAL REGULATION AND LEGISLATION

The European Regulation on construction products 305/2011 has been transposed by the national Cabinet Regulation No. 156 of 25 March 2015: **Procedures for the Market Surveillance of Construction Products**. [1]
This Regulation determines the institutions which shall perform market surveillance of construction products, as well as prescribes the procedures by which market surveillance of construction products shall be performed, samples of construction products shall be requested and received within the framework thereof, laboratory expert-examinations or expert-examinations of another kind shall be performed, and the cases when expenses for performing respective expert-examinations shall be covered by the manufacturer or distributor of construction materials.

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

To date, there are no legal acts or planning documents in Latvia that specifically regulate CDW.
[1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Use of recycled materials in construction and renovation projects is practiced in low, undocumented, levels on a voluntary basis. The most commonly used recycled material from CDW are metals, because of their relatively easy reintegration via closed loop recycling. Bricks, glass and concrete is usually backfilled or landfilled (depending on quality), while wood is used for recovery via incineration. [1]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

No specific information has been found.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

Construction activities in Latvia are governed by the **Construction Law** (Būvniecības likums), initially introduced in 1995, which sets out the main provisions related to the procedures of the construction process, rights and responsibilities of parties involved, certification and licensing of construction participants, principles of construction supervision and control, as well liability and insurance, among others.

In order to simplify the regulatory framework, reduce the administrative burden and thus accelerate and promote the construction of new buildings, the new Construction Law entered into force in 2014.

In addition to the Construction Law, a variety of other laws and regulations make up the construction regulatory environment, governing topics such as planning, design preparation, design, construction product conformity, hygiene requirements, as well as special building regulations. Instances include the **General Construction Regulations** (Vispārīgie būvnoteikumi), **Procedures for the Market Surveillance of Construction Products** (Būvizstrādājumu tirgus uzraudzības kārtība), **Spatial Development Planning Law** (Teritorijas attīstības plānošanas likums) and the **Regional Development Law** (Reģionālās attīstības likums), among others. [3]

Besides, in 2008, the Ministry of Environmental Protection (MEPRD) developed "**Guidelines on the promotion of green procurement in state and municipal institutions**", geared towards six groups of goods and services outside the scope of CDW, along with "Guidelines on promotion of environmentally friendly construction". [1]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [11] , the value of trade of prefabricated elements is € 651 Million in 2016. Export activities account 498 € Millions, while import account 153€ Million. The sold construction products in Latvia between 2012 and 2016 has increase at a rate (CAGR) of 6.7% for export, while import increase by rate of 5.2%.

On the export side, Latvia is a largest exporter of wood structural elements in EU (71.9% of total export), and the export of this elements increase by 4.6% in 2016, passing from 299 million euros in 2012 to 358 million euros in 2016. The second largest exporter goods are concrete and plaster constructional goods, it accounts 22.3% of export, and growth by 21.3% rate

Ceramics structural elements is the 3rd largest export goods, it accounts 4.5% of export, and its export trade growth with a rate of 5.1%

On the import side, Wood and concrete structural elements are confirmed by the main components imported on the market. Their share on import is 62.1% for wood constructional goods, and 19.9% for concrete structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated concrete items (+5.6%) and for wood elements (+6.1%)

increase. Ceramic structural elements are the 3rd largest import goods, it accounts 16.6% of import and its import trade growth with a rate of 6.3%

Approximately 78% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

LATVIA TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	15.043.512	5.844.662	-21,05%	1,17%
Ceramic constructional goods	18.493.844	22.564.431	5,10%	4,52%
Concrete, plaster structural elements	51.464.165	111.597.859	21,35%	22,37%
Wood Structural elements	299.008.110	358.848.746	4,67%	71,93%
TOTAL EXPORT	384.009.631	498.855.698	6,76%	100,00%
IMPORT	2012	2016		Share on Import
Cement, lime and plaster (ready mix)	6.427.218	1.893.390	-26,33%	1,24%
Ceramic constructional goods	19.909.947	25.512.164	6,39%	16,67%
Concrete, plaster structural elements	24.522.160	30.589.824	5,68%	19,99%
Wood Structural elements	74.951.890	95.047.451	6,12%	62,11%
TOTAL IMPORT	125.811.215	153.042.829	5,02%	100,00%

3.2 Market conditions / costs and benefits

Latvia's waste strategy is predominantly centered on urban waste disposal. This implies that the main efforts of efforts, both in political terms (norms and strategies) and in economic terms (European funding and national funds), are directed towards the implementation of waste disposal and collection centers. This means that it would be committed to Latvia to allocate the same efforts and resources for the waste sector from construction demolitions. In summary, currently the main efforts are directed towards the urban waste sector and there are no types of financial incentives to recycle the CDW, thus making the poor market conditions [2].
In Latvia, over the last 3 years the volume of production has remained constant, on a total of 14 million tons of aggregate products, the majority were from Sand & Grave (85%), the other part of production come from crushed rock. At present, the Use of recycled materials in construction and renovation projects is practiced in low, undocumented, levels on a voluntary basis. Furthermore the market for recycled aggregates is not a forefront topic, CDW is perceived as a waste, and not as a viable product for construction works, relevant actors do not see interest in pursuing its use [10].

LATVIA – Estimates of Aggregates Production	2015	2014	2013
Total Number of Producers (companies)	55	55	55
Total Number of Extraction Sites (Quarries and Pits)	105	105	105
Sand & Gravel (millions tonnes)	12	12	12
Crushed Rock (millions tonnes)	2	2	2
Marine Aggregates (millions tonnes)	0	0	0
Recycled Aggregates (millions tonnes)	0	0	0

Re-Used on Site (millions tonnes)	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0
Total Production (millions tonnes)	**14**	**14**	**14**

An interviewed stakeholder from a waste management company in Riga indicated that the most commonly used recycled material from CDW are metals, because of their relatively easy reintegration via closed loop recycling. Bricks, glass and concrete is usually backfilled or landfilled (depending on quality), while wood is used for recovery via incineration [2].

3.3 Construction sector make up

Latvia is a very suitable place for the manufacturing of wooden houses:

- The traditions of Latvian wood construction are centuries old. One of the oldest preserved houses in Latvia is approximately 400 years old and can be seen at the Ethnographic Open Air Museum.
- There are two higher educational establishments that provide training for construction engineers – graduates of these schools are actively involved in wooden construction.
- An excellent price to quality ratio. Latvian manufacturers use the highest quality (certified) raw materials. The manufacturing plants are equipped with the most modern manufacturing devices, and the companies offer competitive prices.
- Highly qualified and experienced experts, who have been involved in wooden construction and implemented projects throughout Europe for several years, participate in the manufacturing and assembly of houses.
- Manufacturing of houses is always performed in covered manufacturing premises, which ensures high durability of houses against weather conditions and other external factors. [4]

The main wood prefab products are:

- timber frame houses,
- modular houses.

<u>Timber frame house</u>

The technology of timber frame house manufacturing is the merger of centuries old wood construction traditions with modern solutions.

The basic construction of the building consists of a wooden frame, which is filled with thermal insulation material. Timber frame construction technology permits a wide range of choice in terms of thermal insulation materials (rockwool, timber wool, ecowool, etc.), as well as finishing materials (finishing boards, decorative plastering, façade bricks, plastic planks, etc.).

The panels of timber frame houses are industrially made at the factory, which ensures high precision and quality. During the manufacturing process the building is produced in a covered area, and therefore is not subject to changing weather conditions. The panels are produced based on computerized plans, which ensure high precision and reduce the influence of the human factor.

Figure 1. Example of timber frame house [4] [5]

<u>Modular houses</u>

Modular housing is a very modern and advanced building system and it's slowly replacing the traditional building technologies. The modular system is based on the technology of timber frame, where fully finished modules are produced in the factory. Modular houses can be built in different sizes – one module can serve as a small apartment or as a part of a larger house. [5]

Figure 2. Example of modular house [5] [6]

Beside the prefabricated wooden houses, there are also building constructed by prefabricated concrete elements, such as columns, wall panels, foundation piles, slabs and so on.

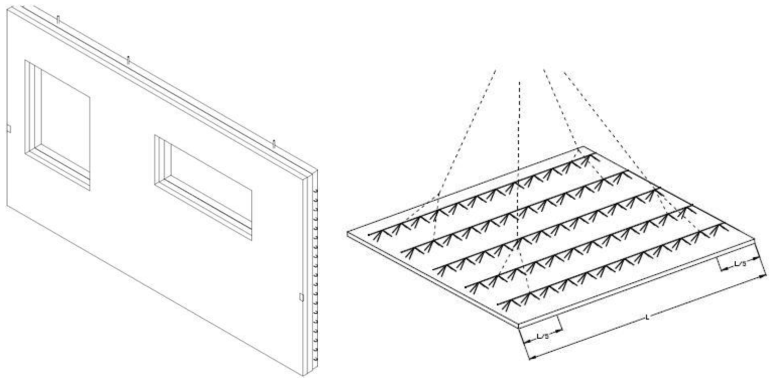

Figure 3. Example of prefabricated concrete elements [7]

3.4 Use of CDW materials for prefabricated elements

An example of the use of CDW materials for prefabricated elements is the product developing in the R&D project "MORE-CONNECT", which has received funding from the European Union's H2020 framework programme for research and innovation under grant agreement no 633477. Objective is to develop and to demonstrate technologies and components for prefabricated modular renovation elements in five geo-clusters in Europe. This includes **prefabricated durable, innovative, modular composed building envelope elements for the total building envelop** for the renovation market, including the prefab integration of multifunctional components for climate control, energy saving, building physics and aesthetics, with advanced easy to use plug&play connections (mechanical, hydraulic, air, electric, prefab airtight joints).

Particularly, product innovation includes the selection of sustainable materials and sustainable detailing based on LCA, including **recycling of materials, biobased materials**, flexible, disassemble, and the **use of secondary materials**. The technologies and components, necessary to come to a NZEB renovation will be combined and integrated as much as possible in multifunctional elements. Low embodied energy will be a criterion in the design and development. [8][9]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

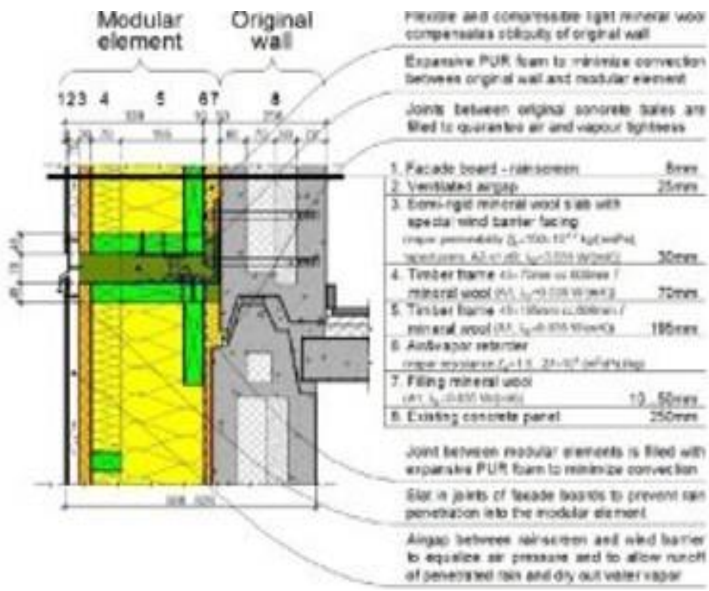

Figure 4. Modified external wall with modular element, based on hygrothermal calculations [9]

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LITHUANIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

In Lithuania there are several legislation regarding CDW management, but no technical regulations.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

CDW in Lithuania are treated to obtain coarse and fine aggregates of various waste fractions. These aggregates, depending on their fraction, are used for the construction of passages and roads, passing ways, sidewalks, as well as for the manufacturing of new construction products. [1]
EU Commission's Working Group on Sustainable Construction Recommendations underline, that the same requirements should be applied to CDW derived aggregates and to raw material. This requirement in Lithuania is applied to materials for roadways (**Construction Technical Regulations (CTR) 2.06.03:2001 "Roadways"**) where the common requirements (characteristics, granular structure, etc.) are described. These requirements do not differentiate between recycled CDW and raw material. Recommendations were published (**R 34-01 "Roadways basics"**) to accomplish the mentioned regulations. The recommendations describe requirements for crushed concrete and for its mixtures with new material. The existing recommendations facilitate conformance evaluation, although there are no particular standards for recycled CDW. [2]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

The Law on Construction is the main piece of legislation governing building works in Lithuania. It establishes all the essential requirements for construction works built, reconstructed and repaired within national territory. It includes detailed procedures of research, design, construction, reconstruction, repair, commissioning, usage and demolition of such works, as well as the relationship between the parties involved in the construction activity. It also includes the minimum requirements for energy performance of buildings.
In addition, the construction process is also regulated by a variety of technical construction regulations, such as **classification of buildings** (STR 1:01:03:2017), **structure design** (STR 1:05:06:2010), **inspection of the project** (STR 1:06:03:2002), **building maintenance** (STR 1:09:05:2002), **project supervision procedure** (STR 1:09:04:2007), **accident investigation** (STR 1.10.01:2002) and **completion of construction** (STR 1.11.01: 2010), among others. [3]
There is the **Construction technical regulation CTR 1.01.07:2002** (2002-04-16, Žin. 2002, Nr. 43-1639, 2004, Nr. 104, 2004, Nr. 136, 2004, Nr. 90), too.

2. POLICY MEASURES

The Lithuanian Ministry of Environment is responsible for matters related to construction and housing, with housing policy being defined by the Lithuanian Housing Strategy (Lietuvos būsto strategija). The strategy, initially approved by the government in 2004, sets the long-term national policy objectives and priorities for the improvement of housing up until 2020, including the design and implementation of housing development, renovation and modernisation, as well as financial and social support programmes and measures. [3]

2.1 Materials from CDW

No specific information has been found.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

Finally, in November 2015, the Ministry of Environment approved the **Lithuanian construction sector development guidelines for the period 2015-2020** (Lietuvos statybų sektoriaus plėtros ir vystymo 2015–2020 metais gaires). The document defines strategic objectives for the sector for 2020, as well as the targets to be achieved, with the aim of addressing the challenges related to qualifications, energy and environmental protection requirements, market access, information technology application and deployment areas. Namely, the guidelines' strategic goals include the improvement of the sustainability of buildings; a more efficient use of resources in the production, transportation and use of construction products; promotion of sustainable cities and infrastructure; and encouraging high-skilled training and continuous professional development. [3]
In order to reduce the energy consumption of the residential building stock, state has adopted a **Program for the Refurbishment of Multi-Apartment Buildings**. Its target group is the multi-apartment buildings, which had been constructed until the year 1993. [4] The programme was initially enforced in 2005, offering state grants of up to 50% of the costs of the renovation works, with the balance provided by commercial banking loans. [3]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [10], the value of trade of prefabricated elements is € 614 Million in 2016. Export activities account 363 € Millions, while import account 251€ Million. The sold construction products in Lithuania between 2012 and 2016 has increase at a rate (CAGR) of -9.5% for export, while import increase by rate of +8.8%.
On the export side, Lithuania is a largest exporter of wood structural elements in EU (79.8% of total export), and the export of this elements increase by 9.4% in 2016, passing from 202 million euros in 2012 to 290 million euros in 2016. The second largest exporter goods are concrete and plaster constructional goods, it accounts 16.4% of export, and growth by 15.1% rate

Ceramics structural elements is the 3rd largest export goods, it accounts 3.2% of export, however it's export trade is in decline with a rate of – 6.8%

On the import side, Wood and concrete structural elements are confirmed by the main components imported on the market. Their share on import is 57.3% for wood constructional goods, and 23.3% for concrete structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated concrete items (+11.7%) and for wood elements (+9.9%) increase. Ceramic structural elements are the 3rd largest import goods, it accounts 15.6% of import and its import trade growth with a rate of 4.9%

LITHUANIA TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	536.807	1.554.672	30,45%	0,43%
Ceramic constructional goods	15.820.448	11.924.918	-6,82%	3,28%
Concrete, plaster structural elements	33.937.025	59.698.721	15,17%	16,43%
Wood Structural elements	202.340.764	290.123.286	9,43%	79,86%
TOTAL EXPORT	252.635.044	363.301.597	9,51%	100,00%
IMPORT	2012	2016		Share on Import
Cement, lime and plaster (ready mix)	15.496.673	9.482.007	-11,56%	3,78%
Ceramic constructional goods	32.343.215	39.194.526	4,92%	15,61%
Concrete, plaster structural elements	37.586.021	58.517.068	11,70%	23,31%
Wood Structural elements	98.571.081	143.858.575	9,91%	57,30%
TOTAL IMPORT	183.996.990	251.052.176	8,08%	100,00%

Approximately 64% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.
Producers of wood houses export about 75% of their products to Scandinavian and Western European countries. The biggest export markets for wooden houses are Norway, Denmark, Sweden, Germany, France and the Netherlands. Some Lithuanian producers of wooden houses carry out their business in foreign countries only. According to the ALHP, about 1200 wooden houses were exported from Lithuania and built in foreign countries in 2007. [6]

3.2 Market conditions / costs and benefits

Lithuania exports almost the whole prefab timber productions; the biggest competitive strengths of these companies are relative low labor costs and fairly modern manufacture devices used. But the biggest problem for the timber sector today is the availability of the raw materials, which is a quite contradictory situation regarding the fact that about 30% of the roundwood is exported. This is happens because the market prices of the raw timber are too high for the local companies, while being attractively low for the foreign ones.
The forests cover about a third of the Lithuanian territory. They slowly grow, as the laws of the sustainable forestry are adopted – the felled wood amount cannot exceed its annual growth, while the actual limits the Government defines each year. In practice only about a half of the annual wood growth (13,8 m m^3) is felled. [4]

3.3 Construction sector make up

In the early 50‟s there started a rapid industrialization, followed by huge urbanization rates. The design and construction methods were taken from the Western countries during the Soviet delegation study trips. The use of the mass-produced **concrete panel structures** enabled a faster and more reliable construction and was clearly advantageous against the typical masonry construction. Large panel buildings are sorted in series. A series is a standardized collection of buildings, which have common structural and functional properties, are designed according to the same building standard and their elements can be manufactured with the same devices. Each series includes building types of different sizes and configurations (Figure 1). [4]

Figure 1. Prefab concrete panel building [4]

Typically, all exterior walls (except self-bearing walls of stairways) are load-bearing and constructed from 300 mm-thick lightweight reinforced concrete panels, which consist of three main layers:

1. Exterior layer of fine dense concrete with various surface finishes
2. Middle core layer of expanded clay lightweight concrete
3. Interior face from the fine dense concrete;

interior walls are made of 14 cm-thick prefab reinforced concrete panels; floors are made of 10 cm thick prefab concrete slab, which is supported on the whole perimeter, and slab is reinforced only on the bottom. [4]

PREFAB TIMBER HOUSE

The prefab timber construction in the local market is not very popular, so prefab timber constructions manufacturers export almost the whole productions (mainly Norway, Sweden and other Western countries). In order to be able to execute bigger projects, 7 big timber construction producers have recently joined into a cluster "**Energy efficient and passive buildings**" [5], which should promote contemporary timber construction methods and declares high cooperation with education institutions.

Therefore, in the last years, prefab timber elements are becoming key elements of the retrofit system. The Timber Element System (TES) has been developed since 2006 and it consist in

prefabricated insulated timber frame façade panels (TES Energyfacade). They are convertible, so allowing the horizontal space extensions even after the main construction works. [4]

The main wood prefab products are:

- timber frame houses,
- panel house;
- modular house.

<u>Timber frame house</u>

Timber-framed walls are assembled from prefabricated elements. Foundation is damp-proofed and the lower course of timber frame is positioned onto it. [6]

Figure 2. Example of timber frame house [7]

<u>Panel house</u>

Panel house originated from timber-framed house. This advanced construction technology has anchored due to simple and quick construction methods and eco-friendliness. Panel frame house are built from prefabricated panels and site-assembled. Improved construction technologies enable designing of all elements of a panel house using a special computer programme, which ensures sound and precise assembly. All elements are checked up in a factory. Manufacturing of walls in a horizontal position and pressing thereafter prevent deformation of panel houses in use.
The main components of a panel frame house are panels and frame structures. Structural components of a wood panel house - external and internal walls, ceiling and roof are assembled from panels up to the selected roofing material. Panels for walls and ceilings are prefabricated on the basis of a wooden frame. [6]

Figure 3. Example of panel house [8]

Modular house

Modular house are built from prefabricated and pre-assembled modules. Special house designs are used in modular construction. The system of modular house is best adapted for large series of homogeneous house; it may be also applied in construction of tenement houses.

The maximum size of modules is such as to suit for the transportation by sea (4.5-5 x 10-12 m). Modular house are transported with full engineering installations and interior finishing.

Modules are transported on sea ferries equipped with special platforms. Due to relatively high overland transportation costs of oversized modules, it is better to manufacture and build modular house in localities close to sea ports. [6]

Figure 4. Example of modular house [9]

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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LUXEMBOURG

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

In Luxembourg there are several legislation regarding CDW management, but no technical regulations (see Deliverable D1.1).

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Regarding norms of recycled materials, it is reported that Luxembourg follows French or German norms. There are not any available norms requiring that materials contain a proportion of recycled material as it is the case in Switzerland and Germany. [1]
In Luxembourg recycled aggregates are mostly used in road construction and as sub-layer in foundation construction, but barely used in concrete production. [2]
Art.26 of the **Law of 21 March 2012 on management of waste (LMW)** set that:

- reuse of collected inert wastes is mandatory in public tender facets relating to construction of roads and other buildings (Par. 7);
- a Grand-Ducal regulation can define quality norms for material coming from recycling of inert wastes. These norms may vary according to different use of those materials (Par. 8);
- **The Sectoral Directive Plan on Inert Waste** provides that inert waste must be disposed of at the closest landfill to the building site. [1]

Recycled aggregates are barely used in concrete production and there are no statistics or accounting of its use as second raw material in concrete production in Luxembourg and it is difficult to find further information of their use in structural construction.
Therefore, there are two important documents which have to be consulted and followed while using recycled aggregates for concrete production:

- Combined document 'concrete', EN 206-1: Concrete - Specification, performance, production and conformity, completed by the national application **DNA EN 206-1:2000**;
- **Specification sheet: Aggregates** (Original title: PONTS ET CHAUSSEES, CAHIER DES CHARGES: 'GRANULATS' (CDC-GRA08)).

Additional to these national documents the following European Standard has high importance:

- EN 12620: Aggregates for concrete is most relevant for aggregates for structural concrete.

According to these documents, the normal-weight aggregates have to be certified conforming to 'EN 12620: Aggregates for concrete' and the national specification sheet '**CDC-GRA Granulats et sables'**.
The aggregates need a valid certification delivered by 'Laboratoire d'Essais des Matériaux des Ponts et Chaussées du Luxembourg' or need to be proved by the producer to have passed all the controls prescribed by the regulations in order to get a certification as aggregates and sand.
The recycled concrete aggregate have to submit a certification of adequacy delivered by an organisation approved in the framework of the directive 'Beton mit rezykliertem Zuschlag' from

DAfStb (Deutscher Ausschuss für Stahlbetonbau; engl. German Committee for Structural Concrete). [2]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

No specific information has been found.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

In 2008, the **Housing Pact** (Pacte Logement) was adopted, aiming to encourage municipalities to promote housing development through financial incentives. [3]
Policies supporting renovation of existing dwellings include measures focused on improving energy efficiency, adapting the housing to special needs, noise reduction and rainwater reuse. [3]
With respect to the construction sector, a number of initiatives have been launched aimed at strengthening skills in construction. Notably, the Luxembourg Chamber of Crafts together with the Construction Sector Training Institute (IFSB) and with myenergy, the public agency dedicated to sustainable energy, joined the initiative **LuxBuild 2020**. This is part of the EU-wide BUILD UP Skills scheme and aims at facilitating training in the fields of energy performance of buildings, renovation, and utilisation of renewables in buildings. Furthermore, the project supports the development of a national roadmap for qualifications in the construction sector. The Ministry of the Economy is one of the supporters of the project, but the initiative also gathers many representatives of the construction industry. The implementation phase of LuxBuild 2020 runs from mid-2014 to mid-2017. [3]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [5], the value of trade of prefabricated elements is € 361 Million in 2016. Export activities account 108 € Millions, while import account 252 € Million.

The sold construction products in Luxembourg between 2012 and 2016 has decrease at a rate (CAGR) of -5.4% for export, while import increase by rate of +1.5%.
On the export side, Luxembourg is a largest exporter of wooden houses in EU (57.6% of total export), however wooden houses export decrease by 2.8% in 2016, passing from 70 million euros in 2012 to 62 million euros in 2016. The second largest exporter goods are concrete structural elements, it accounts 19.7% of export. In the observed period concrete structural elements exports also show a decline by -8.3% rate
On the import side, Wood and concrete are confirmed by the main components imported on the market. Their share on import is 28% for wood constructional goods, and 48.9% for concrete and plaster structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated concrete items (+9.2%) and for wood elements (+4.08%) increase.
Approximately 97% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders

LUXEMBOURG TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on export**
Cement, lime and plaster (ready mix)	29.368.775	17.936.997	-11,60%	16,47%
Ceramic constructional goods	5.858.524	6.780.823	3,72%	6,23%
Concrete, plaster structural elements	30.522.272	21.495.259	-8,39%	19,74%
Wood Structural elements	70.468.489	62.679.900	-2,89%	57,56%
TOTAL EXPORT	**136.218.060**	**108.892.979**	**-5,44%**	**100,00%**
IMPORT	**2012**	**2016**		**Share on Import**
Cement, lime and plaster (ready mix)	20.742.342	16.297.463	-5,85%	6,46%
Ceramic constructional goods	39.140.940	41.945.915	1,75%	16,62%
Concrete, plaster structural elements	110.007.595	123.481.262	2,93%	48,92%
Wood Structural elements	67.854.086	70.702.060	1,03%	28,01%
TOTAL IMPORT	**237.744.963**	**252.426.700**	**1,51%**	**100,00%**

3.2 Market conditions / costs and benefits

The total aggregate production estimated for Luxembourg is 4 million tonnes in 2015, mostly of these are manufactured aggregate. Over the years the production volume has increased from 2 million tonnes in 2012, to 4 million tons in 2014. At present, the weight of recycled aggregates on total production volume is close to zero [6].

LUXEMBOURG– Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	7	7	7	7
Total Number of Extraction Sites (Quarries and Pits)	13	13	10	10
Sand & Gravel (millions tonnes)	0	0	1	1
Crushed Rock (millions tonnes)	1	1	1	1
Marine Aggregates (millions tonnes)	0	0	0	0
Recycled Aggregates (millions tonnes)	0	0	0	0
Re-Used on Site (millions tonnes)	0	0	0	0

Manufactured Aggregates (millions tonnes)	3	3	0	0
Total Production (millions tonnes)	4	4	2	2

There are currently no state/legislation incentives to recycling. Construction companies do not benefit from any state aids or financial support from the state in exchange for recycling. In fact, the treatment of waste represents a cost for the construction companies [1].

3.3 Construction sector make up

Prefabrication in Luxembourg is diffused among steel constructions. Steel prefabricated buildings give the customer a great deal of freedom in the design – turnkey if required. Just like the famous Lego toys – the pieces are designed and produced in a way which assures a fast and easy connection. For steel buildings, the system list of components are: primary and secondary framing systems, wall and roof systems, roof accessories. Pre-engineered steel buildings are designed to your needs based on standard connection details. Assembling on a job site is easy and reliable. This process is usually less expensive and very quick. [4]

Figure 1. Prefab steel building [4]

3.4 Use of CDW materials for prefabricated elements

Steel is 100% recyclable without loss of quality and has a potentially endless life cycle. Together with the choice of the material and all the steps of a building's life, the demolition and recycling phase is one of the key factors influencing the global carbon footprint. Re-using buildings increases resource efficiency and limits the amount of demolition waste. [4]

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MALTA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

In 2014, 75% of the waste generated by economic activities in Malta was derived from CDW. The majority of this waste is either used for backfilling operations or exported for recycling. The performance of CDW recovery is high, however the quality of recycling that does happen on the Maltese islands is considered low.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

A large percentage of the CDW that is recycled is used for screed and concrete production [1]. Other materials are being used for backfilling activities. Currently, there is no mention of materials being made from CDW other than that already mentioned. This could be due to the lack of quality of recycling occurring on the islands, making it easier for Malta to export their CDW. In the Waste Management Plan however, there is mentioned that this mentality may need to change as resources deplete and raw materials become more expensive. However, as there is no market for secondary material established yet in Malta, it is not likely that this switch will happen in the near future.

1.3 Prefabricated elements (with or without CDW materials)

Precast concrete elements are available in Malta (example: GPC). There prefabricated elements offered are: hollow core panels, precast columns, precast beams, double walls, proprietary fittings, delta beams, and other precast elements.

1.4 Prefabricated construction

There are several prefabricated homes for sale in Malta, including modern housing developments. However, the companies offering these houses are international such as Karmod. There are other companies that offer precast pre-stressed floor slabs (Ballut Blocks Ltd.), prefabricated construction swimming pools (Olympicitalia), as well as several other companies. However, there does not seem to be an established prefabricated market currently in Malta.

2. POLICY MEASURES

2.1 Materials from CDW

The majority of CDW material recycling occurs outside Malta, as Malta does not have the appropriate facilities to recycle and therefore most recyclable material is exported. This includes valuable waste material such as metal and glass waste [2].

2.2 Prefabricated elements

There seems to be a precast concrete market in Malta, but outside of bigger international companies, the local market seems to be stringent.

2.3 Prefabricated construction

There seems to be some prefabricated construction, although the scope of this type of construction is unclear. For example, prefabricated container housing units had replaced the tents for 889 asylum seekers in June 2016 [1]. This indicates that prefabricated construction is being used in Malta, however outside of prefabricated concrete casts, the exact nature of this in unclear.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

There is no data available for the export/import of prefabricated elements. Considering the nature of the Maltese market, it is possible the any prefabricated elements would be imported or created within the islands themselves. There does not seem to be an export market, also considering resource concerns within Malta.

3.2 Market conditions / costs and benefits

The construction industry itself seems to have an annual turnover of 390.5 million Euro in 2013. However, it would be fair to conclude that the majority of this turnover is not as a result of prefabricated elements as this does not seem to be very prevalent. Depending on the different needs of the Maltese islands, there may be room in the market however.

A more difficult challenge seems to be the lack of recycling facilities in Malta and the trend towards export of CDW. This would entail export CDW, processing, creating prefabricated elements and importing these elements. Then end cost may be high enough that it would not be more attractive than the system currently in place. This may change in the future as there is growing concerns about the sustainability of the continuous export of resources that could be effectively recycled and reused. If there is a push for treatment facilities, it is possible that CDW prefabricated construction may be an attractive alternative depending on the price of the secondary material and required expertise.

3.3 Construction sector make up

In 2017, the Malta Developers Association (MDA) and the accounting firm KPMG signed an agreement for KPMG to fulfill a study on all aspects of the construction industry. The study will explore all aspects of the growing market in Malta and provide insight into the steps necessary to create a sustainable market. It is possible that part of the study will also address CDW.

3.4 Use of CDW materials for prefabricated elements

There does not seem to be any information on this, although the slight emphasis on secondary material usage in construction would point to this being in the introductory stages in the market.

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NETHERLAND

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

In Netherland there are several legislation regarding CDW management and their requirement, as described in Deliverable D1.1.
Particularly, CDW requirements and standards are reported in the following documents:

- Besluit Bodemkwaliteit (**Decree Soil Quality**) 2008. Among other things, this decree sets quality requirements for the usage of stony building materials in the ground;
- Ladder van Lansink (**Waste recycle hierarchy standard**) 1979. The document describes the waste recycling hierarchy of The Netherlands. [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The application of secondary materials should follow the criteria introduced by the **Building Materials Degree** of 1st July 1999. This Regulation fixes two categories (Category 1 and Category 2) of materials on the basis of the maximum acceptable soil contamination due to the leaching of building materials. Therefore, some building materials obtained from secondary materials arising in the construction industry, such as crushed asphalt aggregate, crushed concrete aggregate, mixed crushed aggregate, crusher fines and washed crushed brickwork aggregate are partly classified as Category 1 materials. Pre-crusher fines and undefined CDW are generally Category 2 materials. This is because CDW may be contaminated with organic compounds. [3]

In the Netherlands, the set of standards which regulates the use of recycled aggregates for concrete production is given by the European existing ones, and additionally by the standard **NEN 5905:2010** *Dutch supplement to NEN-EN 12620+A1 Aggregates for concrete*, where the requirements that recycled aggregates should satisfy are reported. Two types of recycled aggregates are defined, depending on their composition. The current normative allows the use of recycled concrete aggregates (RCA), characterized by at least 95 % of concrete-originated material, for concrete manufacturing for pre-stressed and reinforced structures, but it is limited to the coarse fraction (CRCA). RCA should not contain more than 5 % of masonry, 0.1 % of organic materials, and 1 % of impurities (asphalt is not included in this definition).
It should satisfy three minimum requirements in terms of minimum OD density, maximum chloride and sulfate content, being respectively 2000 kg/m^3, 0.05 and 1 %. CRCA can be applied in structures with a maximum strength class equal to C40/50, and in non-aggressive environments. For non-structural concrete (i.e. strength class lower than C16/20), also mixed RA can be used: this type of aggregate should satisfy the same physical and chemical requirements of RCA, but its composition can be made by until 65 % of masonry and 1 % of organic material. [4]

Since February 2015, according to **Branch organisation breaking and sorting (BRBS)**, recycled aggregates have to respect the following criteria:

- Requirements of the stony waste to be recycled into aggregates
- Production control
- Product quality
- Declaration of Conformity
- Quality assurance

The requirements of the **stony waste** contains:

- Quality
  - No hazardous waste
  - No asbestos, tar, residential waste, gypsum, ground, carbon black and timber
- Registration
  - Date of receipt, quantity, name and address of the supplier, and whether the offered stony waste is accepted or rejected
- A check on the presence of tar and polycyclic aromatic hydrocarbons
- A visual observation for asbestos. [1]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

For many years now, recycled aggregates are prescribed by the Ministry of Transport purely on the basis of its outstanding technical characteristics. The environmental quality is fully assured through certification schemes that include the requirements of the Soil Quality Decree. Increasingly, recycled aggregates are also used in the production of concrete. [5]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [9], the value of trade of prefabricated elements is € 2.39 billion in 2016. Export activities account 882 € Millions, while import account 1.5 € billion. The sold construction products in Netherlands between 2012 and 2016 has increase at a rate (CAGR) of 3.3% for export, while import decrease by rate of -1.2%.

On the export side, Netherlands is a largest exporter of Concrete structural elements in EU (38.7% of total export), and the export of this elements increase by 4.7% in 2016, passing from 283 million euros in 2012 to 341 million euros in 2016. The second largest exporter goods are wood constructional goods, it accounts 31.3% of export, and growth by 3.4% rate
Ceramics structural elements is the 3rd largest export goods, it accounts 4.5% of export, and its export trade growth with a rate of 5.1%

On the import side, Wood and concrete structural elements are the main components imported on the market. Their share on import is 48.8% for wood constructional goods, and 22.2% for concrete structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated concrete items decrease by a rate of -7%, while increase for wood elements (+2.7%). Ceramic structural elements are the 3rd largest import goods, it accounts 14.2% of import and its import trade growth is relatively constant (-0.33%)

Approximately 72% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders.

NETHERLANDS TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on export**
Cement, lime and plaster (ready mix)	17.436.245	18.004.926	0,81%	2,04%
Ceramic constructional goods	230.266.785	246.185.862	1,69%	27,90%
Concrete, plaster structural elements	283.551.956	341.692.907	4,77%	38,73%
Wood Structural elements	241.604.299	276.451.193	3,43%	31,33%
TOTAL EXPORT	**772.859.285**	**882.334.888**	**3,37%**	**100,00%**
IMPORT	**2012**	**2016**		**Share on Import**
Cement, lime and plaster (ready mix)	247.369.007	213.249.623	-3,64%	14,10%
Ceramic constructional goods	218.765.335	215.913.251	-0,33%	14,27%
Concrete, plaster structural elements	461.236.942	344.203.539	-7,06%	22,75%
Wood Structural elements	663.512.590	739.547.837	2,75%	48,88%
TOTAL IMPORT	**1.590.883.874**	**1.512.914.250**	**-1,25%**	**100,00%**

3.2 Market conditions / costs and benefits

Total Dutch aggregate production is 80 million tonnes in 2015, an increase over the last two years but has not fully recovered the production volume of 2012 (83 million tonnes). Recycled aggregates account more of 20% of the Netherlands' total aggregate production, the other 80% comes from primary materials, like sand & gravel (63%) and marine aggregate (15%) [10].

NETHERLANDS – Estimates of Aggregates Production	2015	2014	2013	2012
Total Number of Producers (companies)	245	250	235	235
Total Number of Extraction Sites (Quarries and Pits)	295	185	212	215
Sand & Gravel (millions tonnes)	50	34	33	51
Crushed Rock (millions tonnes)	0	0	0	0
Marine Aggregates (millions tonnes)	12	14	15	16
Recycled Aggregates (millions tonnes)	18	25	16	17
Re-Used on Site (millions tonnes)	0	0	0	0
Manufactured Aggregates (millions tonnes)	0	0	0	0
Total Production (millions tonnes)	**80**	**73**	**64**	**83**

The government takes various measures to make waste incineration or landfilling particularly expensive, and generally countries where landfill costs are higher have generally an high recycling rate. Construction materials producers are benevolent to sell recycled materials, because they recognize the large future market. Moreover, CDW is often cheaper than new materials [1].

3.3 Construction sector make up

In the Netherlands, prefabricated elements are used in over half of all projects. The type of prefab mostly used is panelised system, 3D prefab is used least. [6]
Residential design is increasingly moving closer to the domain of industrial design due to mass customisation. In terms of residential accommodation, aside from mobile homes and RVs, which can also be seen as accommodation, there are catalogue homes, modular hotels, and DIY home kits. Catalogue homes have become a well-known phenomenon in the countryside and many building companies are focusing on supply chain integration and mass customisation. Component parts are manufactured under controlled conditions, instead of being produced in adverse weather conditions at the construction site.[8]

Prefab construction method, named "assembling construction" is characterized by prefabricated construction elements that are delivered at the site, as in timber frame building with prefab wall elements, prefab wooden or concrete floor elements, and an outer surface of wood or brick.
Timber frame is also used to construct houses, apartment buildings up to five stories, and commercial and industrial buildings. Timber frame inner walls form the bearing construction. The outside wall or façade can be realized with different materials: brickwork, plaster, wood, sheets, or ceramic material. The wall elements consist of softwood post and rail work, filled with insulation material and covered with sheet material. Nevertheless timber frame construction remained a new technology in Dutch construction practices and lack of expertise with the materials and

methods led to mistakes and defective buildings. Therefore, two issues became important: establishing acceptable quality standards and aligning the method's technical aspects to existing regulations. By now, in order to be allowed to build under the associations auspices, all members of the timber frame association must possess a "timber frame construction product certificate" and an "attest" that describes the system used by the firm, a judgement on its past performance, and a note on its record of compliance with the Building Decree. [7]

An example of assembling construction is the **Passend Wonen** (Customised Housing), a modularised homebuilding system designed by the Dutch Van Dijk Group construction company. The company supplies standardised modules that can be used for a variety of functions, such as living, sleeping, studying, cooking, etc. Stability is provided by the bathroom module. The design can be adjusted modularly to match the individual needs of the client or occupant. Extensions can also be added to the modules once in use, and all modules can be disassembled for reuse.[8]

Figure 1. The construction of 18 new homes in the centre of Hardenberg according to the Customised Housing concept.[8]

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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POLAND

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

According to the Waste Act 2001, municipalities are obliged to:

- Include the whole population in the organized system of municipal waste collection and the system of separate collection of waste by 2015 the latest
- Create conditions for the operation of a system of separate gathering and collection of municipal waste
- Ensure proper conditions for the construction, maintenance and operation of installations and equipment for the recovery and disposal of municipal waste
- Initiate the creation of points for the collection of waste arising from electric and electronic equipment

Furthermore, Packaging and packaging of waste Act 2005 states that each entity that releases packaged products on the market is obliged to ensure the appropriate level of recovery and recycling of packaging waste. The Act sets the required annual recovery levels for packaging, recycling in general, and for individual packaging. Companies that fail to meet the required goals might face financial sanctions. Next, Maintaining Cleanness and Order in Municipalities Act 2011 mentions CDW as well.

The Waste Management Plan - contains the analysis of CDW management situation, forecast change in waste management, targets and objectives of waste management and strategies to prevent waste generation. Regarding the CDW, the WMP 2022 states the following objectives:

- increasing awareness among investors and companies producing waste from construction and demolition of buildings and infrastructure road on the proper handling of abovementioned waste, in particular in the field of selective collection and recycling;
- maintain the level of preparation for reuse, recycling and other forms of recycling construction and demolition waste at a minimum of 70% by weight.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Recycled CDW aggregates are mainly used for construction of roads, railroad infrastructure and for backfilling. Widely recycled CDW include polystyrene, shredded glass, paper and mineral wool shredded with paper.

1.3 Prefabricated elements (with or without CDW materials)

- Norm C367/C367M-16: Standard Test Methods for Strength Properties of Prefabricated Architectural Acoustical Tile or Lay-In Ceiling Panels
- Norm E477-13e1: Standard Test for Laboratory Measurements of Acoustical and Airflow Performance of Duck Liner Material and Prefabricated Silencers

1.4 Prefabricated construction

- PN-S-10040:1999 - Polish version: Bridges - Concrete, reinforced concrete and prestressed concrete structures - Requirements and tests (The standard specifies the requirements for bridge and reinforced concrete, reinforced concrete components and structures. The technical requirements for concrete, concrete mixture, fresh and hardened concrete, construction, transport, laying and maintenance of concrete, reinforcement and prestressing of concrete are presented. Methods of control and acceptance tests are given. The standard applies to ordinary concrete, not to lightweight concrete with a mass less than 1.9 t / m3 and concrete with a strength of more than 50 Mpa.)
- PN-B-19504:2004 - Polish version: Prefabricated concrete slabs - Compounded concrete slabs - Hollowed blocks (The following standard specifies the properties of floor blocks made of normal and lightweight concrete with fillings of mineral aggregates and plastics. Specified requirements for concrete mix and products. The method of sampling, a test program for certification for safety marking and test methods are given. In addition, the method of marking, storage and transport is given.)
- PN-B-19507:1997 - Polish version: Concrete prefabricated elements - stairway elements (Specified requirements for stairway elements in terms of dimensional deviations and permissible damages. The principles of selection of the method of receiving control, the composition and number of batches and the methods of testing and evaluation of batches of products were given.)

2. POLICY MEASURES

2.1 Materials from CDW

The Waste Management Plan of Poland sets several courses of actions – these are:

- Information and education activities to raise awareness among investors and CDW producing entities to create streams to deal with CDW
- Introduction of a system of incentives to promote the selective collection of CDW waste
- Introduction of a system of incentives to promote the use of recovered CDW
- Continue to monitor CDW generated and its treatment
- Develop technical infrastructure for selective collection, recovery and re-use of CDW.

2.2 Prefabricated elements (with or without CDW materials)

NEEAP in Poland

In promoting the energy efficiency of buildings, the NEEAP[1] 2011 focused mainly on repair investments and thermo-modernisation including lower energy demand for heating. Investors can receive a thermo-modernisation bonus for reaching the requirements set in the Polish legislation

[1] National Energy Efficiency Action Plans

[1]. According to the NEEAP 2014 Poland aims at improving the technical conditions of existing housing resources and simultaneously reducing the demand for heating due to a huge existing renovation gap. Additionally, the Polish government is introducing stricter regulations concerning minimum requirements for energy saving. At the same time, newly constructed buildings are forced to be nearly-zero-buildings. Furthermore, Poland is preparing a National Plan intending to increase the number of buildings with low energy consumption focussing mainly on new build buildings.

Key funding schemes currently operational in Poland

- Programme A – Thermo-renovation Fund
- Programme B – RYS
- Programme C – Air protection
- Programme E – Energy-saving investments in SMEs
- Programme F – Regional Operational Programmes

2.3 Prefabricated construction

See section 2.2

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to the official statistics, the amount of CDW exported and imported is not significant in Poland. In 2013, 1 Mt of waste of group 17 were imported from the EU, 1 Mt imported from outside the EU and 2Mt exported. There are no details identified about its type and treatment that they were transported for.

3.2 Market conditions / costs and benefits

Based on survey conducted among potential clients of the housing construction market [2], the following factors have an undoubted influence on the choice of home construction technology:

- costs of construction (from the construction of the foundations to completion, inclusively)
- the building construction system (independent or including hiring of the appropriate companies)
- financial liquidity (which regulates the time and rate of performed work)
- the site of construction (location, shape, and area of the lot, geotechnical soil parameters, accessibility to traffic)
- individual client preferences,

- the deadline for construction of the buildings and the time clients have available.

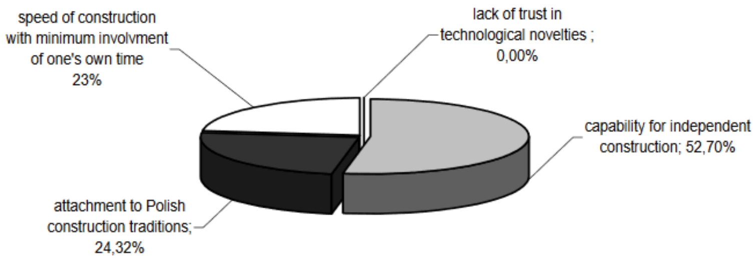

Figure 1. Factors that influence the choice of house construction technology

According to the conducted studies, as many as 88.73% of those surveyed would rather build their own home using conventional technology, with only 11.26% using prefabrication technology. It indicates the dominance of systems using conventional technology over prefabrication. However, 23% considered the speed of construction as an important factor, which can be perceived as the main advantage of "ready-made home" construction using prefabrication.

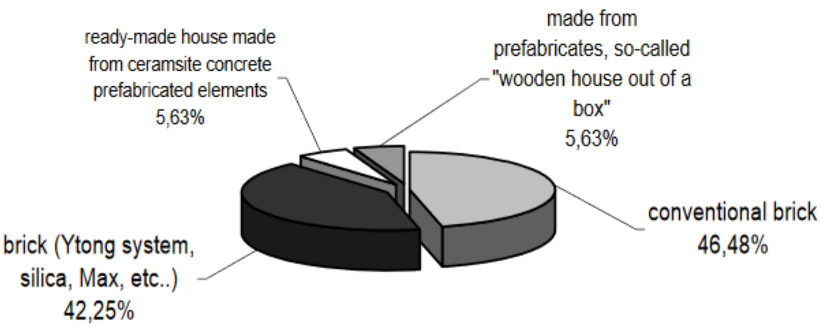

Figure 2. : Factors that influence the choice of house construction technology

Consequently, the question is why there is so little interest in house construction using prefabrication technology. Certainly, associations with systems using modern prefabrication technology do not have their source in the past but are based on current information in the media. Over 89% of those surveyed link prefabrication with ecology, material savings, and the concept of a 'home out of a box'. Only 11% of those studied perceived any relationship with the negative aspects of living in an 'apartment complex from the People's Republic of Poland'. The low level of interest in the construction of ready-made houses is undoubtedly related to the strong market position and development of systems using conventional technology.

Although today the perception of prefabricated technology is much worse than that of conventional technology, it does have its advantages. The prospect of sustainable development that is being achieved from year to year in countries of the European Union may contribute to a growth of interest in prefabricated construction systems, but the main road to success for prefabrication is a reliable construction company that can boast knowledge of technology and capable performance of services. The pace of life and the search for comfortable and convenient decision-making solutions conclusively speak in favour of prefabrication technology systems. The time required to build a ready-made house from prefabricates is only several days.

3.3 Construction sector make up

Production in all subsectors of the Polish construction industry has slumped during the 2015-2016. Businesses specializing in civil and water engineering have been hardest hit, having seen a 17% drop a year. There was also a decline in construction investment, down by 14,9%, and in renovation works by 11,9%. The overall construction and assembly output fell by 13% [3].

Weak construction activity in fact lasted several last years (2011-2015). It was mainly due to a deteriorating business environment, weak economic conditions, currency depreciation and lack of foreign capital investment. But, the industry's future is foreseen to be brighter over the next five years. It is expected to accelerate at a CAGR of 4,17%, the industry's value is expected to increase from USD109.7bn in 2015 to USD134.6bbn in 2020 (measured at a constant 2010 USD exchange rate). Government investments in infrastructure, energy and housing projects will drive growth [4].

In 2014, waste collection, treatment and disposal activities as well as materials recovery sector represented in average 52 000 of employees (50 000 in 2013) [5].

EU funds for construction industry in Poland

In the framework of the EU budget for 2014-2020, Poland will receive 82.5 billion EUR. It is estimated that 19.8 billion EUR will be allocated for transport infrastructure as part of the Infrastructure and Environment Operational program (12 billion EUR for roads and 7.4 billion EUR for rail infrastructure). In addition, 31.2 billion EUR has been allocated for regional programs, which may also cover infrastructure investment projects. The biggest expenditures are expected to be related to road, rail, energy and hydroelectric infrastructure.

Polish prefabricated constructions

The opening of Poland to the foreign market and its entry into the European Union, as well as the requirements of sustainable development, have had an undoubted influence on the development of housing prefabrication in Poland. Even though prefabrication is currently applied and appreciated by engineers who build civil engineering structures, it has still not yet gained recognition among clients on the housing construction market in Poland [2].

However, the perception and understanding of prefabrication in housing construction are undoubtedly starting to change in Poland. Sustainable construction criteria may constitute a significant turning point and support for the development of new prefabricated housing construction technologies. Entrepreneurs are slowly perceiving an opportunity for the development of prefabrication in the construction market. The implementation and popularisation of ready-made homes will undoubtedly constitute a favourable change in the Polish construction market; however, this will require a modification of habits.

Until now, conventional technology has enjoyed the greatest popularity on the Polish housing construction market, although prefabrication has also enjoyed its moments of triumph. For many years, Poles have maintained the conviction that the only good house is a conventionally built brick house. When it comes to methods of erecting residential buildings, the variety of choices is constantly being expanded by new solutions. More and more Poles are slowly starting to appreciate the advantages of light prefabricated construction, especially the short time needed for investment completion related to this method. Time pressure, as one of the leading points impacting contractors' decision-making processes, has a negative influence on the quality of constructed buildings and creates hazards resulting from the necessity to speed up the construction process.

The method of constructing buildings using prefabrication technology in the field of multi-family residential construction is not popular [2]. In consequence, companies offering the construction of residential buildings using systems based on prefabricated technology should focus more on individual private clients interested in building a home.

The Polish market is rapidly following European trends. There are a number of small and medium-sized companies that offer timber frame construction with open and closed elements as well as block houses. Many manufacturers offer their houses with different energy standards, including the passive house standard. Companies that want to carve out their niche in the market are experimenting with different insulating materials to give the houses the best energy efficiency [6].

The Polish market with prefabrication is dominated by Danwood S.A., the largest prefabricated house manufacturer in Poland.

The perception and understanding of prefabricated housing is undoubtedly starting to change, which for foreign investors and entrepreneurs constitutes an opportunity to undertake investment activity. More and more companies in Poland are basing their house-building operations exclusively on the prefabrication system because they see an opportunity for development in doing so [2].

3.4 Use of CDW materials for prefabricated elements

The main recycled materials from CDW are aggregates, used for backfilling and road building. There exists also recycling of different types of waste directly on construction site, such as:

- Polystyrene and polyurethane foam residues that are shredded or dissolved
- Shredded glass
- Paper
- Mineral wool shredded with paper to reinforce materials

Considering the massive amount of construction waste, application of modern MMC[2] construction programmes is seen as a solution to this problem. It concerns, above all, the production of structures in factories, minimisation of defects in residences, and reduction of energy and waste. There is some evidence of MMC leading to a reduction in costs and improved profitability, with 44% of house builders and 27% of housing associations pointing to benefits such as reduced preliminary costs, improved cash flow and faster sales revenues.

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[2] MMC – Modern Methods of construction, it embraces a number of approaches involving off-site manufacture or assembly, involving prefabrication.

PORTUGAL

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

In Portugal, even though the first published law on waste management goes back to 1985, Decree Law No. 488/85, only in 2008 was a specific law concerning CDW management published. In Table 1, an overview of the main legislation frame concerning wastes (all kinds) is presented, in chronological order. Among other changes introduced by the Decree-Law No. 46/2008, the Portuguese Environmental Agency points out (Agência Portuguesa do Ambiente, 2010):

- Definition of the responsibility chain, in CDW production and management;
- Definition of procedures and practices to be adopted in the design and execution of the projects that emphasize the principles of waste hierarchy (reduce, reuse and recycle);
- Possibility of reuse of non-contaminated soils and rocks;
- Enforcement of CDW separation before landfill disposal;
- Definition of minimum technical requirements for sorting and fragmentation facilities;
- Licensing exemption management operations, where the licensing procedure was a major obstacle to waste management in line with the principles of waste hierarchy;
- Utilization of CDW on-site subject to compliance with Portuguese and European technical standards;
- Conditioning the beginning and conclusion of works to the evidence of proper CDW management, a CDW management plan is required and most include an important aspect: waste quantities [1].

Although the relevance of such standards is undeniable, if high level, recycling is to be done in the Portuguese construction industry, more needs to be done. For instance, this decree lacks the tools to estimate the amount of CDW generated at the construction site, in order for the CDW management plan to be properly done. The first step towards the correct management of this type of debris is to determine its quantity. In order to fill this gap, this study produced indicators to estimate the amount of CDW generated on-site.

Table 1. Main legislative documents, which may concern CDW, released in Portugal, in recent years (Source: Coelho and Brito, 2007).

Legislation reference	General description
Decree nº 15/96, 23rd of January, 1996	Approves waste management operations
Decree nº 335/97, 16th of May, 1997	Establishes rules for waste transportation
Decree nº 818/97, 5th of September, 1997	Approves the European list of wastes
Decree-Law nº 239/97, 9th of September, 1997	Establishes general rules for waste management
Decree nº 961/98, 10th of November, 1998	Legislates authorization processes in managing industrial, urban and other kinds of waste

Decree nº792/98, 22nd of September, 1998	Approves the non-hazardous industrial waste map
Decree-Law nº 321/99, 11th of August, 1999	Regulates the installation and management of nonhazardous industrial landfills
Decree-Law nº 516/99, 2nd of August, 1999	Approves the Strategic Plan for non-hazardous industrial waste
Decree-Law nº 152/2002, 23rd of May, 2002	Regulates the installation, use, closure and post closure procedures for landfills
Decree nº209/2004, 3rd of March, 2004	European waste catalogue
Decree-Law nº 178/2006, 5th of September, 2006	Establishes general rules for waste management. Replaces Decree-Law nº 239/97
Decree-Law nº 46/2008, 12th of March, 2006	Establishes general rules for CDW management

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Concerning the waste classifications of the European List of Waste, construction and demolition waste covers a very wide range of materials.

Aggregates

Besides the harmonized European legislation (NP EN), the technical regulations applicable to recycled aggregates in Portugal are shown below:

Decree-law 46/2008, concerning the management of CDW, includes:

- The definition of measures to prevent and reuse CDW
- The costs of dumping
- The possibility of reusing RCDs in construction if Portuguese or European specifications are verified and, in the absence of such standards, the requirements established by the LNEC (National Laboratory of Civil Engineering):
  - E 471: Guide for the use of thick recycled aggregates in hydraulic binder concretes.
  - E 472: Guide for the recycling of hot bituminous mixtures in the plant.
  - E 473: Guide for the use of recycled aggregates in uncontaminated layers of floorings.
  - E 474: Guide for the use of construction and demolition waste in landfill and bed layer of transport infrastructures.
  - E 483: Guide for the use of recycled aggregates from recovered bituminous mixtures for uncontaminated layers of road pavements.
  - E 484: Guide for the use of materials from construction and demolition waste in rural and forestry roads.
  - E 485: Guide for the use of materials from construction and demolition waste in ditch filling

  The application rules are summarized below:
  - Recycled aggregates cannot be used in concrete in contact with water for human consumption.
  - Recycled concrete cannot be used in aggressive environments.
  - Up to 20% recycled aggregate can be included without express notification.

No further information has been found for other type of materials from CDW.

1.3 Prefabricated elements (with or without CDW materials)

In addition to the harmonized European legislation (NP EN in Portugal) which most of them are mandatory for the market commercialization (CE marking) of structural elements, the legislative and regulatory situation in precast concrete products in Portugal is shown below:

- Eurocode 2: Design of concrete structures (abbreviated EN 1992 or, informally, EC 2)
  Part 1-3: Precast concrete elements and structures
- REBAP: Regulation of Reinforced Concrete Structures

1.4 Prefabricated construction

Prefabricated construction has been commonly considered as a key strategy to effectively promote construction waste minimization.

In Portugal there is no Building Act that forms the legal basis for the building regulations and procedures, and defines of obligations and responsibilities of parties involved. The General Building Regulations [2] is the main national building regulation, setting general provisions for building, regarding construction, health, safety and aesthetics. It is in force since 1951 and, although several small amendments, no fundamental revision has been approved. In addition, there are more than 45 national building regulations and other regulatory documents that focus on specific requirements. Most of these were approved in the last two decades and some of them resulted from the transposition of European Directives. [3]

In addition there are other national regulations with construction and/or operational provisions for different types of buildings, which have to be observed to ensure that the building can be used for the intended purpose. For example, social housing, nurseries, elderly homes and stadiums have to comply with specific regulations. In the continental territory there are no building regulations at the regional level. However, the two autonomous regions of Azores and Madeira can approve regional regulations and have the competence to adapt the building regulations approved by the Central Government to the local circumstances. The municipalities can approve building regulations, complementary to national ones, to regulate subjects of municipal competence or local traditions and uses.

Each ministry takes the initiative to developed national building regulations within its attributions, separately or with other ministries. The Ministry for Public Works, Transport and Communications and the Ministry of Economy were involved in the preparation of most of the national building regulations. Several other ministries also participated or promoted the approval of national building. Since 2007, the Institute for Construction and Real Estate (InCI) is responsible for the coordination of the national building regulations. Regional regulations are approved by the regional assembly. Municipal regulations are approved by the municipal council. These regulations have a period of public discussion before their approval, but are not subjected to review or approval by the national authorities.

2. POLICY MEASURES

2.1 Materials from CDW

Besides technical regulations listed in the previous chapter, no other instruments have been found for the materials from CDW in Portugal.

2.2 Prefabricated elements (with or without CDW materials)

Besides technical regulations listed in the previous chapter, no other instruments have been found for the prefabricated elements in Portugal.

2.3 Prefabricated construction

Besides technical regulations listed in the previous chapter, no other instruments have been found for the prefabricated construction in Portugal.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Table 2 below collect the exports of prefabricated elements made of cement, concrete or artificial stone in Portugal, reported in the export portal SmartExport, for 2008.

Table 2. Export market in Portugal

Weight of exportations	Development of exports
-1.0%	-86.7%

3.2 Market conditions / costs and benefits

No specific information has been found.

3.3 Construction sector make up

No specific information has been found.

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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ROMANIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

A part from the "**Best practices Code for CDW Management**", developing among the EU (Project LIFE ENV/RO000727) Recovery of Construction and Demolition Waste in Buzău County, in Romania there is no specific national legislation on CDW. [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The main CDW product is recycled aggregates, used for backfilling and road building. [1]

1.3 Prefabricated elements (with or without CDW materials)

No specific information has been found.

1.4 Prefabricated construction

No specific information has been found.

2. POLICY MEASURES

2.1 Materials from CDW

No specific information has been found.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

To facilitate access to housing loans and stimulate the construction sector, the government launched the First Home Programme in June 2009. Under the programme, managed by the National Guarantee Fund for Loans to SMEs, the state issues guarantees of up to 50% of the value of the mortgage offered by adhering banks. [2]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

For Romania imports of prefabricated elements are higher than exports. Romania is importer of concrete or ceramic products for buildings. Instead, the positive trade balance is observed for prefabricated wooden items.

According to International Trade COMEXT, the value of trade of prefabricated elements is € 971 Million in 2016. Export activities account 423 € Millions, while import account 548 € Million. The sold construction products in Romania between 2012 and 2016 has growth at a rate (CAGR) of 9.4% for export and 6.5% on import.
On the export side, wood elements (88.6%) and concrete elements (8.6%) hold 95% of the exports. In the observed period, their growth rate in exports is 10.8% of prefabricated elements in wood, and 3.2% for prefabricated constructional concrete. Significant decrease in cement exports, mortars and plaster ready mix (-10.2 % CAGR)

On the import side, the ceramic and concrete structural elements are the most imported ones. Their share on import is 33.5% for ceramic constructional goods and 16.3 % for concrete and plaster structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramic items (+5%) and for wood elements (+10,8%) increase, while concrete (+0.8%) and ready mix cement, lime and plaster (+0.01%) are constant.

Approximately 62% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders

ROMANIA TRADE (VALUE_IN_EUROS)				
EXPORT	**2012**	**2016**	**CAGR**	**Share on Import**
Cement, lime and plaster (ready mix)	5.818.561	3.771.407	-10,27%	0,89%
Ceramic constructional goods	8.195.464	7.593.191	-1,89%	1,79%
Concrete, plaster structural elements	32.258.417	36.712.934	3,29%	8,67%
Wood Structural elements	248.856.675	375.184.961	10,81%	88,64%
IMPORT	**2012**	**2016**	**CAGR**	**Share on Import**
Cement, lime and plaster (ready mix)	18.623.682	18.627.796	0,01%	3,40%
Ceramic constructional goods	151.525.947	184.275.044	5,01%	33,59%
Concrete, plaster structural elements	86.608.849	89.732.435	0,89%	16,36%
Wood Structural elements	169.324.424	255.976.499	10,88%	46,66%

3.2 Market conditions / costs and benefits

Regarding the availability and the natural aggregate has cost, these factors depend on the Country, by the mines' availability in a specific area and by the transport's cost. It is currently more expensive in Romania to buy secondary raw materials than primary ones. One of the main reasons is that the large number of pits in Romania leads to an abundance of supply of natural aggregates, and to low prices. For this reason, using recycled CDW for new constructions is not very well perceived in as the actors in the construction sector tend to prefer the use of primary raw material, which they perceive as having higher quality than secondary (recycled CDW) materials. This mentality could be changed if the quality of the secondary raw materials is certified. Furthermore, the lack of infrastructure and high cost of transportation, combined with the lack of financial incentives to recycle CDW deters consumers to buy recovered materials [1].

As demonstrated by UEPG (European aggregates Association) the factor underline previously, such as abundance of supply of natural aggregates and low prices of them, explain why in Romania, on a total of 90 million tons of aggregate products, the majority were from Sand & Grave (62%) and Crushed Rock (38%). Overall, the volume of natural aggregates production increased between 2008 and 2015 by 19% (CAGR), driven mainly by the production of aggregates from Sand & Grave (+17%) e Crushed Rock (+25%). Over the years, the number of companies in the industry has increased (as well as the number of Extraction Sites, the aggregate production volume of aggregates has increased, while the production of recycled aggregates has remained close to zero [10].

ROMANIA - AGGREGATE PRODUCTION	2015	2014	2013	2012	2011	2010	2009	2008
N° of Producers	980	950	900	975	963	430	430	500
Total Number of Extraction Sites (Quarries and Pits)	1100	1090	1050	1210	1600	735	745	730
Sand & Gravel (M tonnes)	55	52	52	68	56	34	25	18
Crushed Rock (M tonnes)	34	31	23	28	38	15	12	7
Marine Aggregates (M tonnes)	0	0	0	0	0	0	0	0
Recycled Aggregates (M tonnes)	0	0	0	0	0	0	1	1
Re-Used on Site (M tonnes)	0	0	0	0	0	0	0	0
Manufactured Aggregates (M tonnes)	0	0	0	0	0	0	0	0
Total Production (M tonnes)	**90**	**82**	**75**	**96**	**94**	**49**	**38**	**26**

As a saw previously, using recycled CDW for new constructions is not very well perceived in as the actors in the construction sector tend to prefer the use of primary raw material, which they perceive as having higher quality than secondary. Furthermore, the concept that recycled aggregates come from wastes meets opposition from both building operators and customers [1].

3.3 Construction sector make up

Romania's total construction output growth for 2016 has been slightly revised up to 3.7% from 3.4% (summer forecast) given by the more optimistic indicators in the residential segment, the better performance in industrial and logistical construction, and finally, the growth in activity in road construction. 2017 is anticipated to register a growth of 5.2% (against 6.6% forecasted in summer) with civil engineering expected to underperform due to an expected lag in the implementation of major projects, following the current election. For 2018, an expansion of 8.6% is awaited now in the overall construction in Romania (compared to the projected 6.9% in summer), mainly driven by residential construction exceeding growth rates of 10%. The reasons comprise historically low mortgage rates, favourable government policies and a market attracting more speculative development [6].

Timber-framed buildings with infill masonry wall can be observed in many European countries, among with Romania too. They are essentially part of a traditional architectural culture that exploited a renewable raw material, the wood, which was once more widespread in the territory. Timber-framed buildings were already documented during the High Middle Ages but it is between the 17th and 18th centuries that these buildings gained (more or less explicitly) their anti-seismic function, especially in high-risk countries. [3]
Nowadays there are several manufactures of timber-framed buildings, and they offer two different solutions:

- To provide timber-frames kit with all necessary components for installation;
- To provide timber frame houses turnkey solutions.

Figure 1. Example of timber-frame house in Romania.[4]

Precast concrete structures were products in Romania, since 1954. [5]

Precast concrete panel apartment buildings were built in Romania form 1960s through the 1990s. The load bearing system is a precast-reinforced-concrete large-panel construction. Buildings of this type are typically high-rises (10 or 11 stories), although there are also low-to medium-rise buildings (4 to 8 stories) with different structural details. In general, these buildings consist of a rectangular plan, with a honeycomb ("*fagare*") layout, typically housing four apartments per floor. Wall panels are laid in both the longitudinal and the transversal direction. The panels are mechanically coupled at the base with continuous vertical reinforcement bars. Currently, this type of construction is not being built.[7]

Figure 2. Typically precast concrete panel apartment building in Romania.[7]

In an attempt to solve the difficult problem of the construction of residential buildings in Romania, standard precast concrete structures using fewer elements with standard dimensions (that can be produced in large numbers on an industrial basis) have been developed.

Nowadays, precast concrete structures mainly consist of long precast concrete columns and precast concrete panels. An innovative **precast concrete dual flat-slab structure** has been developed during 2012, and it consists in long precast columns and precast concrete flat-slab panels, limiting the number of structural inner walls, leading to a dual structural system of the frame-wall type, suitable in seismic areas, such as the Romania. [8]

Figure 3. All-precast concrete dual structure during erection.[8]

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

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DISCLAIMER

SLOVAKIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

- The Waste Act 223/2001 – definition of waste, CDW and waste treatment operations; summarizes the obligations for waste producers
- Decree 284/2001 – establishment of the waste catalogue; definition of procedures for preparing and submitting reports on waste generation and waste treatment
- Regulation 525/2003 - requires regional and district offices to be in charge of waste management and environmental protection in their respective territories
- Notice 75/2001 – specification of methods for the analytical inspection of waste
- Act 17/2004, Act 434/2013 and Act 582/2004 deal with fees for waste handling in general and fees for depositing waste in landfills in particular
- Act 119/2010 on Packaging – rules for both individuals (entrepreneurs) and legal entities which (1) use packaging to pack products or fills the packaging with products, (2) place products in packaging on the market (with the exception of producers and importers of packaging who supply the obliged persons). These are then required to [1]:
    1. register in the register of Ministry of Environment of the Slovak Republic
    2. communicate the changes to this register
    3. keep records of the quantity and types of packaging materials
    4. fill in the registration file of packaging and packaging waste
    5. send the annual report to the ministry
    6. ensure the collection of packaging waste and their recovery and recycling at least in the amount of specified limits, e.g. by the way of an authorized organization.
- The Waste Act 223/2001 – in case that CDW exceeds the total amount of 200 tonnes per year, there is an obligation to separate it.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

- Act 264/1999 on Technical Requirements of Products – CE marking, technical requirements on products which could threaten health, safety or possessions of individuals or endanger environment
- Act 102/2014 on Consumer Protection
- § 19 of the Regulation no. 283/200139 as amended by 310/201340, on removal of materials with asbestos

- The standards for recycled CDW called Standard STN IN 933-11 dictate that recycled aggregates must have a declaration of conformity with the same standards of being harmless for human health and for the environment
- Standard STN EN 1744 provide the assessment method for chemical properties of aggregates. It assesses sustainability of recycled material for various uses and storage conditions.
- Regulation 133/2013 on construction products requires the recycled construction material to have a declaration of conformity with the relevant standards for construction products and prove harmless for the environment and human health.

1.3 Prefabricated elements (with or without CDW materials)

Construction-technical prefabricated concrete must be in line with norm STN EN 13369. There are several norms regarding the concrete prefabricated elements:

- STN EN 12794+A1 foundation pile
- STN EN 12843 electricity pylon
- STN EN 13198 street and garden furniture
- STN EN14844+A2 box culvert
- STN EN 15050+A1 bridge segments
- STN EN 15258 abutment wall
- STN EN 15435 normal and lightweight concrete shuttering blocks
- STN EN 1339 concrete tiles
- STN EN 1340 concrete kerbs
- STN 72 3150 pipes from reinforced concrete
- STN 72 3163 rain-water concrete pipes
- STN 72 3376 cable ducts.

1.4 Prefabricated construction

- Regulation 237/2000 - before any construction work starts, an individual or a company must obtain a permission which can be given only if a project contains a CDW management plan for disposal or recovery treatment.
- Act 50/1976 on Construction activities.

2. POLICY MEASURES

2.1 Materials from CDW

Waste Prevention Plan for 2014-2018 - section 4.3.5 sets measures which aim to prevent CDW from landfill. The WMP sets goals regarding the CDW. The ultimate goal is to reach European requirement of recovering at least 70% of CDW. To meet this goal, Slovakia aims to:

- Develop legislation limiting landfilling of recyclable CDW
- Strengthen the use of uncontaminated dredging soil and other natural material
- Define the EoW criteria for CDW
- Ensure that publicly financed construction projects use recovered materials
- Financially support technology which contributes to recycling of CDW

In the period 2007-2013, the Operational Programme Environment financed by European Funds supported waste management infrastructure in Slovakia with about €570 million.

There are number of attempts to promote and support CDW treatment and reuse. These are summarized in the Table 1.

Table 1. Initiatives aiming to promote and support CDW treatment and reuse [2]

Action	Responsible enforcing and monitoring authority	Responsibility for implementation	Time of completion
Uncontaminated soil and other naturally occurring material excavated during construction works not to consider to be waste (when the material is used for construction in its natural state)	District Environmental Offices	Waste producers	On-going
Increase the control over separation of waste streams in place of generation	MoE SR	Slovak Environmental Inspection, District Environmental Offices	On-going
Promote research and development in the field of recycling, reusing or recovering materials from construction and demolition waste	MoE SR	MoE SR, Universities	On-going
Set criteria for defining end-of- waste for CDW	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic	In the time of approval of the new Waste Act 19/2015
To adapt technical standards for construction materils and their use to increase the proportion of recycled CDW and construction products containing incinerator ashes.	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic	On-going
Support the construction and operation of CDW recovery facilities	MoE	MoE	On-going
To use recycled CDW in construction financed by public funds (mostly road works), provided that they comply with functional and technical requirements; and also to include this as a requirement in the public procurement conditions	All sectors, MoE	Suppliers	On-going
To propose an amendment to the Building Act, which impose an obligation to check the management of CDW of a project at the final inspection	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic	MoE, Ministry of Transport, Construction and Regional Development of the Slovak Republic and Building Authorities	In the time of approval of the new Waste Act 19/2015

2.2 Prefabricated elements (with or without CDW materials)

The National Action Plan for Green Public Procurement in the Slovak Republic for 2011- 2015 provides a strategic objective to increase the proportion of GPP used in Slovakia to 65% at the level of central government bodies and by 50% at the level of self-governing regions and municipalities.

2.3 Prefabricated construction

The SKGBC is an association that are sharing best practices, organizing seminars and conferences and support sustainable construction

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Concerning the export/import of CDW waste, the Slovak Environmental Inspection is responsible for the control of trans-boundary shipments of waste. The MoE issues permits and specifies the conditions for the import, export and transit of waste by Part 4 of the Waste Act.

Similarly to the Czech Republic, the main product of CDW treatment are recyclates that can be used for production of new construction materials. However, data about numbers of final prefabricated elements are not available, less so data about import/export of these elements. However, it can be assumed that the output is very small.

3.2 Market conditions / costs and benefits

In Slovakia recycling of construction and demolition waste is a modern trend in construction sector. The reasons are effective reuse of CDW waste, economic advantages and finally environmental aspects. Processing of CDW is becoming popular due to some factors such as: crushing and processing of CDW directly at a customer's place, storage of CDW waste in recycling centres is cheaper than landfilling, recyclates are comparable with new materials.

For purposes of quantification of CDW waste in Slovakia there is widely used economic software Cenkros Plus [3] across Slovak construction environment. This software allows the determination of costs, volume and type of construction material, machinery and works and the costs of particular items.

Incentives in CDW in Slovakia

Financial incentives in Slovakia are limited not only in the form of landfill or treatment fees, but also in the form of funding for development or penalties. For information, prices from the Recycling Centre ENVIRONCENTRUM, s.r.o. Rastislavova 58, Košice for accepting mixed CDW and selling recycled CDW are summarised in Table 2.

Table 2. Prices for accepting mixed CDW and for selling of recycled CDW in one of Slovak treatment facilities [2]

Price for accepting CDW	€/tonne exc VAT	€/tonne inc VAT
A: CDW max 500mm, contaminated concrete, mixed CDW, excavation	6.58	7.90
B: CDW max 500mm, max contamination 5%	8.42	10.10
C: CDW max 1000mm, no contamination	8.42	10.10
D: CDW max 1000mm, max contamination 5%	11.50	13.80
Price for selling recycled CDW		
Unsorted soil from excavation for terrain modification and backfilling	0.13	0.15
Separated soil fraction 0-32mm for terrain modification and finish use	3.36	4.00
Separated soil fraction 0-10mm for finishing terrain usage	3.36	4.00
Sand		
Recycled bricks 0-6mm, use in concrete for bricklaying	1.58	1.90
Aggregates		
Recycled bricks 0-32mm	0.58	0.70
Recycled bricks 10-32mm	0.58	0.70
Recycled concrete 0-32mm	2.25	2.70
Recycled concrete 10-32mm	2.25	2.70
Recycled bitumen material 10-32mm	1.08	1.30
Stone		
Recycled brick 32-64mm	0.58	0.70
Recycled brick over 64mm	0.58	0.70
Recycled concrete 32-64mm	2.25	2.70
Recycled concrete over 64mm	2.25	2.70
Recycled bitumen 32-64mm	1.08	1.30
Recycled bitumen over 64mm	1.08	1.30

Other benefits of recycling CDW in Slovakia

Construction waste recovery contributes to the saving of natural resources, as effective recycling reduces the need for extraction of gravel, sand and other raw materials used in construction and the energy sector. In addition, material from demolition and demolition works need not be stored in landfills as waste. Thanks to recycling the new building materials are created in the quality comparable with virgin raw materials, and for price significantly lower.

3.3 Construction sector make up

Construction output in Slovakia decreased 18.50 percent in December of 2016 over the same month in the previous year. Construction Output in Slovakia averaged -0.70 percent from 1993 until 2016, reaching an all-time high of 28.90 percent in October of 2015 and a record low of -41.30 percent in December of 1993 [4].

Construction is Slovak 4th largest sector, with gradually increasing importance. It is the 3rd top employer, after industry and trade. In 2015, there were approximately 211 000 jobs in the construction sector which constitutes nearly 9% of total [5].

Prefabricated constructions in Slovakia

Based on a survey [6] about current state of prefabrication in Slovakia, there is a need to improve the impact of prefabrication in the whole building industry. The targeted groups in the survey were contractors of different types of buildings (apartment houses, office buildings, industrial buildings..). That target group was selected because they are in direct contact with the technology of prefabrication and assembly of prefabricated elements. There were 105 total responses.

The initial questions were related to the structure of surveyed firms. From the 105 responses by organizational legal form were 25 freelancers and 80 trading companies. Out of these 80 trading companies, 19 were liability companies and 61 limited liability companies. Survey also examined the number of employees in these companies. Most numerous were small companies (10-99 employees-58 replies) and beyond them micro-enterprises (up to 9 employees-44 replies). To the questionnaire responded 2 medium-sized companies (100-499 employees). Large companies (over 500 employees) probably did not respond to the questionnaire.

To the question what is the most commonly implemented segment of construction, replies revolved around administrative and polyfunctional buildings, after that industrial buildings followed by houses and residential buildings. (Figure 1)

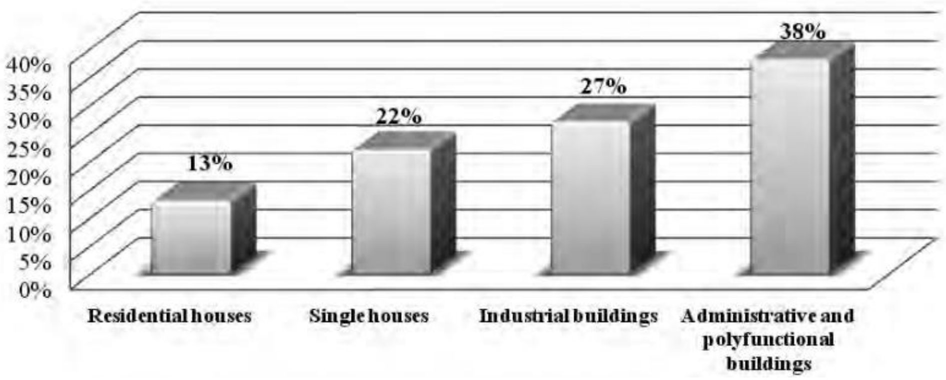

Figure 1. The most commonly realized segment of construction

Regarding the invertors' preferences (Figure 2), survey shows, that the greatest emphasis it put on the overall cost of construction.

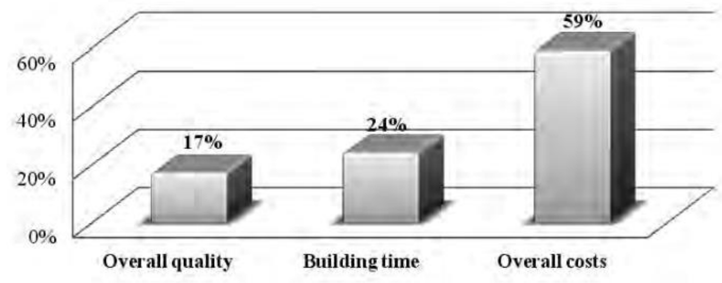

Figure 2. Investors main focus

The survey also examined whether companies know about the benefits of prefabrication (Figure 3). The biggest plus for them seems to be saving the cost of acquisition and construction time saving.

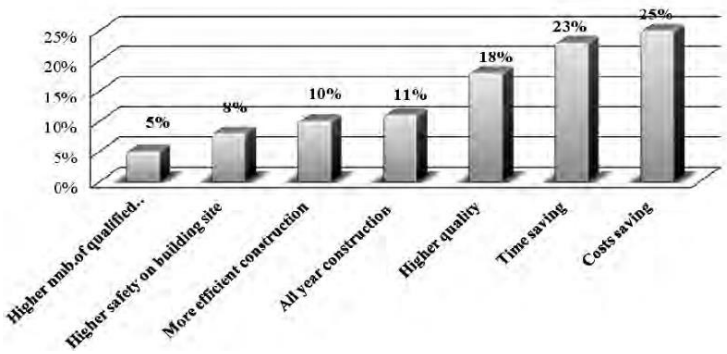

Figure 3. Benefits of prefabrication

The most common prefabricated elements mounted into the building (Figure 4) are prefabricated column structures, wall construction and floor construction.

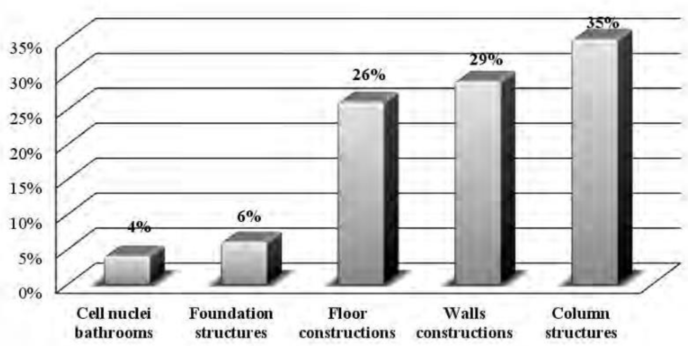

Figure 4. Commonly prefabricated construction

In the last question, the companies were to think about the potential of prefabrication, if it can push the traditional methods of construction to the side-lines. Construction companies are aware that the difficult part is still to convince investors of the benefits of prefabricated technology. They are particularly interested in the effectiveness of the implementation more prefabricated elements into the project and achieved energy savings.

3.4 Use of CDW materials for prefabricated elements

Similarly to the Czech Republic, recyclates are main product from CDW waste treatment. They are then used for various purposes.

Standards for recycled aggregates in Slovakia

There are existing standards for recycled aggregates, STN EN 933-11, where recycled aggregates must have a declaration of conformity with the standard and be harmless for the environment and human health. Standard STN EN 1744 is used for assessment methods for the chemical properties of aggregates. No environmental product declarations (EPDs) for construction products including recycled material were found. No information was found on other incentives to use recycled material in construction products in Slovakia.

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DISCLAIMER

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SLOVENIA

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

A part form the **Decree on the management of waste arising from construction work** of 22 April 2008, which determines the framework for mandatory management of waste arising from construction work in the construction, reconstruction, adaptation, renovation or removal of a building, in Slovenia there are no technical regulation and legislation on CDW.
As in Slovenia a lot of constructions are building with asbestos, it's important to mention the two Decree regulating the obligation for separate collection and management of hazardous waste from C&D operations: Decree on the management of waste containing asbestos (2008); Decree on the conditions for the disposal of materials containing asbestos in the demolition, reconstruction or maintenance of buildings and in the maintenance and decommissioning of plants (2006). [1]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The guideline "The Production of Recycled Aggregates from Inert Waste"[3], developing among the research project SARMa, analyses, among the others, the requirement of recycled aggregate from CDW, according to national and international standards. As reported, the European technical norms of use do not distinguish aggregates according to their origin but according to their characteristics. Therefore the recycled aggregates must be compared to all intents and purposes to natural aggregates. Only those recycled aggregate products that meet the prevailing European norms and specifications and are CE marked can compete with conventional aggregates. Eco-compatibility of recycled aggregates should also be checked through leaching and other appropriate testing in accordance with existing protocols.

1.3 Prefabricated elements (with or without CDW materials)

According to the Construction Product Regulation (EU 305/2011) **Timber Building Kits** (including timber frame kits) are also considered as construction products. Consequently, the manufacturers have to mark their products with CE marking and issue a Declaration of Performance (DOP), based on European Technical Assessment (ETA). Currently, ETA (e.g. ETA, 2010) are prepared on the basis of Guideline for European Technical Approval ETAG 007 used as European Assessment Document (EAD). [2]

1.4 Prefabricated construction

In 2004, Slovenia adopted the Eurocode standards which replaced the former Yugoslavian standards. Since then, prefabricated timber frame structures have been designed according to **Eurocode standards**, in particular: **Eurocode 5: Design of timber structures** - Part 1-1: Common rules and rules for buildings; Eurocode 1: Actions on structures - Part 1-1: General actions - Densities, self-weight, imposed loads for buildings Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings. [2]

2. POLICY MEASURES

2.1 Materials from CDW

Slovenian National Building and Civil Engineering Institute, which is a member of a number of national European institutes working in the fields of buildings and the infrastructure, co-operates actively in numerous joint research projects. Among the other "**InnoWEE** Innovative pre-fabricated components including different waste construction materials reducing building energy and minimising environmental impacts" H2020, which is developing from October 2016 up to September 2020, and "**REBIRTH** Promotion of the Recycling of Industrial Waste and Building Rubble for the Construction Industry", a project founded by the EU's LIFE programme to date.

The aim of REBIRTH is to increase and improve the recycling of industrial and construction and demolition waste for re-use as new regenerated construction material. [5]
The project activities also directly led to better implementation of environmental and construction legislation as a result of the workshops and communication with legislative bodies, as well through new legislative proposals. The project highlighted some inconsistencies in the application of waste legislation and several legislation developments are expected as a consequence, including:

- A proposal for an amendment to green public procurement legislation;
- A proposal for legislation regarding the concentrations of dangerous substances in the leachates of construction materials;
- A proposal for legislation on CDW – harmonisation with decree on waste and defining end-of-waste criteria for CDW; and
- Guidelines for classification of the CDW. [6]

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

In 2015, Slovenia launched its **National Energy Efficiency Action Plan 2014-2020**, which defines measures to be implemented in order to reach the energy efficiency target set in Directive 2012/27/EU. In addition to the Action Plan for energy efficiency, the government adopted the **Long-term Strategy to promote investments in energy refurbishment of buildings in 2015**. The Strategy determines the intermediate goals for energy efficient refurbishment of buildings, namely: reduce the final energy consumption by 15% by 2020 and by 30% by 2030. The National Reform Programme 2016-2017 places the emphasis on financial instruments as tools to stimulate private capital for energy efficient renovation of buildings. Indeed, the **ECO Fund**, the Slovenian environmental public fund, provides soft loans for environmental investments, as well as subsidies for residential and **multi-residential/apartment buildings**. [4]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

According to International Trade COMEXT [8] , the value of trade of prefabricated elements is € 516 Million in 2016. Export activities account 303 € Millions, while import account 213 € Million. The sold construction products in Romania between 2012 and 2016 has growth at a rate (CAGR) of 7.7% for export and 4.1% on import.

On the export side, wood elements (60.2%) and ceramic constructional goods (18.9%) hold more than 78% of the exports. In the observed period, their growth rate in exports is 6% of prefabricated elements in wood, and 18.3% for prefabricated constructional ceramic goods. Concrete structural elements is the 3rd largest export goods, it account 16.7% of export and it's export trade growth with a rate of 5.2%

On the import side, the ceramic and wood structural elements are the most imported ones. Their share on import is 27.5% for ceramic constructional goods, and 43% for wood structural elements. In the observed period, the quantity imported (expressed in euro) of prefabricated ceramic items (+0.8%) is constant, while concrete (+8.1%) and wood elements (+7.3%) are in growth.

Approximately 73% of export and import activities are concentrated in the European borders. The remainder is trade-offs outside the European borders

SLOVENIA TRADE (VALUE_IN_EUROS)				
EXPORT	2012	2016	CAGR	Share on export
Cement, lime and plaster (ready mix)	9.908.971	12.306.550	5,57%	4,06%
Ceramic constructional goods	29.284.538	57.367.252	18,31%	18,91%
Concrete, plaster structural elements	41.418.372	50.826.813	5,25%	16,75%
Wood Structural elements	144.445.121	182.903.733	6,08%	60,28%
TOTAL EXPORT	**225.057.002**	**303.404.348**	**7,75%**	**100,00%**
IMPORT	2012	2016		Share on Import
Cement, lime and plaster (ready mix)	12.848.958	4.860.711	-21,57%	2,28%
Ceramic constructional goods	56.720.739	58.770.129	0,89%	27,54%
Concrete, plaster structural elements	42.391.679	57.938.954	8,12%	27,15%
Wood Structural elements	69.107.655	91.796.312	7,36%	43,02%
TOTAL IMPORT	**181.069.031**	**213.366.106**	**4,19%**	**100,00%**

3.2 Market conditions / costs and benefits

In Slovenia, both from a legislative and economic point of view, efforts are being made to launch the market for recycled material from construction demolition waste.
Though there is no clear line between waste and End of Waste; Chamber of Commerce and Industry of Slovenia is actively participating in discussions for legislation and regulation changes.

Positive measures concern the presence of financial incentive for CDW recycling through waste disposal taxation. The tax base is EUR 0.0022 per kg of inert waste, EUR 0.011 per kg of non-hazardous waste, and EUR 0.022 per kg of hazardous waste. Tax payers are landfill operators [1]. This does that the prices of recycled aggregates in Slovenia are lower than the prices of natural aggregates. When collecting construction waste from which recycled aggregates are produced, collectors charge more for mixed construction waste than for separated construction waste. The transportation of CDW to the processor and of recycled aggregate from the processor to the place of use has a large impact on the price. This is why, in practice, the recycling and use often take place on the site itself. There is no regulation on the national level specifying standard prices, hence the varying prices [1].
The main CDW products are recycled aggregates. Aggregates produced from these plants are used for backfilling purposes, concrete production and other construction purposes. In the observed period on average, the ratio of recycled material to total recovered material is 25%, Provisions on the use of CDW-recycled materials from the Green Public Procurement regulation are optional (additional points are awarded to bidders that include in their tender more than 30 % recycled construction material of all material used)[9]

STE, MEASURES and YEAR					
		2012	**2013**	**2014**	**2015**
17 Construction and demolition wastes	Treatment - amount recovered - TOTAL (tons)	1.557.675,00	1.625.843,00	2.542.745,00	3.085.660,00
	Treatment - incineration of waste as fuel (tons)	1.336,00	1.014,00	440,00	236,00
	Treatment - backfilling (tons)	1.039.736,00	837.142,00	1.821.105,00	2.309.386,00
	Treatment - covering (landfill sites) (tons)	14.711,00	26.258,00	18.081,00	25.489,00
	Treatment - other ways of recovery (tons)	82.992,00	327.571,00	60.140,00	73.777,00
	Treatment - amount of waste composted (tons)	...	170,00	246,00	123,00
	Treatment - recycled amount of waste (tons)	418.900,00	433.688,00	642.733,00	676.650,00

3.3 Construction sector make up

Prefabricated timber frame building is a typical single-family house commonly found in all Slovenian regions. They are usually low-rise with 1-2 stories. The basic building block is a prefabricated composite wall element - panel which may be of different size (large-panels were used in the past; nowadays only small-panels are produced). The wall panel consists of framing members and sheathing panels (e.g. chipboard, OSB, gypsum board, Betonyp, etc) connected with fasteners (staples or nails). The empty space between the framing is filled with insulation (e.g. mineral wool). The panels are extending through a single story and are connected at the top with a

joist floor framing. A framed roof is mainly double-pitched or multi-pitched. Walls and floors are prefabricated while roof structure in built on site.
This structural typology is suitable in area affected by earthquakes, so, following the Friuli earthquake (1976) around 500 prefabricated timber frame buildings were constructed in the north-western region of Slovenia. [2]

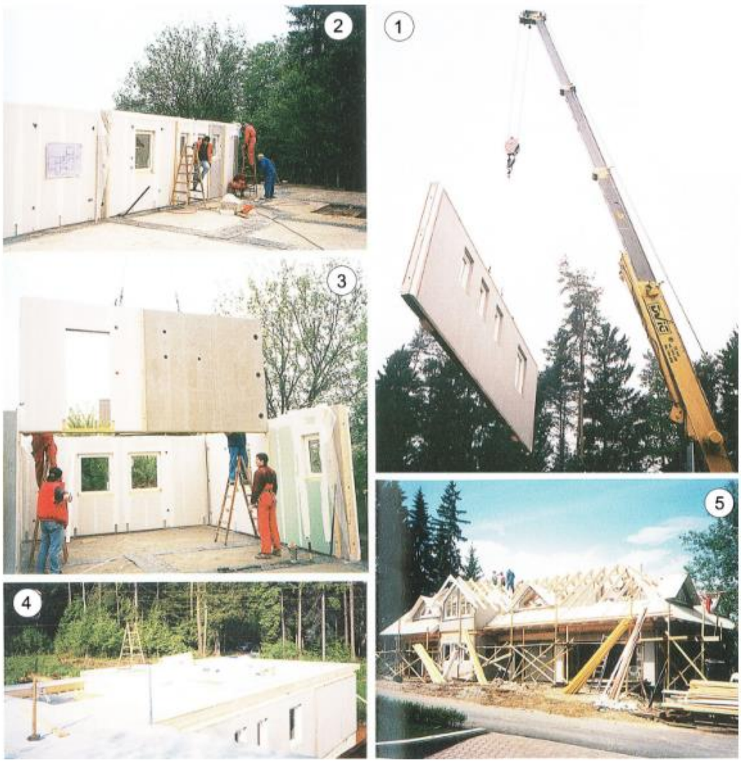

Figure 1. The assembly process of prefabricated timber frame building.[2]

Other typical construction typologies in Slovenia are the mushroom and umbrella structures.

3.4 Use of CDW materials for prefabricated elements

As reported in paragraph 2.1, Slovenian National Building and Civil Engineering Institute **ZAG** is involved in a research project named **InnoWEE** "Innovative pre-fabricated components including different construction and demolition Waste materials reducing building Energy consumption and minimising Environmental impacts", funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723916. In this project, among the others, one of the main result is the development of ventilated façade claddings based on the geopolymer technology. The panels will be composed out of an outer High Density Geopolymer (HDG) layer (6-8 mm thick) incorporating at least 40-50% of selected CDW and an inner layer (10-15mm thick) Wood-Geopolymer Panel (WGP) incorporating at least 50-60% (by weight) of CDW wood. The weight will be ca 20-30 kg/m2 and have an average density of 1,2-1,4 Kg/dm3 compared to 2,2-2,5 Kg/dm3 for concrete and 2,4-3 kg/dm3 for natural stone (basalt, marble, porphyry, granite). [7]

4. REFERENCES

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[8] http://epp.eurostat.ec.europa.eu/newxtweb/submitopensavedextraction.do?extractionId=13829578&datasetID=DS-045409&keepsessionkey=true

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DISCLAIMER

SPAIN

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Spain has implemented two national plans on CDW since 2001 (PNRCD 2001-2006 and PNRCD 2007-2015). Due to a lack of enforcement and supporting regulation, the first plan did not succeed in diverting C&DW from landfills. The Royal Decree 105/2008, regulating the production and management of C&D waste, is the main supporting regulation around CDW. It establishes the responsibilities of the waste producers, holders, and managers, without setting any quantitative targets for recovery. However, this decree requires that construction and demolition waste plans have to be established for every construction or demolition project. A deposit will have to be paid to the authorities, which will be returned when proof of lawful disposal/recycling of CDW is provided (details hereof are regulated at regional level). The new national framework plan on waste (PEMAR 2016-2022) exposes that CDW quantity has strongly decreased in the period 2007-2012, due to the little activity of construction sector in Spain because of the crisis. Moreover, the critical situation of CDW treatment plants, receiving very little waste and facing a very low demand for recycled materials, is described. This plan establishes target objectives (respectively for 2016, 2018 and 2020) for CDW management: minimum recovery from CDW of 60, 65 and 70%; and maximum elimination in landfill of non-hazardous CDW of 40, 35 and 30%, among others.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Concerning the waste classifications of the European List of Waste, construction and demolition waste covers a very wide range of materials.

Aggregates

Besides the harmonized European legislation (UNE EN in Spain), the technical regulations applicable to recycled aggregates in Spain are shown below:

- General Technical Specifications for Road Works and Bridges of the General Direction of Roads and Highways (PG3), specifies that " the preceding material of the milling of hot bituminous mixtures may be used as aggregates for base and intermediate layers, including those of high modulus, in proportions less than 10% of the total mass of the mixture.
- General Technical Specifications for Road Maintenance Works (PG4). Article 22 states that a recycled bituminous mixture shall contain a mass proportion of the bituminous material to be recycled between 10% and 50% of the total mass of the mixture. On the other hand, all recovered asphalt material available (RAP-Reclaimed Asphalt Pavement) in Spain is used from average percentages of recycling of 10-20%, which means that there is no demand for new methods that allow recycling with high rates.
- Code on Structural Concrete EHE-08, approved under the Royal Decree 1247/2008 on 10 July.

Annex 13 ("Structure's contribution to sustainability index"), takes a positive view of the use of recycled aggregates in concrete structures.
Annex 15 ("Recommendations for using recycled concrete"). This Annex recommends limiting the content of coarse recycled aggregate up to 20% by weight out of the total weight of coarse aggregate. With this limitation, the final properties of recycled concrete are hardly affected compared to results obtained for conventional concrete. For higher percentages, special studies and complementary experiments are required for each application. Recycled aggregate may be used for mass concrete and reinforced concrete with characteristic strength no greater than 40 N/mm2 while its use in prestressed concrete is excluded.
Annex 18 ("Concretes for non-structural use") Up to 100% of recycled coarse aggregate may be used for the manufacture of non-structural cement.

Cement slag and fly ash

Besides the harmonized European legislation (UNE EN in Spain), the technical regulations applicable to fly ash in Spain are shown below:

- UNE 83414:1990 EX: Additions for concrete. Fly ash. General recommendation for the addition of fly ashes for concretes produced with cements type I.
- UNE 83420:1991 EX: Additions for concrete. Fly ash. Specifications for fly ashes with a content more than 10% in CaO.
- Code on Structural Concrete EHE-08
- UNE 83452:1988 EX: Additions for concrete. Fly ash: water demand of a fly ash mixed with Portland cement under form of mortar
- UNE 83453:1988 EX: Additions for concrete. Fly ash: Soundness le chaterlier
- UNE 83431:1992: Additions for concrete. Fly ash: Determination of moisture content
- UNE 83433:1986 EX: Additions for concrete. Fly ash: Determination of loss on ignition
- UNE 83432:1986 EX: additions for concrete. Fly ash: Determination of sulfur trioxide (so3) by gravimetric method
- UNE 83442:1996: additions for concrete. Fly ash: Determination of the content of the total coal (TOC).
- UNE 83438:1991: additions for concrete. Fly ash: determination of the content of magnesium oxide
- UNE 83451:1986 EX: Additions for concrete. Fly ash: activity index with Portland cement
- UNE 83454:1991: Additions for concrete. Fly ash: Determination of the beginning and end of setting of Portland cement with fly ash
- UNE 83420:1991 EX: Additions for concrete. Fly ash: Specifications for fly ashes with a content more than 10% in CaO.
- UNE 83421:1987 EX: Additions for concrete. Fly ash: Sampling, preparation, conservation and transportation of the samples

No further information has been found for other type of materials from CDW.

1.3 Prefabricated elements (with or without CDW materials)

In addition to the harmonized European legislation (UNE EN in Spain) which most of them are mandatory for the market commercialization (CE marking) of structural elements, the legislative and regulatory situation in precast concrete products in Spain is shown below:

- Spanish Code on Structural Concrete EHE-08, in force since December 2008, is the Spanish regulatory framework that establishes the requirements that concrete structures must fulfill to meet structural and fire safety requirements, as well as environmental protection, by providing procedures that demonstrate compliance with sufficient technical guarantees.

  Chapter 6. Materials.
  Article 36. Infill elements in floor slabs

  Chapter 12. Structural members.
  Article 59. Structures comprising precast elements

  Chapter 13. Construction.
  Article 76. Precast elements

  Chapter 16. Control of the conformity of the product.
  Article 85. Specific criteria for checking the conformity of the component materials of the concrete
  Article 86.9. Control of the concrete
  Article 91. Control of precast elements

  Chapter 17. Control of the construction
  Article 99. Control of the assembly and joints of precast elements

  Annex 12. Specific construction and calculation aspects of one-way floor slabs with precast beams and hollow-core slabs

1.4 Prefabricated construction

Prefabricated construction has been commonly considered as a key strategy to effectively promote construction waste minimization.

Spanish Technical Building Code, hereinafter referred as CTE (Código Técnico de la Edificación), promulgated by Royal Decree 314/2006, 17 March 2006, is the regulatory framework governing the basic quality requirements that must be met by buildings, including their installations, in order to comply with the basic safety and habitability regulations defined by Law 38/1999, 5 November 1999, on the Organization of building construction, (known by the Spanish acronym LOE). The CTE applies to new construction, except for technically simple structures of negligible constructional consequence not designated for residential or public use. The CTE also applies to the extension, modification, alteration or renovation works that are carried out on existing buildings. The Technical Code includes a set of Basic Documents, BD, for complying with the basic requirements. These documents are to be updated in accordance with technical advancements and social requirements, and shall be approved regularly. The CTE contributes to the transposition of the

Directive 2002/91/EC on the energy performance of buildings, in terms of the minimum energy requirements that must be met.

2. POLICY MEASURES

2.1 Materials from CDW

Construction and demolition waste is one of the heaviest and most voluminous waste streams generated in the EU. It accounts for approximately 25% - 30% of all waste generated in the EU and consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. CDW has been identified as a priority waste stream by the European Union. There is a high potential for recycling and re-use of CDW, since some of its components have a high resource value.

One of the objectives of the *Waste Framework Directive (2008/98/EC)* is to provide a framework for moving towards a European recycling society with a high level of resource efficiency. In particular, Article 11.2 stipulates that "Member States shall take the necessary measures designed to achieve that by 2020 a minimum of 70% (by weight) of non-hazardous construction and demolition waste excluding naturally occurring material defined in category 17 05 04 in the List of Wastes shall be prepared for re-use, recycled or undergo other material recovery" (including backfilling operations using waste to substitute other materials).

On average, Europe generates around 890 million tons of construction and demolition waste (CDW) per year and only 50% of these CDW are recycled. This is far from the objectives determined in the European Directive for 2020 and aware of this situation, the European Countries are implementing national policies to prevent the waste that can be avoidable and to promote measures to increase recycling and recovering. For example in Spain, one of these measures has been the development of a CDW recycling guide for the manufacture of mortar, concrete, brick and lightweight aggregates. However, there is still not enough information on the possibility of incorporating different CDW materials in the manufacture of other products.

The Spanish Guide of recycled aggregates (GEAR) has prepared technical recommendations and operation instructions applicable to all aggregates from CDW which will be used as materials for construction. The technical recommendations of the Spanish Guide are the following:

- GEAR-RT-01: Technical recommendations for aggregates from CDW for bituminous mixtures and surface treatments for roads.
- GEAR-RT-02: Technical recommendations for aggregates from CDW for backfills.
- GEAR-RT-03: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in civil engineering work and road construction
- GEAR-RT-04: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in prefabricated elements.

- GEAR-RT-05: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in concrete.
- GEAR-RT-06: Technical recommendations for aggregates from CDW for hydraulically bound materials for use in roller-compacted concrete layers.

2.2 Prefabricated elements (with or without CDW materials)

Besides technical regulations listed in the previous chapter, no other instruments have been found for the prefabricated elements in Spain.

2.3 Prefabricated construction

Besides technical regulations listed in the previous chapter, no other instruments have been found for the prefabricated construction in Spain.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Table 1 below collect the exports of prefabricated elements made of cement, concrete or artificial stone in Spain, reported in the export portal SmartExport [1], for 2008.

Table 1. Export market in Spain

Weight of exportations	Development of exports
-5.1%	-73.6%
-1.0%	-86.7%

3.2 Market conditions / costs and benefits

No specific information has been found.

3.3 Construction sector make up

No specific information has been found.

3.4 Use of CDW materials for prefabricated elements

No specific information has been found.

4. REFERENCES

[1] http://www.smartexport.com/Default.aspx?lang=es

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SWEDEN

1. TECHNICAL REGULATION AND LEGISLATION

Information included in the main document D1.4.

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Information included in the main document D1.4.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Use of CDW as aggregates in concrete

Rules for this application are detailed given in the Swedish application standard to EN 206:2013, SS137003. The rules are based on the recommendations given in EN 206 with this regard, but slightly adapted to conditions in Sweden. These requirements are valid for both precast concrete and in-situ concrete.

Requirements on the CDW material:

Recycled aggregate are divided into to classes, Type A and Type B.

Requirements on Type A;

- Constituents: ≥ 90 % concrete; ≥ 95 % fconcrete and stone material; ≤10 % masonry mat.; ≤ 1 % bituminous material, ≤ 2 cm3/kg floating material, ≤ 2 % other materials
- ρrd shall be ≥ 2100 kg/m3.

Requirements on Type B:

- Constituents: ≥ 50 % concrete; ≥ 70 % concrete and stone material; ≤ 30 % masonry mat.; ≤ 5 % bituminous material, ≤ 2 cm3/kg floating material, ≤ 2 % other
- ρrd shall be ≥ 1700 kg/m3

Flakiness index shall be ≤ FI40.

Requirements on both Type A and Type B:

- Where suspicion exists that it may contain un-slaked quicklime, special requirements with regard to volume stability may be used.
- It must be ensured that the source concrete does not contain ASR reactive aggregate. If there is a requirement on limited alkali content in the new concrete, the alkali content of the source concrete shall be determined and included in the calculations. For recycled aggregate, including glass filler, it is appropriate to regard the aggregate as potentially reactive, if it is not proven to be non-reactive.
- Water soluble sulfate, ≤ 0,7 % by mass
- Influence on the initial setting time, ≤ A40.

- Freeze thaw resistance of coarse aggregate for XF1 to XF4 exposure classes is required: If the water absorption ≤ 1 %, the coarse aggregate can be regarded as freeze/thaw resistant. If the water absorption > 1 %, the aggregate can be proven freeze/thaw resistant as follows:
  - For XF1 and XF3: If the aggregate fulfils the requirement for category F_1 when tested according to EN 1367-1 or EN 1367-2
  - For XF2 and XF4: If the aggregate fulfils the requirement for category F_{NaCl} ≤ 2 when tested according to SS-EN 1367-7.

Rules for the use of the recycled CDW as aggregate in concrete (precast or in-situ)

For the use of recycled aggregate see Table 2.1. If recycled aggregate of Type A and Type B are combined, the total amount may not exceed the highest value in the table for the exposure class in question.

Table 1. Highest mass fraction of the coarse aggregate[c)] which may consist of recycled aggregate

		Exposure classes			
	Type of material	**XO**	**XC1, XC2**	**XC3, XC4; XF1, XA1, XD1, XS1**	**All other exposure classes**
01	Recycled aggregate Type A	50 %	30 %	30 %	0 % [a)]
02	Recycled aggregate Type B [b)]	50 %	20 %	0 %	0 %

[a)] Up to 30 % recycled aggregate Type A may be used under condition that it is ascertained that it originates from concrete with at least the same compressive strength and that it least fulfils the requirements valid for the exposure class in which the new concrete will be used.
[b)] Recycled aggregate Type B may not be used in compressive strength classes above C30/37.
[c)] Coarse aggregate is defined in SS-EN 12620+A1:2008 as follows: "designation given to the larger aggregate sizes with D greater than or equal to 4 mm and d greater than or equal to 2 mm"

There exist no rules for recycling of the fine fractions of crushed CDW, neither for reuse of reinforcement or binders.

1.3 Prefabricated elements (with or without CDW materials)

As a basic principle, the materials requirements for concrete with CDW in prefabricated elements are the same requirements as for in-situ concrete. However, for elements covered by harmonized standards these standards apply. There is thought a big problem originating from the fact that the harmonized concrete element standards refer to an older version of the support standard EN 13369 - *General rules for prefabricate concrete elements*, which has not been updated to the latest version of EN 206, in which the more elaborated recommendations about recycled aggregate were introduced. It is thus for the moment difficult to apply the new rules (given in 1.2) regarding recycled aggregate in prefabricated concrete elements. For elements not covered by harmonized standard the same rules as for in-situ cast concrete or other type of structures apply.

The same principle, i.e. that there should be no difference between the requirements between prefabricate and in-situ constructed structures is valid for all sorts of materials and elements.

1.4 Prefabricated construction

The national Board of Housing Building and Planning (Boverket) 1999 issued a handbook for the recycling of construction materials comprising chapters on Recycled concrete for the use as concrete aggregate, Reuse of structural timber elements, Reuse of steel products and Reuse of masonry units. The first chapter is no longer valid since it is replaced with the rules given in SS137003 (see 2.1.2). Since this handbook was issued the earlier national design regulations has been replaced by the Eurocodes but this handbook has not been updated on this regard.
Some general recommendations for use in load-bearing structures are:

- Structural timber elements that by evaluation has be proven to fulfil the valid regulations may be used
- Structural timber elements not fulfilling the valid regulations but assumed to be possible to use, may be used in the lowest reliability classes, under condition that they have not been damaged by rot, insects and fungi.
- Used structural and glued laminated timber can be classified according to the same rules as new timber.
- Used steel products with known quality can be used as new ones, but eventual corrosion depths shall be deduced and geometrical deformations taken into account in the design.
- Used steel products with unknown quality can be tested and used in the lowest reliability classes.
- Used steel product may not be used in structures exposed to fatigue actions.
- Used masonry units may be used in non-reinforced structures when properly sorted and classified according to the same rules as for new units. The units shall not be damaged by frost or erosion or contaminated by pollutions, as for instance units used in chimneys.
- These rules are valid for timber elements, steel products and masonry units under condition that they are not damaged during the demolition, storage and installation processes. The structural and environmental actions in the new structure must not be more severe than in the former position.

Use of used timber elements, steel products and masonry units in non-load bearing applications is up to the judgement of the individual.

2. POLICY MEASURES

2.1 Materials from CDW

Information included in the main document D1.4.

2.2 Prefabricated elements (with or without CDW materials)

There are no policies actively favoring prefabricated elements before in-situ made constructions, nor vice versa.

2.3 Prefabricated construction

There are no policies actively favoring prefabricated construction before in-situ made constructions or prefabricated elements, nor vice versa.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports/imports of prefabricated elements

The percentage of prefabricated elements produced in Sweden that are exported is very low. If this happens it will be to Norway, or possibly Denmark. The import of prefabricated concrete elements is much larger. About 20 % of the element factories that are using the largest Swedish certification body to assess elements for the Swedish market, are situated abroad. They are located in the baltic countries, Poland, Germany, Czech Republic and Russia. However, elements fabricated abroad with a foreign certification body involved are also used in Sweden. In order to ensure that the Swedish requirements are fulfilled, as for instance frost resistance, the larger Swedish contractors often prefer a Swedish certification of the elements.

3.2 Market conditions / costs and benefits

Prefabricated elements/construction and in-situ constructions are competing under the same conditions in Sweden. Other parameters, such as if the site is located in a busy city centre or in less congested areas, the sensibility of the site as regards disturbances (noise, traffic, etc), requirement on construction time, proximity to prefabrication plants and ready mixed concrete plants that forms a basis of the decision whether to use prefabricated elements/constructions or in situ construction.

3.3 Construction sector make up

The total turnover of the Swedish construction sector in 2013 was SEK 500 billion (EUR 53 billion). The number of companies in the construction industry in 2014 was about 96 700 (The Swedish Construction Federation, 2015). Employment in the construction sector and in the whole social construction sector in Sweden is about 311 000 and 500 000, respectively (The Swedish Construction Federation, 2015).

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In 2014, the total construction investments in buildings were SEK 380.9 billion (EUR 41 billion). The investments are forecasted to increase by 8 % for 2015 and by 2 % for 2016.

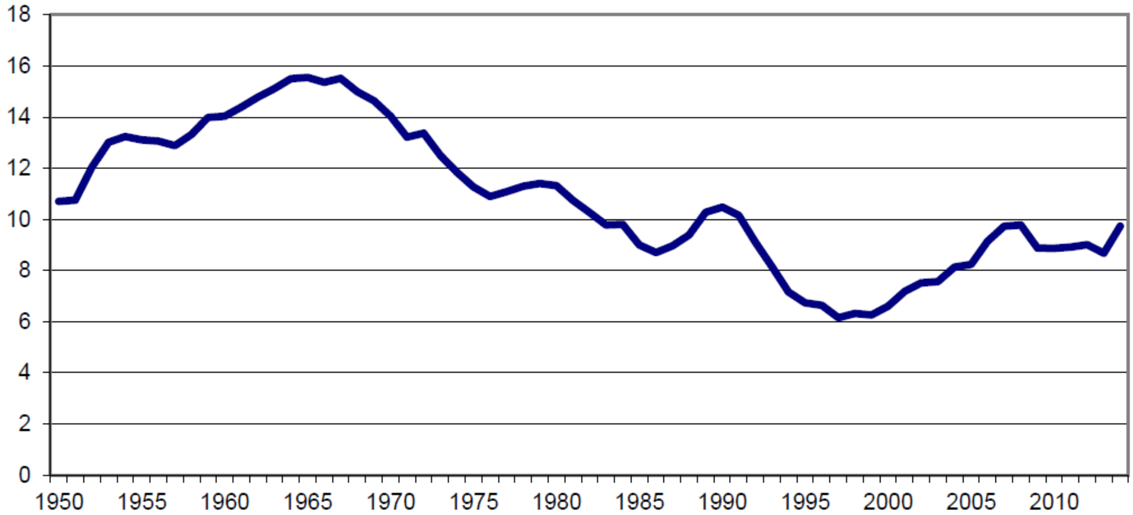

Figure 1. Building investments as percentage of GDP in Sweden during 1950-2014. (Swedish Construction Federation 2015)

In 2014, there were 37 992 buildings started, which is an increase of 25% compared to 2013. Fig 2 illustrates the share of construction sector of GDP in Sweden.

Investments in housing construction:

In 2012, the investments in housing amounted to SEK 121 billion (EUR 13 billion). Of the investments, SEK 55 billion (EUR 5,9 billion) was linked to new buildings and SEK 66 (EUR 7.0 billion) to refurbishment. (Figure 2)

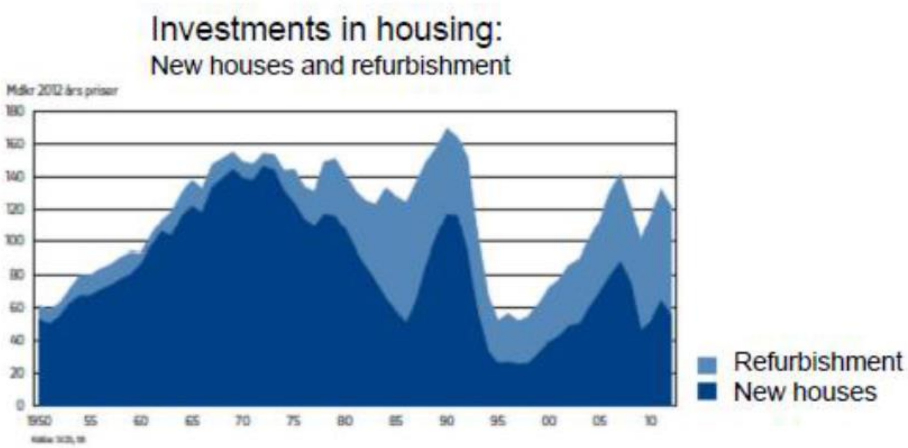

Figure 2. Investment in housing (SEK billion) according to price level at 2012) for building of new houses and refurbishment in housing in 2012. (Swedish Construction Federation 2013)

3.4 Use of CDW materials for prefabricated elements

Since recycled CDW as aggregate were introduced in Swedish regulations as late as in 2015, and the harmonized standards for prefabricated elements has not yet incorporated these new rules, the use of CDW in prefabricated elements is still insignificant in Sweden. Moreover, there is also a lack of companies marketing CDW for use in concrete.

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SWITZERLAND

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TILES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Switzerland has several regulations regarding waste management:
It has recently introduced its revised Ordinance for Avoidance and Disposal of Waste (VVEA). It contains general waste regulation and classification, including CDW-specific rules such as maximum content of harmful substances for cement production, on-site sorting and rules of reporting.

The "Ordinance on the Avoidance and Disposal of Waste" contains an obligation for cantons to report to the Federal Office for the Environment (Bundesamt für Umwelt, abbr. BAFU) on incurring waste, landfill and waste treatment facilities (Chapter 2, Art. 6). In addition, the regulation requires the use of combustible fractions of construction waste in suitable installations (Chapter 3, Section 1, Art. 10).

If more than 200 m^3 of building waste is involved in construction work, the builder must notify the competent authority of the nature, quality and quantity of waste to be expected and how these should be disposed of. This notification obligation also applies to substances which are hazardous to the environment or to health. (Chapter 3, Section 3, Art. 16)

On the construction site special waste must be separated from the rest and disposed of separately. (Chapter 3, Section 3, Art. 16)

It is also necessary to separate asphalt, concrete demolition, road breaking, mixed demolition, bricks and gypsum. "Unpolluted [mineral] burst material" without foreign and pollutants shall be recycled as completely as raw material for the production of hydraulic or bituminous bound building materials. (Chapter 3, Section 3, Art. 17).

Mineral wastes are classified as Class 4 of waste, as specified in Ordinance, and are given different four-digit codes, depending on the type and any harmful substances that may be present. Concrete demolition is therefore given the code 4303, clean gypsum the code 4306. [1]

Swiss standard SN 670 071 regulates general recycling of mineral CDW into RC construction materials.

- SN 670 902-11-NA regulates geometrical properties of mineral aggregates and is part of the Swiss version of EN 933-11.
- SN 670 102b-NA regulates aggregates for concrete production and has integrated the use of recycled aggregates according to EN 933 under compliance with the BAFU guideline.

– SN 670 119-NA regulates aggregates for use in hydraulically bonded and loose applications, e.g. construction of roads, train tracks etc. It is part of the Swiss version of EN 13285.
– BAFU (Federal Agency for Environment) regulations:
– The Guideline for the use of mineral construction waste (2006) regulates how mineral construction waste is to be sorted, labelled, treated and quality controlled before it is used to create new RC materials.

Technical specifications for the recycling and recovery of CDW are contained in Swiss standards:
– SN 640 740a General information
– SN 640 741a Recovery of asphalt
– SN 640 742a Recovery of roadbreak
– SN 640 743a Recovery of concrete demolition
– SN 640 744a Recovery of mixed demolition

The implementation of the legal requirements of the Environmental Protection Act (USG), the Technical Regulation on Waste (TVA) and the Ordinance on the Transport of Waste (VeVa) is carried out by:
– "Multi-skip-concept”" by the Swiss Association of Builders,
– Recommendation 430 of the Swiss Association of Engineers and Architects (abbr .: SIA Recommendation 430): "Disposal of construction waste for new construction, conversion and demolition work"

Gypsum:
The gypsum demand in Switzerland is currently around 840 000 t/a. A total of 240,000 t/a gypsum-containing building materials is being reconstructed. Only 4000 t/a of gypsum is recovered from these construction waste, while 200,000 t of gypsum waste is deposited annually. Due to the problematic landfilling, gypsum recycling is to be increased across Europe, including in Switzerland. [4]

1.2 Materials from CDW (aggregates, binders, reinforcement…)

The Environmental Protection Act (USG), the Water Protection Act (GSchG) and the Technical Ordinance on Waste (TVA) contain the basic requirements for the environmentally sound handling of construction waste. However, these regulations do not contain specific, directly applicable ecological requirements for mineral construction waste which is primarily to be recycled. For this reason, the Swiss Federal Office for the Environment (abbr.: BAFU) issued the directive for the recycling of mineral construction waste in 1997, which has been revised and expanded since 2006.[5]

The directive establishes the ecological requirements for the recycling of mineral construction waste. The aim is a high-quality, environmentally compatible use of recycled materials. In this way, the acceptance of the recycling products and thus the securing of the sales markets are improved by material qualities which meet the ecological and structural requirements.

In Swiss waste management, the recycling of waste, including construction waste, is clearly a priority over treatment and deposition. The authorities can therefore act in accordance with Article 12 of the TVA and require that it is clarified whether there are possibilities for recycling or being created for construction waste.

The directive applies only to mineral construction wastes, which can be separated in removal asphalt, road breaking, concrete demolition and mixed demolition. Six recycled building materials are being produced during the preparation of the four mineral construction waste categories:

– Asphalt granules
– Recycling gravel sand P
– Recycling gravel sand A
– Recycling gravel sand B
– Concrete granules
– Mixed demolition granules

The following quality standards are defined for these:

Table 1. Quality standards for recycled construction material [5]

Demolition waste category / Recycled construction material	Removal asphalt	Gravel sand	Concrete demolition	Mixed demolition	impurities
Asphalt granules	80	20	2		0.3*
Recycling gravel sand P	4	95	4	1	0.3
Recycling gravel sand A	20	80	4	1	0.3
Recycling gravel sand B	4	80	20	1	0.3
Concrete granules	3**	95		2	0.3
Mixed demolition granules	3	97			0.3 without gypsum 1% gypsum 1% glass

Main part, minimum Mass-%
Beside part, maximum Mass-%
impurities, maximum total share in Mass-%
*Asphalt granules, which are hot-processed, must not contain any foreign substances for technical reasons
** Concrete granulate, which is intended as an

additive for classified concrete, must not contain any asphalt

The excavation, dismantling and recycling organization Switzerland (abbr.: ARV) provides appropriately qualified recycled construction materials which fulfill structural requirements similar to those of the primary building materials. To this end, there is a Swiss-wide guideline of the ARV for recycling building materials. Since July 1997, ARV quality assurance has been aiming at a consistent approach to the production of recycled building materials and creating uniform designations in order to guarantee high quality standards for recycled building materials.

1.3 Prefabricated elements (with or without CDW materials)

Requirements for the performance criteria for and the conformity assessment of reinforced and non-reinforced prestressed concrete parts made of light, normal and heavy concrete are listed in the European standard EN 13369: 2013-08 "General rules for concrete parts". This is used in Switzerland as SN EN 13369: 2013, SIA 262.520: 2013.

A large proportion of the relevant harmonized european standards are also published as Swiss standards.

1.4 Prefabricated construction

No technical regulations and legislations could be investigated for prefabricated constructions in Switzerland.

2. POLICY MEASURES

2.1 Materials from CDW

As an important foundation for sustainable building in the exemplary Zurich region, the "7 Mile Steps for Environmentally and Energy-Efficient Building" program, which has been in use since 2001, has been the direction of the building development department, which was further developed in 2007 so that it can also be used by other public builders. The use of recycling (RC) concrete is a central component of the milestones 1 "New Buildings", 2 "Existing Buildings", 3 "Health and Building Materials" and 6 "Sustainability in Architectural Competitions and Study Contracts".

More detailed guidelines were formulated in 2009 in the "Resource strategy - Bauwerk Stadt Zürich" program. An inventory survey made here shows that in 2005 almost 1/3 of the building material volume consisted of concrete, 1/4 each of gravel and sand. Many buildings from the 1960s and 1970s are today considered to be necessary for restoration and are frequently demolished. Thus the building park, if efficiently used, becomes the largest resource warehouse of the future. Approx. 11% of the entire building stock in Zurich belongs to the city.

Thanks to the subsidized use of recycled building materials, a proportion of between 70% and 90% has already been achieved with the use of RC concrete in new city owned buildings. In addition, the use of RC building materials in public building construction should promote their general dissemination. [6]

2.2 Prefabricated elements (with or without CDW materials)

Political measures for the use of prefabricated elements could not be researched for Switzerland.

2.3 Prefabricated construction

Swiss housing promotion is taking place at different levels, primarily at federal and municipal level. In total there are over 200 construction promotion programs.

For example, the Confederation promotes non-profit housing by granting a CHF 500 million fund loan that is subordinated and thus also helps younger or newly established cooperatives to build with less equity. Secondly, the Confederation guarantees the bonds.

Another federal instrument in the Housing Promotion Act is the granting of interest-free loans. The interest rate differential is intended to reduce housing for households with limited income.

Most of the cantons do not actively promote housing and have no legal basis for this. There are municipalities that are active in land policy and promote non-profit housing. The cities of Zurich, Lausanne and Geneva are sure to be the precursors, and Bienne, Berne, Basel and Lucerne are also new.

There is no explicit promotion of prefabricated constructions. Prefabricated constructions are, however, also promoted if defined eligibility criteria are met.[7]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

The main trading partners of Switzerland are the countries of Europe and especially Germany. The extent to which prefabricated parts are exported or imported can not be derived from the available data.

For investment goods, including building materials, statistical surveys for 2015 show an export surplus of around CHF 7900 million. In the case of the raw materials and semi-finished products, also including RC aggregates, there is an import surplus of CHF 3394 million. The import building supplies sector (CHF 4.0 billion) shrank by 9% in 2015 compared to the previous year. [8]

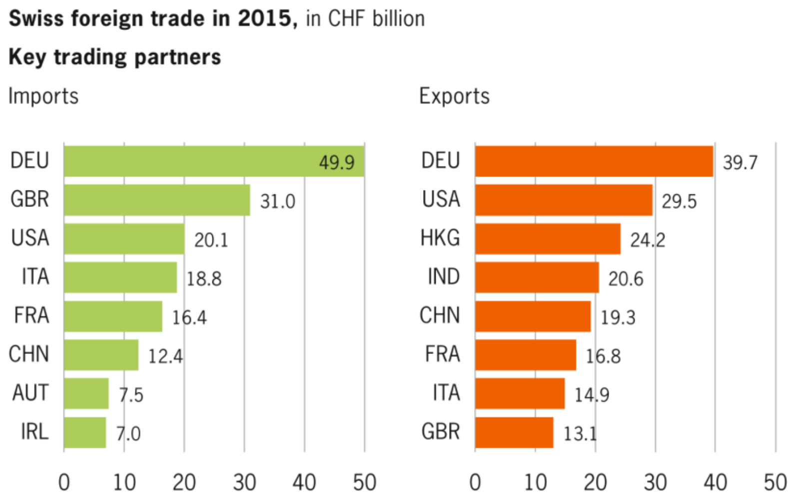

Figure 1. Key trading partners of Switzerland [8]

3.2 Market conditions / costs and benefits

The Swiss market for prefabricated houses suffered last year, severely under the strong franc. In 2015 the number of residential units built in the prefabricated house sector fell slightly. Sales in the industry fell by 0.1% to CHF 720 million (approximately EUR 655 million). It is not until 2018 that the prefabricated house sector is expected to record higher sales.

Both building permits (-3.9%) and building completion (-2.3%) declined in 2016. In addition, a national decision in 2013 led to the fact that only 20% of all houses and apartments in the holiday areas can be used as secondary residences, so that many municipalities are no longer allowed to approve new second residences. The fact that is particularly damaging the production of the finished products, as the market for secondary residences is an important sales segment for the industry.

Due to the sharp rise in property prices, apartments are becoming cheaper compared to houses. As a result, there is a growing demand for multi-storey residential buildings. This represents a challenge for the prefabricated house sector, which traditionally focuses on the construction of detached houses and two-family dwellings. Although the proportion of multi-storey residential buildings rose by only 0.2% to 8.5% last year, stronger growth rates are expected in the coming years in this segment.

The market share of one- and two-family housing construction is relatively low (19.3%) compared to other European countries and is also expected to rise slightly in the coming years.

In Switzerland practically every prefabricated building is constructed in wood-based bolt construction (94.4%). The classic solid construction is rarely used in the prefabricated area in Switzerland (5.6%).

A strong trend is energy efficiency. In addition, the trend in prefabricated construction continues in the direction of higher price classes. In the meantime, 61.5% of all production booths cost more than 400,000 CHF (365,000 €).

The market concentration of the Top 10 players continued to grow in 2015 and rose by 4.5% to 39.5%. Even if companies from abroad are increasingly trying to gain a foothold in the Swiss market, many fail to ensure that the cantons have different building codes, which means that regional firms have an advantage. [9]

3.3 Construction sector make up

In 2014, the construction sector in Switzerland listed around 7,900 companies with 91,266 employees. 82% of the companies employed less than 10 people. There existed 28 companies with more than 250 employees. 67 % of all employess are working in micro or small companies. More details are provided in below graphs. [10][11]

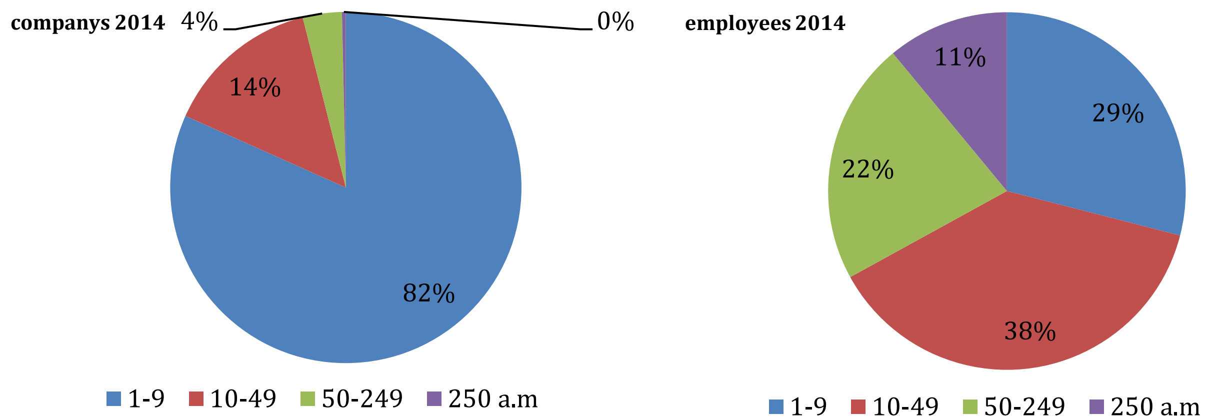

Figure 2. Structure of companies and employees by company size in the building sector in Switzerland [10][11]

The production and sales of the Swiss construction industry declined substantially in 2015 and 2016, which is likely to be due to monetary policy reasons. [12]

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

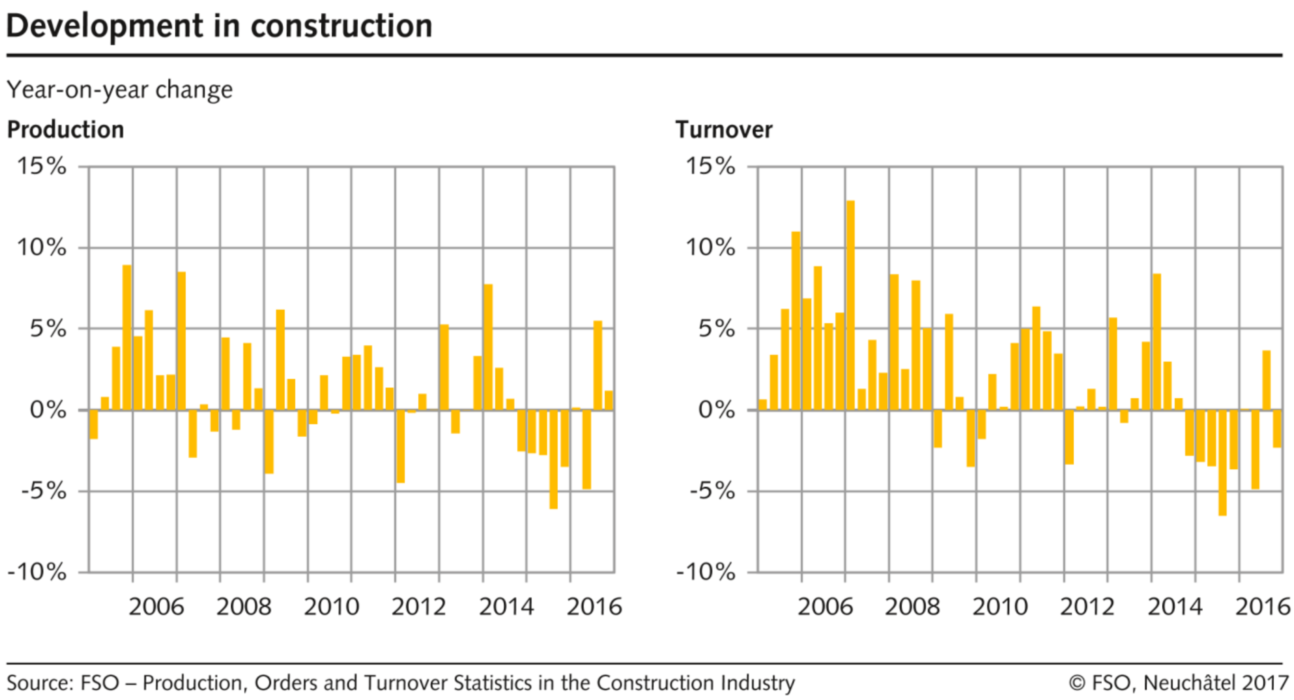

Figure 3. Development in the Swiss construction sector [12]

Statistical surveys relating to the prefabricated construction sector alone could not be researched.

3.4 Use of CDW materials for prefabricated elements

There are no figures for the use of recycled materials in the prefabricating industry in Switzerland.

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UNITED KINGDOM

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Please refer to Deliverable D1.1 (United Kingdom).

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Please refer to Deliverable D1.1 (United Kingdom).

1.3 Prefabricated elements (with or without CDW materials)

The following British Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of precast concrete elements:

BS 8500-2:2015+A1:2016 [1UK] which is the complementary standard to BS EN 206:2013+A1:2016 [2UK] sets the requirements for the use of recycled coarse aggregates in the production of concrete including precast concrete. Recycled aggregates are classified into two types: Crushed Concrete Aggregate (CCA) which is produced by crushing hardened concrete of known composition that has not been in use and has not been contaminated during storage or processing and Recycled Aggregate (RA) produced from demolition waste which contains concrete, masonry and asphalt. CCA can be used in the production of structural concrete (Exposure classes X0, XC1-XC4, XF1 and DC-1 in accordance with BS EN 206:2013+A1:2016 [2UK]), whereas RA can only be used for non-structural concrete. The maximum replacement level of virgin aggregate by RCA is set at 20% for concrete classes RC20/25 to RC40/50. Allowable limits of contaminants are shown in Table 1 below.

Table 1. Recycled aggregates composition requirements for use in the production of concrete [1UK].

Type of aggregate	Max. clay and masonry content	Max. fines content	Max. floating material by volume	Max. bituminous material content	Max. other materials(1) (%)	Max. acid soluble sulfate
CCA	10	4	2	5	1	0.8
RA	100	4	2	10	1	*

1-It includes clay, soil, metals, wood, plastic, rubber, gypsum plaster and glass.
*-To be determined on a case by case basis.

BS EN 12602:2016 [3UK] sets the requirements for the use of Autoclaved Aerated Concrete (AAC) (including AAC made from recycled AAC) in structural (such as load bearing walls, retaining walls, roofs, floors, beams and piers) and non-structural (such as non-load bearing walls, cladding without fixtures for external facades of buildings, small box culverts and noise barriers) prefabricated elements.

BS EN 13369:2013 [4UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for unreinforced, reinforced and pre-stressed precast concrete products made of compact lightweight, normal-weight or heavy-weight concrete. It allows the use of crushed recycled aggregate (up to 10% in weight of the total content of aggregates in the concrete mix) obtained from precast concrete products manufactured in the same factory. The above replacement level can be increased up to 20% provided certain conditions are met. Recycled coarse aggregates from external sources which are composed of pure concrete debris can be used under the same conditions described above provided the source and mix properties of the crushed concrete are known by the manufacturer. It should be noted that BS EN 13369:2013 [4UK] does not allow the use of recycled aggregates in concrete for which durability requirements are higher than those for the concrete from which they originate (This does not apply for exposure classes X0, XC1 and XC2 as defined by BS EN 206:2013+A1:2016 [2UK]).

BS EN 1168:2005+A3:2011 [5UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast hollow core slabs made of reinforced or pre-stressed normal-weight concrete.

BS EN 12794:2005+A1:2007 [6UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete foundation piles manufactured and stored in a factory, transported and finally installed on a construction site.

BS EN 12839:2012 [7UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete products (reinforced or pre-stressed with or without fibres) to be used together or in combination with other elements in order to erect fences such as boundary fences.

BS EN 12843:2004 [8UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast concrete poles and masts (reinforced or pre-stressed) to be used for overhead electrical lines, telecommunication lines, overhead electrical lines (railways and trams), supports for lighting, supports for loudspeaker installations, antenna and telecommunication poles, supports for wind turbines and similar installations.

BS EN 13224:2011 [9UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast ribbed floors or roofs made of reinforced or pre-stressed normal-weight concrete.

BS EN 13225:2013 [10UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast linear elements such as beams, columns and frames made of reinforced or pre-stressed lightweight or normal-weight concrete to be used in the construction of buildings and other structures (except bridges).

BS EN 13693:2004+A1:2009 [11UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for special precast roof elements made of reinforced or pre-stressed normal-weight concrete to be used in the construction of buildings.

BS EN 13747:2005+A2:2010 [12UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast floor plates made of reinforced or pre-stressed normal-weight concrete to be used together with cast-in-situ concrete in the construction of composite floor slabs.

BS EN 13978-1:2005 [13UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast reinforced concrete garages built as monolithic units or as kits of single sections with room dimensions in precast concrete factories.

BS EN 14843:2007 [14UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast (reinforced or pre-stressed) concrete monolithic stairs as well as precast concrete elements such as individual steps used to make reinforced or pre-stressed concrete stairs. It is applicable to structural stairs for indoor or outdoor use.

BS EN 14844:2006+A2:2011 [15UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for large (structural) and small (non-structural or light structural) box culverts of monolithic construction and rectangular cross-section designed as continuous elements with a joint detail shaped to allow the possible incorporation of sealing materials.

BS EN 14991:2007 [16UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast foundation elements (such as columns with integrated foundation elements, pocket foundation elements or sockets) made of reinforced normal-weight concrete to be used in the construction of buildings.

BS EN 14992:2007+A1:2012 [17UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for prefabricated walls made of lightweight, normal-weight or fibre (steel, polymer or other fibres) reinforced concrete.

BS EN 15037-1:2008 [18UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast beams made of reinforced or pre-stressed normal-weight concrete to be used together with blocks with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

BS EN 15037-2:2009+A1:2011 [19UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of lightweight or normal-weight concrete to be used together with precast concrete beams conforming to BS EN 15037-1:2008 [18UK] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

BS EN 15037-3:2009+A1:2011 [20UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of clay to be used together with precast concrete beams conforming to BS EN 15037-1:2008 [18UK] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

BS EN 15037-4:2010+A1:2013 [21UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for blocks made of expanded polystyrene (EPS) to be used together with precast concrete beams conforming to BS EN 15037-1:2008 [18UK] with or without cast-in-situ concrete for the construction of beam-and-block floor and roof systems.

BS EN 15037-5:2013 [22UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for lightweight blocks to be used together with precast concrete beams conforming to BS EN 15037-1:2008 [18UK] with or without cast-in-situ concrete as formwork during the construction of a beam-and-block floor systems.

BS EN 15050:2007+A1:2012 [23UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast structural elements made of reinforced or pre-stressed normal-weight concrete and produced in a factory to be used as deck elements in bridge construction (footbridges as well as road and railway bridges). Deck elements can be either single elements from which the deck is composed (beams, slabs, ribbed or cellular elements) or elements which form a segment of the entire deck.

BS EN 15258:2008 [24UK] states the requirements (materials, production and finished product), testing methods and evaluation of conformity for precast elements made of plain, reinforced or pre-stressed normal-weight concrete to be used for the construction of retaining walls.

The following British Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated timber elements:

BS EN 336:2013 [25UK] specifies two classes of permitted cross-sectional deviations from target sizes for structural timber of softwood or hardwood species. In addition, it specifies the moisture content to be used as a reference point for measuring sizes and provides average values for changes in size as a result of changes in moisture content.

BS EN 338:2016 [26UK] specifies a system of strength classes to be used in design codes. It provides characteristic strength, stiffness and density values for each class. It is applicable to all softwood and hardwood species of timber used for structural applications.

BS EN 14081-1:2016 [27UK] states the requirements (mechanical resistance, fire resistance, reaction to fire release of dangerous substances, biological durability and geometrical data) for structural timber with rectangular cross-sections (either visual or machine graded) and shaped by sawing, planning or other methods.

BS EN 14081-2:2010+A1:2012 [28UK] states additional requirements to those in BS EN 14081-1:2016 [27UK] for initial type of testing of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in BS EN 336:2013 [25UK].

BS EN 14081-3:2012 [29UK] states additional requirements to those in BS EN 14081-1:2016 [27UK] for factory production control of structural timber with rectangular cross-sections (machine graded) and shaped by sawing, planning or other methods, which deviates from the target sizes specified in BS EN 336:2013 [25UK].

BS EN 14250:2010 [30UK] states the requirements (material, product and documentation), testing methods and evaluation of conformity for prefabricated structural members (such as trusses for roofs, walls and floors, frames, composite beams and girders) to be used in construction of buildings made from solid structural timber with or without finger joints assembled with punched metal plate fasteners.

BS EN 15644:2008 [31UK] states the specifications and requirements for prefabricated stairs in which the components contributing to the fulfilment of mechanical resistance and stability are made of solid wood (traditionally designed stairs).

BS EN 15736:2009 [32UK] describes a test method for determining the withdrawal behaviour of punched metal plate fasteners.

DD CEN/TS 15680:2007 [33UK] provides test methods for evaluating the mechanical performance of prefabricated timber stairs.

The following Technical Information Sheets and Best Practice Information Sheets published by The Steel Construction Institute have been identified when it comes to light steel framing and modular construction:

Technical Information Sheet ED010: Light Steel Solutions for All Applications [34UK]

Technical Information Sheet ED011: Light Steel Residential Buildings [35UK]

Technical Information Sheet ED012: Light Steel Framed Housing [36UK]

Technical Information Sheet ED013: Light Steel Infill Walls [37UK]

Technical Information Sheet ED014: Light Steel Modular Construction [38UK]

Technical Information Sheet ED015: Acoustic Performance of Light Steel Construction [39UK]

Technical Information Sheet ED016: Fire Safety of Light Steel Construction [40UK]

Technical Information Sheet ED019: Technical Performance of Light Steel Construction [41UK]

Technical Information Sheet ED020: Sustainability of Light Steel Construction [42UK]

Technical Information Sheet ED021: Robustness of Light Steel Construction [43UK]

Technical Information Sheet ED022: Durability of Light Steel Construction [44UK]

Technical Information Sheet ED027-Best Practice for Light Steel Framing: Design and Detailing [45UK]

Technical Information Sheet ED028-Best Practice for Light Steel Framing: Pre-Start Requirements [46UK]

Technical Information Sheet ED029-Best Practice for Light Steel Framing: Installation [47UK]

Technical Information Sheet ED030-Best Practice for Light Steel Framing: Follow-On Trades [48UK]

Technical Information Sheet P407-BIM and 3D Modelling in Light Steel Construction [49UK]

Technical Information Sheet P408-Light Steel Load-Bearing Walls [50UK]

Technical Information Sheet P409-Value Benefits of Light Steel Construction [51UK]

The following British Standards/European Norms have been identified, which set the requirements, testing methods and evaluation of conformity for the manufacture of prefabricated aluminium elements:

BS EN 507:2000 [52UK] states the requirements (general, materials and products), testing methods and designation (sheet, coil, slit coil, cut length, roof panel, clip or tile) for all discontinuously laid and fully supported aluminium sheets with or without additional organic coatings to be used for pitched roofs. Products can be pre-formed (prefabricated), semi-formed or as strip, coil and sheet for on-sit-formed applications.

BS EN 508-2:2008 [53UK] states the requirements (general, materials and products), testing methods and designation for all discontinuously laid self-supporting external profiled aluminium sheets with or without additional organic coatings to be used for roofing.

BS EN 14782:2006 [54UK] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made self-supporting metal (copper, zinc, steel, stainless steel and aluminium) sheets and tiles with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining. It also covers ceiling and soffit applications and cassettes.

BS EN 14783: 2013 [55UK] states the requirements (materials, nominal thickness, mechanical resistance, water permeability, vapour and air permeability, dimensional change, dimensional tolerances, durability, external fire performance, reaction to fire and release of regulated dangerous substances), testing methods and evaluation of conformity for factory made fully-supported metal (copper, zinc, lead, steel, stainless steel and aluminium) coil, strip and flat sheets with or without coatings (metallic, organic, inorganic or multi-layer) to be used for roofing and wall cladding or lining.

BS EN 13830:2015 [56UK] states the product characteristics, testing methods and assessment and verification of constancy of performance of curtain walling systems to be used as part of the building envelope.

1.4 Prefabricated construction

Currently, approved documents for England, Wales, Scotland and Northern Ireland [57-60UK] set the minimum standards for the construction of all types of buildings including alternative forms of residential building construction (such as prefabricated buildings made of precast concrete, prefabricated timber, light steel framing or prefabricated aluminium) in accordance with The Building Regulations 2010 [61UK]. More specifically, the above approved documents provide practical guidance (including examples and solutions for some of the more common building situations) on the expected performance of materials and workmanship in order to comply with all requirements set by The Building Regulations 2010 [61UK]. They refer to the following British Standards/European Norms and National Documents for structural design purposes:

Basis of structural design and loading

BS EN 1990:2002+A1:2005 [62UK]

UK National Annex to BS EN 1990:2002+A1:2005 [63UK]

BS EN 1991-1-1:2002 [64UK]

UK National Annex to BS EN 1991-1-1:2002 [65UK]

PD 6688-1-1:2011 [66UK]

BS EN 1991-1-3:2003 [67UK]

UK National Annex to BS EN 1991-1-3:2003 [68UK]

BS EN 1991-1-4:2005+A1:2010 [69UK]

UK National Annex to BS EN 1991-1-4:2005+A1:2010 [70UK]

PD 6688-1-4:2009 [71UK]

BS EN 1991-1-5:2003 [72UK]

UK National Annex to BS EN 1991-1-5:2003 [73UK]

BS EN 1991-1-6:2005 [74UK]

UK National Annex to BS EN 1991-1-6:2005 [75UK]

BS EN 1991-1-7:2006 [76UK]

UK National Annex to BS EN 1991-1-7:2006 [77UK]

PD 6688-1-7:2009 [78UK]

BS EN 1991-3:2006 [79UK]

UK National Annex to BS EN 1991-3:2006 [80UK]

Structural work of reinforced, pre-stressed or plain concrete

BS EN 1992-1-1:2004 [81UK]

UK National Annex to BS EN 1992-1-1:2004 [82UK]

PD 6687-1:2010 [83UK]

BS EN 13670:2009 [84UK]

Structural work of steel

BS EN 1993-1-1:2005 [85UK]

UK National Annex to BS EN 1993-1-1:2005 [86UK]

BS EN 1993-1-3:2006 [87UK]

UK National Annex to BS EN1993-1-3:2006 [88UK]

BS EN 1993-1-4:2006 [89UK]

UK National Annex to BS EN 1993-1-4:2006 [90UK]

BS EN 1993-1-5:2006 [91UK]

UK National Annex to BS EN 1993-1-5:2006 [92UK]

BS EN 1993-1-6:2007 [93UK]

UK National Annex to BS EN 1993-1-6:2007 [94UK]

BS EN 1993-1-7:2007 [95UK]

UK National Annex to BS EN 1993-1-7:2007 [96UK]

BS EN 1993-1-8:2005 [97UK]

UK National Annex to BS EN 1993-1-8:2005 [98UK]

BS EN 1993-1-9:2005 [99UK]

UK National Annex to BS EN 1993-1-9:2005 [100UK]

PD 6695-1-9:2008 [101UK]

BS EN 1993-1-10:2005 [102UK]

UK National Annex to BS EN 1993-1-10:2005 [103UK]

PD 6695-1-10:2009 [104UK]

BS EN 1993-1-11:2006 [105UK]

UK National Annex to BS EN 1993-1-11:2006 [106UK]

BS EN 1993-1-12:2007 [107UK]

UK National Annex to BS EN 1993-1-12:2007 [108UK]

BS EN 1993-5:2007 [109UK]

UK National Annex to BS EN 1993-5:2007 [110UK]

BS EN 1993-6:2007 [111UK]

UK National Annex to BS EN 1993-6:2007 [112UK]

BS EN 1090-2:2008+A1:2011 [113UK]

BRE Digest 437 [114UK]

Structural work of composite steel and concrete

BS EN 1994-1-1:2004 [115UK]

UK National Annex to BS EN 1994-1-1:2004 [116UK]

Structural work of timber

BS EN 1995-1-1:2004+A1:2008 [117UK]

UK National Annex to BS EN 1995-1-1:2004+A1:2008 [118UK]

PD 6693-1:2012 [119UK]

BS 8103-3:2009 [120UK]

Structural work of masonry

BS EN 1996-1-1:2005+A1:2012 [121UK]

UK National Annex to BS EN 1996-1-1:2005+A1:2012 [122UK]

BS EN 1996-2:2006 [123UK]

UK National Annex to BS EN 1996-2:2006 [124UK]

PD 6697:2010 [125UK]

BS EN 1996-3:2006 [126UK]

UK National Annex to BS EN 1996-3:2006 [127UK]

BS 8103-1:2011 [128UK]

BS 8103-2:2005 [129UK]

Geotechnical work and foundations

BS EN 1997-1:2004 [130UK]

UK National Annex to BS EN 1997-1:2004 [131UK]

BS EN 1997-2:2007 [132UK]

UK National Annex to BS EN 1997-2:2007 [133UK]

Seismic aspects

BS EN 1998-1:2004+A1:2013 [134UK]

UK National Annex to BS EN 1998-1:2004+A1:2013 [135UK]

BS EN 1998-5:2004 [136UK]

UK National Annex to BS EN 1998-5:2004 [137UK]

PD 6698:2009 [138UK]

Structural work of aluminium

BS EN 1999-1-1:2007+A1:2009 [139UK]

UK National Annex to BS EN 1999-1-1:2007+A1:2009 [140UK]

BS EN 1999-1-3:2007+A1:2011 [141UK]

UK National Annex to BS EN 1999-1-3:2007+A1:2011 [142UK]

PD 6702-1:2009 [143UK]

BS EN 1999-1-4:2007+A1:2011 [144UK]

UK National Annex to BS EN 1999-1-4:2007+A1:2011 [145UK]

BS EN 1999-1-5:2007 [146UK]

UK National Annex to BS EN 1999-1-5:2007 [147UK]

BS EN 1090-3:2008 [148UK]

PD 6705-3:2009 [149UK]

2. POLICY MEASURES

2.1 Materials from CDW

Please refer to Deliverable D1.1 (United Kingdom).

2.2 Prefabricated elements (with or without CDW materials)

Please refer to Paragraph 2.3 below.

2.3 Prefabricated construction

The United Kingdom has significant experience of prefabricated residential building construction with approximately 1 million dwellings constructed using a large number of prefabrication techniques. Towards the end of Second World War there was a surplus of steel and aluminium production. In addition, British Construction and Manufacturing Industries were still fully committed to the war effort and needed diversification. As a result, a strong move towards prefabrication took place during the period between 1940s and 1960s leading to a large number of new pre-cast concrete, steel and timber framed systems. According to Building Research Establishment (BRE) more than 500 prefabricated systems were used between 1919 and 1976. The above number excludes the Rationalised Traditional Construction and post 1976 Timber Frame

Construction systems described below [150UK]. The main prefabrication systems used in post war UK until early 1980s included:

- Industrialised Building Construction (precast concrete)
- Volumetric Construction (lightweight frame made of timber or aluminium)
- Rationalised Traditional Construction (masonry cross walls and in filled timber framed panels)
- Timber Frame Construction (modern platform frame type)

Industrialised Building Construction based on precast concrete became a very popular form of prefabricated housing during 1950s and 1960s. It was mainly used for high rise buildings and was based on the idea that as much work as possible should be done to prefabricated factory premises leaving only a simple assembly operation to be performed on site. There were two main types of industrialised building systems in UK, which were known as closed and open. In closed systems most of the structure was made from a fixed set of pre-fabricated elements, which allowed very little room to substitute parts from other manufacturers. In contrast, open system aimed to create a shell from a relatively small number of parts which allowed the designer significant room to create a unique design. Many industrialised building systems were based on the large panel method of construction using factory-made precast concrete slab floors and wall panels. These structural elements were transported on site and then assembled with the aid of cranes. Promoters of Industrialised Building Construction had a lot of confidence in it. However, the catastrophic collapse of Ronan Point 22-storey large panel tower bloc due to a gas explosion revealed a serious flaw in the philosophy of design codes dealing with such type of construction. More specifically, existing design codes did not require panels to be tied together in the vertical direction. In addition, they only required limited horizontal ties. As a result of the catastrophic collapse, design codes were revised and became stricter. Furthermore, all existing large panel structures were required to receive remedial work to tie panels together both in the horizontal and vertical directions [150UK]. During the 1980s corrosion of steel reinforcement due to cast-in chlorides or carbonation started to affect the durability and structural integrity of these structures. In addition, many dwellings started to suffer from water ingress due to ageing and failure of the materials used in the construction of joints. Poor thermal performance was also observed in many cases. Although most of these problems occurred due to poor workmanship rather than design, they left a negative public perception of prefabricated construction associated with poor quality structures [151UK].

Volumetric Construction was mainly used in 1960s and 1970s. It was used for creating buildings in the form of boxes assembled on site. In most cases it involved a lightweight frame construction made using either timber or metal (mainly aluminium). However, pre-cast concrete volumetric systems were also built [150UK]. First volumetric construction dwellings built in 1940s were constructed of four aluminium framed units one of which contained the entire pluming. These were later replaced by aluminium panellised construction units which pioneered the concept of bathroom and kitchen service cores [152UK].

Rationalised Traditional Construction became popular form of pre-fabricated housing during the 1960s. It was based on masonry cross walls with the front and rear elevations in-filled with storey-height timber framed panels [150UK]. All dimensions and details were standardised. For example, all joists were cut to a standard length and eaves details were suitable for a range of external wall designs [152UK]. By using this technique improvements in productivity could be achieved by simplifying the design and construction of traditional buildings [150UK].

Timber Frame Construction (modern platform frame type) dominated prefabricated housing during the late 1970s and early 1980s. It was based on an inner leaf of storey height timber wall panels and an outer leaf (or part of the outer leaf) of bricks [150UK]. The use of Timber Frame Construction in new build dwellings grew to approximately 30% of the market before experiencing a dramatic decline after negative coverage on the World in Action TV programme. More specifically, the programme was severely critical to a small number of timber frame dwellings in West England concluding that the timber frame construction was not watertight giving rise to rot in the structure. The programme also implied that this defect applied to all timber frame dwellings and that many more owners of this type of construction could experience this type of problem in the future [152UK].

Modern prefabrication methods used in the UK include a large number of prefabricated systems for a wide variety of applications. These range from the simple prefabricated construction site office hut to volumetric units which are easily and quickly installed into the structure of the building once delivered to site [153UK]. The main types of prefabrication systems used are:

- Frame and Deck Construction (precast concrete)
- Cross-wall Construction (precast concrete)
- Hybrid Construction (combination of precast and in-situ concrete)
- Volumetric (modular) Construction (steel or precast concrete)
- Timber Prefabricated Systems

Frame and Deck Construction is based on precast concrete decks supported by precast concrete beams and columns (Fig. 1). It is mainly used for building multi-storey car parks with maximum spans of 16 m which allow columns to be placed between car parking spaces [154UK].

Fig. 1: Precast concrete beams and columns [155UK]

Cross-wall Construction is a modern and effective form of construction in which load bearing walls provide the main vertical support and lateral stability for precast floors. The required lateral stability is provided by lift cores, staircases or external wall panels (Fig. 2 a-d). The method is well suited for buildings with cellular and orthogonal grids (with rooms up to 4 x 9 m), up to five storeys in height and in which internal separation walls are required such as hotels, student residences, prisons and barracks. It offers durable structures with good sound insulation [156UK].

a) Wall units are lifted into place

b) Bathroom pods are craned into rooms

c) Floor slabs are lifted into place

d) Stairwells are installed

Fig. 2 (a-d): Cross-wall Construction sequence [156UK]

Hybrid Construction is based on using precast concrete elements in order to provide permanent formwork for in-situ concrete (Fig. 3). Consequently, it combines the speed, accuracy and high-quality finish of precast concrete with the economy and versatility of cast in-situ concrete. By eliminating the need for in-situ concrete formwork, significant time and money savings can be made. In addition, a safer work platform is created [157UK].

Fig. 3: Hybrid Concrete Construction (Precast twin wall and lattice girder slab with in-situ concrete), Hilton Hotel, Tower Bridge, London [157UK]

Volumetric (modular) Construction transfers most of the construction site activities into the factory premises of the prefabrication company. The technique consists of building large modules that are designed to include services (electrical, mechanical and public health systems) and finishes (both exterior and interior). Modern volumetric construction covers a very broad spectrum of applications which include: private housing (including multi storey buildings), hotels (low and medium rise), schools, hospitals (operating theatres and rooms), office buildings (multi-storey as well as temporary), student residences, barracks and construction site office huts [153UK].

The main forms of Volumetric (Modular) Construction in UK are:

- Shipping Container (steel)
- Modular Construction (light steel frame)
- 3D Volumetric Construction (precast concrete)

Shipping Container method is based on the strength and flexibility of the shipping container design. These blocks have dimensions of 2.5 m (width) by either 20 m or 40 m (length). Their interior is fully equipped with fixtures and fittings such as offices, kitchens, toilets and storage area. They are mainly used in construction sites [153UK]. However, over the last decade, they have slowly started to find their way to the housing market (Fig. 4 a-b) [158UK].

a)

b)

Fig. 4 (a-b): Example of Shipping Container house in Derry, Northern Ireland [158UK]

Modular construction using light steel framing is becoming a popular form of construction in the UK. It is used for private housing, hotels, schools, hospitals, student residences and barracks. Structural stability is achieved by the diaphragm effect of walls, floors and ceilings. The typical building height is 4 to 12 storeys and module width ranges from 2.7 to 4 m [159UK]. Four main types of modules are used:

- Four-sided modules with load bearing walls (mainly used for cellular type of spaces) (Fig. 5a)
- Open-sided modules with corner posts (Fig. 5b)
- Stair and lift modules (Fig. 5c)
- Non-load bearing modules

Four-sided modules with load bearing walls are mainly used for cellular type of spaces, whereas open-sided modules with corner posts are typically used for large open-plan spaces. Finally, non-load bearing modules include bathrooms and balconies [159UK].

For high-rise buildings, modules are supported by a separate (external) steel or reinforced concrete frame structure which acts as a podium (Fig. 5 g-h). The external frame is responsible for providing the required stability (mixed modular-frame construction) [159UK].

a) Light steel frame of four-sided module with load-bearing walls

b) Light steel frame of open-sided module with corner posts

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 723583

c) Stair module

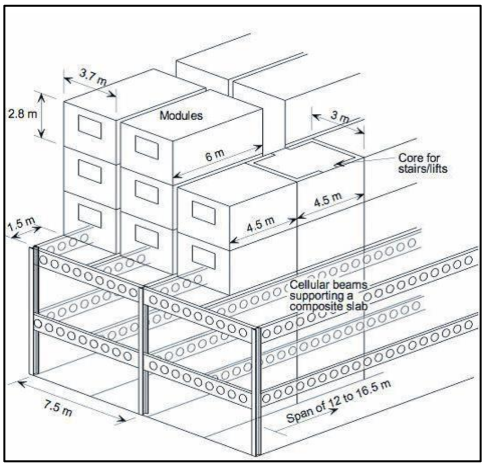
d) Module transportation

e) Crane lifting of open-sided module

f) Installation of open-sided module

g) Modules on a steel frame structure (podium)

h) Installation of a module on a steel podium



i) Colchester Hospital

j) Hotel in Southwark, London

k) Student accommodation in Wembley, London

l) Student accommodation in Wolverhampton (tallest modular building in UK with 24 storeys)

Fig. 5: (a-l): Modular Construction using light steel framing [159UK]

3D Volumetric Construction using precast concrete is based on the production of 3D units under controlled factory conditions prior to their transportation to construction sites. Units come in a large variety of forms, ranging from a basic structural form to one in which all services and internal and external finishes are installed (Fig. 6 a-b). This form of construction greatly benefits from the good thermal, sound and fire resistance properties of concrete [160UK].

a) Installation of a precast concrte modular unit

b) Construction of 20 m high modular stair and lift core

Fig. 6 (a-b): 3D Volumetric Precast Concrete Construction [161UK]

Timber Prefabricated Systems include:

- Glued Laminated Timber (Glulam) Beams
- Cross Laminated Timber (CLT) Panels for walls, floors and roofs
- Structural Insulated Panels (SIPS)
- Open Panel or Closed Panel Timber Frames
- Roof Panels, Roof Trusses and Spandrel Panels
- Floor Panels/Cassettes, I-Joists and Open Web Joists

Glued Laminated Timber (Glulam) Beams are engineered to high specifications and fabricated by bonding together stress-graded planed timber laminations, with their grain in the direction of the member. As a result, a structural unit of excellent strength and dimensional stability is obtained [162UK].

Cross Laminated Timber (CLT) Panels for walls, floors and roofs are solid panel products manufactured in a similar way to Glulam beams. These panels have an odd number of softwood plank layers laid on top of each other at right angles and glued together under pressure. CLTs are fast becoming a popular solution for the construction of schools and educational institutions. In addition, due to their speed of manufacture and on-site installation together with their ability to go more storeys than traditional timber frames, have the potential for extensive use in high-end residential projects [162UK].

Structural Insulated Panels (SIPS) are composite panels which consist of two parallel faces (orientated strand boards) containing a rigid core of polyurethane or expanded polystyrene (Fig. 7). They offer superior strength and thermal properties when compared to traditional construction methods. In addition, they are lightweight and easy to install on site. SIPs are used for walls, floors and roofs in residential, educational and industrial buildings [163UK].

Fig. 7: Installation of SIPS [163UK]

Open or Closed Panel Timber Frames are engineered to high specifications and offer excellent structural strength and durability properties. In timber frame construction the framed wall panels support all horizontal and vertical loads before transfer them to foundations. Open Panel Timber Frames consist of studs, rails, lintels, sheathing on one face and a breather membrane (Fig. 8). Closed Panel Timber Frames on the other hand, are made of studs, rails, sheathing, insulation and internal lining. A vapour control layer is also provided on the warm side of the insulation and a breather membrane on the outer face of the panel. Closed Panels may also include fitted windows and services [164UK]. Currently, the vast majority of timber frame structures built in the UK use Open Panel Timber Frames which account for approximately 25% of new homes built in the UK [164-165UK].

Fig. 8: Installation of Open Panel Timber Frame [164UK]

Roof Panels, Roof Trusses and Spandrel Panels are prefabricated elements which provide practical, economical and easy to install solutions for roofs (Fig. 9) [166UK].

Fig. 9: Prefabricated Roof Trusses [166UK]

Finally, Floor Panels/Cassettes are prefabricated modular floor systems, which are manufactured using I-Joists or Open Web joists or traditional joists to meet customer requirements. They provide an easy to install and low maintenance flooring option (Fig. 10) [167UK].

Fig. 10: Installation of prefabricated Floor panel [167UK]

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

Data of UK Exports/imports of prefabricated elements for the period 2010-2015 is shown in Table 2 obtained from the Office for National Statistics [168UK]. As it can be seen in Table 2 below, the UK is a net importer for almost all products and components related to prefabricated elements.

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Table 2: UK Exports/Imports of products and components related to prefabricated construction [168UK]

United Kingdom		Current Prices (£'000)											
Year		2010		2011		2012		2013		2014		2015	
Products and Components		**EU**	**Non-EU**	**EU**	**Non-EU**	**EU**	**Non-EU**	**EU**	**Non-EU**	**EU**	**Non-EU**	**EU**	**Non-EU**
Windows (wood)	Imports	96,281	15,653	106,390	12,502	104,849	8,238	112,793	7,235	131,894 r	6,524	144,577	6,449
	Exports	7,236	551	9,145	740	8,286	285	8,832	632	10,759 r	721	11,344	1,237
Doors (wood)	Imports	87,394	130,416	81,098	120,908	71,499	119,206	67,929	134,606	75,937 r	133,992	79,454	149,322
	Exports	15,621	1,252	11,387	1,936	12,572	3,236	10,901	2,717	14,598 r	1,807	14,799	2,342
Doors & Windows (steel)	Imports	26,497	9,491	23,849	11,582	27,736	10,915	29,544	11,924	32,920 r	14,725	31,776	15,122
	Exports	8,412	10,809	8,524	10,472	8,974	15,007	10,695	15,352	8,049 r	18,953	10,928 r	18,525
Doors & Windows (aluminium)	Imports	62,247	10,118	59,474	11,052	59,331	12,638	63,359	8,489	62,964 r	8,756	65,201	11,699
	Exports	16,284	3,666	15,783	8,358	14,707	3,822	12,802	4,175	11,970 r	6,280	13,889	7,674
Doors & Windows (plastic)	Imports	32,516	13,820	28,435	24,302	26,222	30,368	19,320	36,036	20,929 r	41,044	20,369	43,392
	Exports	42,334	2,099	36,931	2,492	27,493	2,639	27,071	3,911	29,861 r	3,314	35,693	3,251
Concrete Blocks & Bricks	Imports	4,054	315	6,594	872	6,687	1,774	11,955	1,516	12,008 r	2,498	9,440	2,760
	Exports	8,215	988	7,698	1,722	6,683	1,196	5,496	1,808	5,068 r	1,181	4,192	1,143
Concrete Roofing Tiles*	Imports	4,971	46	-	-	-	-	-	-	-	-	-	-
	Exports	2,796	154	-	-	-	-	-	-	-	-	-	-
Other Concrete Tiles & Paving*	Imports	11,271	2,026	-	-	-	-	-	-	-	-	-	-
	Exports	11,752	1,843	-	-	-	-	-	-	-	-	-	-
Concrete Tiles and Pavings*	Imports	-	-	17,910	1,654	15,512	2,606	14,109	3,681	14,771 r	5,471	17,437	6,289
	Exports	-	-	13,056	422	10,705	1,149	10,168	1,262	10,578	1,327	8,218	1,209
Prefabricated Concrete Products	Imports	23,679	5,132	19,446	1,069	22,826	311	32,733	2,748	44,974 r	2,365	67,545	5,468
	Exports	11,631	760	3,823	610	3,028	1,049	1,481	2,237	1,719	1,345	861	420

Concrete Pipes	Imports	17,487	27,999	29,399	32,027	22,852	28,810	26,212	33,981	41,301 r	44,378	50,470	55,492
	Exports	10,996	13,342	11,791	14,788	10,655	14,572	21,176	14,732	24,355 r	13,470	25,528 r	12,790
Concrete Reinforcing Bars	Imports	78,993	7,850	128,957	6,844	140,790	12,976	122,792	54,886	118,896 r	121,034 r	78,651	119,186
	Exports	51,917	8,334	45,739	1,232	37,343	18,438	38,325	11,497	22,579 r	2,482	31,509 r	4,275
Structural Units (steel)	Imports	478,334	125,803	497,719	150,298	308,180	21,264	319,035	41,875	209,811 r	55,347	193,880 r	48,783
	Exports	262,853	224,038	228,087	244,702	92,917	72,302	113,463	89,040	110,173 r	102,788	86,578	101,369
Structural Units (aluminium)	Imports	155,455	22,742	211,848	24,017	202,607	43,164	219,067	35,307	232,703 r	42,707	197,552 r	31,910
	Exports	33,433	21,538	30,194	31,030	31,477	29,699	31,432	37,904	27,203 r	50,179	27,415	45,422
Prefabricated Buildings (wood)	Imports	31,065	1,621	31,339	3,570	27,442	3,374	36,409	3,412	46,199	1,382	62,238	1,773
	Exports	6,355	4,191	6,535	1,855	5,081	5,137	1,443	1,357	3,024 r	974	1,694	3,745
Prefabricated Buildings (steel)	Imports	17,694	12,089	23,066	14,299	15,805	10,861	31,717	10,976	32,091 r	13,880	35,960 r	23,268
	Exports	18,701	18,458	27,182	22,887	36,957	20,798	26,901	23,628	20,321 r	16,660	24,829	13,548
Prefabricated Buildings (other)	Imports	11,760	22,563	6,831	23,032	10,616	25,802	11,576	16,029	24,755 r	19,454	14,323	24,450
	Exports	8,623	9,020	5,923	13,158	11,631	16,305	5,897	21,115	10,029 r	25,001	5,791 r	21,197
Mobile Homes	Imports	1,898	267	1,159	271	729	1,460	1,107	810	599	195	33	256
	Exports	3,121	545	1,770	657	7,085	1,077	7,332	3,176	8,528 r	1,362	7,717	3,068

* - Due to changes in European Commission product classifications Concrete Roofing Tiles and Pavings have been combined.
r - revised

3.2 Market conditions / costs and benefits

During the last 20 years a shift towards prefabrication (both low and high-rise buildings) has been witnessed in UK. This is mainly due to political pressure to build more affordable quality homes and by the need for improvement of the under-achieving construction industry [169-170UK]. In addition, house builders and new home developers are becoming increasingly interested in prefabrication due to skill shortages and an aging workforce. Finally, revised Building Regulations [61, 171UK] have imposed stricter acoustic and thermal performance requirements. Consequently, prefabricated construction appears to be the best option for achieving consistently high standards compared to traditional on site masonry construction [152UK].

Many UK prefabricated construction firms (either precast concrete, light steel modular construction or prefabricated timber frame manufacturers) use state of the art manufacturing techniques in modern and highly automated factories. As a result the following benefits can be achieved using prefabricated solutions (precast concrete or light steel frame modular construction) [172-173UK]:

- Significant levels of recycling of raw materials
- Reduction in construction waste
- Controlled construction environment (better finishes and fewer defects)
- Shorter construction times
- Fewer operatives on site
- Cost savings (due to shorter construction times and fewer operatives on site)
- Creation of employment in areas away from construction sites
- Less noise and dust
- Reduction in accidents

3.3 Construction sector make up

The prefabricated construction sector is dominated by precast concrete, light steel frame modular construction and prefabricated timber manufacturers. Precast concrete manufacturers are represented by the British Precast Concrete Federation (BPCF), whereas the work and activities of light steel frame modular construction manufacturers are promoted by the Steel Construction Institute (SCI) and the Modular and Portable Building Association (MPBA). Finally, prefabricated timber frame manufacturers are represented by the Timber Research and Development Association (TRADA) and the Structural Timber Association (STA).

Precast concrete companies produce a wide range of products which are not limited to residential buildings. These include: prefabricated buildings, architectural cladding, structural elements (for most types of structures), bricks & blocks, roof tiles, piles and foundations, pipes and drainage systems, box culverts, railway sleepers, tunnel linings, retaining walls, water storage & treatment tanks, paving blocks, sea & river defence units, lighting columns & transmission poles, vehicle safety barriers, garden products, fencing and street furniture & bollards. According to BPCF latest figures for year 2015, the total production of precast concrete products for all applications was estimated to be 20 million tonnes [174UK].

Light Steel Frame Modular construction is gathering momentum in UK. Currently, approximately 6000 modules are built per year by 7 major manufacturers [159UK].

3.4 Use of CDW materials for prefabricated elements

According to BPCF's latest reported data [174UK] 19% of aggregates used for the production of precast concrete in 2015 were recycled or of secondary origin compared to 16.6% and 23.9% in 2014 and 2012, respectively. A target of 25% is set for the use of recycled or secondary origin aggregates by 2020.

According to SCI all steel used in modular construction can be recycled. In addition, up to 50% of new steel used in modular construction comes from old steel scrap [172UK].

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TAIWAN

1. TECHNICAL REGULATION AND LEGISLATION

1.1 CDW – CONCRETE, BRICKS, TTLES AND CERAMIC, ASPHALT, WOOD, GYPSUM

Most buildings in Taiwan have been built longer than 50 years and it have been threat by earthquake. Hence, urban renewal of city residential building is necessary policy for the safety of residents. The urban renewal of the old buildings will demolish large amount buildings and generate large amount of wastes. Such construction demolished wastes including concrete, bricks, ceramic tile, glass debris, wood and bamboo chips, metal chips, plastic, asphalt, are needed be treated and the recycling of such CDW is necessary as the national requested as green material for the recycling economy. Since, the amount of production is very impressive for the narrow, thick space buried in Taiwan, the case will undoubtedly cause serious environmental impact.
The Ministry of the Interior in 2002 announced the "**construction of waste recycling management approach**" Increase the construction of waste resources recycling pipeline; the other to reduce the construction of waste disposal of the situation occurred, the Department began in 2005 to control the area or the amount of the construction of the project, and the construction of the demolition of the waste generated by the Internet to declare. In addition, in 2008 announced the delivery of waste to build the removal of vehicles should be installed satellite positioning system (GPS) to implement the management of the construction of waste flow.
Using the concept of urban mine and sustainable material management, the Department has completed the "**Construction Waste Management Strategy**" to encourage operators to implement site waste reduction and sorting operations at the construction site, implement the construction of waste flow management and enhance the resources of the recycling organizations Technology to promote the development of renewable green building materials industry, and then produce environmentally friendly renewable green building materials, can reduce the consumption of natural resources and reduce the environmental burden, and can make the national health living in high quality green building environment, and further to achieve the establishment of resource recycling green city.

1.2 Materials from CDW (aggregates, binders, reinforcement…)

Urban road and ancillary engineering design standards [2] mentioned that the lane is made of environmentally friendly recycled materials. To implement the goal of sustainable development of green construction projects, to promote the recycling of limited sand and gravel resources. Government host for asphalt concrete recycling [3]. Asphalt concrete excavation material as part of the hot mix of recycled asphalt concrete material, with the design mix ratio, not more than 40 percent.
In the standard specification for National Standard and Construction [4], CNS 12549 granulated ground blast furnace slag (GGBFS) for using in concrete and cement mortar; CNS 11824 Blast furnace slag for using as coarse aggregate in Concrete; CNS 11890 granulated ground blast furnace slag (GGBFS) as fine aggregate in concrete; CNS 12223 Granulated ground blast furnace slag

(GGBFS); CNS 11827 Blast furnace slag for road; CNS 15305 gradation base, bottom and surface layer; CNS 15358 Road or airport slab, gravel grading with grass; CNS 15310 steel ballast for asphalt pavement mixes, allow construction use furnace ballast.

Code of Practice for Water Resources Department, Ministry of Economic Affairs, No. 02722 [5] also mentioned that the material used in the grading of the aggregate shall be a rock, a gravel-grade, a natural grade ingredient or a **recycled aggregate grade**. Recycled aggregate grade refers to waste concrete and brick-like materials removed from buildings or other concrete structures, suitably processed.

In previous research [6], the authors prove that the construction of waste recycling aggregates used in the public Road engineering constructs have their applicability.

In the reference [7], the government host a project to aim at proposing a preliminary draft of construction specifications for the recycled concrete.

In Taiwan, government wants to promote "green building blocks system" from 2004 [8]. For the "health" green building materials, "recycle" green building materials are reviewed and marked for the two categories, while the technical part of the green building materials "general" and "health", "ecological", "recycle", "high performance" four categories of green building materials assessment benchmark.

1.3 Prefabricated elements (with or without CDW materials)

Since the natural resources are short the prefabricated element usually contain small amount of solid waste such as CDW.

1.4 Prefabricated construction

RUENTEX group has prefabricated many building by prefabricated elements.

2. POLICY MEASURES

2.1 Materials from CDW

In Taiwan, Environmental Protection Administration, R.O.C. released policy from 2006 [9].

1. The July 2006 issue of the Waste Disposal Act was published.
2. On January 29, 2001, the Environmental Protection Agency of the Department of Health of the Executive Yuan was established.
3. On August 22, 76, the Environmental Protection Department of the Executive Yuan was established.
4. On May 8, 1978, the Department promulgated the "Disposal and Disposal Standards for Waste Disposal of Business Waste".
5. On May 2, 1980, the Ministry of the Interior promised to implement the "Construction Waste Disposal Scheme" for the construction of waste land types, including waste dirt, stone and concrete produced by construction works, public works and building demolition works block, etc. will not cause secondary pollution; but does not include the construction, removal of the resulting metal, glass, plastic, wood, bamboo, scraps of paper, asphalt and other waste.

6. On December 31, 2006, the Executive Yuan sent a letter of responsibility to the competent authority of the "Construction of Waste Disposal" business, and the construction of waste land is not a waste area. The competent authority is still the Ministry of the Interior. As for the waste, glass fragments, plastic, wood chips, bamboo chips, scraps of paper, asphalt and other wastes arising from the construction, it is a general business waste and is in charge of the waste disposal law.
7. In July 14th of the Republic of China, the "Waste Disposal Law" was amended to clarify the provisions of the Company, including the self-cleaning of the business waste, the common removal process, the entrustment and removal procedures, and the incorporation of the joint responsibility and penalty provisions for the clean-up of the business waste.
8. On May 17, 1989, the Ministry of the Interior decided to "build a waste disposal scheme", which was promulgated as "the construction of the remaining earth and stone handling scheme".
9. On 21 October 1989, the Department established the "Business Waste Control Center" to expand the reporting and flow tracking of waste management.
10. In December 31st of the Republic of China, the Department of Construction of the Ministry of the Interior of the Ministry of the Interior called for the "Administrative Measures for the Establishment of Joint Disposal of Waste Disposal".
11. On July 3, 1991, the "Recycling and Recycling of Resources" was published.
12. On July 29, 1991, the Ministry of the Interior signed the Measures for the Administration of Recycling of Wastes for Construction.
13. On August 14, 1991, the Ministry of the Interior promulgated the Provisions on the Type and Quantity of Waste Disposal by Waste Disposal.
14. On July 4, 1992, the Ministry of the Interior signed the "Reuse of waste for construction business and the management method". Seven kinds of recyclable types of waste for construction business were announced.
15. On September 16, 1992, the Ministry of the Interior promulgated the "Construction of the remaining earth and stone processing plan" to increase the amount of land and the handling of the building.
16. On August 1, 1994, the Department announces that the construction of the first phase of the construction of the project (the contract or separate contract is the construction of the construction of the air pollution control fee since August 1, The project area of more than 2,000 square meters or engineering contract funds up to NT $ 50 million) and construction demolition works.
17. On October 31, 1994, the Ministry of the Interior signed the Administrative Measures on the Recycling of Recycling Resources for Construction.
18. On May 8, 1995, the Ministry of the Interior Administration of the Ministry of the Interior announced that it would cease to accept the declaration of "building a mixture" and cancel the land code B8.
19. On 15 March 1995, the Ministry of the Interior signed the "Construction of the remaining earth and stone processing plan", and the removal of the land for the construction of the mixture was handled.

20. On April 23, 1996, the Ministry of the Interior signed the "Renewable Resources Project and Regulation" for the recycling of the construction business.
21. On May 1, 1996, the Department announces that the construction of the second phase of the operation of the project (the package or individual contract is the construction project of the construction of air pollution control fee from May 1, 1996, the Republic of China With an area of more than one thousand square meters or more than NT $ 10 million for construction contracts) and construction demolition works.
22. On August 1, 1996, the Department announces that the construction of the second phase of the construction of the project (the package or individual contract is a construction project for the construction of air pollution control fee from August 1, 1996 With an area of more than 500 square meters or more than NT $ 5 million for construction contracts) and construction demolition works.
23. The Republic of China on August 25, 1997 Amendments to the "Immediate Tracker System Waste Disposal Equipment" Notice Delivery of civil or building waste and construction of vehicles should be fitted with satellite positioning system (GPS) for immediate tracking.

2.2 Prefabricated elements (with or without CDW materials)

No specific information has been found.

2.3 Prefabricated construction

No specific information has been found.

3. PREFABRICATED CONSTRUCTION SECTOR CHARACTERISTICS

3.1 Exports / imports of prefabricated elements

No specific information has been found.

3.2 Market conditions / costs and benefits

No specific information has been found.

3.3 Construction sector make up

No specific information has been found.

3.4 Use of CDW materials for prefabricated elements

In Taiwan, government want to promote "green building blocks system" from 2004 [7]. In 2015 Ministry of the Interior has assigned green building material label to promote the use of recycling CDW in "green concrete" building materials including pre-cast element. In addition, requires at least 40% of the recycled material to replace the concrete aggregate.

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