21. PORTUGAL

21.1 Legal Framework – Waste Management Plans and Strategies

The European Commission (EC) and the European Environment Agency (EEA) agreed to enhance efforts to improve knowledge on implementation of waste policies through tasks to review municipal solid waste, management in EEA member countries, using indicators, country factsheets and relevant European Commission studies. Together, these instruments establish a range of waste management targets and broader goals for the years to 2020.

The Legal framework in the field of waste management includes 16 acts, most of which have already been transposed in Portuguese legislation, as indicated in the Table 75:

Table 75. European legislation on CDW management

European Law
1) Framework Directive on waste no. 75/442/EEC, as amended by Directive no. 91/156/EEC.
2) Directive no. 91/689/EEC on hazardous waste.
3) Directive no. 75/439/EEC on the disposal of waste oils, as amended by Directive no. 87/101/EEC and Directive no. 91/692/EEC.
4) Directive no. 91/157/EEC on batteries and accumulators containing certain dangerous substances
5) Directive no. 93/86/EC on the marking of batteries.
6) Directive no. 2000/76/EC on the incineration of waste.
7) Directive no. 94/62/EC on packaging and packaging waste.
8) Directive no. 96/59/EC on the disposal of biphenyls and polychlorinated terphenyls (PCB and PCT)
9) Decision no. 2000/532/EC, as amended by Decision no. 2001/119 establishing a list of wastes (replacing Decision no. 94/3/EC establishing a list of wastes Decision no. 94/904/EC establishing a list of hazardous waste).
10) Regulation no. 259/93 on the supervision and control of shipments of waste within, into and out of the European Community.
11) Directive no. 86/278/EEC on the protection of the environment, and particular of the soil, when sewage sludge is used in agriculture
12) Directive no. 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment, as well as
13) Directive no. 2002/96/EC on waste electrical and electronic equipment (WEEE).
14) Directive no. 78/176/EEC on waste from the titanium dioxide industry.
15) Directive no. 82/883/EEC on procedures for the surveillance and monitoring of environments concerned by waste from the titanium dioxide industry
16) Directive no. 92/112/EEC on procedures for harmonizing the programmes for the reduction and

European Law
eventual elimination of pollution caused by waste from the titanium dioxide industry.
17) Framework Directive on waste no. 75/442/EEC, as amended by Directive no. 91/156/EEC.
18) Directive no. 91/689/EEC on hazardous waste.
19) Directive no. 75/439/EEC on the disposal of waste oils, as amended by Directive no. 87/101/EEC and Directive no. 91/692/EEC.

In the following sections the legal framework governing CDW management and waste management plans in *Portugal* are explored.

21.1.1 National Legislation concerning CDW

Overview of National legislation in Portugal

- Decree-Law 46/2008 of 12 March (Decreto-Lei 46/2008, de 12 de março) [232],that establishes the legal framework for waste management resulting from construction works or demolition of buildings or collapses, including prevention and reuse and the operations of collection, transport, storage, treatment, recovery and disposal.
- Ordinance 40/2014 of 17 February (Portaria 40/2014, de 17 de junho)[233],establishes the rules for the correct removal of materials containing asbestos, and for packaging, transport and management of the respective CDW generated, regarding the protection of the environment and human health. This Ordinance also aims at clarifying aspects related to the inventory of materials containing asbestos and their characterisation, in the project phase (Ministérios da Saúde, da Solidariedade, Emprego e Segurança Social do Ambiente, Ordenamento do Território e Energia, 2014);
- Decree-Law 73/2011 of 17 June (Decreto-Lei 73/2011, de 17 de junho)[234],transposes the Waste Framework Directive 2008/98/EC, and introducesthe target of incorporating at least 5% of recycled materials or materials containing recycled components, regarding the total amount of raw materials used in public construction works (Ministério do Ambiente e do Ordenamento do Território, 2011);
- Decree-Law 26/2010 of 30 March (Decreto-Lei 26/2010, de 30 de março)[235], obliges the CDW holder from private construction works (with mandatory permit) to keep record on CDW generated (Presidência do Conselho de Ministros, 2010).
- Decree-Law 183/2009 of 10 August (Decreto-Lei 183/2009, de 10 de agosto)[236], establishes the criteria to accept codes 17 01 01, 17 01 02, 17 01 03, 17 01 07, 17 02 02 and 17 05 04 of European LoW in landfills for inert wastes without testing (Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, 2009);
- Decree-Law 18/2008 of 29 January (Decreto-Lei 18/2008, de 29 de janeiro)[237], establishes the elaboration and implementation of a CDW prevention and management

plan for all public construction works (Ministério das Obras Públicas, Transportes e Comunicações, 2008);

- Ordinance 417/2008 of 11 June (Portaria 417/2008, de 11 de junho)[238], defines the documentation which certifies CDW transport and reception at private waste management facilities (Ministério do Ambiente, do Ordenamento do Território e do Desenvolvimento Regional, 2008);
- Ordinance 209/2004 of 3 March (Portaria 209/2004, de 3 de março), transposes Decision 2000/532/EC and its amendments concerning the European LoW (Ministérios da Economia, da Agricultura, Desenvolvimento Rural e Pescas, da Saúde e das Cidades, Ordenamento do Território e Ambiente, 2004)[239].
- Ordinance 335/97 of 2 September (Portaria 335/97, de 2 de setembro)[240], regulates the transportation of waste (Ministérios da Administração Interna, do Equipamento, do Planeamento e da Administração do Território, da Saúde e do Ambiente, 1997).

21.1.2 Waste management plans (WMP) and Strategies

Implementation of environmental policies, especially waste policies, is one of the European Commission's key priorities, as confirmed by its proposal for a 7th Environment Action Programme (EC, 2012) and the Roadmap to a resource efficient Europe (EC, 2011). While the EU's Waste Framework Directive (EU, 2008) and Landfill Directive (EU, 1999) set binding targets for recycling municipal waste and diverting biodegradable municipal waste from landfill, EEA analysis indicates large differences in municipal waste management performance between countries (EEA, 2009).

The national Waste Management Plan for 2014-2020 (Resolution of the Council of Ministers 11-C/2015 of 16 March; *Resolução do Conselho de Ministros 11-C/2015, de 16 de março*)[241] includes also the national Waste Prevention Strategy. In this plan, a general description of CDW and the target set on article 11 of the WFD are included. However, there are no new specific measures regarding CDW prevention or CDW management.

Apart from the WMP, there are no other strategic documents/plans in place in Portugal with reference to CDW. However, article 4 of Decree-Law 46/2008 of 12 March, regarding the legal framework for CDW management, established that *'the quantitative and qualitative goals to be achieved in accordance with the goals set by national or EU law applicable to CDW, as well as the priorities, targets and actions for its management will be set out in a specific plan for CDW management, approved in accordance with article 15 of Decree-Law 178/2006 of 5 September (republished by Decree-Law 73/2011 of 17 June)'*. This plan is being prepared by the Portuguese Environment Agency with specific objective to analyze and implement the EU and national targets for CDW [242].

21.1.3 Legal framework for sustainable management of CDW

Concern about the amount of CDW generated and its environmental impact is growing. For this reason, governments and public authorities are reviewing their policies on how these wastes should be managed. In order to improve this management, it is necessary to know the composition and magnitude that should be dealt with, as well as some estimating method of waste generated in a project, in a region or a country.

Despite all the problems that CDW may cause, and difficulties on their treatment, when waste is properly managed become resources, or products that contribute to saving raw materials, conservation of natural resources, avoid climate change and thus to sustainable development, in accordance with the principles of the circular economy.

Waste management

Portugal is facing multiple problems with MSW management and is attempting to tackle them by passing legislation in order to improve the performance of waste management systems. The country has made substantial progress in the waste domain from the situation that existed at the end of the last century when depositing in open dumps was the dominant (if not exclusive) treatment method. Portugal has an average level of waste generation compared to other EU countries (514 kg/cap in 2010). Waste management is currently dominated by landfilling, but Portugal has invested in many other treatment options including incineration, composting and MBT technology. The drivers behind the developments in MSW include the national legislation, which predominantly transposes the EU Directives, and the National Waste Management Plans (PERSU)[243]. There have been two PERSUs in Portugal: PERSU I was ratified in 1997 and covered the period until 2006, when PERSU II came into play which targeted the period 2007-2016. PERSU I set both quantitative and qualitative targets for Portugal's MSW management system following in parallel the developments at the EU level. The main objective of the PERSU I was to eliminate open dumps and divert the waste, according to specific quantified targets, to recycling, incineration and composting. This has been a difficult task, as in 2001, more than 340 dumps were yet to be closed (Magrinho et al., 2006). Despite the plan's success in eradicating the open dumps, most of the targets set were not achieved (Ribeiro et al., 2011). Therefore, by taking into account the need to modernize the MSW system, PERSU II was ratified in 2006. PERSU II aims to eliminate inefficiencies observed in the implementation of the previous plan:

- Adapt EU legislation to Portuguese reality;
- Rationalize the costs;
- Encourage participation of all stakeholders, based on input from all of them;
- Support incineration with energy recovery and MBT as solutions to MSW treatment;
- Introduce separate collection of organic wastes and other measures to divert them from landfills, and

- Maximize by-products utilization. The quantitative targets included in PERSU II are adopted from EU legislation. The legal framework governing waste management has been consolidated over the last few years, with systems for managing certain specific flows, and placing the onus on producers to pursue targets for prevention, separate collection, recycling and other forms of recovery (SOER, 2010). Besides the general frameworks such as PERSU, there are various other decrees regulating specific waste streams or treatment options (ETC/SCP, 2006). The Ministry of the Environment is responsible for all waste legislation. The organization of the waste management system involves three other types of organizations (Magrinho et al., 2006):
- Municipalities which are responsible for collection of (normally only mixed) waste;
- SGRSU which are entities dealing with waste treatment;
- SPV which is the Portuguese Green Dot System responsible for recycling packaging wastes.

21.1.4 Targets

In Portugal, Decree-Law 73/2011 of June, 17, namely article 7 (principle of the waste hierarchy), paragraph 6, transposes from the WFD the 70% target of preparing for reuse, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous CDW excluding naturally occurring material defined in category 17 05 04 of European LoW.

In order to achieve the mentioned target, article 7 - paragraph 8 defines within the context of public construction works that when technically feasible, it is mandatory to use at least 5% of recycled materials or materials containing recycled components of the total amount of raw materials used. Aside from that statement, there are no other targets in Portugal regarding CDW management.

Also based on historical *Municipal waste management* (MSW)[244] data for Portugal and EU targets linked to MSW in the Waste Framework Directive, the Landfill Directive and the Packaging Directive, the analysis undertaken for each country includes:

- *The historical performance on MSW management based on a set of indicators,*
- *Uncertainties that might explain differences between the countries' performance which are more linked to differences of what the reporting includes than differences in management performance,*
- *Relation of the indicators to the most important initiatives taken to improve MSW management in the country, and*
- *Assessment of the future possible trends and achieving of the future EU targets on MSW by 2020.*

The launch of the second national waste management plan (PERSU II) in 2006 aims at tackling the inefficiencies of the previous national plan and aligning the country with EU standards and targets;

- Increasing the incorporation of waste in the economy – from 56 % in 2012 to 68 % in 2020 and 86 % in 2030 (GGC).
- Achieving 47 kg per person per year of recyclable waste recovered after sorting, by 2020 (PERSU 2020, GGC).
- Increasing the preparation of construction and demolition waste for reuse, recycling and other forms of material recuperation to 70 % by 2020 (PNGR 2020).
- Increasing the preparation of municipal waste for reuse, recycling and other forms of material recuperation to 50 % of the recyclable content, until 2020 (PERSU 2020).
- Reducing waste production by 18 % by 2020 (PNGR 2020).

21.1.5 End of Waste (EoW) status

The Decree-Law 73/2011 of 17 June has set requirements for substances or objects resulting from a production process, which can be considered as by-products and not waste. The Decree-Law also establishes conditions for end of waste (EoW) criteria. The by-product and EoW criteria, are explained respectively in articles 44 a) and 44 b). Both concepts introduce a distinction between waste and non-waste, but they have different legal context.

Regarding article 44 a), a by-product or a non-waste material is a substance or object resulting from a production process, whose principal purpose is not its production when the following conditions met:

- the material's or substance's future application is determined;
- the substance or object can be used directly without further processing, aside from that which takes place via normal industrial practice;
- the production of the substance or object is an integral part of a production process;
- the substance or object fulfils the relevant health and environmental requirements in regards to its intended use, meaning that they do not lead to overall adverse impacts from an environmental or human perspective.

The classification of a by-product must be made by stakeholders, through sectorial associations or individually, at the Portuguese Environment Agency, by submitting a specific application form. The application is evaluated within 90 days with a submission fee of € 5 000.

The by-product classification does not apply to waste that is excluded from the scope of national waste management legal framework (Decree-Law 73/2011 of 12 June), nor to the consumption of waste generated in production activities (e.g. empty packages).

Prior to the submission of the application form, it is essential to evaluate if the substance or object has the potential to be classified as a by-product. To date, none of the existing classifications of by-products in Portugal is applicable to CDW[242].

Taking into account article 44 b), EoW criteria can apply to certain waste that has undergone a recovery operation, including recycling, and complies with specific requirements developed in accordance with the following conditions:

- the substance or object is commonly used for specific purposes;
- a market or demand exists for such a substance or object;
- the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products;
- the use of the substance or object will not lead to overall adverse environmental or human health impacts;
- the criteria may include limit values for pollutants and take into account any adverse environmental effects of the substance or object.

In the absence of common EU criteria, the National Waste Authority may, after consulting the directly interested economic operators or their representative structures, set specific requirements that must be fulfilled in order a certain object or substance to be considered a by-product or qualify for EoW status. In the present case, Portuguese Environment Agency should:

- prepare an Ordinance specifying the requirements for waste declassification;
- communicate the decision to the European Commission through the Portuguese Institute for Quality, in accordance with Decree-Law 58/2000 of 18 April (Decreto-Lei 58/2000, de 18 de abril), which provides the rules to administrative procedures in these cases.

Once it is declassified, the waste legal framework is no longer applicable to that specific object or substance, but the legislation concerning products or substances applies, namely the Regulation (EC) 1272/2008 (classification, packaging and labelling) and the Regulation (EC) 1907/2006 (REACH - EU regulation concerning the Registration, Evaluation, Authorization and restriction of Chemicals).
Currently, no specific EoW criteria for CDW exist in Portugal [242].

21.2 Non legislative instruments (best practices, guidelines, recommendations…)

Any other instruments that may specify how the country is addressing the question of CDW management are highlighted, as these instruments might be creating conditions for a sustainable management of CDW.

Instruments

- Description Sustainability standards that cover CDW (e.g. BREEAM)
- Level of occurrence (Yes/No) Key Scope/Exemptions Yes/LiderA Sustainability Assessment System/PTPC Portuguese Technological Platform to

Construction/SBTOOLPT Adaptation of the assessment tool for sustainable construction SBTool International
- Year established and policy reference LiderA: 2005/ PTPC: 2011/ SBTOOLPT: not available

<u>Identification of technical guidelines/standards/ codes of practice for use of CDW in construction application</u>

- Description of guidance/ tool: *Code of practice RERU (Outstanding Regime for Urban Rehabilitation).*
- Scope: Consists in a set of rules, releasing the works of urban rehabilitation from certain technical standards for the construction (because these standards are oriented to new construction).
- Year established/ produced: 2014 Decree-Law 53/2014 of 8 April (Decreto-Lei 53/2014, de 8 de abril).
- National or regional (specify if regional): National.
- Description of guidance/ tool: *Best Practices Guide for Municipalities Sustainable Development*
- Scope: Supports municipalities on implementation of eco-conscious measures, promoting in Public Administration more efficient and responsible actions in terms of energy and environment.
- Year established/ produced: 2013.
- National or regional (specify if regional): National.

21.3 CDW management performance – CDW data

In this section the performance of CDW management in Portugal is presented. This section particularly seeks to gather all available data and information about CDW generation and treatment, exports/imports, and treatment facilities.

21.3.1 CDW generation data

In Portugal, CDW generation data are recorded every year in the Integrated Map for Waste Registration (MIRR) of the Integrated Registration System developed by the Portuguese Environment Agency (SIRAPA), namely in on-line forms available to waste producers.
Data can be disaggregated by economic sector, taking into account the National Classification about Economic Activities, Rev. 3 (fully integrated at 4 digit level with the NACE Rev. 2.). However, it is not possible to separate data by type of activity (e.g. new construction, demolition).
Households are not included in the data, because municipal waste systems operators have no means and capacity to do such evaluation and distinction of the proportion of waste resulting from households and businesses (industry, commerce and services).
The annually reported CDW data in SIRAPA can be obtained from two sources: Statistics Portugal (INE – Instituto Nacional de Estatística) and the Portuguese Environment Agency

(APA – Agência Portuguesa do Ambiente). According to the Waste Statistics Regulation, data presented between 2008 and 2012, has some methodology differences.

21.3.2 CDW treatment data

Similarly to CDW generation data, CDW treatment data are recorded every year in the platform MIRR of SIRAPA, namely in the on-line forms available for the waste management companies.
Data can be disaggregated by economic sector, taking into account the National Classification about Economic Activities, Rev. 3 (fully integrated at 4 digit level with the NACE Rev. 2.). However, it is not possible to disaggregate the data by type of activity (e.g. new construction, demolition).
Taking into account the data recorded every year in SIRAPA, data to quantify CDW treatment can be obtained from two sources: Statistics Portugal and the Portuguese Environment Agency. Statistics Portugal presents data between 2008 and 2012, according to Waste Statistics Regulation. CDW treated on-site are not reported in the data for recycling. There is no estimated volume for CDW treated per year on-site in Portugal. This fact can interfere with the quality of the data reported, although this interference cannot be quantified.

21.3.3 CDW exports/imports data

The European legal framework of trans-boundary movements of waste is the Regulation (EC) 1013/2006 from the European Parliament and the Council of the European Union of 14 June. The national Decree-Law 45/2008 of 11 March (Decreto-Lei 45/2008, de 11 de março), ensures the implementation and the compliance with the Regulation.

The Portuguese Environment Agency provided data on trans-boundary movements of CDW for exports (2013-2014) and imports (2012-2013)[242], the first two tables below illustrate export data (the first table organized by LoW code and the second table by country). The consecutive tables outline import data (the third table organized by LoW code and the fourth table by country). In the case of exports and imports alike, hazardous CDW represent a small percentage of the total, always less than 1.4% of the annual amount of CDW generated.

Table 76. Export data organized by LoW code. Source: APA (2015)

CDW exports (tonnes)					
LoW code		2013		2014	
17 01 02	Bricks	0.39	0.39	4.94	20.44
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	-		15.50	
17 02 01	Wood	-	5.00	0.35	183.67
17 02 03	Plastic	5.00		183.32	
17 04 01	Copper, bronze, brass	1 957.51	3 535.02	3 433.87	5 602.92
17 04 02	Aluminium	551.63		1 139.09	
17 04 03	Lead	23.69		2.44	
17 04 04	Zinc	180.28		167.70	
17 04 05	Iron and steel	243.92		307.46	
17 04 06	Tin	-		9.20	
17 04 07	Mixed metals	131.69		-	
17 04 11	Cables other than those mentioned in 17 04 10	446.30		543.16	
17 09 02*	CDW containing PCB	0.67	0.67	-	-
Total			3 541.08		5 807.03

Table 77. Export data organized by country. Source: APA (2015).

CDW exports (tons)		
Country	**2013**	**2014**
Belgium	26.70	-
Brazil	162.00	-
China	999.98	2673.10
Korea (Republic of)	20.80	
France	75.31	-
Germany	22.90	-
Greece	-	68.54
Hong Kong	-	141.62
India	779.46	464.42
Italy	23.60	49.38
Netherlands	24.88	-
Spain	1332.25	2364.05
Switzerland	41.16	25.12
Thailand	52.84	-
Total	**3541.08**	**5807.03**

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Regarding 2013-2014 export data, the most representative four-digit chapter of the LoW is 17 04 (metals, including their alloys).

Table 78. Data organized by LoW code and the fourth table by country.

CDW imports (tonnes)					
LoW code		2012		2013	
17 01 01	Concrete	909.70	2 563.92	-	144.50
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	1 654.22		144.50	
17 02 01	Wood	43.18		103.44	
17 02 02	Glass	4.56	54.82	0.60	111.27
17 02 03	Plastic	7.08		7.23	
17 03 02	Bituminous mixtures other than those mentioned in 17 03 01	5.88	5.88	-	-
17 04 01	Copper, bronze, brass	360.60		717.13	
17 04 02	Aluminium	201.12		88.36	
17 04 03	Lead	176.40		46.81	
17 04 04	Zinc	263.37	4 072.70	105.20	4 296.43
17 04 05	Iron and steel	1 886.58		2 888.09	
17 04 07	Mixed metals	965.88		359.98	
17 04 11	Cables other than those mentioned in 17 04 10	218.75		90.86	
17 05 03*	Soil and stones containing dangerous substances	47.50	539.44	-	-
17 05 04	Soil and stones other than those mentioned in 17 05 03	491.94		-	
17 06 01*	Insulation materials containing asbestos	9.74		-	
17 06 04	Insulation materials other than those mentioned in 17 06 01 and 17 06 03	9.12	18.86	5.32	72.40
17 06 05*	Construction materials containing asbestos	-		67.08	
17 08 02	Gypsum-based construction materials other than those mentioned in 17 08 01	-	-	6.96	6.96
17 09 04	Mixed construction and demolition wastes other than those mentioned in 17 09 01, 17 09 02 and 17 09 03	218.09	218.09	267.66	267.66

CDW imports (tonnes)		
LoW code	2012	2013
Total	**7 473.71**	**4 899.22**

21.3.4 CDW treatment facilities data

According to the national Waste Management Plan (Resolution of the Council of Ministers 11-C/2015 of 16 March), Portugal has landfills for inert CDW disposal distributed as described in the following table. These inert CDW landfills are compliant with EU legislation.

Table 79. Data landfills in Portugal for inert CDW disposal. Source: APA (2014b).

Territorial unit	Inert disposal landfills		Capacity[56]	
	Sector	N.º		
Portugal mainland	Public	3	Licensed capacity (tonnes): Expected operating capacity (tonnes): Anticipated useful life (years):	103 156 100 437 37
			Licensed capacity (tonnes): Expected operating capacity (tonnes): Anticipated useful life (years):	420 000 399 869 13
			Licensed capacity (tonnes): Expected operating capacity (tonnes): Anticipated useful life (years):	160 000 133 132 13
	Private	7 (quarries)	*n.a.*	
Autonomous Region of Azores	Private	4	*n.a.*	
Autonomous Region of Madeira	Private	2	*n.a.*	

Data regarding the inert CDW landfills were only available for Portugal's mainland. Lack of information can also be observed: i) concerning the capacity of the landfills and if it will increase or decrease, despite the fact of the slowdown of the construction sector for the last years has decreased the amount of CDW generated; ii) the amount of CDW planned to be used for covering/rehabilitation of existing landfills; and iii) data on mobile and fix treatment units available.

Regarding the facilities for CDW treatment, while quarries can use CDW for landscape rehabilitation purposes and furthermore be considered as a backfilling operation, it has not been reported as such. There are also sorting facilities. No consistent information for the CDW treatment capacity is available, and therefore it is not possible to evaluate the relation between CDW generation and treatment. A study for the CDW stream conducted by the Portuguese Environment Agency (APA, 2015) indicates the number of licensed operators by treatment code (R or D) for 2009. Regarding the operation R5 (recycling/reclamation of other inorganic materials) and considering only the mainland of Portugal, the distribution is the Table 80:

Table 80. Treatment facilities data. Source: APA (2015).

LoW 4-digit code		Number of facilities
17 01	Concrete, bricks, tiles and ceramics	17
17 02	Wood, glass and plastic	7
17 03	Bituminous mixtures, coal ta rand tarred products	8
17 04	Metals (including their alloys)	6
17 05	Soils (including excavated soil from contaminated sites), stones and dredging spoil	13
17 06	Insulation materials	4
17 08	Gypsum-based construction material	6
17 09	Other construction and demolition wastes	17

21.3.5 Future projections of CDW generation and treatment

There are no projections available about future CDW generation, treatment, planning of management operations or planned waste management infrastructures.

21.3.6 Methodology for CDW statistics

There are two sources of CDW management data in Portugal, namely Statistics Portugal (from 2008 to 2012) and the Portuguese Environment Agency (only for 2009).

Statistics Portugal reports to Eurostat data regarding CDW management according to the respective guidelines, with few adaptations.

Regarding waste generation, the data was collected according to national legislation through the national waste registration platform, the MIRR.

Waste producers and waste management operators are obliged to report data through the MIRR platform, being identified according the following criteria:

- all businesses and individuals running local units (establishments) with 10 or more employees which generate non municipal waste;
- all businesses and individuals responsible local units which generate hazardous waste;
- all businesses and individuals performing waste management as their economic activity;
- all businesses and individuals performing waste collection and transportation as their economic activity;
- all businesses responsible for municipal waste management systems;
- all businesses responsible for separate systems for the management of specific waste streams;
- all businesses and individuals which participate on waste markets whether as traders or brokers;

- all businesses which produce and/or place on markets specific products that require registration according the legislation on specific waste streams like packaging, used tires, mineral lubricants, end of life vehicles, batteries and accumulators, electrical and electronic equipment, etc.

Although data reported by waste producers is provided by local units, data matching on waste is made at the business level. It is currently not possible to have a single code to identify the local units, as it is challenging to match data at local units' level. Therefore the sample size and selection is made at the business level (enterprise), as well as the matching of quantities of waste generated by local units and the businesses sample selected from the statistical office registers database (statistical units register). The specification of the scope of the data and the respective statistical units for sampling/stratification and estimations is done at business level (enterprises).

Concerning waste treatment, data on quantities treated are based on the information reported by the waste producers and waste operators according to the specific web forms. The data reported by producers and waste operators include a registration code declaring the waste management operation (R or D codes). The amounts of waste generated and managed or treated do not match because a significant number of businesses identified as final treatment or end of cycle of waste management some of the R and D codes are not covered (namely: D8; D9; D11; D12; D13; D14; D15; R12 and R13).

In collaboration with the Portuguese Environment Agency, Statistics Portugal made recent changes in Waste Statistics for the 2012 reference year, taking into account the following aspects:

- Taking into account the experiences from previous years, reported outliers, which correspond to higher than the maximum or lower than the minimum values compared to previous years of reported waste quantities, are excluded or re-examined;
- Data from waste operators were superimposed with data reported by waste producers in order to increase the coverage of reporting (including data from businesses which not report and fill in the webform for waste producers) and also to improve the data quality for some replies. Validation of data was performed by comparing the different forms of reporting (both from waste producers and waste management operators) in order to eliminate duplications and to avoid double counting which results from the integration of data.

21.4 C&D waste management in practice

In Portugal, according to the *Management and C & Waste Report of the Euorpa DG ENV*, the generation of CDW in Portugal can be estimated at 1.09 t / hab / year.

21.4.1 CDW management initiatives

Since the adoption of the *Thematic Strategy on the Prevention and Recycling of Waste*, the Commission has taken continuous action to make the EU waste legislation more cost-effective in order to provide the basis of sustainable growth.

Waste prevention remains a clear priority in waste management. Since the adoption of the Strategy, the Waste Framework Directive (WFD) introduces a number of new provisions aiming to maximize prevention efforts, in particular, through national waste prevention programmes. The Commission will publish prevention guidelines and update its set of best practice examples from across the EU.

In this section the "on the ground" CDW management in Portugal is presented. Current and specific CDW obligations, initiatives, voluntary agreements and any other management practice are outlined

a) **Description of initiative:** RCD Valor
   Scope: Investigates the replacement of the natural soil as backfill materials in structures reinforced with geosynthetics (walls and embankments), regarding economic and environmental sustainability in the construction sector.
b) **Description of initiative:** Multi Valor RCD – Optimization of the Process of Recovery of CDW Trough Mechanical, Physical, Chemical and Environmental Characterization.
   Scope: Extend the range of marketed products and improve their quality. Optimization model of the production process. Comply with legal requirements in terms of recovery. Demonstrate for the companies the potential of CDW.
c) **Description of initiative**: SUPREMA - Sustainable application of construction and demolition recycled materials in road infrastructures
   Scope: The promotion of the sustainable use of CDW in pavement base and sub-base layers and in capping layers, by improving the knowledge concerning the mechanical and environmental characteristics of these materials, their performance as unbound aggregates and the determination of parameters to be used in pavement design.

21.4.2 Drivers / barriers to increase CDW recycling

Drivers and barriers to increasing CDW recycling were identified essentially through communication with relevant stakeholders and are presented in the table below. The stakeholders contacted and that gave their contribute to the present task are: the Portuguese Environment Agency, three Commissions for Coordination and Regional Development (Norte, Centro and Algarve), the Portuguese Association of Waste Management Operators and Recyclers (APOGER), the Industrial Association of Construction and Public Works (AICCOPN), the National Association of Portuguese Municipalities (ANMP) and two environmental non-governmental organizations (Quercus [253] and GEOTA – Grupo de Estudos de Ordenamento do Território e Ambiente). Additionally, a background document addressed to stakeholders, produced by the Portuguese Environment Agency, entitled "How to achieve the target of 70% of recovery of CDW in 2020?" was used.

21.5 CDW sector characterization

The following actors are involved in the management of CDW in Portugal: national waste authority (Portuguese Environment Agency), regional waste authorities (five Commissions for Coordination and Regional Development), construction companies, private waste management companies, municipalities and MSW management systems. National and regional authorities are responsible for licensing and monitoring of CDW policies and management activities.

The construction companies existing in Portugal are organized in classes of qualification. It is possible to conclude that, regarding the maximum values of permissible works, the small and medium sized enterprises are the most relevant in the Portuguese construction sector.

In 2013 FCT-UNL produced a report regarding the CDW management in 48 municipalities from the North Interior Region of Portugal. The construction companies were contacted by surveys and telephone, with the main goal of identifying the means by which companies implement the planning and management practices of CDW. The study concluded that large construction companies which responded to the survey affirmed that they comply with legal requirements through the following practices and documents: i) Environmental Management Plan to the construction work; ii) Plan for the Prevention and Management of CDW (in the case of public works); iii) consideration of construction methods oriented to selective demolition; iv) imposition of contractual provisions in contracts for subcontractors; v) construction site planning, taking into account the logistics directed to the management of CDW; and vi) consideration of the best available technologies that enable to extend the life cycle through the reuse of materials.

Concerning the construction phase, those companies said that they implemented some kind of action in respect to the management of CDW, namely: i) sorting and minimizing the generation and the hazardousness of CDW; ii) reusing uncontaminated soils and rocks; iii) reusing materials on site; iv) recycling on site; and v) transportation to licensed waste management companies, including landfills.

Additional procedures to those required by law were also confirmed the companies: i) recording environmental monitoring and measurement data (including transportation); ii) operational control procedures (work instructions); iii) a work waste generation map; iv) a general waste management plan; v) a recording map regarding CDW management companies and permits; and vi) training and awareness of workers.

21.5.1 CDW materials (CONCRETE, BRICKS, TILES AND CERAMIC, ASPHALT, WOOD, GYPSUM)

The construction industry in *Portugal* does not have a tradition in re-using or recycling wastes, which are generated in construction and demolition activities. In Portugal, about 7.5

million tons of waste are produced every year [249], representing 20% of the total volume of waste generated[250]. In this context, in order to preserve the environment and guarantee a sustainable growth, a great number of environmental regulations and initiatives have been developed. Most of these laws seek to minimize and control CDW production.

Product description and applications

Nowadays, a greater effort is being made to try to recover and reuse this kind of materials. As a result, the CDW material recovery in Europe has evolved from 28% at the beginning of the decade [252] to current 50%. After of the previous data, a summary about the characteristics of these materials as wastes is presented [296].

Concrete

Concrete is the predominant material in foundations and structures. It can be recycled as aggregate for new concrete, but to do this, it needs to be cleaned of masonry waste as well as wood, metals and plastics. It can also be used in the modification of the landscape, for example in gardened zones or in civil works as sub-bases of roads or filling of embankments. Depending on the type of work and the subsequent use of the waste, the crushing treatment will be different. On the other hand, the dust produced in the extraction of stones can be used as an aggregator and achieve a stony appearance in the manufacture of monolayer mortars. It can also be recycled into prefabricated concrete elements such as beams, pillars, joists, panels, alveolar slabs, pipes or pieces of urban furniture. Ultimately, they could be placed in vats next to other inert debris and taken to landfill and debris.

Bricks, tiles and ceramic waste

This material forms part of the main component of products fundamentally used in walls of facade and interior partitions, mainly bricks, tiles, and ceramics. They therefore account for a fraction of the CDWs. It is very usual to cut these pieces or to do rubs to facilitate the passage of the facilities, so it is advisable to prepare a space for the storage in order to be reused in the same work or in other place. If the recycling is not viable, it can be stored as debris or rubble from work site together with other inert CDWs (aggregates, soil ...) and can be deposited in controlled landfills. Stoneware can also be recycled, although the process is more complicated because of its diversity and small amount. Thus, it can ultimately be used as filler or storage material in controlled landfills. Porcelain waste can be used as filling of works and highways or for the manufacture of pre-crushed recycled concrete.

Asphalt waste

In construction, they originate mainly in the installation of waterproofing systems for roofs and basement walls. They can be recycled as asphalt or as fill mass in the work outside it, in a plant, by cold or hot processes. Efficient selective collection must be carried out without deterioration of the material. For this, it is necessary to carry out a pretreatment for the separation of other materials adhered in the contact zone, mainly residues of thermal insulation (glass fiber, polystyrenes) or separating layers (geotextiles, mortars ...).

Subsequently a grinding should be carried out to achieve a uniform size for use in other mixtures.

Wood waste

Represents a significant proportion in CDW in Europe. The wood content in mixed CDW varies in between different EU countries and can reach up to 40% by weight, especially in countries where significant amounts of wood are used in the building sector. Wood waste includes clean lumber, but also painted or treated wood, plywood, pallets and furniture etc. Intact, massive wood parts might be reused for furniture, flooring, cabinets or other specialist reuse. Waste wood can be used for material recycling or energy recovery, depending on the quality and characteristics of the waste wood. The mixture of different wood qualities in CDW, like hardwood and softwood, engineered wood fractions (chipboards, particleboards etc.) and painted and/or treated wood complicates the material recycling, especially for higher grade applications.

Gypsum waste

Gypsum waste is usually generated in the trim and plaster coatings phases. Concrete elements (columns, walls, joists, etc.) must be covered with plaster because their sulfate content renders them unusable as components of a new concrete. They should be stored in rubble dumps. This type of gypsum waste from renovation, refurbishment and demolition works is more likely to present a certain degree of contamination, which can be in the form of nails, screws, wood, insulation, wall coverings etc. For this waste to be recyclable, it is required that the equipment processing the waste is capable of separating such contamination from the gypsum to arrive at a pure recycled gypsum.

Quantitative analysis

In the next figure, a data example of the composition of CDW generated in the coastal region, in the north of Portugal is shown:

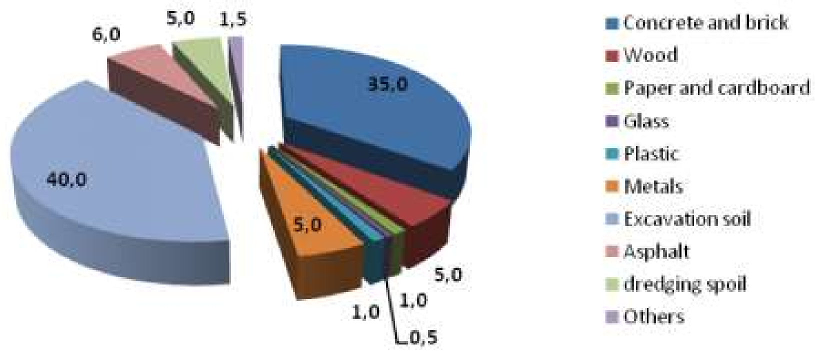

Figure 17. Composition of CDW generated in the coastal region, in the north of Portugal (Source: Pereira et al.)[251]

Depending of final use the different materials in study (Concrete, bricks, tiles and ceramic, asphalt, wood, gypsum), there are a number of treatment requirements that should be evaluated for use these material as waste. These requirements are related with the specific characteristics for each material for can be used as demolition and construction wastes

Recovery techniques

<u>CONCRETE</u>

Although an important fraction of concrete waste is still landfilled within the EU, this practice is being increasingly discouraged. The main options in Portugal for re-use, recycling and other material recovery of concrete waste are described below.

✓ **Re-use**

Concrete can be re-used in various ways in its original form. An example is to leave the concrete structure in place while modernizing the inside space or façade/curtain wall of the building.

Another option is the re-use of specific concrete elements with little processing: pre-fabricated elements and concrete blocks are cut in smaller elements and cleaned of mortar. This requires the careful and therefore time-consuming dismantling of the building to avoid damaging the elements and the transportation to the other construction site.

✓ **Recycling and other material recovery**

Concrete can be reprocessed into coarse or fine aggregates.

The first step is to remove all impurities such as insulation and steel reinforcement before crushing and grading. As a consequence, an effective sorting out at the construction site or at the treatment facility is essential to maximize the recycling potential. Mobile sorters and crushers are often installed on construction sites to allow on-site processing. In other situations, specific processing sites are established. Sometimes machines incorporate air knives to remove lighter materials such as wood, joint sealants and plastics. Magnet and mechanical processes are used to extract steel, which is then recycled.

Once sorted and processed, these aggregates can be used as such in road works, or reintroduced into the manufacturing of concrete. These different possible applications are described below.

Coarse aggregates can be used for road base, sub-base and civil engineering applications. Finish research has found that recycled concrete specified to an agreed quality and composition in the sub-base and base layers can allow the thickness of these layers to be reduced due to the good bearing properties of the material. Indeed, for such an application the unbound cementitious material present in recycled aggregates has proved superior behavior than virgin aggregates such that the strength is improved providing a very good construction base for new pavements.

Therefore, the use road construction sector represents one of the main applications for recycled concrete aggregates and can significantly contribute to reaching the 70% target (the demand of recycled aggregates for road construction could already buffer up to 75% of the concrete waste generated).

Coarse aggregates can also be used as a filling material in quarries (referred to as backfilling) which is in practice especially in Eastern Europe whereas in Western Europe quarries are rehabilitated into leisure spaces. Crushed concrete can also be used in earthwork constructions, to build streets, yards and parking areas, as backfilling for pipe excavations, environmental construction, foundations for buildings, etc.

Fine aggregates can also be obtained from concrete waste and used in place of natural sand in mortars. However, the use of recycled concrete fine aggregates could affect directly the mortar content and therefore its workability, strength and can cause shrinkage due to high water absorption. This could increase the risk of settlement and dry shrinkage cracking. For these reasons, recycled fine aggregates are not used in the production of structural concrete. Moreover, the contamination of concrete with gypsum may hinder the recyclability of the material, as cleaning represents important additional costs, both economic and environmental.

The above applications are often referred to as "down-cycling"[254] as opposed to reintroducing recycled concrete directly into concrete production, where it can be used as a substitute to natural aggregates. Both coarse and fine recycled aggregates can be used in concrete production. However, as cement is not recyclable, this option still requires the consumption of virgin cement. Technically, the use of recycled aggregated in the production of concrete is limited for structural reasons.

BRICKS, TILES AND CERAMIC

✓ **Recycling**

A high proportion of ceramic CDW is well suited to being crushed and recycled as a substitute for newly quarried (primary) aggregates in certain lower grade applications such as engineering fill and road sub-base. This practice has been common (though not necessarily widespread) in several MS for many years[255].

Using bricks, tiles and ceramics waste from demolition sites raises however some issues. Indeed, if the technical criteria for the use of granulated ceramic material are few, it needs to be absolutely free of contaminating elements such as mineral wool, concrete, heavy metals and PAHs77 (Polycyclic Aromatic Hydrocarbons) that may leach and cause ground water pollution. This often mixed and contaminated fraction needs therefore to go through cleaning, crushing and sieving processes before further recycling.
The different recycling options promoted by the European Tiles and Bricks Association[256] are described below:

- To fill and stabilize minor roads, especially in wet areas such as woods and fields. The practice is common in countries that lack adequate stone supplies such as Denmark. The material is generally used uncrushed.
- Crushed clay bricks, roof tiles and other masonry can be used on larger road building projects, especially as unbound base material. It is used to build roads in countries such as Germany, Denmark, the Netherlands, Switzerland and UK. In Germany, the maximum brick content for such use is 30%, due to quality requirements for frost attacks and impact resistance. The material replaces natural materials, such as sand and gravel, which are normally used in large amounts for this purpose.
- Aggregates for in-situ. Crushed clay bricks and other masonry can also be used to level and fill pipe trenches. The fine crushed material will replace natural materials such as sand.
- Crushed clay bricks, tiles and other masonry can also be used as aggregate in concrete. The crushed material replaces other raw materials such as sand. This is commonly practiced in Austria, Denmark, Switzerland and especially the Netherlands[296].
- Tennis sand produced by crushing red bricks and roof tiles. The fine surface layer is laid over courser-grained layers that can comprise crushed clay brick matter. The process is most efficient when it occurs at brick or tile factories where there is an abundance of scrap material.
- Crushed bricks and tiles can also be used as plant substrates. The material may be mixed with composted organic materials and is especially suited for green roofs: the porosity of the material allowing retaining water plants can rely on during dry periods.

✓ **Re-use**

Extracting roof tiles and storing them for re-use is not difficult and bricks that are left over from building projects can also be diverted to other uses among which the incorporation into new buildings : for example, a new architectural trend in Berlin is to reuse facing bricks in new buildings. To do that, building deconstruction is imperatively required. However, these materials are often contaminated which raises several issues:

- Cleaning bricks is time consuming, difficult and dusty work that, if mechanized, is apparently rarely successful.
- Cement rich mortars are difficult to remove. In countries like Greece, where mortar from ancient constructions is a full ceramic material, it does not need to be removed.
- Excess mortar dust can inhibit the adhesion between mortar and bricks and lead to weaker masonry, depending on the mortar composition.
- Bricks may vary in quality. It is therefore difficult to assess the strength and load-bearing capacity of masonry made from recycled bricks. European and national standards

are very strict and it is extremely difficult to be sure that re-used bricks used in new structures will be durable.

- Due to the difficult nature and high labor costs associated with the process, the use of re-used bricks may be more expensive than the use of new bricks.

ASPHALT

Landfilling and energy recovery not being recognised as interesting options by the Asphalt Industry because of the associated costs and the loss of a "secondary raw material", the recovery and recycling of reclaimed asphalt have become more widespread in the last decades. If reclaimed asphalt is free of contamination, it can be guaranteed that the total amount of this reclaimed asphalt can be recovered or recycled as a construction material.

Strict guidelines on the nature of the reclaimed material (size distribution, bitumen content, filler content, bitumen viscosity or hardness, etc.) are enforced in the asphalt industry to guarantee good quality end materials.

A distinction is made in the following subsection between recycling, where the reclaimed asphalt is reprocessed into new mixes, and other forms of material recovery.

✓ **Recycling**

Recycling means adding the reclaimed asphalt to new asphalt mixes, with the aggregates and the old bitumen performing the same function as in their original application. Therefore, reclaimed asphalt replaces virgin aggregates and part of the binder. If asphalt is known as 100% recyclable material, the recycling rate depends on the applied technique.

The recycling processes can be divided into two major methods: hot or cold mix recycling techniques. These can be further sub-divided into stationary plant or in-situ recycling. Stationary plant recycling (or "Offsite recycling") consists in removing the material from the site to a plant located elsewhere which recycles the reclaimed asphalt in order to re-introduce it either on the original project or on other projects. In-situ recycling allows the reclaimed material to be incorporated directly back into the new asphalt pavement under construction or maintenance.

The recycling options that are further described in this chapter are available since 1975 and are considered at the point of being able to deal with the current amount of recycled asphalt.

Within both the cold and hot recycling process, screening and crushing of the reclaimed asphalt could be needed and special storage facilities at the mixing plant may be necessary. Modern plants are engineered to facilitate the addition of reclaimed material.

The maximum amount of recycled material that can be incorporated in the new mix is determined by the mixing equipment but also by some parameters related to the old asphalt like consistency of material, moisture content, etc. To achieve the highest levels of recycling it is necessary to either confirm the lack of variability in the feedstock or to have precise data on its range of properties. The requirements for reclaimed asphalt are formulated in the European Standard EN 13108-8 "Reclaimed asphalt".

✓ **Other forms of material recovery**

Material recovery refers to the utilization of reclaimed asphalt as road base course material, with the recovered aggregate and bitumen performing a lesser function than in the original application. To this end, reclaimed asphalt has to be crushed and sieved into different fractions for more accurate mix designs.

WOOD

The main existing options for recovery are the following:

- Energy recovery
- Recycling in the production of derived timber products
- Other forms of material recovery: landscaping, animal bedding, equestrian surfaces, composting, etc.

Before the recovery of wood waste, pre-treatment steps are usually required.

✓ **Pre-treatment**

The pre-treatment applied to bulk wood CDW are the following:

- Manual sorting to remove contaminants
- Single-stage, two-stage or three-stage crushing
- Segregation of ferrous and non-ferrous materials (by magnets or cyclones)
- Segregation of minerals like concrete through sieving
- Segregation of light-weight elements like plastics through single-stage or multi-stage air sieving

✓ **Energy recovery**

Ways to obtain energy from wood waste can be:

- In small heating systems
- In heating systems requiring authorization
- In facilities for gasification
- In facilities for the production of cement and cement clinker

- In municipal waste incinerators

Energy recovery is, most of the time, the only option available for wood waste contaminated with hazardous substances. Moreover, it is encouraged by European (Directive on the production of electricity from renewable energy sources) and national policies on renewable energies.

✓ **Recycling into derived timber products**

In the past few years, the wood recycling has known improvements along with the development of companies dedicated to this activity. Wood CDW can be remanufactured into high added-value products such as medium density particle boards or fibre boards or even wooden plastic that can contain a high proportion of recycled materials.

The particle board production in the EU-27 is estimated to be around 30 million m3. 1m3 of particle boards necessitating 0.65 tons of wood on average, 19.5 million tons of wood are needed each year to sustain the European production of particle boards. The share of post-consumer recycled wood input into this production shows high geographical differences (from 20% in France to 80% in Italy), and is estimated to reach 24% on average (5 million tons). This represents 25% to 50% of the CDW wood generated in Europe. This estimation is in line with the average EU-27 recycling rate of 31% proposed by the JRC [298].

✓ **Other forms of material recovery**

Other forms of recovery of non-contaminated wood waste include:

- Landscaping, where recycled wood can be used as decorative mulches, surface material for pathways, or impact absorbing playground surfaces
- Equestrian surfaces, for both indoor and outdoor arenas
- Animal bedding products

The extent of such applications in the EU is currently unknown. However, WRAP's study shows that the production of animal bedding and equines surfaces is the third most important end user industry of recycled wood.

GYPSUM

This point will focus only on gypsum construction waste due to the aforementioned reasons. Gypsum construction waste consists in pieces of plaster and fibreboards that had to be cut off to fit special arrangements in the building, of damaged boards during transportation or because of the weather when they are stored outside. Such waste represents around 5%[259] of plasterboard used on construction sites and is considered to be clean (free of paints and nails) and recyclable into the manufacturing process for the production of new plasterboards as described below.

- ✓ **Recycling**

The collected plasterboard stream has to undergo several steps in the recycling process. First, paper layers of the plasterboards are removed as much as possible, then gypsum is crushed into powder and eventually this powder is sent back to plasterboard manufacturers so that they can make new plasterboards from it.

The gypsum powder is estimated to represent 94% of the total plasterboard waste collected [260]. The remaining 6% refer to paper and cardboard (and the related contaminants) composing plasterboards and can be re-used in various ways such as composting (as very little gypsum is left on the paper) or heat generation.

There is always a residual paper fraction that remains in the powder and which hinders the improvement of the introduction rates of recycled powder into the processes that are currently in place. The associated risks are the damage of the manufacture machinery and an effect on the acoustic or thermal quality of the final product.

According to Eurogypsum, between 5 and 10% of gypsum powder resulting from construction plasterboard waste is re-integrated in the closed-loop system. This figure is a European average and huge differences exist between MS. Indeed, recycling practices exist in Denmark, Germany and other Northern European countries while recycling is limited in Greece and Spain or is not applied at all in Eastern Europe countries. In some MS where comprehensive gypsum recycling schemes have been established (e.g. Denmark) overall recycling rates of 65% can be achieved.

Environmental and economic impacts of CDW waste management

- ✓ **Environmental Impacts**

CONCRETE

This point describes the environmental and economic impacts of concrete by focusing on the impacts of the various treatment options, including the benefits of re-use and recycling of concrete CDW.

Direct impacts of landfilling

When landfilling concrete, the release of constituents into groundwater is low. The chemical analysis of water samples show dissolved substances at levels much lower than the very stringent limits set by the World Health Organization for drinking water. Only the sulphate ion (S042-) is regularly found at high concentrations, but always much lower than the levels found in many popular brands of mineral waters.

The major environmental impact of landfilling comes from the use of space for the storage of inert CDW. This is particularly relevant in countries where land is scarce and disposal costs are expensive.

Direct impacts of reprocessing into aggregates

Recycling of concrete involves processing into coarse or fine aggregates, through processes that are similar to those used with natural aggregates (screening, crushing and transportation).

The emissions of dust and particles produced during the crushing step of concrete but also during the storage phase before re-using, are probably the most important environmental impact during the treatment of concrete CDW [263] and can cause serious health problem for workers. The activities that can generate dust are the following:

- Loading of aggregate onto storage piles (batch or continuous drop operations).
- Wind erosion of pile surfaces and ground areas around piles.
- Load-out of aggregate for shipment or for return to the process stream (batch or continuous drop operations).

The emissions from the sorting processes can be controlled by spraying water on the piles of crushed concrete to avoid dust dispersion into the air. The noise from the machines at the crushing step of aggregates, both virgin and recycled, for the production of concrete is one of the major health concerns. Indeed, at some work stations it can reach 85Db55 during the production process. Efforts have been made to mitigate the effects on workers thanks to quieter machines and the use of hearing protection inside concrete plants which is compulsory. When concrete is being placed, it is usually compacted by vibration which can damage workers hands and can be avoided through the re-use of concrete.

Net benefits of re-use and recycling

The benefits of re-use and recycling of concrete depend on the material that recycled concrete substitutes.

- **Substitution to coarse or fine aggregates**

After recycling into coarse or fine aggregates, waste concrete simply replaces virgin aggregates (crushed rocks, gravel, sand) that would otherwise have been extracted from quarries and processed. Recycling therefore avoids the use of natural resources and land space in quarries. Quarrying activities might also generate biodiversity issues, which are avoided through recycling.

On the other hand, avoided impacts related to transportation and processing of virgin aggregates are not significantly different from those generated to prepare recycled aggregates. In some cases, however, recycled aggregates can be locally available, reducing the transportation distances. This would result in positive net benefits, particularly in fuel consumption and greenhouse gases emissions[264] .Overall, the environmental benefits of recycling of concrete into coarse or fine aggregates are probably moderate.

- **Re-use – Substitution to manufactured concrete**

The direct re-use of concrete blocks avoids the production of concrete, and therefore the associated impacts of cement production. Indeed, most environmental impacts of concrete production originate from the production of the cement composing it (at least 80% of the impacts during the production process).

BRICKS, TILES AND CERAMIC

Direct impacts of landfilling

Landfilling bricks, tiles and ceramics does not raise serious environmental issues especially for the release of pollutants into water except when these materials are coming from C&D activities and therefore often contaminated with potentially dangerous fractions: insulation wool, mortar, concrete.

The major environmental impact of landfilling comes from the use of space for the storage of inert CDW, particularly in countries where land is scarce.

Direct impacts of recycling as a road works material

As presented in the above sections, the recycling of bricks, tiles and ceramics involves processing steps (crushing, sieving, transportation) in almost all cases, except for the use for minor roads where crushing is not necessary. These processes are therefore similar to the processing of natural materials which balances the environmental effects.

The production of dust and particles during the crushing, sieving, transportation and storage steps is avoided , for example by spraying water on the crushed materials, by covering the conveyor belts and machineries, by enclosing dust producing processes and maintaining cleanliness of the industrial vehicles used for loading and transporting recycled bricks, tiles and ceramics [266].

The noise from the aforementioned processes is a serious concern for the workers health and can be mitigated through appropriate personal training and equipment and through the use of quieter machines.

Net benefits of re-use and recycling

- **Substitution to coarse and fine aggregates**

The use of recycled bricks, tiles and ceramics in the form of coarse and fine aggregates in the different recycling options developed in the above sections replaces virgin materials that would have been extracted and processed, which thus saves the use of raw aggregates and land space used for quarries. However, the use of raw materials is not really the issue since it is largely available locally in Europe and the extraction of clay for construction products represents only 5% of the total mineral extraction. Such a material is therefore not threatened by intensive exploitation. Finally, the impact of transportation of raw materials that is avoided through the use of recycled coarse and fine aggregates is limited since clay brick and tile plants are often situated alongside clay deposits or sand quarries, minimizing the energy spent on transportation.

- **Re-use – Substitution to bricks, tiles and ceramics produced from virgin materials**

The direct re-use of reclaimed bricks and tiles avoids the manufacturing processes, the associated energy consumption and gaseous emissions. Indeed, the Ceramic Industry is very energy intensive with an energy share of up to 30% of production costs [267] .

As an example, the specific energy consumption for the brick and roof-tile industry varied in 2001 between 1.4 and 2.42 GJ per ton [268] which represents between 80 and 138 CO2 equivalents per ton considering that the most commonly fuel used in this industry is natural gas61. This amount of CO2 equivalent is avoided thanks to the re-use of bricks and roof-tiles.

However, it must be noted that the specific energy consumption for the production of 1 m^2 brick wall was reduced by 40% from the 1990s to 2007, as the initially required 190 kWh were reduced to 115 kWh.

The re-use of bricks and roof tiles also allows avoiding gaseous emissions to the atmosphere that normally occur during the manufacturing process. They are mainly of three kinds:

- Emissions coming from ceramic conversion of the raw material in the kiln. The emissions are HCl (hydrochloric acid), HF (hydrofluoric acid), SOx (sulphuric acid) and C02.
- Exhaust gas emissions from combustion processes (from drying and firing plants).
- The emissions are CO (carbon monoxide), CO2, NOx (nitrogen oxides) and particles. Emissions of VOC's (Volatile Organic Compounds) due to the use of organic substances (additives).

ASPHALT

Direct impacts of landfilling

According to the EAPA111, asphalt pavement (new or containing reclaimed asphalt) does not leach significantly. Therefore the major environmental impact is the use of land space, as for the other studied fractions.

However, a potential complicating factor may be the presence of contaminants such as tar 112, whose higher concentrations of PAH's (polycyclic aromatic hydrocarbons) and/or phenol content and associated effects on human health (carcinogenic) led to the end of its use. Although it has been replaced entirely by bitumen for asphalt mixes in Europe, it may still be encountered in various proportions in some areas when old pavements are removed.

In this case, RAP is classified as hazardous waste and must be managed according to the European legislation.

Direct impacts of recycling

For both recycling in a stationary or mobile plant, reclaimed asphalt might have to go across the crushing and screening steps before being reintroduced into the manufacturing process. This is expected to produce particles and may raise health concerns if the machinery is not covered. However, these impacts are also related to the processing of raw materials. Moreover, when the reclaimed asphalt is obtained from milling operations (by a milling machine) the particle size might be the right one and then no additional crushing is needed.

The direct impacts of transportation are highlighted only when RAP is being sent back to asphalt manufacturer (i.e. for recycling in stationary plants). Fuel consumption and greenhouse gases emissions are comparable to the ones associated with the transportation of raw materials.

Direct impacts of material recovery

They are similar to the ones developed in the above subsection: related to transportation of both reclaimed asphalt and recycled aggregates and the production of particles and noise. These impacts are estimated to be the same as for virgin aggregates.

WOOD

Impacts of landfilling

As for other organic materials, landfilling of wood CDW leads to emissions of methane which is a greenhouse gas showing a global warming potential of 72 over 20 years, while carbon dioxide's is 1. Moreover, landfill of wood is associated with the unnecessary use of land and may lead to the contamination of the water table in the case the contaminated fractions has not been properly removed or isolated from the environment. The sources of contamination come from the surface chemicals that are used as glue, varnish, coating or wood preservatives to increase the material durability.

Impacts of energy recovery

Both Directive 2001/77/EC on the production of electricity from renewable energy sources and the Renewable Energy Directive favor the recycling market of waste wood and in particular wood CDW.

Impacts of recycling into derived timber products

Compared to incineration, recycling of wood CDW allows avoiding the production of particulates, carbon monoxide and various volatile organic compounds, i.e. PAHs, from the inefficient burning of wood. These hazards should however be limited when incineration takes place in a plant compliant with the Waste Incineration Directive. To ensure good quality products made from secondary wood, the standard limits for toxic elements in recycled wood are the same as for raw materials. The limit values of chemical contamination in supplied material have to comply with existing regulations.

GYPSUM

Direct impacts of landfilling

The main environmental issue associated with gypsum waste management is the production of the dangerous hydrogen sulphide (H2S) gas when plasterboard waste is disposed of in landfills. H_2S gas is a dangerous gas that is lethal in high concentrations and releases odors in low concentrations. The plasterboard waste itself is not dangerous, but when mixed with organic waste, and exposed to rain in an anaerobic environment, H_2S gas can be released. For this reason, the EU has decided that plasterboard waste and other gypsum-based products can no longer be disposed of in simple inert landfills but in controlled cells where no organic waste is accepted. However, this would require gypsum waste to be collected separately or sorted afterwards, which is not always the case. Therefore, in many cases gypsum waste is landfilled under improper conditions thus posing an environmental risk. Moreover, landfills use can also be a problem in some areas (around highly populated urban centres) due to use of land space. At last, transportation of waste to the landfill implies environmental impacts.

Direct impact of reprocessing plasterboards waste collected from construction sites

The processing of plasterboards waste collected from construction sites need energy-relying steps before further re-introduction into the manufacturing process. Other related impacts include dust and noise production, as well as transportation of construction plasterboard waste from the construction site to waste processors, and of recycled gypsum to plasterboards manufacturers.

Net benefits of recycling gypsum powder resulting from plasterboard waste collected from construction sites

Net benefits are low to medium as the production of plasterboards from recycled gypsum or from virgin material mainly are likely to have similar environmental impacts. The benefits are to avoid the use of natural resources, that is to say virgin mineral gypsum extracted from quarries, avoiding quarrying activities (thus reducing land use and avoiding potential biodiversity losses). Despite gypsum is estimated in good supply presently, there is only a limited amount available within the EU, so steps to preserve the natural gypsum resources should be encouraged.

- ✓ **Economics Impacts**

CONCRETE

Despite the environmental benefits of recycling concrete, its limited production costs do not encourage re-use and recycling. Nevertheless, using recycled concrete can also show economic advantages, depending on the local situation. The identified factors include:

- Proximity and quantity of available natural aggregates
- Reliability of supply, quality and quantity of CDW (availability of materials and capacity of recycling facility)
- Government procurement incentives
- Standards and regulations requiring different treatment for recycled aggregate compared to primary material
- Taxes and levies on natural aggregates and on landfill

Recycled concrete aggregates in Europe can sell for 3 to 12 € per ton with a production cost of 2.5 to 10 € per ton. The higher selling prices are obtained on sites where all CDW is reclaimed and maximum sorting is achieved, there is strong consumer demand, lack of natural alternatives and supportive regulatory regimes.

BRICKS, TILES AND CERAMIC

The harnessed extraction of clay and the development of new manufacturing techniques maintain clay bricks and tiles as competitive building materials that have good quality, long life, and minimal maintenance requirements and provide energy efficient solution during the use phase. The reduced costs of bricks, tiles and ceramics produced from raw materials are therefore not encouraging the development of recyclingb[270]. The SMEs would also decrease the chances for developments in recycling (heavy financial burden to SMEs while relatively small financial gains) except with the development of specific recycling facilities covering larger areas in a MS.

ASPHALT

The processes for the preparation of reclaimed aggregates (crushing, sieving) being the same as virgin materials, the production costs are estimated to be identical. On the other hand, the availability of virgin aggregates explains why the supply costs for these materials are limited which therefore does not encourage asphalt producers to turn to reclaimed asphalt as a substitution. However, landfilling and incineration for energy recovery are not considered as viable asphalt management options according to the industry as asphalt is an added-value material that is easily recycled thanks to the existing techniques [271].

WOOD

Due to the competition of utilization and the limited supplies, the market price for recycled wood is going up. The margin of the market price is influenced by the following elements:

- The regionally available amount of waste wood
- The intensity of the competition between material and energy recovery
- Seasonal variations (winter stock etc.)

In general, the prices for sorting, storage and treatment of specific waste wood fractions are not an incentive to the development of waste wood recovery.

GYPSUM

Two main economic factors push towards gypsum recycling: raw material price and landfilling costs increase.

- Gypsum raw material is not threatened by intensive extraction yet but the available amount is finite which is calling for saving measures such as recycling. The first effect is the increasing price of raw gypsum material as observed in some plants where it has gone up with more than 50% the last 3 years[272].

- The other economic aspect linked to gypsum waste management is the cost associated with landfilling. The effect of the increasing landfill costs is assumed to be the development of recycling practices among gypsum waste producers and gypsum manufacturers.

Drivers / barriers to increase recycling

Taking into account that some countries have achieved higher recycling targets and exhibit more advanced CDW management systems than others, it is expected that countries with higher recycling rates would exhibit similar barriers and drivers in their effort to improve performance, and countries with lower recycling rates might also face similar barriers and drivers with each other. The drivers as well as the barriers in the following points are presented in a random order and are not ranked in relation to significance and improvement potential.

Drivers

Market conditions

- Economic incentives play a crucial role in driving CDW management performance, measures such as landfill taxes and charges for unsorted CDW favor selective collection and recycling of CDW.

- The existence of quality standards and norms which apply to recycled CDW and ensure the circulation and marketing of a high quality product, ready for use in new construction projects.

Recycling capacity

- Adequate number and extensive network of CDW treatment facilities covering satisfactorily the countries.

Legislative framework

- Strong legal framework that enables a good level of CDW management leading to higher recycling rates of CDW.
- 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 also considered as an important driver.

<u>Barriers</u>

Market conditions

- Low prices of natural raw materials undermine the market circulation of recycled materials which usually bear higher costs due to the treatment and recycling processes.
- Lack of trust in recycled CDW materials, despite the fact that they fulfil requirements and quality standards equal to the primary raw materials.
- Small market for recycled materials, as a direct result of both the above barriers in the use of recycled CDW by the construction sector actors.
- In some countries which are achieving high recycling rates, the market may not be able to absorb the quantities of recycled CDW in the future.
- In some countries low prices of natural raw materials.

Recycling efficiency

- Mixed CDW materials and/or the presence of hazardous substances in CDW makes recycling difficult.

Legislative framework

- No overarching legislation, especially in the case of MS with decentralized waste management.
- Non-specific CDW legislation, relying mostly in soft steering frameworks such as Waste Management Plans or Local government regulations.

21.5.2 Recycled materials from CDW

One of the main issues for the incorporation of recycled materials at construction works is the higher price of recycled materials in comparison to natural raw materials.

In Portugal, the Decree-Law 46/2008 of 12 March, which establishes the legal framework for CDW management, outlines that the incorporation of CDW at construction works must comply with national or EU standards or in their absence with technical guidelines defined by the National Laboratory for Civil Engineering (article 7). This entity has established four technical requirements to date, namely:

- E 471/2009 - Guide for the use of recycled coarse aggregates in concrete: establishes the minimum requirements that the coarse recycled aggregates covered by EN 12620 must comply with in order to be used in concrete;
- E 472/2009 - Guide for the production of recycled hot mix asphalt86: classifies reclaimed asphalt materials covered by EN 13108-8 and provides guidelines for their use in hot mix recycled asphalt;
- E 473/2009 - Guide for the use of recycled aggregates in unbound pavement layers: establishes the requirements that recycled aggregates covered by EN 13242+A1 and EN 13285 must comply with in order to be used in unbound sub-base and base pavement layers;
- E 474/2009 - Guide for the use of construction and demolition recycled materials in embankments and capping layers88: establishes the minimum requirements that construction and demolition waste must comply with in order to be used in embankment and capping layer of transport infrastructures.

In the meantime, the National Laboratory for Civil Engineering, together with the Portuguese Environment Agency, are developing the following technical standards which are set to be applied to the CDW in construction works:

- Materials for rural, agricultural or forestry roads;
- Materials for filling ditches (backfilling);
- Materials for sub-base and base layers resulting from asphalt mixtures.

21.5.3 Market conditions / costs and benefits

Economic instrument is indubitably perceived as effective for encouraging or forcing contractors to conduct environmentally friendly construction practices. The initiatives that have been analyzed from of point of view that presents financial incentives for increased recycling, such as landfill taxes, shows particularly good practices and results in terms of CDW prevention and management in the waste market.

In Portugal, direct financial incentives to recycle CDW do not exist. However, a landfill tax for inert CDW exists, established in the Decree-Law 46/2008 of 12 March (CDW legal framework; with the main purpose of divert these wastes from landfill disposal. Currently this tax is € 4.28 per tonne. Case studies are not available on this subject.

In Portugal, aggregates and other natural raw materials scarcity is not a problem. At present, there are two major obstacles regarding CDW recycling identified by the stakeholders. Firstly, Portugal's economy still faces difficulties and the construction sector has not recovered yet. Secondly, the prices of the recycled materials are higher than natural raw materials. Currently EoW criteria for aggregates and/or other materials do not exist. In Portugal the role of construction materials producers and construction operators insurers (in the process of marketing and use of recycled CDW as construction materials) is not clear.

Regarding the recycling contents and recyclability, the environmental product declarations (EPDs) and the Green Public Procurement (GPP) criteria for construction products only consider general principles, they are not specific for CDW.