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Emerging Challenges of Waste Management in Europe

Limits of Recycling

Final Report

Trinomics

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Emerging Challenges of Waste Management in Europe

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Abbreviations

C&DW	Construction and demolition waste
DMC	Domestic material consumption
EAP	Environment Action Programme
EC	European Commission
EEA	European Environment Agency
EEE	Electrical and electronic equipment
EP	European Parliament
EU	European Union
LoW	List of Waste(s)
MS	Member State(s)
MSW	Municipal solid waste
PET	Polyethylene terephthalate
POM	Placed on the market
UMD	Unmet material demand
WEEE	Waste electrical and electronic equipment
WFD	Waste Framework Directive

Key messages

The following key messages can be drawn from this report:

- There is **potential to increase the percentage of material collected for recycling** in the C&DW, MSW and WEEE waste streams. In absolute terms, the largest potential appears to exist in the MSW stream, calculated at approximately **111 or 139 million tonnes** (depending on the method used). In relative terms, WEEE shows the highest increase in potential recycling (**+103%** or **+112%**, depending on the method used);
- The most important **barrier** to the recycling of C&DW, MSW and WEEE is the **low market price for natural resources/virgin raw materials** followed by the mixed and complex composition of the waste stream, which causes problems in waste treatment (processing);
- A **high degree of regulation and high levels of enforcement** appear to be the most important **enablers** for the recycling of C&DW, MSW and WEEE followed by measures that can help improve the economics of recycling.

Executive summary

In light of increasing recycling targets at European level, this report aims to assess the limits of such ambitions and to better understand the emerging challenges of waste management, as well as the factors that could improve recycling performance in Europe.

Maximum recycling potential

The report covers three waste streams: construction and demolition waste (C&DW) (particularly, mineral C&DW)[1], municipal (solid) waste (MSW), and waste from electrical and electronic equipment (WEEE). The definition of recycling potential used in this study reflects the amount of waste that can potentially be collected for recycling (in line with reporting requirements and targets of current EU waste legislation.[2] The definition, therefore, reflects limitations that relate to source separation of waste. **Maximum recycling potential** in this study is defined as follows:

$$Maximum\ recycling\ potential = \frac{\text{Maximum collection potential (for recycling)}}{\text{Waste generated}}$$

Two different methods were used to assess the maximum recycling potential (i.e. the limits of recycling) in Europe for each of the three waste streams:

1. **Bottom-up (literature review) approach**, which broke down each waste stream into material fractions. The recycling potential of each fraction was then combined to make an assessment of the overall recycling potential of the waste stream;
2. **Top-down (benchmarking) approach**, which took the best European performance as a benchmark. The benchmark was then applied to the whole waste stream.

[1] Unless otherwise stated, all analysis on this waste stream focuses on the mineral portion of it, which constitutes close to 92% of the waste stream.

[2] Please note that the calculation of MSW recycling targets beyond 2020 are required to reflect the weight of municipal waste that *enters* recycling, and should exclude losses that occur prior to this. However, the target for 2020 can be measured by the waste *collected* for recycling.

The results of the analysis are presented in Table 0-1 below.

Table 0-1 Current recycling rates versus estimated recycling potential, per waste stream

Waste stream	Current recycling rate	Recycling potential (bottom-up)	*Change from current recycling (%)*	Recycling potential (top-down)	*Change from current recycling (%)*
C&DW[3]	74%[4]	96%	*+30%*	96%	*+29%*
MSW	43%	80%	*+88%*	90%	*+110%*
WEEE	37%	78%	*+112%*	75%	*+103%*

Source: Own development.

It should be noted that the results of the analysis are subject to a number of limitations. The bottom-up approach is highly influenced by the availability and quality of data and literature, which sometimes varies in its definition of 'maximum recycling potential'. Furthermore, the break-down of the waste streams into material fractions is based on an 'average' break-down of materials, whereas this might vary from country to country. The top-down method faces the question of how transferable one benchmark is to the whole of Europe, as each country has its own unique barriers and challenges. In addition to this, each waste stream has a different size 'pool' of potential 'benchmarks' (or historical data). This means that some benchmarks may be more reliable than others. It is important to note that no comparison has been made between the results of the two methods.

This report also considers the effect of higher recycling ambitions against the quality of recycling. In other words, if waste collection targets continue to rise, it is essential not only for the capacity of facilities to recalibrate to this influx of waste, but for waste quality (i.e. the heterogeneity of waste collected) to be effectively managed to ensure separation of recyclates. This is a future challenge of waste management operations.

Main barriers to recycling

We conclude that, according to literature, the most important barrier to the recycling of C&DW, MSW and WEEE is the *low market prices for natural resources / virgin raw materials*. In combination with low landfill taxes in some cases and high costs of treatment overall, this affects the viability of recycling of these three waste streams. The recovered products struggle to remain competitive in relation to cost, quantity and quality with the virgin alternative. Another significant barrier to the recycling of C&DW, MSW and WEEE is the *mixed and complex composition of the waste* stream, which causes problems in waste treatment (processing) with contamination by hazardous materials. This is a particular problem for WEEE and C&DW. Other key barriers are the *lack of end of waste criteria*, which constrains the collection of C&DW waste as well as MSW. The *lack of a suitable network of recycling infrastructure or facilities* for collection, separation and treatment is a problem for C&DW and WEEE. For MSW and WEEE, another barrier is that collection of *waste requires citizens to participate*. MSW and WEEE also face issues with adequate *enforcement of regulation and sanctions* for those engaging in illicit activities.

[3] Referring to mineral C&DW only.
[4] Recycling rate of mineral waste without backfilling quantities included.

Main enablers for improving recycling

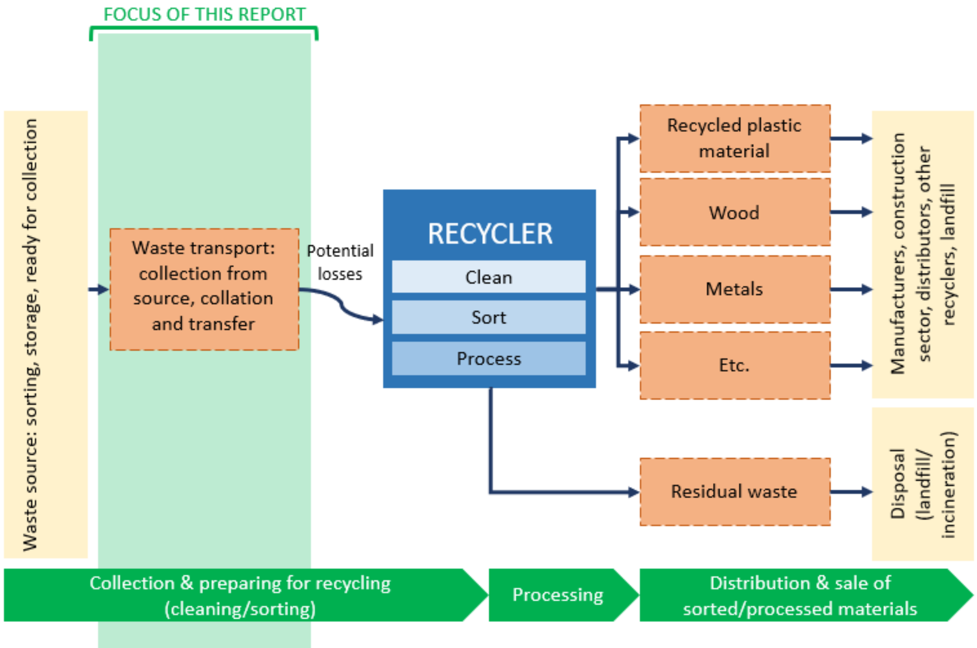
A *high degree of regulation* and *high levels of enforcement* appear to be the most important enablers for all three waste streams. Adequate *punishment (i.e. sanctions) for offenders* are specifically mentioned as important for MSW and WEEE recycling. Overall, while the details vary, leading nations tend to have effective packages of policy levers in place. Measures that can help the economics of recycling become more viable, and support the waste hierarchy are found in literature for all C&DW, MSW and WEEE. For C&DW and MSW, f*inancial incentives such as landfill taxes* to discourage landfilling are common enablers. *Design for disassembly* is an enabler for all three waste streams. For C&DW and MSW an enabler for successful recycling is having a sufficient number of *waste treatment facilities* that can deal with key material streams.

1 Introduction

The overall aim of this report is **to better understand the emerging challenges of waste management in Europe and the upper bounds of recycling in terms of collection potential**. It is important to note that, when referring to maximum recycling or recycling potential, the report primarily focuses on amounts of waste that can be **feasibly collected for recycling** **(i.e. maximum recycling rate (%) = maximum collection potential (for recycling) / waste generated)**, in line with the reporting requirements and targets of current EU waste legislation. This can be distinguished from the technical potential for recycling, which corresponds to the ratio between final recycled amounts versus amounts collected for recycling. The technical potential refers, for example, to reject rates of different waste streams during sorting and the technical limitations of recycling plants. The definition of recycling potential used in this study reflects the amount of waste that can potentially be collected for recycling, reflecting limitations that relate to source separation of waste (see Figure 1-1). Examples of these limitations are difficulties due to composite materials that cannot be separated in a mono-material recycling scheme (though it is possible to separate and recycle some composite materials), difficulties of consumers in recognising materials and the presence of foreign materials in products (e.g. paper labels on plastic bottles), etc.

On the other hand, the technical potential for recycling relates to the technological limitations of sorting plants to separate materials from each other and the technical limits in recycling plants (e.g. some paper fibres are too short to be recycled). More information on such losses and the recycling flow of various material fractions relevant for this report can be found in the study supporting the development of the recent Commission Implementing Decision (EU) 2019/1004 laying down new rules for the calculation, verification and reporting of data on waste in accordance with the Waste Framework Directive (Eunomia Research & Consulting et al., 2019).

Figure 1-1 The different steps in the recycling chain



Source: Own development, adapted from Srinivasan et al. (2016).

This report focuses on three waste streams: construction and demolition waste (C&DW), municipal (solid) waste (MSW), and waste from electrical and electronic equipment (WEEE), as for each of these streams there is a recovery or recycling target in place within the European legislation. For C&DW, the focus of the report is only on mineral C&DW, due to a lack of data on recycling rates of non-mineral C&DW. Mineral waste of C&DW makes up approximately 92% of the total C&DW stream, as reported by Eurostat (2019b). For each of these waste streams, we have reviewed the existing literature to investigate the **maximum recycling level** (focussing on collection for recycling) that can be achieved. This maximum potential is compared to current recycling levels in Europe[5], and is linked to existing recycling targets, as defined by relevant EU legislation. Based on an analysis of the divergence between current and potential recycling, the report seeks to identify the hurdles that stand in the way of achieving higher recycling rates, as well as the enabling factors that could contribute to improved waste management in the future.

The report is structured as follows:

1. **Introduction;**
2. **Presentation of the waste streams;**
3. **Recycling gaps;**
4. **Barriers to recycling;**
5. **Enabling factors and the way forward; and,**
6. **Conclusions.**

The aim of **Chapter 2** is to provide an overview of the definitions, targets, and material composition of the three waste streams in question. **Chapter 3** provides a description of the methodology used to quantify the maximum recycling potential of each waste stream, as well as the gaps that result from the data analysis. Alongside this report, we have prepared an Excel document containing data on waste generated and recycled, per material fraction (where possible). Meanwhile, **Chapters 4 and 5** look into barriers to recycling and the enabling factors that could improve recycling in the future. Conclusions are presented in **Chapter 6**.

[5] The geographic scope of the report is the EEA countries, at an aggregated level.

2 Presentation of the waste streams

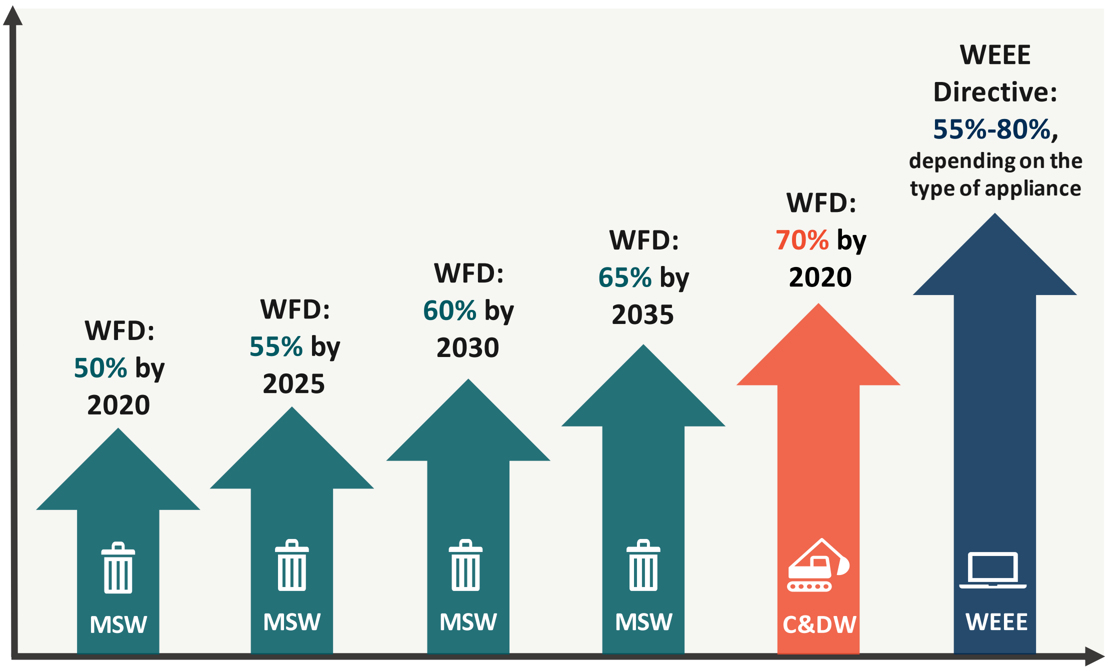
Waste policy in Europe has evolved over the last two decades through a series of environmental action plans and a framework of legislation that aims to reduce negative environmental and health impacts and helps create a more energy and resource-efficient economy. The **Waste Framework Directive (WFD) (2008/98/EC)** is a key piece of European legislation in this area, and is responsible for framing **waste as a valued resource** (EC, 2010). The Directive was recently amended in the context of the Circular Economy Package (EC, n.d.[a]), along with other important directives such as the Landfill (2018/850/EU). The directives were amended to include, inter alia, a number of new targets and measures beyond 2020, with the objective of moving closer to a circular economy where waste is managed as a resource. To achieve this, preparing for re-use and recycling are critical treatment operations (EC, 2019a). In light of increasing recycling targets at European level, this report aims to assess the limits of such ambitions given the current (maximum) potential of waste collection and preparation for recycling.

Recycling is defined in the WFD as *"any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations"* (EU, 2008). For the three waste streams in question, targets for recycling have been established at EU level (Figure 2-1). With regard to C&DW and MSW, the methods used to calculate these targets were established through Commission Decision 2011/753/EU and remain valid for the 2020 targets. Some revisions have been made on the reporting requirements of waste statistics and the methods for calculation progress towards the targets set for 2025 and onwards (Commission Implementing Decision (EU) 2019/1004). In relation to WEEE, a calculation method of recovery targets is established in Directive 2012/19, whereas an approach to calculating the weight of EEE placed on the market is established in Commission Implementing Decision (EU) 2017/699. More detail on the methods for calculating the targets, the definition, and material composition of each of the waste streams are described below and in Annex I.

Box 2-1 Possible implications of more ambitious recycling targets

An important point to consider throughout this report is that increasing the collection of waste for recycling is likely to result in implications for waste treatment and subsequent waste markets. If waste collection targets continue to rise, it is essential not only for the capacity of facilities to recalibrate to this influx of waste, but for waste quality (i.e. the heterogeneity of waste collected) to be effectively managed to ensure separation of recyclates. This will require efforts to introduce efficiency waste sorting and collection systems, in addition to raising consumer awareness (EEA, 2019). Furthermore, increasing the collection of waste could have impacts on waste exports. For example, if waste collection rates exceed the quantities that management systems can successfully process then a consequence could be that waste exports (potentially to areas with less stringent waste management regulations) increase.

Figure 2-1 Recycling targets for C&DW, MSW and WEEE



Source: Own development based on information extracted from the WFD and the WEEE Directive.
Note: The C&DW target includes backfilling and the WEEE target varies depending on the type of appliance[6].

Construction and demolition waste

Construction and demolition waste (C&DW) is the waste generated by the **construction, maintenance, demolition and deconstruction of civil works and buildings** (JRC, 2018). The waste stream contributes approximately one third of all waste generated in Europe (EC, 2014). The main directive which governs C&DW is the **Waste Framework Directive (2018/851)**, which establishes a target of 70% (of weight) of construction and demolition non-hazardous waste to be recovered by 2020. **Commission Decision 2011/753** provides an overview of which material fractions should be established in waste recovery calculations by countries, where 27 waste types are listed as being covered by the target. These wastes are shown in Annex I. Within this list, hazardous substances are excluded, as are the majority of soils. Something to consider when assessing C&DW recovery statistics is data on 'backfilling' activities. Backfilling is a low-quality form of recovery, which includes using the material for the reclamation of excavated areas, landscape engineering and landfill covering (Deloitte, 2017). This form of recovery should be a 'last resort' option, and has, therefore, been excluded from recycling rates in this report (unless otherwise stated). Further information on backfilling and its consideration within the context of recycling potential is presented in Chapter 3.

Municipal solid waste

Municipal solid waste (MSW) makes up approximately **10% of total waste** generated in Europe, and consists of waste collected **by or on behalf of municipal authorities** through the waste management system (JRC, 2018). MSW results from household waste and waste from other similar sources (e.g. restaurants, offices, schools), and includes **both mixed and separately collected waste**, making it a challenge to manage (Eurostat, n.d.[b]; JRC, 2018). As with C&DW, the main directive governing MSW is the **Waste Framework Directive (2018/851)**, which

[6] Targets for WEEE are relevant for the current period defined in the WEEE Directive, which started on the 14th of August 2018 – no end date to the period is specified.

establishes a target of (minimum) 50% of municipal waste to be prepared for re-use and recycling by 2020; 55% by 2025; 60% by 2030; and 65% by 2035.[7] Progress towards the 2020 target can be measured in four alternative ways, as established by Commission Decision 2011/753. Some calculation methods focus on recyclable materials such as paper, metal, plastic and glass, while others are more general (see Annex I for more information). The targets for 2025 and beyond refer to total municipal waste generated. Commission Implementing Decision (EU) 2019/1004 describes the new methodology behind the calculation, verification and reporting of data on municipal waste as of 2025. The WFD also states that the calculation of the recycling targets, beyond 2020, should be based on the weight of municipal waste that enters recycling (and should exclude any losses that occur prior to this). This is important because the target for 2020 can be measured by the weight of waste collected for recycling and any losses that occur during the recycling value chain (e.g. because of contamination) are not necessarily deducted[8]. As such, data on recycling in this report might include materials that are removed during the sorting process and might not be recycled. Recent literature refers to losses in weight occurring after collection and during the recycling value chain (Eunomia Research & Consulting et al., 2019).

Waste electrical and electronic equipment

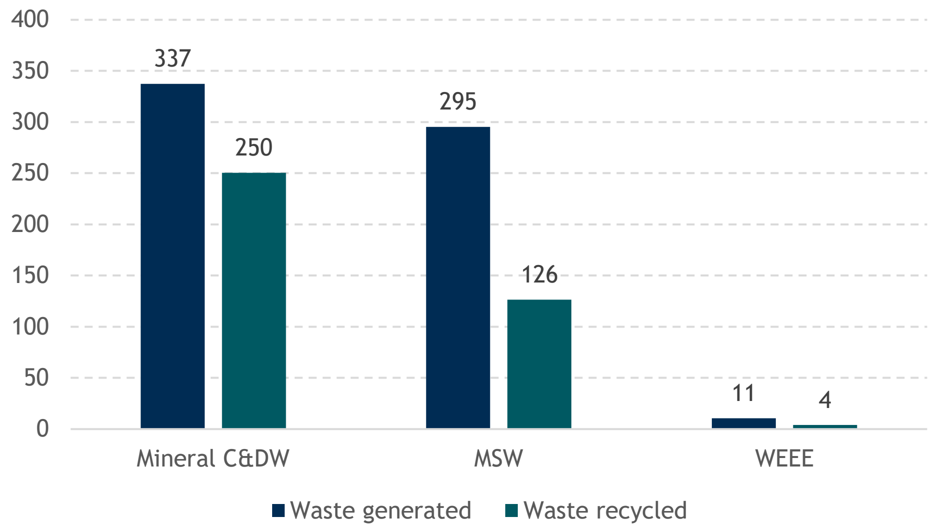
Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams in the EU (+3-5% per year), with approximately **10 million tonnes generated per year** (EEA, 2019; EP, 2018). The waste stream includes both **large and small appliances and electronic equipment** such as computers, TV-sets, fridges and cell phones. The first WEEE Directive (2002/96/EC) grouped EEE into 10 primary categories (EU-10) for which statistics on collection, recovery, and recycling of WEEE needed to be collected, while the recast of the **Directive (2012/19/EU)** regrouped EEE into six categories (EU-6). The classification systems and the material composition of WEEE is further described in Chapter 3 and Annex I. Directive (2012/19/EU) also introduced new targets for collection (65% of annual EEE placed on the marked (POM) in the preceding three years, or 85% of WEEE generated), recovery (75%-85%, depending on the EEE category), and reuse and recycling (55%-80%, depending on the EEE category). The method for calculating the weight of EEE placed on the market can be found in **Commission Implementing Decision (EU) 2017/699**, and can be used to calculate WEEE (see Annex I).

[7] Countries that prepared less than 20% of their municipal waste for re-use and recycling or landfilled more than 60% of their municipal waste in 2013 can apply for derogations to extend the time for complying with these targets.
[8] Some countries may deduct losses to some extent, but there is no clear overview of this.

3 Recycling gaps

The three waste streams which are covered in this study vary in their scale, current level of recycling, and potential for further recycling improvements. As shown in Figure 3-1 below, gaps remain between how much waste is generated and how much is collected for recycling, which could be further exploited. The purpose of this section is to further explore this ‘gap’, by **estimating the maximum potential recycling rates of each waste stream**. As highlighted in the previous chapter, the term ‘maximum recycling potential’ relates to the maximum quantities of waste which can be feasibly collected (for recycling). This refers to waste that is transported to processing facilities, but importantly this does not include the next stage of the recycling process - the technical sorting and processing, and conversion of waste into new materials.

Figure 3-1 Waste generated and recycled (in million tonnes)



Source: Eurostat (2020; 2019b; 2019c; 2019d) and EC (2019b).
Note: For C&DW, the data covers 30 EEA countries and only refers to non-hazardous mineral waste; for WEEE, the data covers 31 EEA countries; and for MSW, the data covers 32 EEA countries. Data for C&DW is from 2016, for MSW, 2017-2018 (depending on data availability), and for WEEE, 2014-2017 (depending on data availability).

Each waste stream studied shows significant potential for further recycling, with **WEEE showing a potential increase of 103% or 112%** compared to current recycling levels, depending on the method used. This is followed by MSW (+88% or +110%, depending on the method) and C&DW (+29% or +30%, depending on the method) (Table 3-1).[9] In absolute numbers, the widest gap between current and potential recycling can be found in MSW, representing nearly 111 or 139 million tonnes of waste, depending on the method used. A summary of the findings is presented in Table 3-1 below.

These figures should be approached with caution as uncertainties with data exist in each waste stream, and the different methods used to calculate the recycling potential of each waste stream have some limitations. The most significant of these inconsistencies resulted from a lack of data surrounding material fractions. For example, in C&DW, few estimates regarding the composition of mineral waste

[9] For each waste stream, two methods of calculating potential recycling were used, so the percentage increase between current and potential recycling varies depending on the method used.

could be located, despite this sub-stream constituting a significant proportion (approximately 92%) of C&DW. Furthermore, most estimates on the material composition of the different waste streams are often based on (rather infrequent) sampling exercises. This means that the actual composition of waste streams may vary with changes in consumer behaviour, with technological improvements (e.g. in the case of WEEE), and economic growth. Furthermore, when it comes to MSW, there are different ways of calculating countries' recycling performance vis-à-vis the target set by the WFD. Eurostat provides guidance on how to harmonise this data across countries, but some countries may not fully adhere to the guidance. Further information on the methods used to calculate recycling rates across the different waste streams, as well as data uncertainties surrounding these methods can be found in Annex I. Consequently, the potential recycling quantities and rates, as described in this report, should only be considered as **estimated** figures.

Methodological notes

To calculate the maximum recycling rates for each of the three waste streams, two methodological approaches have been used. The results of the different approaches provide two possibilities on where the future recycling potential stands in Europe. The two approaches are as follows:

1. **Bottom-up (literature-review) approach:**
    - Each waste stream was split into their respective material fractions;
    - A literature review was conducted to find information on the recycling potential of each material fraction;
        - When literature was lacking, assumptions were made based on current recycling achievements in Europe;
        - For example, each waste stream has an "other" category of material fractions. In this case, we assumed that there is potential to recycle part of this fraction, but that this potential is not high. Given the lack of information on the composition of this category and on its recyclability, we applied the European recycling rate (per waste stream) to this fraction as an optimistic estimate;
        - The evidence base used for each waste stream is listed in Annex II, along with explanations on what data and information was extracted from each source, and what assumptions have been made for each material fraction (if applicable);
        - As shown in Annex II, the way maximum collection for recycling is defined varies across the different sources used.
    - The total 'potential' (i.e. adding up the potential of each material fraction) was divided by the total amount of waste generated;
2. **Top-down (benchmarking) approach**, whereby the best performing country (or municipality) was selected as a benchmark for the whole of Europe (at a waste stream level).

Both of the methodological approaches have limitations. In the first case, the results of the calculations are subject to the availability of data and literature. Furthermore, data on waste generated was broken down by material fraction according to data on average material composition of different waste streams. This break-down was used as the basis of calculating the potential recycling rate of each material fraction. In practice, the material composition of the waste streams differs across Europe, depending on a variety of factors, such as economic wealth, technological development, consumption patterns, etc. Due to these limitations, the analysis done using the 'bottom-up' approach, was complemented by the 'top-down' approach.

However, the benchmarking (top-down) approach faces its own limitations. For example, in a number of cases, recycling rates, as reported on Eurostat, exceeded 100%. This apparent contradiction results from the fact that it is possible for countries to keep (or collect, as a result of a publicity campaign) some stocks of waste from previous periods and to recycle them in subsequent periods. The benchmarking method is also subject to transferability limitations. A high recycling rate in a certain country or municipality may not be transferable (in the same way) to another country or municipality for a variety of reasons such as urban planning, costs, infrastructure, and high citizen engagement requirements. The transferability of 'best practices' is, thus, contingent upon numerous characteristics that are unique to each country, region, or municipality. Examples of barriers, which may vary across geographic areas, are presented in Chapter 4. Furthermore, the selection of benchmarks was constrained by the available 'pool' of potential 'benchmarks' (or historical data). Studies on best practices of municipal waste management are selected from a large pool of municipalities in Europe; whereas data on the collection of WEEE, for example, is obtained at national level and the systems that are in place to collect WEEE are still relatively new.

It is important to remember that **each method is subject to its own limitations and assumptions**, and that the results of each method should be considered as **distinct results**, rather than a range of possibilities. No further analysis has been made to compare the credibility of the different results, so no one method can be regarded as being more conclusive than another.

The main source of data that was used across all waste streams was Eurostat. When necessary, the data was complemented by data from other studies or datasets. All sources are referenced accordingly in the following sections. The methods used to calculate the maximum recycling potential are also described in more detail in the following sections.

Based on the two methods described above, the following results were found:

Table 3-1 EU recycling rates, recycling potential and recycling targets

Waste stream	Current recycling rate	Recycling potential (bottom-up)	*Change from current recycling (%)*	Recycling potential (top-down)	*Change from current recycling (%)*
C&DW[10]	74%[11]	96%	*+30%*	96%	*+29%*
MSW	43%	80%	*+88%*	90%	*+110%*
WEEE	37%	78%	*+112%*	75%	*+103%*

Source: Own development.

3.1 Construction and demolition waste

3.1.1 Waste generated

As shown in Annex I, the main non-hazardous material fractions of waste generated from construction and demolition activities are **mineral, metal (ferrous), and wood wastes**, respectively. Mineral waste is the majority material fraction, accounting for **approximately 92%** of waste from construction and demolition (excluding soils[12]) (Eurostat, 2019b). Within the mineral waste sub-stream, the main fractions are estimated to be concrete, masonry and asphalt (Galvez-Martos et al., 2018).

[10] Referring to mineral C&DW only.
[11] Recycling rate of mineral waste without backfilling quantities included.
[12] Soils are not included in Annex III of Decision 2011/753/EU.

3.1.2 Current recycling

A factor to consider when looking at waste recovery of C&DW is the backfilling quantities reported by EEA member states. Backfilling activities that fall within the scope of the Waste Framework Directive include: reclamation of excavated areas (by filling these areas with earth and environmentally suitable construction waste), landscape engineering (the shaping of land), and landfill covering (the final soil layer placed above capped landfill sites) (Deloitte, 2017). Backfilling is a *low-quality form of recovery* (Deloitte, 2017), and is recommended to be used as a 'last resort option' as it can undermine incentives to re-use or recycle into higher value applications (Ecorys, 2016). Due to differences in the definition of materials and activities which are suitable for backfilling, countries can utilise such waste in various ways. This can result in contrasting integration of C&DW backfilling within recycling figures (Deloitte, 2017).

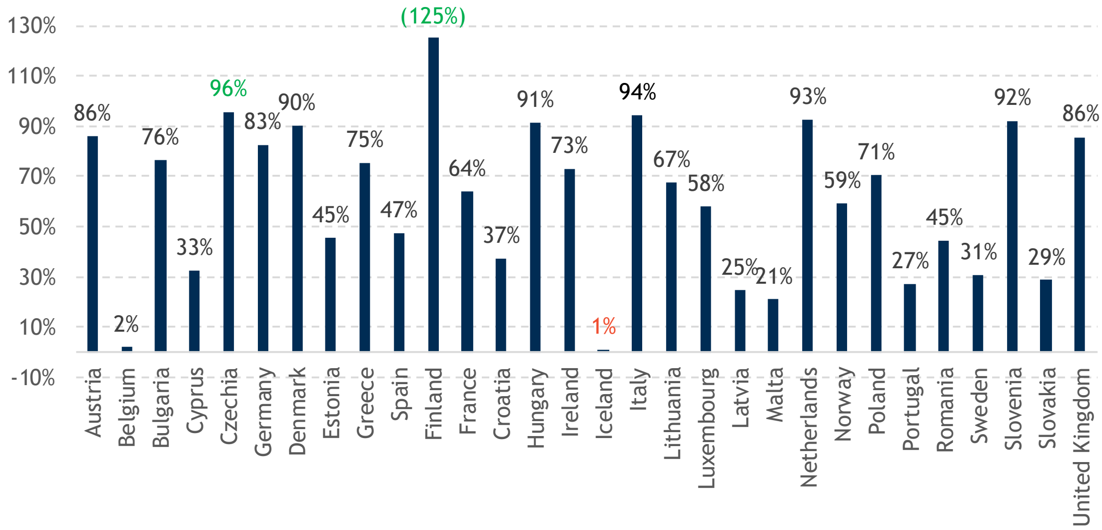
Bearing these points in mind, Eurostat 'was_trt' data from 2016 shows that the average backfilling rate for waste treatment of non-hazardous mineral waste from construction and demolition is estimated at 4%[13] (with a total reported mineral waste backfilling quantity of 11.2 million tonnes). A number of countries do not report data on backfilling operations, even though they are known to carry out backfilling activities (Deloitte, 2017).

Eurostat allows for data on reported recovery of mineral waste to be isolated, with and without backfilling inclusion in recycling statistics. When backfilling of mineral waste data is removed from recovery figures, approximately **250 million tonnes of mineral waste** are currently reported as being recycled, at an average recycling rate of 74% across EEA-30[14]. These values should be approached with caution, because, as stated above, reported recycling data may include backfilling operations in certain countries where backfilling appears to be inexistent. The analysis presented in section 3.1.3 below incorporates backfilling within potential recycling calculations, based on the assumption that some of the C&DW that is backfilled (outlined in Annex I) could be recycled.

As shown in Figure 3-2 below, the recycling performance varies greatly in EEA-30 countries.[15] The highest recycling rate (considered in this study) of mineral waste in 2016 was achieved by Czechia[16], with 96% of mineral waste generated being recycled; meanwhile, Iceland only recycled 1% of its mineral waste.

[13] The backfilling rate was calculated by dividing backfilling quantities by waste generated data for EEA-28 (excluding Germany and Luxembourg due to no backfilling data).
[14] No data available for Liechtenstein, Switzerland and Turkey. In addition, it should be noted that the recycling rates were calculated by dividing mineral waste recycled data by mineral waste generated data (envwas_gen). In six of the 30 EEA countries assessed, data on waste generated was reported higher within the 'env_wastrt' database than the 'env_wasgen' database, meaning that their calculated recycling rates would be lower than currently calculated. The difference between the datasets may be explained by the fact that the 'env_wastrt' data includes data on imports and exports of waste, meaning that some countries can process more waste than they generate while others have a lower capacity to process waste.
[15] Excluding Liechtenstein, Switzerland, and Turkey due to no data.
[16] As stated in footnote #14, contrasting data regarding waste generated is formulated depending on whether data is extracted from Eurostat databases (env_wasgen) or (env_wastrt). Using the (env_wasgen) data for Finland, a recycling rate of 125% has been calculated, which may be due to the fact that Finland treats more waste than it generates. As such, this value has not been used as part of the top-down approach. Instead, the next best calculated recycling rate of Czechia has been used.

Figure 3-2 Recycling rates of mineral waste from construction and demolition in 2016 in EEA-30 countries



Source: Eurostat (2019b; 2019c).

Note: The recycling rates in the above figure have been calculated as 'waste recycled' divided by 'waste generated'. Due to imports of waste, countries may recycle more waste than they generate. This may have been the case in Finland in 2016, as the country's recycling rate exceeded 100%. As such, all further analysis on maximum recycling potential (using the top-down approach) will use the next highest recycling rate, Czechia (96%).

3.1.3 *Maximum recycling*

To calculate the maximum recycling rates of mineral waste, two methods were used. The **first method** (bottom-up approach) consisted of the following steps:

- **Step 1:** As described in the previous sections, total C&DW waste generated was broken down into waste generated per material fraction for mineral waste (Table 3-2)[17];
- **Step 2:** A literature review was conducted to form an evidence base of assumptions on (maximum) recycling rates, per material fraction (as cited in Table 3-2 below);
- **Step 3:** The maximum recycling rates found in the literature were applied to the material-specific quantity of C&DW mineral generated;
- **Step 4:** The quantity of waste (of each material fraction) with the potential to be recycled was used to estimate the tonnes of waste that could be recycled if EEA-30 countries achieved the highest possible rate of recycling (as found in literature);
- **Step 5:** The number found in Step 4 was divided by the total waste generated in the EEA-30 to derive a maximum recycling rate for C&DW.

[17] Estimates for the material fraction composition of C&DW were taken from Galvez-Martos et al. (2018). The report provided a range of material-fraction estimates per material component of mineral waste, with the average percentage calculated per material totaling 78%. The range of material fractions provided in Galvez-Martos et al. (2018) referred to the whole waste stream, not just mineral waste, which makes up 91.6% of the waste stream. Therefore, the average material fraction from Galvarez-Martos et al. (2018) were upscaled to 100% of mineral C&DW waste.

Table 3-2 Potential recycling rates of construction and demolition mineral waste fractions

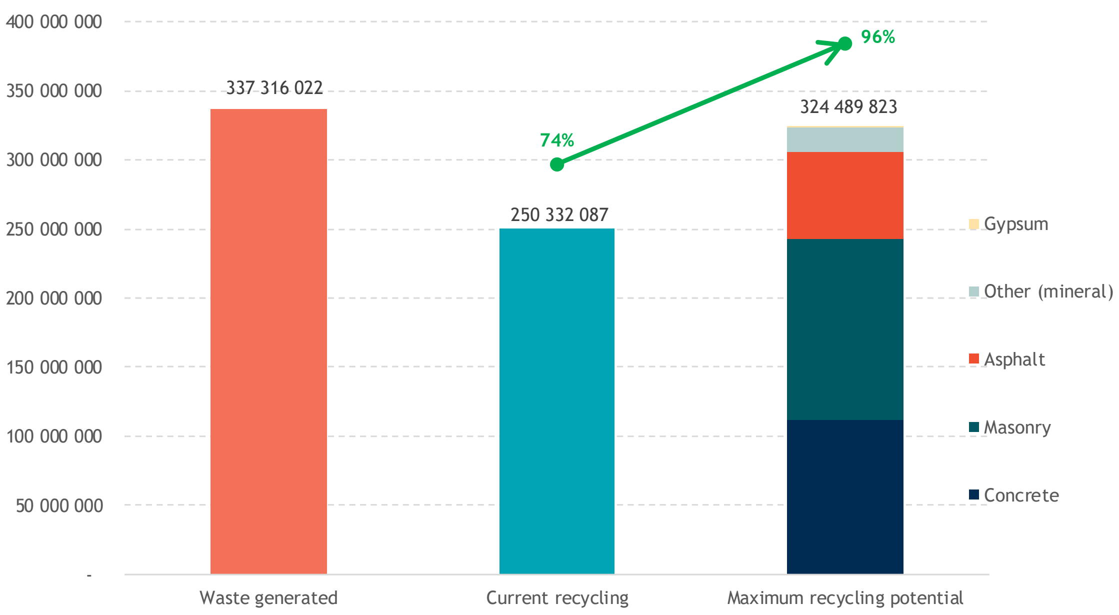
Material fraction	Maximum recycling potential (%)	Maximum recycling potential (t)	Evidence base or assumptions
Concrete	99%	111,600,442	Kleemann et al. (n.d.)
Masonry	98%	131,718,004	Kleemann et al. (n.d.).[18]
Asphalt	97%	63,084,166	Poulikakos et al. (2017).
Gypsum	30%	390,211	Vrancken and Laethem (2000).
Other mineral waste	74%[19]	17,696,998	EEA-30 recycling rate - without backfilling.
Total	-	**324,489,823**	-

Source: Own development with data from Eurostat (2019b; 2019c) and various other sources referenced in the table.

Note: An elaborated version of this table is presented in Annex II, further detailing what the maximum potential recycling rate refers to in each study.

As shown, if we assume that these material fractions make up 100% of mineral waste composition, then the maximum recycling rate for mineral waste reaches **over 324 million tonnes** (or **96%** of mineral C&DW generated). When compared to the current recycling rates of mineral waste, this estimates that a recycling gap of approximately **74 million tonnes** of waste exists in EEA-30.

Figure 3-3 Current and maximum recycling rates of mineral waste from construction and demolition in tonnes (in 2016, EEA-30), using the bottom-up approach

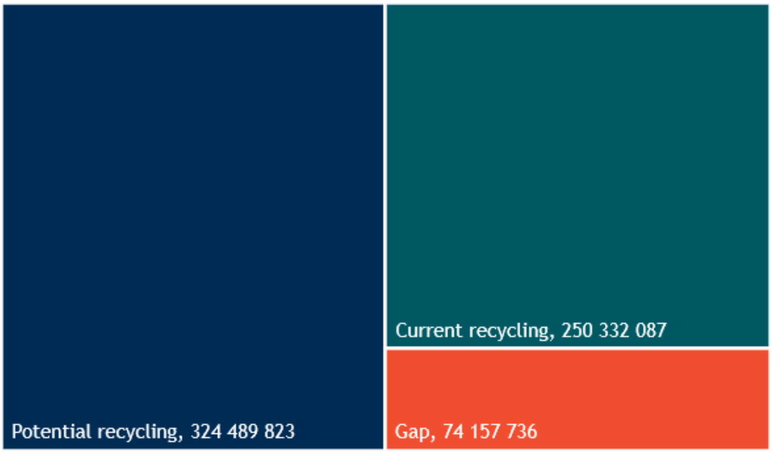


Source: Own development, with data from Eurostat (2019b; 2019c) and various other sources, as shown in Table 3-2.

[18] For masonry, the data from Kleemann et al. (n.d.) is presented in various waste management streams (with demolition material available for 'cement', 'other sectors' and 'reuse in the building stock'). As such, the cumulative quantities of brick collected for each of these waste management streams was calculated and compared to the overall brick output from demolition, resulting in a total of 98% of bricks collected for recycling.

[19] As no specific data on the composition or recycling potential of 'other mineral waste' could be found. As such, this remains an optimistic estimate.

Figure 3-4 Recycling gap for mineral waste from construction and demolition in tonnes (in 2016, EEA-30), using the bottom-up approach

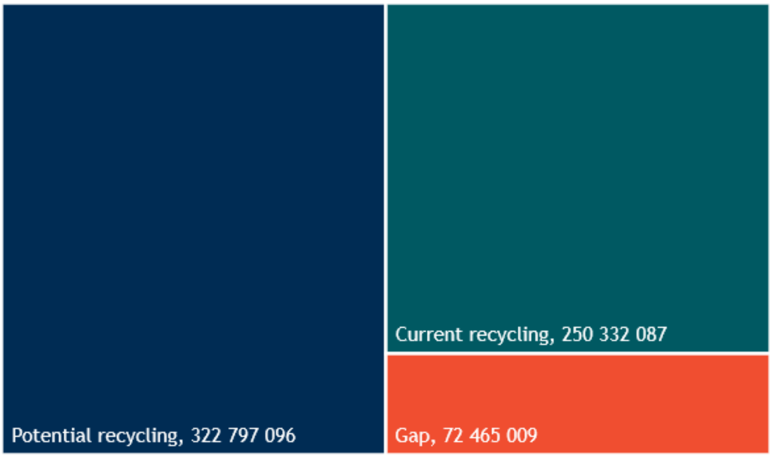


Source: Own development, with data from Eurostat (2019b; 2019c) and various other sources (see Table 3-2).

The Eurostat 'was_trt' database also provides data on the amount of waste that has been backfilled in Europe. In 2016, backfilling quantities reported by EEA-30 countries amounted to **10.6 million tonnes** of waste (although it is worth noting that several countries did not report any backfilling data). Due to a lack of information on the exact composition of backfilling waste, no further analysis has been done on backfilling quantities However, in a scenario where recycling potential is maximised, it can be assumed that backfilling quantities will be recycled to their maximum potential.

A **second method** (top-down approach) to estimating the maximum recycling rate of mineral waste from C&D utilises the country with the highest recycling rate as a benchmark for potential recycling across the entire waste sub-stream. As is shown in Figure 3-2 above, the highest recycling rates of mineral waste in 2016 was 96% (Czechia).[20] Given a 94% potential recycling rate across all EEA-30 countries, the quantity of mineral waste that could be recycling results in over **322 million tonnes** (i.e. more than 72 million additional tonnes in comparison to what is currently recycled).

Figure 3-5 Recycling gap for mineral waste from construction and demolition in tonnes (in 2016), using the top-down approach



Source: Own development with data from Eurostat (2019b; 2019c).

[20] According to Deloitte (2017), a landfill ban has been implemented in Czechia, which could contribute to the high recycling rate recorded.

As stated in earlier sections, the two approaches to estimate the potential recycling rates are very different and each has its limitations. The potential recycling rate of mineral C&DW calculated at 96%, with both methods deriving the same estimate.

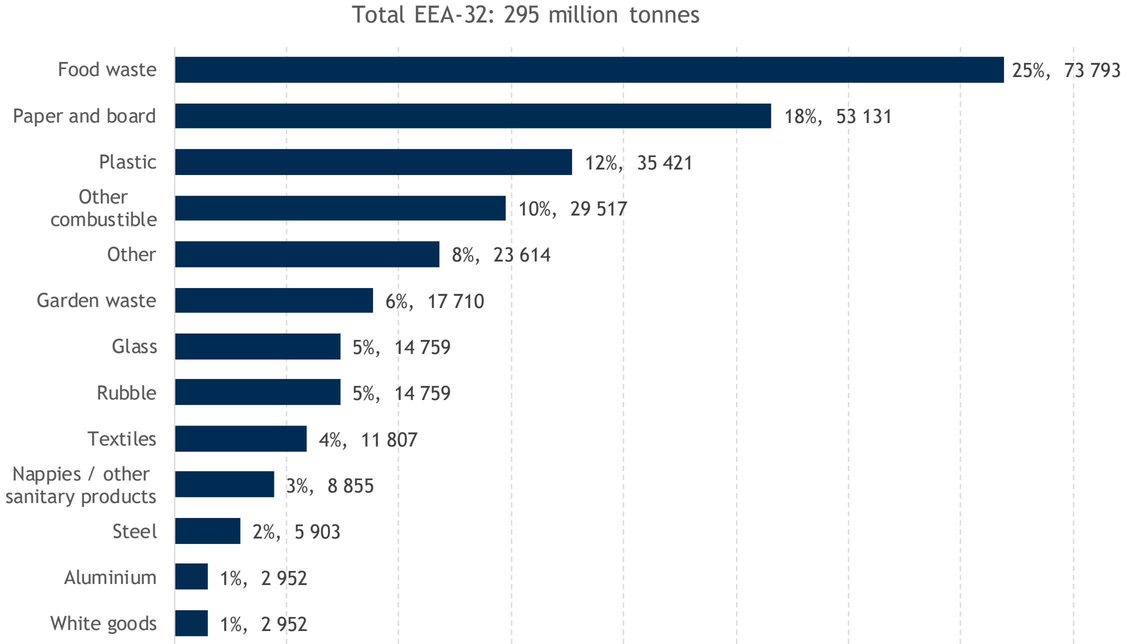
3.2 Municipal solid waste

3.2.1 *Waste generated*

Municipal waste constitutes approximately 10% of all waste generated in Europe (JRC, 2018). According to the latest available Eurostat data, **295 million tonnes** of municipal waste were generated in the EEA in 2018 (Eurostat, 2020).[21] Waste generated per country varied from 0.2 million tonnes (Iceland) to over 51 million tonnes (Germany). In terms of waste generated per capita, the numbers ranged from 272 kg/capita (Romania) to 766 kg/capita (Denmark). These differences could, in part, be explained by statistical discrepancies and economic wealth, since wealthier countries generate more waste per capita (EEA, 2015).

More than two thirds of MSW consists of organic waste and recyclable materials such as paper and board, plastic, metals, and glass (JRC, 2018). Based on the average composition of municipal waste, as described in JRC (2018), Figure 3-6 illustrates the breakdown of waste generated in Europe per material fraction.

Figure 3-6 Waste generated per material fraction in EEA-32 in 2018 (in kt and %)



Source: Own development based on Eurostat (2020) and JRC (2018) data.
Note: Data for Cyprus, Greece, Iceland and Ireland is for 2017.

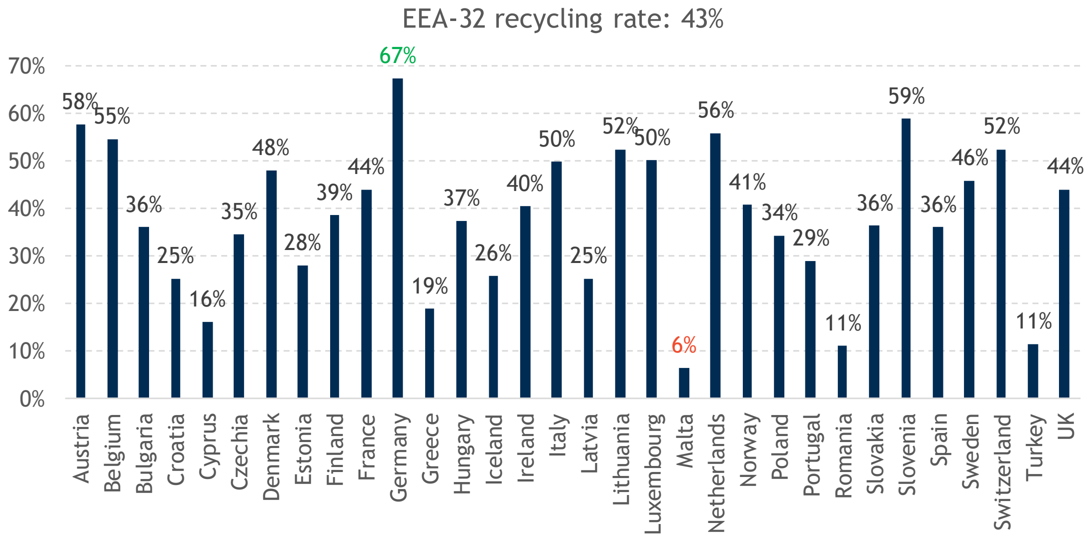
3.2.2 *Current recycling*

Eurostat data on municipal waste (env_wasmun) includes data on different waste management operations, including material recycling and recycling through composting and digestion (Eurostat, 2020). In 2018, over **126 million tonnes of municipal waste** (or **43%**) underwent recycling operations in EEA-32 countries (both through material recycling operations and composting and digestion), with national recycling rates ranging from 6% (Malta) to 67% (Germany) (Figure 3-7). The Eurostat database

[21] All Eurostat data on municipal waste from the 'env_wasmun' database excludes Liechtenstein. Furthermore, 2018 data was available for all countries except for Cyprus, Greece, Iceland and Ireland, for which 2017 data was used.

(2020) defines recycling as *"any recovery operation by which waste materials are reprocessed into products, materials or substances"*. Composting and anaerobic digestion is classified as recycling when *"compost (or digestate) is used on land or for the production of growing media"*. Eurostat does not explicitly provide information on whether municipal waste data includes hazardous substances, but it can be assumed that a portion of MSW can be hazardous (e.g. substances found in white goods) or potentially hazardous (FhG-IBP, 2014). The WFD states that the presence of hazardous substances in household waste should be reduced through more specialised collection schemes (e.g. separate collection of paints, varnishes, and solvents). As such, this waste stream includes both hazardous and non-hazardous materials or substances.

Figure 3-7 Recycling rates in EEA-32 in 2018



Source: Own development based on Eurostat (2020) data.

3.2.3 *Maximum recycling*

Our **first step** in estimating the recycling potential of municipal waste in Europe was a literature review to collate data and opinions on the maximum recycling potential of each material fraction of the waste stream (bottom-up approach). The following steps were taken:

- **Step 1:** Total municipal waste generated was broken down into waste generated per material fraction (as shown in Figure 3-6);
- **Step 2:** A literature review was conducted to collate an evidence base of data on potential (maximum) recycling rates, per material fraction (as cited in Table 3-3 below);
- **Step 3:** The potential recycling rates found in the literature were applied to the material-specific quantity of MSW generated. For example, the World Economic Forum (2019) concluded that South Korea now recycles 95% of its food waste through a series of innovative actions. South Korea is considered a leader in food recycling, so this rate can be considered an upper limit to recycling. In Step 1, European food waste was shown to amount to over 73 million tonnes. Applying a (maximum) recycling rate of 95% results in nearly 70 million tonnes of food waste having the potential to be recycled;
- **Step 4:** The quantity of waste (of each material fraction) with the potential to be collected for recycling was calculated and combined, resulting in a total of over 209 million tonnes of waste that could be recycled if all countries in Europe achieved the highest possible rate of recycling (as found in literature);
- **Step 5:** The number found in Step 4 was divided by the total waste generated in EEA-32. The potential recycling rate of MSW resulted in 80%.

Table 3-3 MSW material fractions and their recycling potential (EEA-32), as found in literature

Material fraction	Share of the waste stream (kt, %)	Maximum recycling potential (%)	Maximum recycling potential (kt)	Evidence base or assumptions
Food waste	73,793 (25%)	95%	70,103	World Economic Forum (2019).
Paper and board	53,131 (18%)	96%	50,894	IMPACTPaperRec (2016).
Plastic	35,421 (12%)	70%	24,794	Nordic Council of Ministers (2014).
Other combustible	29,517 (10%)	43%	12,646	*The make-up of this material fraction is unknown and no definition could be found.* The current recycling rate of EEA-32 countries was used as a proxy.[22]
Other	23,614 (8%)	43%	10,117	*The make-up of this material fraction is unknown and no definition could be found.* The current recycling rate of EEA-32 countries was used as a proxy.[23]
Garden waste	17,710 (6%)	100%	17,710	Danish Environmental Agency (1999).
Glass	14,759 (5%)	77%	11,305	Dutch Waste Management Association (2015).
Rubble	14,759 (5%)	96%	14,192	The maximum estimated potential recycling rate of mineral C&DW (as found in section 3.1.3) was used.
Textiles	11,807 (4%)	74%[24]	8,737	Bartl (2018).
Nappies and other sanitary products	8,855 (3%)	70%	6,199	EC (n.d.[b]).
Steel	5,903 (2%)	95%	5,608	Deloitte (2017).
Aluminium	2,952 (1%)	97%	2,863	Green Alliance (2019).
White goods	2,952 (1%)	75%	2,215	Estonia's recycling rate of large household appliances (Category 1 WEEE), the highest recycling rate for such appliances in the EU, was used as a proxy (based on data from Eurostat, 2019d; and EC, 2019b).
Total	**295,171 (100%)**	**80%**	**237,383**	-

Source: Own development with data from Eurostat (2020), JRC (2018), EC (2019b), and various other sources referenced in the table.

Note 1: The material composition of municipal waste (presented as a % of the waste stream) is based on a sampling exercise conducted by Zero Waste Europe[25] and referenced in JRC (2018).

Note 2: For "other" and "other combustible", we have used the European recycling rate to estimate the potential of these material fractions. However, this remains an optimistic estimate. These fractions of MSW are highly mixed, difficult to separate, and their composition is unknown; so their potential to be recycled is limited (although not inexistent).

Note 3: Further explanations on the evidence base and assumptions made with regard to the recycling potential of each material fraction is provided in Annex II.

[22] This refers to the recycling rate of EEA-32 countries, as shown in Figure 3-7.

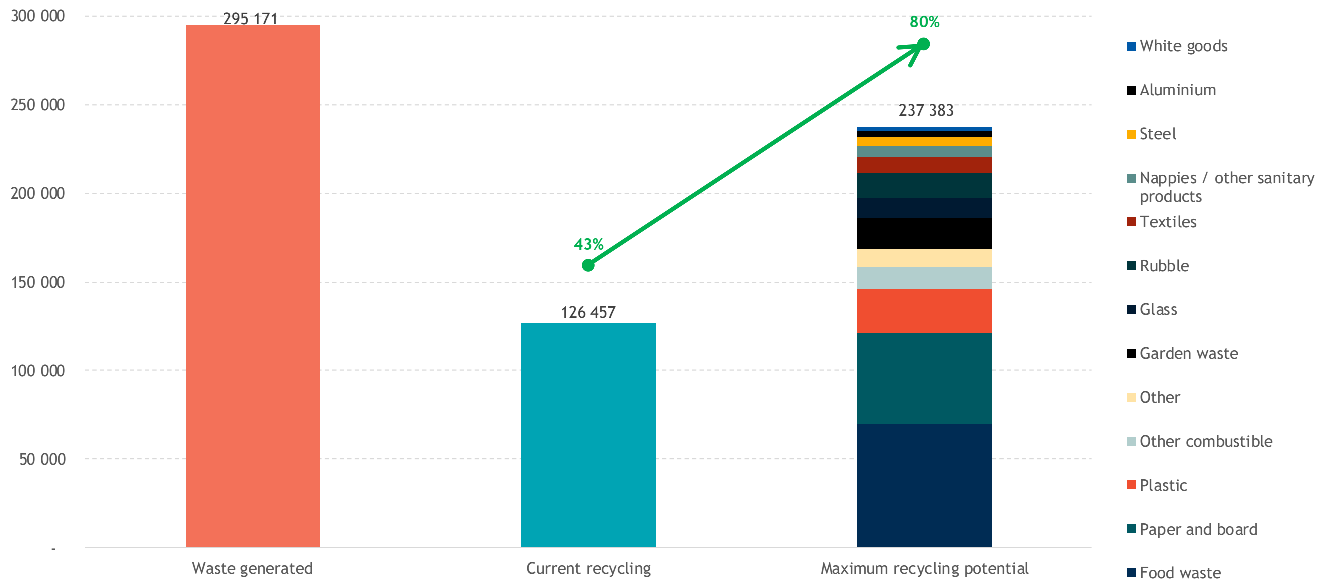
[23] This refers to the recycling rate of EEA-32 countries, as shown in Figure 3-7.

[24] The US-based Association of Wiping Materials, Used Clothing and Fiber Industries (SMART) (https://www.smartasn.org/) states that 95% of textiles can be reused/recycled. Part of the reuse/recycling process described includes converting used textiles into wipes. In this study, we maintained a conservative estimate based on a 75% recyclability rate.

[25] See https://zerowasteeurope.eu/.

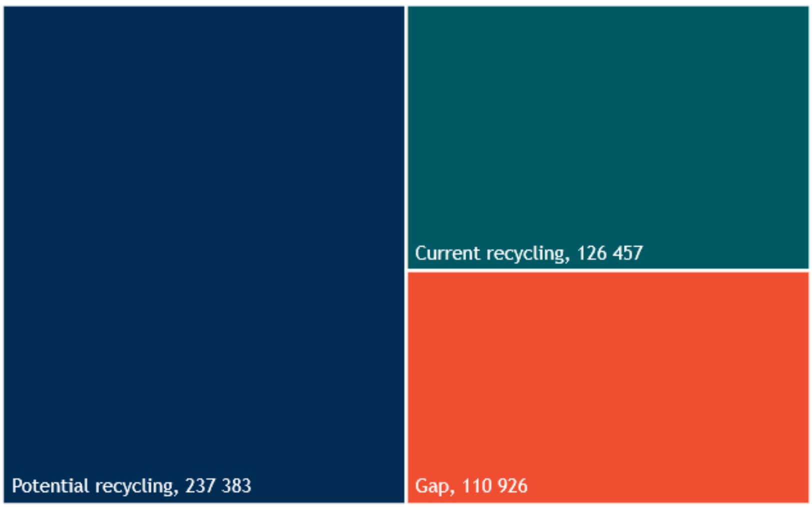
Based on the bottom-up approach, we estimate that the maximum recycling potential of MSW is approximately **80%** of waste generated in EEA-32 countries (Figure 3-8). This means a difference of approximately 40 percentage points compared to current waste recycling and over 30 percentage points above the 2020 recycling target of the WFD. The gap between current and potential recycling is approximately **111 million tonnes**, as illustrated in Figure 3-9.

Figure 3-8 Current and potential recycling in 2018 (kt, EEA-32)



Source: Own development with data from Eurostat (2020) and various other sources (see Table 3-3).

Figure 3-9 Gap between current and potential recycling in 2018 (kt, EEA-32), using the bottom-up approach



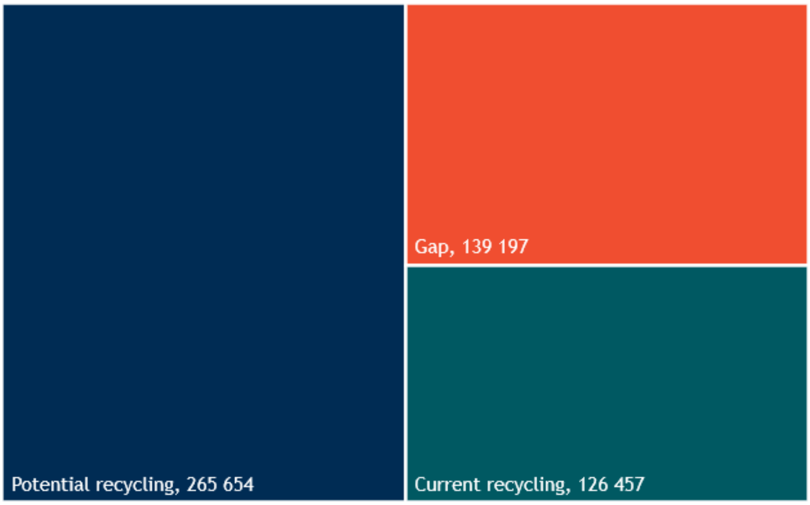
Source: Own development with data from Eurostat (2020) and various other sources (see Table 3-3).

As a **second approach**, looking at potential recycling from a 'best practice' or 'benchmarking' perspective, municipalities in Sweden have demonstrated that **90%** of household waste can be collected for recycling (JRC, 2018). Sweden achieved this by implementing multi-stream collection systems, thereby increasing the efficiency of waste separation. A similar achievement (86%) was found in

Aschaffenburg, Germany, through the enhanced monitoring of waste data and the implementation of weight-based waste management systems (i.e. pay-as-you-throw schemes) (JRC, 2018).

A 90% maximum potential recycling rate applied to all EEA countries results in almost 213 million tonnes of waste having the potential to be recycled – an **additional 139 million tonnes** compared to current recycling (Figure 3-10).

Figure 3-10 Gap between current and potential recycling in 2018 (kt, EEA-32), using the top-down approach



Source: Own development with data from Eurostat (2020) and JRC (2018).

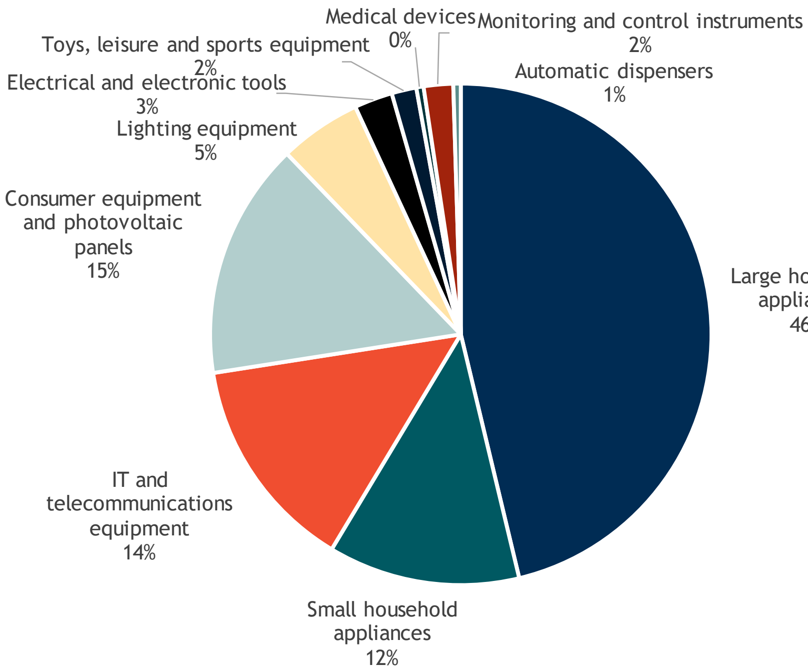
3.3 Waste electrical and electronic equipment

3.3.1 *Waste generated*

As described in Commission Implementing Decision (EU) 2017/699, WEEE generated is a function of EEE placed on the market (POM), the year in which products were first placed on the market, the discard-based lifespan profile of the products, and, implicitly, the probable discard rate in the respective evaluation year.[26] Using country-specific calculation tools provided by the European Commission and POM data from Eurostat (env_waselee), the quantity of waste generated was calculated for all EU member states, across all EU-10 WEEE categories (Eurostat, 2019d; EC, 2019b). Additional data on total waste generated was extracted for Iceland and Norway from the Global E-waste Monitor 2017 (Baldé et al., 2017). Finally, for Liechtenstein, Eurostat data on waste collected in 2016 was used to represent waste generated (in the absence of other data) (Eurostat, 2019d).[27] The total amount of EEE waste generated in EEA-31 countries in 2017 was over **10 million tonnes.**[28] The spread of this waste across the EU-10 WEEE categories is shown in Figure 3-11 below).

[26] The complete formula is provided in Annex I.
[27] Data for Turkey and Switzerland does not exist in the Eurostat database (env_waselee); therefore, all analysis related to WEEE has been scoped to the EEA-31 countries.
[28] Data for 2017 was not available for all countries. For Belgium, Iceland, Ireland, Liechtenstein, Luxembourg, Netherlands, Norway, Slovenia, and Sweden, 2016 data was used; for Italy, 2015 data was used; and, for Cyprus, Malta, and Romania, 2014 data was used.

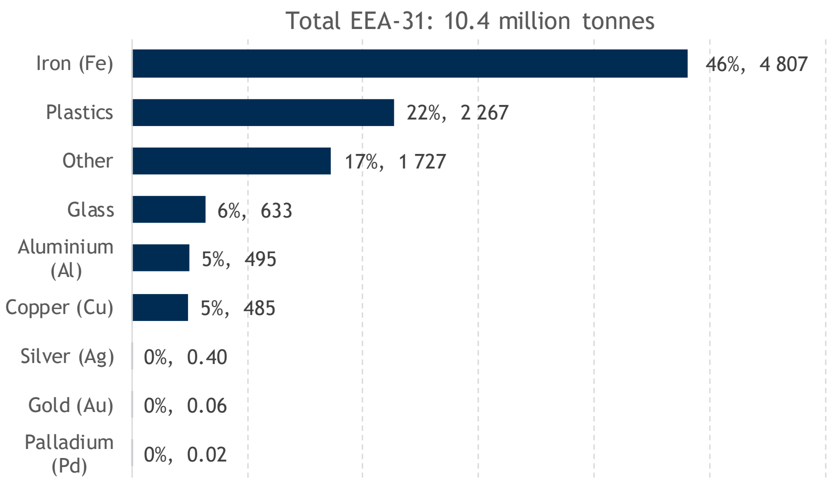
Figure 3-11 Split of WEEE across EU-10 product categories in 2017 (%)[29]



Source: Own development based on data from Eurostat (2019d) and EC (2019b).

This data was further broken down by material fractions on the basis of data presented in BiPRO, BIO, and UNU (2015)[30]. The main material fractions that make up WEEE are iron (46%), plastics (22%), and other materials (17%). The latter materials are unclassified but could include materials such as metals, wood, rubber, oil, hazardous substances like CFC/HCFC, or mercury. As such, WEEE includes both hazardous and non-hazardous materials or substances.

Figure 3-12 WEEE generated in 2017 in EEA-31 (in % and in kt)



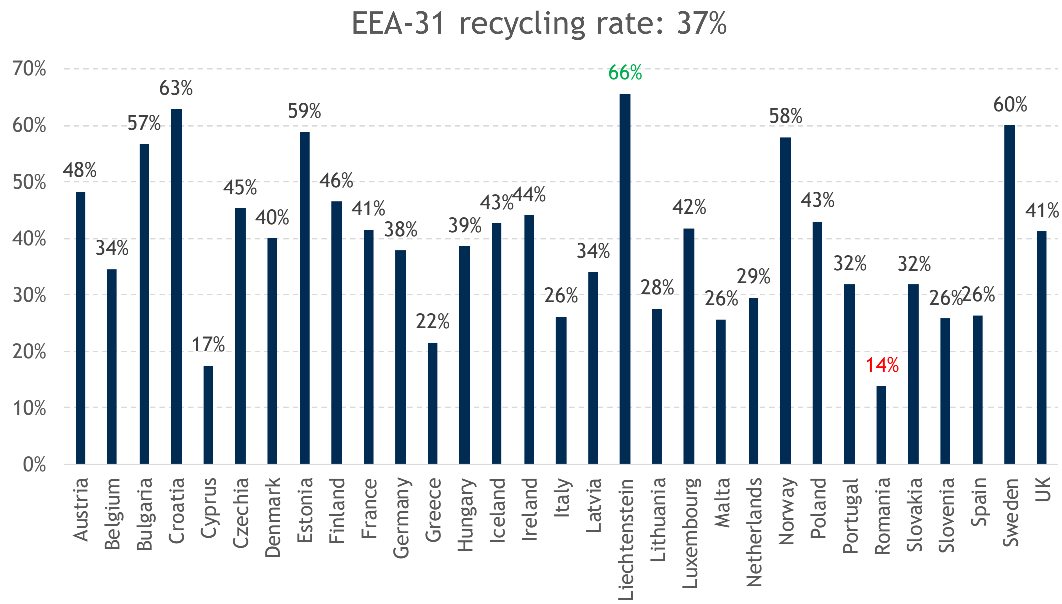
Source: Own development based on data from Eurostat (2019d), EC (2019b), Baldé et al. (2017), and BiPRO et al. (2015).

[29] Data on WEEE per EU-10 category was only available for EU countries (EC, 2019b); so the split of WEEE across these categories is based on EU data only. The shares were calculated based on the weight of WEEE in tonnes, resulting in large household appliances (Cat. I) taking up close to half of the waste stream.
[30] Table 25 in BiPRO et al. (2015).

3.3.2 Current recycling

Out of the total WEEE generated in EEA-31 countries, close to **4 million tonnes (or 37%)** were recycled in 2017. In the same year, recycling rates across EEA countries ranged from 14% (Romania) to 66% (Liechtenstein) (Figure 3-13).[31] Further comparing recycling rates across the different categories of WEEE, recycling rates ranged from 12% (monitoring and control instruments) to 54% (automatic dispensers), over the same period. The latter calculations were based on EU MS only. This shows that the **degree of recyclability varies across the different product categories**. This is likely to be partly due to the design and material composition (including composition of hazardous substances) of the different products. Another difficulty with WEEE is to get it into the collection system; and it is possible that certain products make it into the collection system more than others. More details on the barriers to recycling WEEE are provided in Chapter **Error! Reference source not found.**.

Figure 3-13 WEEE Recycling rates in EEA-31 in 2017



Source: Own development based on data from Eurostat (2019d), EC (2019b), and Baldé et al. (2017).
Note 1: Recycling rates represent the amount of WEEE recycled (from the 'env_waselee' Eurostat database) divided by WEEE generated. WEEE generated was calculated using country-specific calculation (Excel) tools provided by the European Commission and POM data from Eurostat (env_waselee) (EC, 2019b; Eurostat, 2019d). To calculate the amount of WEEE generated in each country, POM data for 2017 and the previous years where data was available was inserted into the tool (split across EU-10 categories). The tool provided the amount of WEEE generated in the latest year for which data was inserted. See EC (2017a) for more information on the Excel tools. The Excel tools were only available for EU countries. For non-EU countries, data on waste generated was extracted from Baldé et al., 2017.
Note 2: Liechtenstein's recycling rate has been calculated as the share of WEEE recycled in the total amount of waste 'collected', as opposed to 'generated'. This is because no data was available on WEEE generated in the Global E-Waste Monitor (Baldé et al., 2017).
Note 3: Reporting on products placed on the market, waste collected, waste reused, and waste recycled may diverge from country to country (EC, 2020); so, the recycling rates shown in the figure above are subject to data uncertainties.

3.3.3 Maximum recycling

In a **first attempt** to estimate the recycling potential of WEEE in Europe, a literature review was conducted to collate data on the maximum recycling potential of each material fraction of the waste stream (bottom-up approach). More specifically, the following steps were taken:

[31] Data for 2017 was not available for all countries. For Belgium, Iceland, Ireland, Liechtenstein, Luxembourg, Netherlands, Norway, Slovenia, and Sweden, 2016 data was used; for Italy, 2015 data was used; and, for Cyprus, Malta, and Romania, 2014 data was used.

- **Step 1a:** As described in the previous section, total WEEE generated was broken down into waste generated per material fraction (as shown in Figure 3-12);
- **Step 2a:** A literature review was conducted to collate data on potential (maximum) recycling rates, per material fraction (as cited in Table 3-4 below);
- **Step 3a:** The potential recycling rates found in the literature were applied to the material-specific quantity of WEEE generated;
- **Step 4a:** The quantity of waste (of each material fraction) with the potential to be recycled was calculated and summed, resulting in a total of over 3.6 million tonnes of WEEE that could be collected recycling if all countries in Europe achieved the highest possible rate of recycling (as found in literature);
- **Step 5a:** The number found in Step 4 was divided by the total waste generated in EEA-31. The potential recycling rate of WEEE was found to be 78%.

Table 3-4 WEEE material fractions and their recycling potential, as found in literature

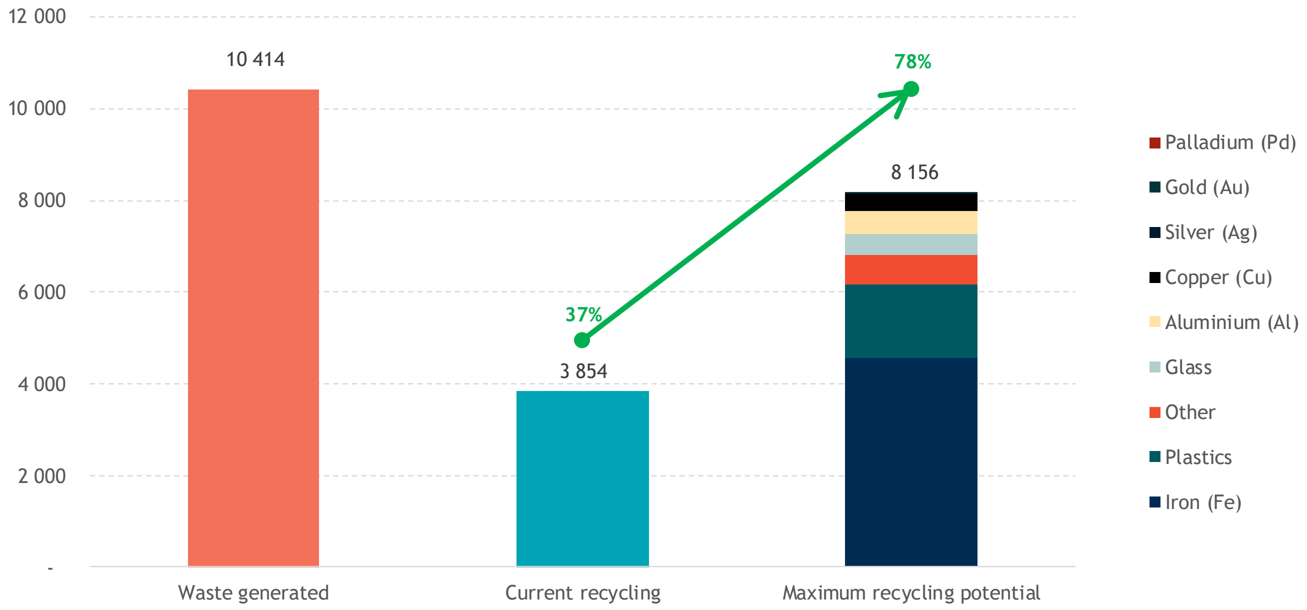
Material fraction	Share of waste stream (kt, %)	Maximum recycling potential (%)	Maximum recycling potential (kt)	Evidence base or assumptions
Iron	4,808 (46%)	95%	4,567	Deloitte (2017).
Plastics	2,269 (22%)	70%	1,587	Nordic Council of Ministers (2014).
Other	1,725 (17%)	37%	639	The make-up of this material fraction is unknown. The current recycling rate of EEA-31 countries was used as a proxy.[32]
Glass	633 (6%)	77%	485	Dutch Waste Management Association (2015).
Aluminium	494 (5%)	97%	480	Green Alliance (2019).
Copper	485 (5%)	82%	398	European Copper Institute (2018).
Silver	0.4 (0%)	55%	0.22	EC (2017b).
Gold	0.06 (0%)	10%	0.01	EC (2017b).
Palladium	0.02 (0%)	10%	0.00	UNEP (2011).
Total	**10,414 (100%)**	**78%**	**8,156**	**-**

Source: Own development based on data from Eurostat (2019d), EC (2019b), Baldé et al. (2017), BiPRO et al. (2015), and various other sources referenced in the table.
Note: Further explanations on the evidence base and assumptions made with regard to the recycling potential of each material fraction is provided in Annex II.

Using this approach, the maximum recycling potential of WEEE is **approximately 78%** of waste generated in EEA-31 (Figure 3-8). This is a difference of close to 50 percentage points compared to the current EEA-31 WEEE recycling rate. The gap between current and potential recycling, therefore, results in more than **4 million tonnes** of waste, as illustrated in Figure 3-9.

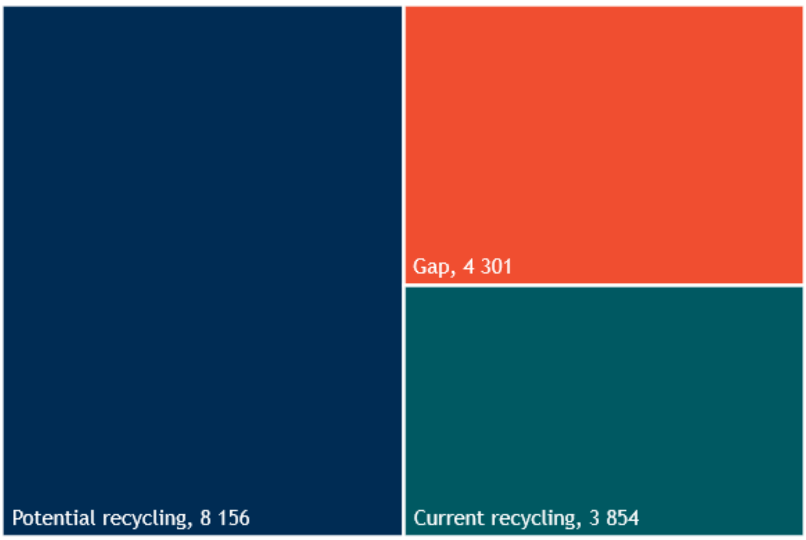
[32] This refers to the recycling rate of EEA-31 countries, as shown in Figure 3-13.

Figure 3-14 Current and potential recycling in 2017 (kt, EEA-31)



Source: Own development with data from Eurostat (2019d), EC (2019b), and various other sources (see Table 3-4).

Figure 3-15 Gap between current and potential recycling in 2017 (kt, EEA-31), using the bottom-up approach



Source: Own development with data from Eurostat (2019d) and various other sources (see Table 3-4).

A **second approach** was taken to quantify the maximum recycling potential in Europe (top-down approach). This used the following steps:

- **Step 1b:** Having quantified the recycling rates per EU MS per EU-10 product category, a maximum and minimum recycling rate per product category could be calculated (as shown in Table 3-5). In some cases, the recycling rates exceeded 100%. This is reportedly caused either by stock effects or by specific collection campaigns, collecting WEEE generated in previous periods 'historical' WEEE (EC, 2020). Following a similar approach to the one used in the WEEE Directive Implementation Report (Eunomia Research & Consulting et al., 2018c), if recycling rates exceeded 100%, a recycling rate of 100% was used to estimate the maximum recycling potential of a given product category;

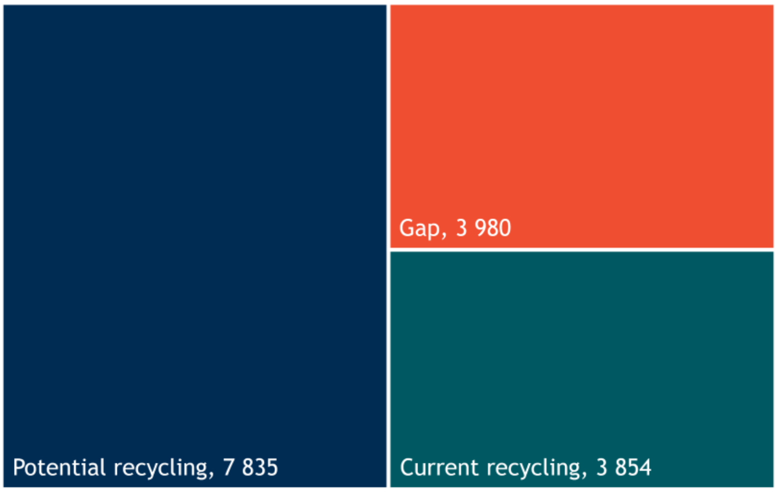
Table 3-5 Minimum and maximum recycling rates across different EU-10 product categories in the EU

	EU-10 product categories (see Annex I)									
	1	2	3	4	5	6	7	8	9	10
Min.	18%	2%	18%	8%	0%	2%	0%	2%	0%	0%
Max.	75%	64%	74%	*100%*	50%	*100%*	46%	*100%*	76%	*100%*

Source: Own development based on data from Eurostat (2019d), EC (2019b), and Baldé et al. (2017).
Note: Recycling rates in italics were capped at 100%.

- **Step 2b:** The maximum recycling rates of each product category were applied to WEEE generated (per product category) in each country. Data on WEEE generated per product category was not available for non-EU MS (namely, Norway, Iceland and Liechtenstein), so for those countries an average maximum recycling rate of 78% (based on the average of all maximum recycling rates found in Step 1a) was applied to the total WEEE generated;
- **Step 3b:** The quantity of waste with the potential to be recycled in each country was added together, resulting in a total of over 7 million tonnes of waste that could be recycled (and a gap of almost 4 million tonnes compared to current recycling) (Figure 3-16);
- **Step 4b:** The total that was found in Step 3b was divided by the total waste generated in EEA-31. As such, the potential recycling rate of WEEE was found to be **75%**.

Figure 3-16 Gap between current and potential recycling in 2017 (kt, EEA-31), using the top-down approach



Source: Own development based on data from Eurostat (2019d), EC (2019b), and Baldé et al. (2017).

As such, the second approach results in a maximum recycling potential of **75%**.

4 Barriers to recycling

Waste management and specifically recycling face various challenges. Based on the most recent literature available, the sections below provide an overview of barriers that apply to the waste streams that are the focus of this study i.e. MSW, WEEE and C&DW. We have distinguished between collection barriers and processing barriers. *Collection barriers* refer to barriers that affect the 'intention' to recycle waste and therefore happen 'before' any waste is processed. These barriers therefore concentrate on the collection of waste for recycling. *Processing barriers* refer to barriers to the conversion process that sees material turned from waste into a new product or raw material. These barriers are encountered after collection of waste, 'during' the sorting and recycling processes. In this chapter, we elaborate further on the 'collection' barriers. The reason for this focus is that the scope of this report refers to limits to recycling in terms of separate collection of waste. An analysis of the "collection" barriers is therefore relevant in order to understand why there is a gap between the current and maximum levels of collection for recycling. For details on 'processing'-related barriers please refer to Annex III. We further subdivide the barriers into the following categories: *Technical*, *regulatory*, *market and financial*, *awareness raising and knowledge* related.

Regulatory barriers: legislation or policy hindering recycling (collection and/or processing of waste)

Technical barriers: technical difficulties hindering the recycling process (collection and/or processing of waste) either due to the property of materials or to available technology

Market / financial barriers: characteristics of the waste product or recycling process (collection and/or processing of waste) that make recycling economically unattractive

Awareness / knowledge barriers: barriers related to stakeholders (industry, citizens, authorities) not being (well-) informed or lacking the knowledge about recycling

The primary source of information for this review is EU-level literature. Therefore, it should be noted that barriers may vary in importance from country to country. When literature specifies which (type of) countries the barriers specifically apply to, this has been noted in the text.

4.1 Barriers to the recycling of C&DW

C&DW has been widely studied in literature and the barriers to its recycling are relatively well known. In the table below, we synthesise the most relevant barriers according to the main categories found in recent literature. The barriers concerning collection are explained in the text below.

Table 4-1 Overview of barriers to C&DW recycling in the EU per category

Category	Collection barriers	Processing barriers (see annex)
Regulatory barriers	· Lack of enforcement / implementation / compliance / high sanctions (leading to illegal practices) · Lack of political drive · No overarching legislation · No specific legislation · No end-of-waste criteria (in the majority of EU countries) · Recycling targets by weight promotes the recycling of heavy materials and reduces the emphasis on lighter weight materials · Contradictions and confusion between national, regional and local legislation	· No sorting requirements · No policy / lack of obligations regarding recycled materials or recycled content in construction materials · Standards that allow low replacement rates in low-grade concrete
Technical barriers	· The lack of a suitable network of recycling infrastructure / facilities · No technical / business solutions for certain fractions (e.g. mineral wool) · Potential presence of hazardous substances · Transport of recyclables · Design for deconstruction or disassembly (DfD) design is still negligible · Old buildings not designed for deconstruction	· Mixed materials high heterogeneity of C&DW · Technical challenges to incorporate concrete waste into new concrete · Inadequate at-source segregation · Lack of traceability / information on product · Technical properties of the recycled products that can undermine the quality of the recycled waste
Market and financial barriers	· Low cost of landfill (next to low cost raw materials) · Low cost of extracted natural aggregates · No financial incentives for recycling	· Selective demolition is expensive · High cost of sorting technology · High cost of treatment and recycling · Low prices of natural raw materials · Small market for recycled materials · Acceptability of secondary materials · Geen Public Procurement potential not fully utilised
Awareness and knowledge related barriers	· Mentality in the construction sector / lack of awareness · Lack of coordination between actors	· Lack of understanding and know-how of industry players · Lack of standards, guidance

4.1.1 *Legislative barriers*

There are several legislative barriers preventing waste from being sorted, collected and transported to recycling plants. For example, Deloitte (2016) note that some EU countries lack specific legislation for the collection and recycling of C&DW and rely on general waste management procedures (e.g. Austria, the Netherlands) or on local government legislation (e.g. Estonia). The study also considers that enforcement is sometimes an issue even in the highest performing countries. In addition, EU countries with decentralised waste management tend to lack overarching legislation (e.g. Germany and Spain). In the countries with lower C&DW collection rates, the study identified barriers relating to the lack of enforcement, implementation and compliance as well as a lack of political will to drive improvements. In addition to the lack of sufficiently high sanctions to punish illegal disposal, this leads to persistent illegal practices. The lack of EoW criteria in the majority of EU countries has been pointed out as a barrier in subsequent studies (Deloitte, 2016; Deloitte, 2017; ECN, 2017). Deloitte (2017) add that current recycling targets which are defined by weight, promote the recycling of heavy materials while reducing the emphasis on lighter weight material. In line with this, ETC/WMGE (2020) identify the lack of national guidelines /instructions for the use of recovered material in new concrete in some countries as barrier. Moreover, contradictions in, and confusion between, national, regional and local legislation also hinder recycling (Deloitte, 2017).

4.1.2 Technical barriers

With respect to treatment capacity, barriers have been identified in that an adequate number of C&DW treatment facilities are not in place (Deloitte, 2016). ETC/WMGE (2020) explains that further technical barriers stem from the fact that the use of ‘Design for deconstruction or disassembly’ (DfD) in building design is rare. DfD remains largely unknown to the general public, and there is little awareness of its advantages. In particular old buildings are not designed for deconstruction from building to components – or disassembled – from components to materials – easily. Neither is material identification yet available in older buildings. In addition, the study explains that some construction materials, are not possible to separate economically and that transport distances – and derived cost - is a barrier to transporting recyclables when virgin raw materials are widely available near the end user.

4.1.3 Market and financial barriers

The aforementioned barriers link to market barriers that show that there is often not a compelling business case for the private sector to invest in establishing recycling/recovery facilities. Galvez-Martos et al. (2018) state that the barriers to C&DW recycling across many EU countries are not technical, but commercial. According to BIO by Deloitte (2016), in lower performing countries insufficient financial incentives and for low gate fees[33] and absence of landfill taxes and pollution charges hinder recycling.

4.1.4 Awareness and knowledge related barriers

Awareness / knowledge related aspects to C&DW collection revolve around the attitudes of the construction sector (where waste management may not be a priority) and the lack of coordination between actors (BIO by Deloitte, 2016).

4.1.5 Other barriers

There is an “indirect” barrier that affects the ‘accounting’ or ‘calculation’ of recycling rates. This barrier is related to the leeway for interpretation in legally binding obligations. Different definitions of C&DW are applied throughout the EU, which makes cross-country comparisons difficult (Deloitte, 2017). Reported lower / higher recovery rates in EU countries could be due to the misallocation of items in the waste category, therefore not reflecting the “real” figures of C&DW treatment in the country. BIO by Deloitte (2016) also identified problems with data reporting in the countries where C&DW is least developed. These range from unreliable data, to ‘missing’ amounts of C&DW, caused by poorly tracked or unknown waste management and treatment.

4.2 Barriers to the recycling of MSW

The amendment of the WFD in 2018 (EU, 2018e) states that barriers to MSW management result from its complex and mixed composition, direct proximity to citizens, high public visibility, and its impact on the environment and human health. Given these barriers, the amended Directive emphasises the importance of efficient collection schemes and sorting systems, infrastructure that can process the specific waste composition, an elaborate financing system, and that citizens and businesses are engaged. Where this is not the case, recycling levels will be constrained. The table below provides a summary of the main MSW recycling barriers found in the EU according to recent literature.

[33] A ‘gate fee’ is the charge levied upon a given quantity of waste received at a waste processing facility.

Table 4-2 Overview of barriers to MSW recycling in the EU per category

Barrier category	Collection barriers	Processing barriers
Regulatory barriers	· Ambiguous definitions	· Illegal shipments · Lack of end-of-waste criteria · Bureaucratic barriers for recycling permits · Differences in regulations, registrations and permits obtention · Weaker treatment norms outside the EU (incentivising export)
Technical barriers	· No appropriate collection systems · Limited space at home	· Complex and mixed composition of the waste · Waste collected as mixed cannot in principle be recycled or re-used to a significant degree, or generates low-quality recyclables · Impurity levels / contamination · Lack of recycling technologies for some materials · Climate conditions affecting quality of collected waste
Market and financial barriers	· Insufficient financial incentives for separate collection · Investment and running costs · Climate conditions affecting frequency of waste collection (and hence costs) · No one size (system) fits all · High costs of door to door collection	· Investment and running costs · Waste management and treatment capacities that are not economically and environmentally viable · Requirements to protecting consumers' health which increase recycling costs · Low and volatile market prices · Energy recovery of waste competes with recycling · Markets for recyclables in their infancy for certain fractions
Awareness and knowledge related barriers	· Cultural differences · Active participation of citizens needed	

4.2.1 *Legislative barriers*

The main collection related barriers are the ambiguous definitions of waste (Oeko, 2016).

4.2.2 *Technical barriers*

BiPRO and CRI (2015) identified the lack of an appropriate collection system that separately collects specific fractions from municipal waste as a barrier to MSW recycling. Also, space for waste separation at the source is limited, due to small kitchens and a lack of space for waste storage particularly in (densely populated) cities where people live in apartment buildings (Koerkamp, I., 2019).

4.2.3 *Market and financial barriers*

A key barrier is the lack of financial incentives for separate collection for example market-based instruments such as extended producer responsibility or "pay-as-you-throw" schemes (Zero Waste Europe, 2017). BiPRO and CRI (2015) explain that although door-to-door separate collection schemes are proven to be the most efficient for some MSW fractions, they cost more, which tends to be consider a barrier. It should be noted though that when looking both at collection costs and processing costs, this system could lead to potential revenues and savings from reduced need for residual waste management. The same study also points at climate conditions as a factor affecting the quality of collected waste (e.g. when warm, collected bio-waste might have started to degrade) and the cost of the system (increasing the frequency of collection e.g. when the weather is warm, costs more). The study concludes that there is no one size fits all system that works everywhere. Systems differ depending on the population density, urban architecture, climate conditions, income level, and funding mechanisms. The local ownership and management responsibility for the collection system(s) also determines the limits for public authority intervention. Partially or fully privatised systems need different incentives for improvement than systems run exclusively by pubic authorities.

4.2.4 Awareness and knowledge related barriers

When cultural differences are not taken into account in awareness campaigns and in the planning separate collection systems, this can pose a barrier to the recycling of MSW (Oeko, 2016). Knowledge transfer processes that do not acknowledge cultural differences are easily blocked and pass on the lessons learned from other systems more slowly. Oeko (2016) also address barriers related to the engagement of the public, as waste producers (companies or private citizens) are required to participate actively in the waste management system, for example by separating waste at source. Consequently, waste systems largely depend on the performance of waste producers in order to increase recycling levels. BiPRO and CRI (2015) echo the need for active participation of citizens to separate their waste as a barrier (which can also be understood as a prerequisite for recycling). The level of citizen engagement has a direct impact on the efficiency of a collection system, for example, in the level of impurities included in the separately collected fraction.

4.3 Barriers to the recycling of WEEE

As discussed in Chapter 3 of this report, there is a large gap between WEEE generated and WEEE collected. A summary of the most important barriers are presented in the table below. The barriers are then explained in more detail below.

Table 4-3 Overview of barriers to WEEE recycling in the EU per category

Barrier category	Collection barriers	Processing barriers (see annex)
Regulatory barriers	· Informal e-recycling systems · Lack of accounting mechanisms for cross-boundary transport · No punitive measures for citizens if they do not engage in the waste system · Waste-flows are not properly reported as collected	· Waste-flows are treated under non-compliant conditions with other metal scrap · Illicit waste shipments
Technical / process barriers	· Lack of infrastructure for collection and separation	· Lack of commercial-scale technologies · Technological development leading to smaller components · Complex composition that frequently contains hazardous materials · Remaining toxic potential of already prohibited or restricted hazardous components
Market / financial barriers	· High value materials / high content of metals in some products drive illegal collection routes & trade · Low contents of a material making recycling not interesting	· Low market prices of plastics · High cost of legal treatment of waste that contain hazardous materials
Awareness/ knowledge related barriers	· Lack of awareness · Improper disposal of WEEE by consumers	· Lack of awareness and training for the safe handling and processing of materials during recovery at uncontrolled recycling operations

4.3.1 Legislative barriers

In terms of regulation, informal e-recycling systems are a barrier to recycling (Bakhiyi, B., 2018). Waste flows are often not properly reported as collected (EC, 2019c). In relation to this Tansel (2017) report that the lack of accounting mechanisms for cross-boundary transport is a barrier.

4.3.2 Technical barriers

Tansel (2017) identifies the lack of infrastructure for collection and separation as a barrier to recycling of WEEE.

4.3.3 Market and financial barriers

On the market and finance related aspects, Thiebaud et al. (2018) explain that many critical metals, such as indium, gallium, tantalum, or the rare earth elements, are not recycled, for example, because of low contents of these materials within electronic equipment, low market prices that do not cover recycling costs, lack of recycling technologies at the commercial scale, and metallurgical limits to recovery processes. At the same time the high value of some WEEE components (e.g. gold, silver) as well as the high contents of metals in some WEEE (for example fridges contain 60% weigh in metals) drive illegal collection routes and trade (CWIT, 2013).

4.3.4 Awareness and knowledge related barriers

The gap between generated vs. collected WEEE can also be partly be explained by the lack of awareness amongst consumers, preventing e-waste from being collected (Weeforum, 2020) and by improper disposal of WEEE by consumers (e.g. in waste bins) (EC, 2019c). This is also because there are generally no punitive measures (regulations) in place for inappropriate disposal of WEEE (Schevchenko, T. et al., 2019).

4.3.5 Other barriers

As with MSW, there is too much leeway for interpretation in legally binding obligations relating to WEEE. Eunomia (2017) explains that there are differences in how the scope of electrical and electronic equipment (EEE) placed on the market is defined between Member States. This results in ambiguities, such as where an item forms part of another item which is not in scope (e.g. car radio, or removable control devices which form part of a fixed installation). There is also ambiguity around the point at which WEEE is reported as recycled. There is ambiguity on how the battery resource efficiency targets should be calculated (in the Batteries Directive[34]), with latitude for manipulation of reported figures clearly possible .

[34] Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators.

5 Enabling factors and the way forward

This chapter presents an overview of factors that could enable an increase in the recycling of C&DW, MSW and WEEE. As with the barriers section, we distinguish between enabling factors for collection and enabling factors for processing. The enablers for 'collection' are further explained in this chapter. In line with the focus of this report on collection (rather than processing) the enablers for 'processing' are found in Annex IV. The enabling factors identified refer to the key features/elements of the recycling system as well as to the main success factors of a system.

5.1 Enablers for C&DW recycling

Enabler category	Collection enablers	Processing enablers (see annex)
Regulatory enabler	· Mature legislation (incl. landfill bans; Requirements for having a site waste management plan; for having to undertake a pre-demolition audit) · High levels of enforcement · Specific recycling targets	· Regulation (EoW criteria; Requirements for at-source separation) · Quality protocols & certification schemes · Mandatory selective demolition · Mandatory decontamination · Quality certificates for recycled products · Green Public Procurement requiring recycled content in new construction materials · Requirement for the use of C&DW in new products
Technical / process enabler	· BIM technologies, new techniques for material recognition, robots for demolition · Pre-demolition audits and management protocol	· Good spread of recycling facilities that can deal with key material streams · Design for disassembly · Phasing-out of substances of concern in production processes · Improved tracking system · Selective demolition · Sorting at source
Market / financial enabler	· Demand for material reuse for road construction, railway infrastructure and land levelling · Landfill taxes / reduced value added tax rate for recycled products / levies on virgin materials · Public and private sector partnerships to establish recycling facilities and share best practices · Voluntary schemes / agreements and commitments / action plans led by industry · Green Public Procurement (demanded by client) · Higher value of pure material fractions	· A large number of actors adopting design for disassembly · Commitments between different stakeholders in the value chain · Treatment costs are lower following selective demolition · Identify and connect to a market for recovery before demolition · Creation of jobs
Awareness/ knowledge related enablers	· Software/apps to inspect, track and report waste generation	· Best practice guidelines and tools · Education on the circular economy · Software/apps to inspect, track and report levels of recycling and recovery

5.1.1 *Legislative enablers*

Deloitte (2017) explains that regulatory aspects such as mature legislation and high levels of enforcement are prerequisites for high levels of C&DW recycling. Proof of this is found in some EU Member States with high recovery rates of C&DW who have landfill bans (or partial bans) in place. For example, the Netherlands has a landfill ban on recyclables and Belgium has bans on landfilling of mixed C&DW in Wallonia and Flanders. Denmark has a ban on landfilling of waste suitable for incineration, which explains the low levels of landfilling and relatively high levels of C&DW incineration (5%). According to the same study, specific targets also enhance higher volumes of recycling of C&DW. Requirements for having a site waste management plan, and for having to undertake a pre-demolition audit can also enhance collection rates (Deloitte, 2017). A requirement for the use of C&DW in new products (such as the use of recycled concrete in new concrete) as well as (mandatory) selective demolition, which is already mandatory in many member states, lead to higher quality recovery of materials (ETC/WMGE, 2020).

5.1.2 *Technical enablers*

Following the EU guidance on pre-demolition audits and management protocol are enablers for the collection of C&DW (EC, 2018b). In addition technological advancements such as Building Information Modelling (BIM) technologies, new techniques for material recognition, and the use of robots for demolition can increase collection rates (ETC/WMGE, 2020).

5.1.3 *Market and financial enablers*

The higher value of pure C&DW materials (resulting from selective demolition for instance), incentivises recycling of such fractions (ETC/WMGE, 2020). There are some financial and market approaches that can stimulate C&DW recycling. As Deloitte (2017) explains, demand for material reuse for road construction, railway infrastructure and land levelling stimulates recycling of C&DW. The key is to use economic instruments to divert this waste stream from landfills (EC, 2018b). ETC/WMGE (2020) refers, inter-alia, to landfill taxes in combination with a reduced value added tax (VAT) rate for recycled products to drive recycling levels up. Landfill taxes help prevent C&DW from being landfilled and VAT reduction for recycled products increases the relative price of virgin raw materials. The study says that increasing the market value of recycled aggregate is crucial to making recycled concrete aggregates competitive with virgin materials. In some Member States, including Belgium and the Netherlands, the use of concrete aggregate is made economically attractive through government measures including levies on virgin materials and taxes on landfilling waste. Deloitte (2017) also mentions that landfill taxes to increase the cost of waste disposal are effective means of increasing levels of recycling. Ensuring the availability of suitable facilities to recycle or recover waste within a reasonable proximity of its origin is also identified as important.

Public and private sector partnerships that establish recycling facilities and share best practices, as well as voluntary schemes and action plans led by industry (especially for key material streams/ product sectors) are enabling factors for recycling of C&DW (Deloitte, 2017). In a similar vein ETC/WMGE (2020) mention agreements and commitments between stakeholders in the value chain and voluntary schemes for sustainable buildings as enablers of C&DW recycling. Client requirements set through the procurement process (both public - Green Public Procurement - and private) can stimulate recycling by requiring recycled content in new construction materials (Hamidreza Ghaffar, S. et al., 2020; Deloitte, 2017).

5.1.4 *Awareness and knowledge related*

Software tools and apps can be beneficial in the inspection, tracking and reporting of waste generation (Deloitte, 2017).

5.2 Enablers for MSW recycling

Enabler category	Collection enablers	Processing enablers
Regulatory enabler	· Regulation (the Landfill Directive, landfill bans) · Clear recycling targets · Enforcement · Sanctions · Mandatory requirements to sort/collect bio-waste · (Improved) Extended Producer Responsibility (EPR) schemes	· Creating quality standards for secondary plastics · Clear recycling targets · Certification to increase the trust of industry and consumers · Mandatory rules on minimum recycled content in certain products · Encouraging member states to consider reducing VAT on recycled products
Technical / process enabler	· Appropriate collection infrastructure and handling · Providing higher collection frequency for separated streams · Door to door collection encouraging separate collection · Bring systems only for some fractions and when a dense network of bring sites exists · Civic amenities with wide opening hours and accepting several material fractions	· Treatment infrastructure that matches collection systems · Extensive technical infrastructure · Incorporating recyclability of plastics in design
Market / financial enabler	· Financial incentives to move away from landfilling e.g. Landfill taxes · Extended Producer Responsibility · Pay as You Throw schemes · Reducing VAT for products containing recycled materials · Deposit return systems	· Cooperation between municipalities on infrastructure planning · Cooperation between municipalities on service procurement
Awareness/ knowledge related enablers	· Instructing citizens on how to separate waste · Having a way to motivate citizens to sort waste · National level technical support and capacity-building · Guidance e.g. a minimum service standard for separate collection · Technical support	

5.2.1 *Legislative enablers*

Regulation is essential to ensure MSW collection. As explained in Chapter 4 on barriers, the mixed and dispersed nature of municipal waste typically makes it complex to collect. Traditionally the treatment options have been limited to landfilling and, in recent decades, incineration. Against this backdrop the EP (2017) states that the Landfill Directive represents the most significant piece of European legislation in relation to avoiding MSW ending up in landfill. More specifically, clear recycling targets are one of its key elements. All leading actions in the world have clear recycling targets in common (Eunomia, 2017). Other regulatory tools to help enable increased collection of MSW for recycling, as explained in (EEA, 2018) and EC (2018b). The reports highlight the importance of enforcement, by cascading national recycling targets down to the municipal level. Sanctions are mentioned, to ensure that there are consequences for those municipalities that fail to meet targets. The introduction of mandatory requirements to sort bio-waste, and improving Extended Producer Responsibility (EPR) schemes are also seen as enablers for higher collection rates. BiPRO and CRI (2015) corroborate the idea that countries with mandatory separate collection of certain municipal waste fractions have high(er) municipal waste recycling levels.

5.2.2 *Technical enablers*

Appropriate collection infrastructure and handling help increase the amount of municipal waste being recycled (EEA, 2018; EC, 2018b). Also providing higher collection frequencies for separated streams (as compared to those for mixed waste) can help drive up recycling levels (EC, 2018b). Door-to-door collection systems are widely believed to be particularly successful. For example, BiPro and CRI (2015) state that door-to-door collection systems that encourage separate collection and discourage mixed waste provide the highest recycling rates and the best quality of recyclables. Collection costs for such schemes are higher than alternatives, but collection rates and revenues are also usually higher, and the resultant rejection rates and treatment costs lower. As a less effective alternative, co-mingled collection of recyclables (which several EU Member States have in place) tends to result in lower costs. Two-stream co-mingled collection (e.g. plastics and metals) is a reasonable way to reduce costs and maintain good material quality. Mixing several fractions together, however, can result in a higher incidence of cross contamination, and the quality of recyclables tends to be lower and rejection rates higher. Lastly, the study mentions that bring systems (which often struggle to encourage inhabitants to separate their waste and result in a larger percentage of impurities) are a reasonable solution for certain fractions (e.g. glass) and when a well-planned, dense network of bring sites exists. Civic amenity sites have the potential to improve the overall recycling rate, on the condition that they are convenient to use (close-by and suitable opening hours) and that the number of sorted fractions is significant.

5.2.3 *Market and Financial enablers*

In its Environmental Implementation Review 2019, the EC (2019d) states that economic instruments such as landfill taxes, Extended Producer Responsibility and Pay as You Throw schemes can foster recycling, by making it more economically attractive. The (EEA, 2018) supports this view and also names a range of other fiscal and economic measures that can improve the competitive position of recycling vis-à-vis virgin raw materials. The EC (2019d) also names other enablers such as reducing VAT for products containing recycled materials and shifting the tax burden from labour to polluting activities. A proven method to motivate citizens to separate waste are deposit-return systems, which deliver the purest material fractions (BiPRO and CRI, 2015).

5.2.4 *Awareness and knowledge related enablers*

Enablers to tackle the awareness raising / knowledge related barriers identified revolve around properly educating and informing citizens about the type of waste that should be placed in separate bins. This is vital for reducing impurities and obtaining a high-quality recyclable material (BiPRO and CRI, 2015). To help tackle knowledge deficits on the municipality side, local authorities can receive technical support, access to capacity-building programmes as well as guidance; for example, in the form of a minimum service standard for separate collection (EC, 2018b).

5.3 Enablers for WEEE recycling

Enabler category	Collection enablers	Processing enablers (see annex)
Regulatory enabler	· Regulation (e.g. WEEE Directive) · Better enforcement · Performance targets · Extended Producer Responsibility schemes · Current joint targets for preparation of reuse and recycling · Harmonisation in reporting and a system to check what is being reported (e.g. Regulation 2019/290) · Mandating that all actors report their data	· Regulation (e.g. Minimum quality standards for treatment) · Enforcement of current regulation for proper treatment (incl. Controls & inspections; action against unauthorized operators; shared responsibility of waste producers and other chain operators for hazardous waste management) · Introducing a separate ‘preparation for re-use’ target · Harmonisation in reporting and a system to check what is being reported (e.g. Regulation 2019/290)
Technical / process enabler	· Design for disassembly · Good product tracking / improved data through e.g. electronic systems · Take-back schemes	· Design for disassembly
Market / financial enabler	· To establish an "observatory" to monitor scavenging and the economic losses of scavenging · Inclusion of "scavenging index” should be considered in the negotiation of contracts · Creating a stakeholder group to bring all actors together	· Establish an observatory" to monitor operational costs · Define minimum operational costs for auditing and compliance (non-negotiable costs) · Make CENELEC EN 50625 (Collection, logistics & treatment requirements for WEEE) standards applicable for every operator
Awareness / knowledge related enablers	· Incentives for citizens to recycle i.e. residual restriction, differential Pay As You Throw, deposit refund · Providing practical guidance to distinguish between preparation for reuse and reuse · Undertaking studies to inform ‘substantiated estimates of "all WEEE flows" · Providing disassembly instructions to users	· Mechanisms for exchanging product information relevant for recycling and preparation for re-use between producers and recyclers · Establish a ‘preparation for re-use’ network of registered and authorized / certified operators at national level. · Create, publish, disseminate and use clear and harmonised guidance on waste classification and management

5.3.1 Legislative enablers

Better enforcement of existing legislation to avoid illegal waste collection and further legislation are enablers widely found in literature. On the collection side of WEEE recycling, EC (2018b) mentions the improvement of EPR schemes, in line with the general minimum requirements in the revised Waste

Framework Directive, as an enabler. Evaluations show that sectoral legislation such as the directives on Waste Electrical and Electronic Equipment (WEEE) have led to a strong increase in the amount of materials being recycled, even if in some cases the performance in some Member States fails to meet the targets set (European Commission, 2019c). Clear performance targets and policy objectives, extended producer responsibility and incentives to encourage citizens to recycle e.g. residual restriction, differential Pay As You Throw, deposit refund schemes are believed to help drive recycling of MSW up (Eunomia and Resource Media, 2017). Joint targets established for both the preparation of reuse and recycling in the new WEEE Directive, can lead to Member States increasing recycling efforts as it is a lower hanging fruit than reuse (despite the latter being a higher priority within the waste hierarchy and hence the preferred option) (BiPro et al., 2015). Harmonised reporting and checks on reported data have been identified as enablers. Participants in a workshop organised by the European Commission and DIGITALEUROPE in 2017 gives a set of enablers for improving information as regards collection of WEEE, such as mandating that all actors report their data; developing a system to check what is being reported to ensure the quality and completeness of the data; and ensuring harmonisation and common understanding between Member States on what to track, trace and report to the European level. This would help create a level playing field for the treatment of WEEE in a way that all WEEE is treated according to the same standards (as per Dutch model). This is currently addressed by Regulation 2019/290 (EU, 2019c) which aims to establish a single format for WEEE (Waste Electrical and Electronic Equipment) registration and reporting across the European Union (applied from 1 January 2020).

5.3.2 Technical enablers

Design for disassembly (disassembly being the first step in the recycling process) can help ensure EEE is recycled and enable whole components to be reused (Circular Economy Practitioner Guide, 2018). Other technical aspects that enhance recycling concern waste treatment infrastructure and tracking data. Good product tracking and take-back schemes are an important first step to circular global value chains (World Economic Forum, 2020). EC (2018b) also calls for improvements to data quality, including through quality checks and by reinforcing traceability procedures to account for all waste. This would imply that fully fledged, reliable and interoperable electronic record-keeping and tracing systems are in place and integrated within national statistics systems. Also EU waste shipment data are mentioned as particularly useful for the management of hazardous waste (Ibid). DIGITALEUROPE (2017) states that IT tools and reporting platforms are essential to measure all WEEE flows. They give examples of the range of tools developed by Member States to measure WEEE flows and overcome unaccounted waste (one of the main barriers hindering WEEE). In Spain, for example, collected WEEE is registered in the so-called 'WEEE Platform', an electronic database designed to provide a single source of information on the collection and management of WEEE at the state, regional and municipal level. In the Flanders Region of Belgium, Recupel/Cronos have developed a mandatory e-Tool 'BeWEEE', which is made available to all authorities. In the Netherlands, the WEEELabex treatment standards have been mandated for all WEEE treatment facilities as of July 2015, thanks to which there is a mandatory reporting of EEE by all compliance schemes and individual producers, as well as a mandatory reporting of WEEE by collective compliance schemes, WEEELabex certified operators and those exporting WEEE for treatment. Italian WEEE treatment facilities are obliged to subscribe to the Italian WEEE Coordination Centre and provide their relevant data. The Coordination Centre seeks intelligence on WEEE managed by Italian WEEE treatment facilities as well as WEEE received by distributors (take-back obligation) on an annual basis. Lastly, one can presume that technical breakthroughs in recycling may drive demand for collected WEEE in order to recover precious materials.

5.3.3 *Market and financial enablers*

EERA (2018) provides a series of recommendations to help the economics of recycling and facilitate recycling of WEEE. Relating to collection, it suggests that an "observatory" is set up to monitor the scavenging level in different countries/markets and define a common basis (indicators based on average market values of fractions) to estimate the economic losses due to scavenging[35]. This might eventually include the assessment of entire products (including valuable ones, like mobile phones) in the waste stream, which is further decreasing the intrinsic economic value of the incoming material. Next to that, the inclusion of a "scavenging index" should be considered in the negotiation of contracts with compliance scheme, as the economic impact of scavenging might be higher than the profit gained on the individual waste stream processing. Participants in a workshop by the European Commission and DIGITALEUROPE in 2017 claimed that creating a stakeholder group to bring all actors together would help improve the accounting of WEEE flows (EC, DIGITALEUROPE, 2017).

5.3.4 *Awareness and knowledge related enablers*

Improving consumer awareness (EC, 2018b) is key in engaging consumers in recycling WEEE and providing disassembly instructions will help users understand how to take it apart (Circular Economy Practitioner Guide, 2018). Other enablers identified by participants in a workshop organised by the European Commission and DIGITALEUROPE (2017), are providing practical guidance to distinguish between preparation for reuse and reuse to advance a better of accounting of all flows and undertaking studies to inform 'substantiated estimates of "all WEEE flows".

[35] 'Scavenging' refers to people taking either whole items or components of WEEE from places where electrical equipment has been left for recycling, such as at designated collection facilities. It is essentially 'theft'.

6 Conclusions

The analysis shows that significant recycling gaps exist across the C&DW, MSW and WEEE waste streams. In absolute terms, the largest recycling gap exists within the MSW stream, calculated at approximately 111 or 139 million tonnes (depending on the method used). The recycling potential of each waste stream, calculated as a percentage of the whole waste stream (and its associated percentage increase in recycling), is presented in Table 6-1 below. However, the size of the recycling gap differs significantly for certain waste streams, depending on the methodological approach used. This indicates that difficulties exist in the comparability and consistency of data reported by EEA countries and throughout the literature used in this report. Furthermore, the recycling gap estimates derived in this report do not take into account the impacts of increased recycling targets on recyclate quality. This remains an important aspect to consider in deriving recycling gap estimates.

Table 6-1 Current recycling rates versus estimated recycling potential, per waste stream

Waste stream	Current recycling rate	Recycling potential (bottom-up)	*Change from current recycling (%)*	Recycling potential (top-down)	*Change from current recycling (%)*
C&DW[36]	74%[37]	96%	*+30%*	96%	*+29%*
MSW	43%	80%	*+88%*	90%	*+110%*
WEEE	37%	78%	*+112%*	75%	*+103%*

Source: Own development.

In relation to barriers, the study shows that while some barriers are common to some or all waste streams, other barriers are stream specific. Some barriers occur more often than others. For some barriers we know whether they are either country specific or common across countries. Based on this, we conclude that according to literature, the most important barrier[38] to the recycling of the three waste streams is the *low market prices for natural resources / virgin raw materials*[39] which (in combination with low landfill taxes in some cases and high costs of treatment overall) reduce the viability of recycling of C&DW, MSW and WEEE. The recovered products struggle to remain competitive in relation to cost, quantity and quality with the virgin alternative. Another barrier to recycling of C&DW, MSW and WEEE is the *mixed and complex composition of the waste* stream (with the risk of contamination by hazardous materials, particularly in the case of WEEE and C&DW), which hinders waste treatment (processing). Other important barriers are the *lack of end of waste criteria*, which hinders the processing of waste (for C&DW as well as for MSW) and the *lack of a suitable network of recycling infrastructure or facilities* for collection, separation and treatment (for C&DW and WEEE). For MSW and WEEE, an important barrier is that collection of waste requires citizen participation in order for waste to be collected. MSW and WEEE also face issues with adequate *enforcement of regulation and sanctions* for those engaging in illicit activities.

[36] Referring to mineral C&DW only.
[37] Recycling rate of mineral waste without backfilling quantities included.
[38] The criteria used to identify 'Importance' of a barrier have been: 1) does the barrier affect to at least two of the three waste streams? 2) Is the barrier in question mentioned frequently in different studies? 3) Is it a barrier affecting many / all EU countries?
[39] This barrier fulfils the three criteria above.

As with the barriers, we can conclude which enablers are the most important based on 1) whether they cover all or at least two of the waste streams we have studied, and 2) how often the enablers in question come up in literature. Based on this, a *high degree of regulation* (including recycling targets) and *high levels of enforcement* appear to be the most essential enablers for all three waste streams. Adequate *punishment (i.e. sanctions) for offenders* are specifically mentioned as important for MSW and WEEE recycling. Overall, while the details vary, leading nations tend to have effective packages of policy levers in place. Measures that can help the economics of recycling become more viable, and support the waste hierarchy are found in literature for all C&DW, MSW and WEEE. For C&DW and MSW, *financial incentives such as landfill taxes* to discourage landfilling are commonly agreed enablers. *Design for disassembly* is an enabler for all the three waste streams. For C&DW and MSW an enabler for successful recycling is having a sufficient number *of waste treatment facilities* that can deal with key material streams.

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Annex I Waste stream factsheets

Construction and demolition waste

Key legislation, targets and provisions

The main governing tool for C&DW is the **Waste Framework Directive (2018/851/EU)**. The Directive aims to have 70% (of weight) of construction and demolition non-hazardous waste reused and recycled by 2020. This target also includes "backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste", yet excludes naturally occurring (uncontaminated) soils and stones.

Within the Directive, construction and demolition waste is defined as "waste that results from construction and demolition activities in a general way, it also includes waste arising from minor do-it-yourself construction and demolition activities within private households. Construction and demolition waste should be understood as corresponding to the types of waste included in **Chapter 17** of the list of waste established by Decision 2014/955/EU in the version in force on 4 July 2018".

The Commission Decision 2011/753/EU, provides a method for Member States to calculate recovery rates of C&DW. However, this Directive also allows Member States to report on their recovery rates based on their own reporting system, which can lead to reporting differences. The approach for calculating the recovery rate of C&DW is:

$$Recovery\ rate\ of\ construction\ and\ demolition\ waste = \frac{\text{Materially recovered amount of construction and demolition waste}}{\text{Total amount of generated constuction and demolition waste}}$$

The term "backfilling" is an important factor to consider in C&DW data, as the manner in which it is defined can impact whether it is included in country recycling data reported. Backfilling is often considered as low-quality recovery, which often takes the form of aggregate waste placed in previously excavated areas. As such it is seen as a relatively simple solution to the disposal of waste, despite potential environmental concerns and potential to re-use or recycle the materials used in backfilling into higher quality applications. The definition of backfilling provided by Commission Decision 2011/753/EU aligns with the definition for 'recovery' presented within the Waste Framework Directive, yet there is no definition regarding "suitable waste" as part of backfilling operations. In addition, the Waste Framework Directive states that the 70% recovery target excludes soils and stones, whereas the Landfill Directive implies that inert waste with low environmental risk would be "suitable" to replace non-waste materials. As such, the unclear definition of backfilling can lead to data discrepancies regarding recovery rates and the composition of mineral waste reported (Deloitte, 2017). To address this, Eurostat developed a document "Guidance on the interpretation of the term backfilling" (Eurostat, n.d.[a]), which provides clarity on some issues:

- *Any backfilling operation has to comply with the recovery definition by replacing other materials or being prepared to fulfil a particular function. Associated with the term backfilling is the notion of a permanent placement of the material on/in particular sites, it is not intended be returned to the economic material cycle;*
- *Backfilling operation involves reclamation purposes in excavated areas or engineering purposes in landscaping, however it has to substitute other materials that are not waste;*

- *The condition of substituting other (non-waste) materials suggests that the reclamation or landscaping measures will be undertaken anyway, whether a suitable waste for this purpose is available or not;*
- *For landscaping measures on landfills using waste materials, if the waste is used instead of other virgin materials, is suitable for the application (complying with the necessary properties for the particular performance), and is applied in a process of landscaping engineering it falls under the definition of backfilling.*

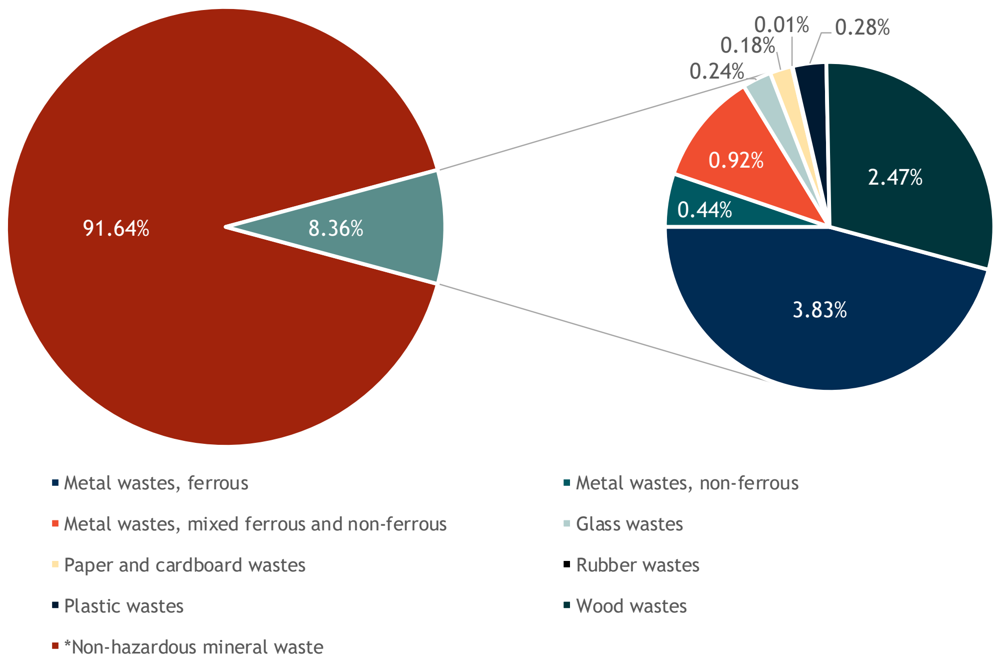
Size of waste stream

C&DW waste constitutes around **a third of total waste generated** in the EU, with waste generated for EEA-30 (no data available for Liechtenstein, Switzerland or Turkey) estimated at approximately 368 million tonnes of non-hazardous waste in 2016 (out of which 337 million tonnes consisting of non-hazardous *mineral* waste). Despite the large quantities of waste generated, the majority of Member States recover less than 50% of C&DW (EC, 2014). Within *mineral* C&DW, more than 70% of waste generated is separated into different materials, whilst approximately 11% is recovered for backfilling and 18% placed in landfill (IDEA Consult, 2018).

Material fractions of the waste stream

The composition of C&DW largely falls within Category 17 of the European List of Wastes. Soils constitute the largest material fraction of the waste stream, yet these are excluded from the Waste Framework Directive definition of C&DW. Taking this into consideration, the next largest material fraction originates from mineral wastes, which constitute around 2/3 of all construction and demolition waste across EEA countries.

Figure 0-1 Non-hazardous construction waste generated from the primary material fractions in 2016



Source: Eurostat (2019b).
Note: The amount of C&DW generated is calculated as the sum of waste (hazardous and non-hazardous) categories W061 ferrous metal wastes, W062 non-ferrous metal wastes, W063 mixed ferrous and non-ferrous metal-wastes, W071 glass wastes, W072 paper and cardboard wastes, W073 rubber wastes, W074 plastic wastes and W075 wood wastes generated by the NACE Rev. 2 Section F (construction sector) and total of waste category W121 mineral waste from construction and demolition across all activities (all NACE Rev.2 sectors) wastes. The data is derived for EEA-30 countries, with data unavailable for Liechtenstein, Switzerland and Turkey).

The Eurostat 'was_gen' dataset allowed C&D mineral waste (across all NACE activities including households) to be isolated from other waste fractions, yet a lack of data on the exact composition of this waste sub-stream exists (Eurostat, 2019b). Galvez-Martos et al. (2018) calculated the material composition of mineral waste based upon material fractions which fall within the mineral wastes prescribed in the European List of Wastes (EU, 2014) and supplementary documents (Eurostat, 2010). These average composition estimates were then applied to Eurostat 2016 data on mineral waste generated, to derive an estimate of the composition of mineral waste:

- Analysing data from 'was_gen', a total of **337 million tonnes** of non-hazardous C&D mineral waste was calculated across all NACE activities;
- Applying the *average* composition of mineral waste from literature (Galvez-Martos et al., 2018), the overall mineral waste composition was estimated;
- Assuming that these material fractions constitute 100% of the total of mineral waste generated, the quantities estimated in the previous step were upscaled from approximately 78% to 100% (of mineral waste). Their composition within the mineral C&DW waste stream was then recalculated. The results are shown in the table below.[40]

The table below shows the **estimates of these material fractions within mineral waste**. As shown, the greatest estimated material fraction of mineral waste generated belongs to masonry and concrete, collectively contributing approximately 246 million tonnes of the total 337 million tonnes of total mineral C&DW generated within EEA-30.[41]

Table 0-1 Estimated average composition of mineral waste generated within EEA-30 in 2016

Material fraction	Average material composition (%) upscaled from Galvez-Martos et al. (2018)	Waste generated based on Eurostat data
Concrete	33%	112,727,719
Masonry	40%	134,406,127
Asphalt	19%	65,035,223
Other mineral waste (stones, gravel and other aggregates)	7%	23,846,248
Gypsum	0.4%	1,300,704
Total mineral waste generated		**337,316,002**

Source: Own development based on data from Galvez-Martos et al. (2018), Eurostat (2019b) and Eurostat (2019c).
Note: Galvez-Martos et al. (2018) provided a range of material compositions per material. An average of each range was calculated and upscaled to 100%.

A lack of data exists regarding the composition of backfilling, however, it can be deduced from the WFD recovery target (which excludes "naturally occurring materials- e.g. soils and stones) and from the Landfill Directive (EU, 1999) (which states that only inert waste that poses minimal environmental concern is suitable for backfilling) that reported backfilling materials predominantly

[40] Galvarez-Martos et al. (2018) provided a range of material-fraction estimates per material component of mineral waste. As such, an average percentage was calculated per material, but this totaled 78%. For this reason, the estimates obtained in tonnes needed to be upscaled to 100%.
[41] No mineral waste data could be retrieved for Liechtenstein, Switzerland or Turkey.

consist of **concrete, bricks, tiles and ceramics, glass, and mixtures of these fractions** (Deloitte, 2017).

The analysis was complemented with further research into the maximum recycling potential of other material fractions of C&DW (i.e. non-mineral C&DW - for which no data on current recycling exists on Eurostat).[42] These potential recycling rates were then applied to the waste generated data for each material fraction of C&DW for the EEA-30.[43] The potential recycling rates of these fractions are shown below. Calculating the maximum recycling potential of the non-mineral materials in C&DW, a total of approximately **26 million tonnes** of waste could be recycled; however, no comparisons could be made to current recycling due to a lack of data on current recycling of non-mineral C&DW waste. Despite this, it is important to consider potential contamination occurring in such waste, which would likely impact the feasibility of recycling. In addition to this, the potential recycling rates quoted below do not represent material fractions as part of the C&DW stream, rather, these rates reflect the potential of the material fractions in isolation- which will likely presents a more optimistic overview.

Material fraction	Potential recycling rate	Evidence base or assumptions	Potential recycling quantity (tonnes)
Ferrous metals	95%	Deloitte (2017).	13,396,834
Non-ferrous metals	70%	INFA (2014).	1,127,286
Mixed metals	83%	INFA (2014), no specific potential recycling rate specified, so an average recycling rate between ferrous and non-ferrous metal was used.	2,819,540
Glass	50%	Deloitte (2017). The report develops an 'optimised scenario', which realises more ambitious recovery targets for C&DW. For the scenario, the study calculated the potential recycling rate of glass waste from C&DW with Glass for Europe. No explicit mention of collection rate of steel could be located.	438,754
Paper and cardboard	96%	IMPACTPaperRec (2016). *Case study on Kempten, Oberallgäu and Lindau (Germany).*	641,247
Rubber	80%	No data could be found on maximum recycling potential rates of rubber from C&DW, therefore, the average recycling potential of the other material fractions in this table was applied (80%).	22,369
Plastic	70%	Nordic Council of Ministers (2014).	710,072
Wood	80%	NL Agency (2013).	7,260,123
Total non-mineral maximum recycling potential			**26,416,226**

[42] The further research complements the first approach used in section 3.1.3, and excludes the potential recycling of backfilling quantities.
[43] No waste generated data available for Liechtenstein, Switzerland or Turkey.

Source: Own development with data from Eurostat (2019b; 2019c) and various other sources referenced in the table.   *Note: This analysis builds on the bottom-up method in section* ***Error! Reference source not found****. (see Table 3 -2).*
Waste challenges
A challenge to the recycling of this waste is the low cost associated with the extraction of natural aggregates in the production of concrete. The costs of this extraction can be similar to the costs of recycled aggregates, leading to a lack of incentives to recycle concrete. As such, the predominant market barriers to the uptake of C&DW recycling are the availability of recycled aggregates, economic incentives, and acceptability (the notion that recycled aggregates have a lower performance) (JRC, 2018). The lack of data available on waste abandonment/ dumping and the absence of a systematic inclusion of excavated material within national reporting means that the robustness of data can be difficult to assess regarding C&DW (Giorgi et al., 2018).

Municipal solid waste

Key legislation, targets and provisions
Like C&DW, MSW is primarily governed by the **Waste Framework Directive (2018/851/EU)**. The Directive aims to increase re-use and recycling of municipal waste to at least 55% of waste generated by 2025, 60% by 2030, and 65% by 2035. Countries that prepare less than 20% of for re-use and recycling or landfilled more than 60% of their municipal waste in 2013 can apply for derogations to extend the time for complying with the targets by up to five years. The current target for municipal waste is of 50% of waste generated, as set out in the previous WFD (2008/98/EC).   The WFD specifies that waste from large commerce and industry that is not similar to waste from households, as well as waste from production, agriculture, forestry, fishing, construction and demolition, septic tanks and sewage network and treatment, and end-of-life vehicles are to be excluded from the scope of municipal waste. Municipal waste is to be understood as corresponding to the types of waste included in **Chapter 15 01 and Chapter 20 (with the exception of codes 20 02 02, 20 03 04 and 20 03 06) of the List of Waste (LoW) established by Commission Decision 2014/955/EU**. Waste falling under other chapters of that list is not to be considered as municipal waste except in cases where municipal waste undergoes treatment and is assigned codes listed in Chapter 19 of that list.   As stated in the WFD, the calculation of the recycling targets should be based on the **weight of the municipal waste that enters recycling**, and should exclude losses of materials occurring before the waste enters recycling operations. However, the calculation of recycling targets should take into account the recycling of metals that are separated after the incineration of municipal waste. To measure progress towards the targets set out in the WFD, countries can choose between **four calculation methods**, as established by Commission Decision 2011/753/EU (see Figure 0-2). The option of choosing between different calculation methods makes it difficult to compare data across countries, and may explain some of the disparity in the waste management performance between different countries.

Figure 0-2 Alternative methods for the calculation of the target on municipal waste pursuant to Article 3(3) of Commission Decision 2011/753/EU

Calculation method 1	Calculation method 2
Recycling rate of paper, metal, plastic and glass household waste (in %) = the share of recycled paper, metal, plastic and glass household waste out of the total generated amount of paper, metal, plastic and glass household waste	**Recycling rate of household and similar waste (in %)** = the share of recycled paper, metal, plastic, glass waste and other single waste streams from households or similar waste stream out of the total generated amount of paper, metal, plastic, glass waste and other single waste streams from households or similar waste
Calculation method 3	**Calculation method 4**
Recycling rate of household waste (in %) = the share of recycled household waste out of the total household waste amounts (excluding certain waste categories)	**Recycling of municipal waste (in %)** = share of municipal waste recycled out of the total municipal waste generated

Source: Annex I, Commission Decision 2011/753/EU.

To improve the comparability and accuracy of waste data in Europe, new rules for the calculation, verification and reporting of data on waste have been introduced. The methods used by each country and the material fractions that they consider when defining municipal waste will be reported following the guidelines of **Commission Implementing Decision (EU) 2019/1004**. The new Decision also includes methodologies on calculating municipal bio-waste and recycled metals separated after the incineration of municipal waste, however, reporting on the latter two waste fractions is not mandatory. The four calculation methods defined in Commission Decision 2011/753/EU remain relevant. An overview of the methods used my EU MS in the period 2013-2015 to quantify their MSW is found in Annex A-2 of the Implementation Report for the Waste Framework Directive (Eunomia Research & Consulting et al., 2018a).

In addition to the WFD, the Landfill Directive (2018/850/EU), the Packaging and Packaging Waste Directive (2018/852/EU), and the Single-Use Plastics (SUP) Directive (2019/904) provide some relevant information on municipal waste and its evolution in terms of quantity and composition of waste generated. These Directives are expected to affect MSW in the future through landfill restrictions and dedicated extended producer responsibility (EPR) schemes. For instance, the Landfill Directive aims to **reduce the landfill of municipal waste to a maximum of 10% by 2035**, and waste suitable for recycling or other material or energy recovery will be banned from landfilling as of 2030. Several other provisions are made with regard to what can be reported as landfilled, namely:

- Reporting should be based on the amount of municipal waste landfilled after treatment operations and on the input into disposal incineration operations;
- Waste resulting from treatment operations prior to recycling or other recovery of municipal waste, which is subsequently landfilled shall be included in the weight of municipal waste reported as landfilled;
- Waste produced during recycling or other recovery operations of municipal waste that is subsequently landfilled shall not be included in the weight of municipal waste reported as landfilled;

- Municipal waste that enters incineration disposal operations and waste produced in the stabilisation operations of the biodegradable fraction of municipal waste in order to be subsequently landfilled shall be reported as landfilled; and,
- Municipal waste that is shipped to another country for the purposes of landfilling shall be counted towards the amount of waste landfilled.

The Packaging and Packaging Waste Directive has set a target of 65% of packaging waste to be recycled by the end of 2025, and 70% by the end of 2030. For those countries that include packaging waste in their municipal waste statistics, efforts to increase the recycling of packaging waste can be expected to contribute to the recycling rate of municipal waste on the whole. The Directive also urges countries to take action through national programmes, incentives through EPR schemes, and other economic instruments. EPR schemes need to be established for all packaging (and need to comply with the minimum requirements established under the WFD) by 2025.

Similarly, the SUP Directive calls for the creation of EPR schemes for fishing gear containing plastic, and states that for the majority of banned products, producers will be responsible for waste management clean-up, data-gathering, and awareness raising. The Directive bans single-use plastic cutlery, plates, straws, cotton bud sticks, beverage stirrers, sticks to be attached to and to support balloons, food containers made of expanded polystyrene, and products made from oxo-degradable plastic (where alternatives exist). Furthermore, the Directive sets a collection target for plastic bottles (of maximum 3L) of 77% by 2025, and 90% by 2029. Countries can achieve this target through deposit-refund schemes or separate collection targets for relevant EPR schemes.

Although different directives may affect municipal waste and may impact recycling rates in the future, this report has focused on MSW as defined in the WFD and as reported in Eurostat.

Size of waste stream

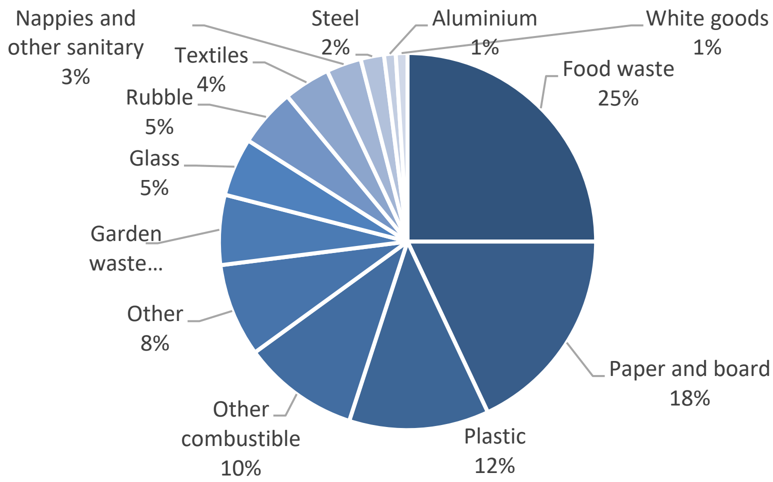
Municipal waste makes up **about 10% of waste generated** in Europe (JRC, 2018), with about 295 million tonnes of waste generated in EEA-32 in 2018 (no data available for Liechtenstein), according to Eurostat (2020). Out of this total, approximately 43% is recycled through both material recycling and composting and digestion. Material recycling makes up just over 28% of waste generated.

Material fractions of the waste stream

Municipal waste is a highly mixed and complex waste stream. Eurostat does not report data on the material fractions of municipal waste, but rather reports data on waste generated, waste landfilled, waste incinerated and recovered (through energy recovery), and waste recycled (through material recycling or composting and digestion) (Eurostat, 2019). However, Figure 0-3 below shows the material composition of municipal waste based on a **sampling exercise** conducted by Zero Waste Europe[44], as referenced in JRC (2018).

[44] See https://zerowasteeurope.eu/.

Figure 0-3 Sample material composition of municipal waste



Source: Own development based on Zero Waste Europe data, as cited in JRC (2018).

As one can observe, just over 30% of municipal waste consists of bio- or organic waste (i.e. food waste and garden waste), while a bit more than 35% consists of recyclable materials such as paper and board, plastic, metals, and glass. The remainder is made up of other combustible materials, rubble, textiles, nappies and other sanitary products, white goods, and other materials.

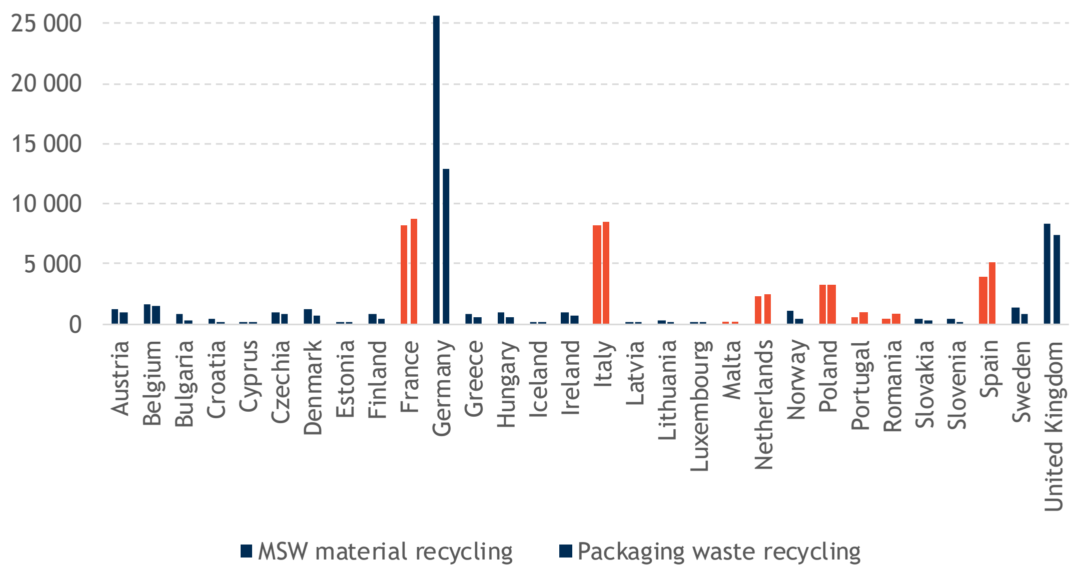
Waste challenges

The challenges of managing MSW arise from its complex and mixed composition, direct proximity to citizens, high public visibility, and its impact on the environment and human health. Given these challenges, it is important to have efficient collection schemes and sorting systems, infrastructure that can process the specific waste composition, an elaborate financing system, and citizens and businesses that are engaged (JRC, 2018). Furthermore, as highlighted above, countries may report on their progress towards the recycling target established by the WFD based on four different methods. This makes it difficult to compare data across countries, and makes it difficult to identify what material fractions (and in what proportion) are part of the waste reported as treated.

Note on uncertainties in MSW reporting:
Municipal waste is a highly mixed waste stream, which poses challenges for its management (JRC, 2018). Various measures have been proposed to support the aim of less waste reaching landfill (as per the Landfill Directive) and more waste being recycled. One important example are **extended producer responsibility (EPR) systems**, which aims to shift the responsibility of waste management away from municipalities and towards producers (Eunomia Research & Consulting et al., 2018b). EPR schemes are encouraged by EU directives such as the Packaging and Packaging Waste, the Single-Use Plastics, and the WEEE Directives. The implementation report on the Packaging and Packaging Waste Directive demonstrates that many of the EU MS have introduced EPR schemes or other similar producer obligations (Eunomia Research & Consulting et al., 2018b). The benefit of EPR schemes is that they take responsibility for collecting or taking back used goods or materials (such as packaging), as well as sorting and treating the goods or materials for prospective recycling (BIO IS et al., 2014). Although their effectiveness varies, EPR schemes have the goal of improving separate collection and, ultimately, facilitating recycling. However, since reporting on waste statistics varies from country to country, the introduction of private separate collection schemes brings into question the consistency of statistics on the generation and recycling of municipal waste.

A report by the EEA (2013) noted that countries use varying definitions of MSW, leading to uncertainties when assessing waste management performance across Europe. This is partly explained by the significant overlaps between waste categories; notably, between recycled municipal waste and recycled packaging waste. It is, therefore, possible that some countries do not include recycled packaging waste from households when reporting on recycled municipal waste.[45] Using the same approach as the EEA (2013), Figure 0-4 below compares recycling statistics on municipal waste (material) and packaging waste. The comparison illustrates that some eight countries reported recycling more packaging waste than material recycling of municipal waste in 2017.[46] This means that **real recycling figures could be higher than reported in municipal waste statistics** if packaging waste is isolated from MSW data.

Figure 0-4 Comparison of MSW material recycling and packaging waste recycling in the EU in 2017



Source: Own development based on Eurostat (2020) and Eurostat (2019a) data.
Note: In the figure above, data on MSW material recycling from 2017 was used, to compare to packaging waste recycling in the same year.

Another factor that affects the consistency of data across Europe is the method of calculating MSW, which varies greatly between countries. An overview of the different methods used by EU MS is provided in Annex A-2 of the Implementation Report for the Waste Framework Directive (Eunomia Research & Consulting et al., 2018a). The choice of method could depend on the extent to which waste is 'commingled' and whether the country has the technology to effectively deal with mixed waste in their waste management facilities. For example, the same report states that Ireland collects the majority of its (dry recyclable) waste commingled but still achieves effective recycling yields and quality due to sorting in purpose-built Material Recovery Facilities; in France, waste streams are subject to an EPR system and are collected separately. In Latvia, it is stated that separate collection in certain municipalities is considered not viable due to low population density and lack of vehicle access (Eunomia Research & Consulting et al., 2018a).

[45] Data on packaging waste was only available for EU MS, therefore, the analysis was only done on EU countries.
[46] For Cyprus, Ireland, Italy, Malta, and Romania, 2016 data was used.

Waste electrical and electronic equipment

Key legislation, targets and provisions

The main directive governing this waste stream is the **WEEE Directive (2012/19/EU)**[47], which sets a number of different collection, recovery, and re-use and recycling targets depending on the different categories of EEE. The first WEEE Directive (2002/96/EC) grouped EEE into 10 categories for which statistics had to be collected, while the recast WEEE Directive (2012/19/EU) regrouped EEE into six categories, as shown below. However, both classification systems remain valid.

Table 0-2 EU-10 and EU-6 EEE classification

EU-10 categories (Annex I of Directive 2012/19/EU)	EU-6 categories (Annex III of Directive 2012/19/EU)
1 - Large household appliances 2 - Small household appliances 3 - IT and telecommunications equipment 4 - Consumer equipment and photovoltaics 5 - Lighting equipment 6 - Electrical and electronic tools 7 - Toys, leisure, and sports equipment 8 - Medical devices 9 - Monitoring and control instruments 10 - Automatic dispensers	1 - Temperature exchange equipment 2 - Screens, monitors, and equipment containing screens having a surface greater than 100 cm^2 3 - Lamps 4 - Large equipment (any external dimension more than 50 cm) 5 - Small equipment (no external dimension more than 50 cm) 6 - Small IT and telecommunication equipment (no external dimension more than 50 cm)

Source: Own development based on the WEEE Directive.

The WEEE Directive (2012/19/EU) states that from 2019 onwards, the minimum collection rate of annual EEE placed on the market in the preceding three years is of 65% (of weight), or 85% of WEEE generated. Meanwhile, for WEEE falling within the following categories (of the EU-6 classification system), the minimum recovery targets as of August 2018 are:

- Category 1 or 4: 85 % shall be recovered, and 80 % shall be prepared for re-use and recycled;
- Category 2: 80 % shall be recovered, and 70 % shall be prepared for re-use and recycled;
- Category 5 or 6: 75 % shall be recovered, and 55 % shall be prepared for re-use and recycled;
- Category 3: 80 % shall be recycled.

The achievement of targets should be calculated for each category by dividing the weight of the WEEE that enters the recovery or recycling/preparing for re-use facility (after proper treatment in accordance with Article 8(2) with regard to recovery or recycling) by the weight of all separately collected WEEE for each category, expressed as a percentage.

According to **Commission Implementing Decision (EU) 2017/699**, there are two methods of calculating **the weight of EEE placed on the market**:

1. Annex X, Part B of Directive 2012/19EU requires Member States to report:
- The category of EEE according to Annex I or III of the Directive;
- The quantity and category of EEE placed on the national market by weight;

[47] In 2018, the directive was amended by Directive (EU) 2018/849. It is to be noted that Directive (EU) 2018/849 primarily aims to ensure consistency and harmonisation of reporting obligations and legislation across the different waste streams that it covers (namely, WEEE, waste of batteries and accumulators, and end-of-life vehicles) and does not include significant changes to the WEEE Directive.

- The quantity, by weight, and category of waste of EEE separately collected, recycled (including preparation for reuse) recovered and disposed within the Member State or shipped within or outside the EU

2. If method 1 is not applicable, Member States should use the following equation:

$$\text{EEE placed on the market}(t) = \text{Domestic production}(t) + \text{Imports}(t) - \text{Exports}(t)$$

In method 2, 'domestic production' refers to the weight (tonnes) of finished EEE produced in a reference year (t) within a Member State; 'imports' refer to the weight (tonnes) of EEE entering a Member State in a reference year (t) coming from another Member State or a third country for distribution, consumption or use; and 'exports' refer to the weight (tonnes) of EEE leaving a Member State in a reference year (t) for another Member State or a third country for distribution, consumption or use.

Furthermore, a methodology is provided to calculate the total quantity of **WEEE generated**:

$$W(n) = \sum_{t=t_0}^{n} POM(t) \cdot L^{(p)}(t, n)$$

Whereby, W(n) refers to the quantity (tonnes) of WEEE generated in evaluation year n, POM(t) refers to the quantity (tonnes) of EEE placed on the market in any year t; t_0 refers to the first year when an EEE was placed on the market; and L(p) (t, n) refers to the discard-based lifespan profile for the batch of EEE placed on the market in year t, which reflects its probable discard rate in evaluation year n.

Size of waste stream

Over **11 million tonnes** of WEEE were reported in 2016 for EEA-32 (excluding Liechtenstein) (Baldé et al., 2017). According to Thiebaud et al. (2018), approximately 40% of WEEE is collected for recycling, but many rare materials are still unable to be effectively recovered from this waste stream due to lack of market incentives and commercial-scale technologies. Amongst the collected WEEE, 46% constitutes large household appliances, while another 40% is made up of IT and telecommunications equipment and consumer equipment (EP, 2015).

Material fractions of the waste stream

WEEE contains a vast array of components and materials, including **base metals, precious metals, critical raw materials (e.g. indium, gallium, cobalt), plastics, glass, ceramics, and hazardous substances**. Of these fractions, it is estimated that within the EU-10 classification of WEEE, iron constitutes the largest material fraction of waste generated, followed by plastics, other materials, glass, copper and aluminium (NewInnoNet, 2016). However, the composition of this waste stream is constantly changing due to ongoing technological developments, legislative pressures (such as the Restriction of Hazardous Substances Directive (RoHS) 2011/65/EU), and subsequent consumer preferences. These technological developments can also lower the incentives to recover materials from WEEE products, due to the trend for products to decrease in size, meaning that a smaller weight and value of exotic materials can be recovered (NewInnoNet, 2016).

Waste challenges

Achieving the recovery targets established under Article 11 of the WEEE Directive presents several challenges, namely that all targets are **input-based targets**, calculated as WEEE enters the recovery or recycling/preparing for re-use facility. As stated above, this waste is then divided by the weight of all separately collected WEEE for each category, meaning that difficulties can be presented if, for example, inputs are shredded (BiPRO et al., 2015). Furthermore, there are **joint targets** established for both the preparation of re-use and recycling, which can lead to countries only increasing recycling efforts as it is a lower hanging fruit than re-use, despite the latter being a higher priority within the waste hierarchy.

Annex II Evidence base for the 'bottom-up' method

The following tables provide a list of literature used to estimate the recycling potential for C&DW, MSW and WEEE using the 'bottom-up' method (as described in Chapter 3). Additional information on what data was extracted from each study is provided in the column "Comments" in each table.

Table 0-1 Potential recycling rates of construction and demolition mineral waste fractions

Material fraction	Potential recycling rate	Source	Comments
Concrete	99%	Kleeman et al. (n.d.).	The study garners information from LCA, construction and demolition plans, and literature on building demolition material composition in Vienna, Austria. The study estimates that the current material flows of buildings in Vienna results in 99% of concrete waste is made available for transfer to other sectors (civil infrastructure) after demolition.
Masonry	98%	Kleeman et al. (n.d.).	This source follows the same study detailed in the row above, Kleemann et al. (n.d). For this estimate, it is assumed that masonry is 100% composed of bricks. Bricks are presented in various waste management stream outputs in Figure 1 of the report (reuse, recycling for other sectors, recycling for cement), resulting in a cumulative output from waste management of demolition (i.e. collection for recycling and reuse) of 3,248,000 tonnes. The total output of bricks for demolition is calculated in table 3 of the report, at an estimated 330,000 tonnes. Therefore the cumulative output of bricks post-waste management constitutes 98%.
Asphalt	97%	Poulikakos et al. (2017).	The study states that data supplied by the European Asphalt Pavement Association recorded asphalt pavement was reclaimed and recycled for use in new roads at 97% in Germany.
Gypsum	30%	Vrancken and Laethem (2000).	The study noted that 30% of gypsum could be separated from wall boards, blocks and plaster work in a Dutch case study. This was achieved through mechanical screening, followed by handpicking.
Other mineral waste	74%[48]		Current EEA-30 recycling rate – without backfilling.

Source: Own development.

[48] As no specific data on the composition or recycling potential of 'other mineral waste' could be found, the average recycling rate of EEA-30 countries was applied here. As such, this remains a relatively conservative estimate as the average recycling rate is derived from data on material collected for recycling.

Table 0-2 MSW material fractions and their recycling potential, as found in literature

Material fraction	Potential recycling rate	Source	Comments
Food waste	95%	World Economic Forum (2019).	In 2019, it was reported that South Korea recycles 95% of its food waste. The article explains that the country's recycling performance is due to the following measures: • Dumping food in landfills was banned in 2005, after which the government introduced compulsory food waste recycling using special biodegradable bags (2013); • Smart bins weigh food waste and charge residents according to the weight; Waste collected using the biodegradable bag scheme is squeezed at the processing plant to remove moisture and dry waste is turned into fertilizer.
Paper and board	96%	IMPACTPaperRec (2016).	The European project IMPACTPapeRec[49] was launched in 2016 and aims to further increase the separate collection of paper for recycling (PfR) and promote appropriate schemes to avoid landfilling and incineration. One of its case studies (on Kempten, Oberallgäu and Lindau, DE) shows a recycling rate of paper & cardboard of nearly 96%, achieved through improved collection systems/schemes.
Plastic	70%	Nordic Council of Ministers (2014).	The study looked at the collected quantities of plastic packaging (defined as packaging waste, bulky packaging waste and small plastic waste other than packaging, from households and other MSW sources) from MSW in Nordic countries, and compared the collection rates to the estimates of plastics placed on the market. For Sweden, the estimated plastic packaging placed on the market (excluding PET bottles) was 176,478 tonnes (2010), whilst 123,500 were collected (2010) by municipalities, therefore resulting in an approximate 70% collection rate.
Other combustible	43%	*The make-up of this material fraction is unknown and no definition could be found*. The current recycling rate of EEA-32	This remains an optimistic estimate.

[49] See http://impactpaperec.eu/en/about/the-project/.

Material fraction	Potential recycling rate	Source	Comments
		countries was used.[50]	
Other	43%	*The make-up of this material fraction is unknown.* The current recycling rate of EEA-32 countries was used.[51]	This remains an optimistic estimate.
Garden waste	100%	Danish Environmental Protection Agency (1999).	*"Some types of household waste - glass and paper - are covered by collection schemes with source separation and recycling. Total recycling of household waste is around 28 per cent. Especially garden waste is recycled. […] Garden waste is composted with a recycling rate of almost 100 per cent."* (p. 16)
Glass	77%	Dutch Waste Management Association (2015). *This study refers to glass packaging.*	The study reports 546 kilotonnes of glass packaging being produced in the Netherlands, out of which 418 kilotonnes is collected (p. 4). This results in a collection rate of nearly 77%.
Rubble	96%	Potential recycling rate of C&DW mineral waste, as found in section 3.1.3.	
Textiles	74%	Bartl (2018).	The study found that Germany has the highest textile collection rate in Europe, in 2013. The data was taken from the following study: Korolkow, 2016, *Konsum, Bedarf und Wiederverwendung von Bekleidung und Textilien in Deutschland, Studie, im Auftrag des bvse-Bundersverband Sekundarrohstoffe und Entsorgung e.V. RWTH- Aachen*. The study calculated the per capita consumption of textiles (clothing and home textiles such as curtains and linen, excluding carpets) to derive an upper estimate of textile availability within Germany. The study then gathered data on the collection rates of textiles throughout Germany, calculated that 75% of the

[50] This refers to the recycling rate of EEA-32 countries, as shown in Figure 3-7.

Material fraction	Potential recycling rate	Source	Comments
			textiles made available within the country are then collected for reuse or recycling.
Nappies and other sanitary products	70%	EC (n.d.[b]).	*"AHP [absorbent hygiene products] waste currently represent about 2-3% of the total municipal solid waste, and represent up to 15-25% of the residual waste stream in some treatment facilities, where selective collection rates above 70% are in place."*
Steel	95%	Deloitte (2017).	The report develops an 'optimised scenario', which realises more ambitious recovery targets for C&DW. For the scenario, the study calculated the potential recycling rate of metallic waste (including steel) with Eurofer (The European Steel Association). No explicit mention of collection rate of steel could be located.
Aluminium	97%	Green Alliance (2019). *This study refers to aluminium packaging.*	The report makes four proposals on how to achieve "near 100 percent recycling rate for aluminium packaging" (p. 1). They are as follows: • Improve deposit-return schemes (i.e. a well run DRS can collect 95% of cans for high quality recycling); • Improve kerbside services for aluminium products not dealt with through DRS; • Ensure best practice at sorting plants; • Recover the remainder from incinerator bottom ash.
White goods	75%	Own calculations based on Eurostat (2019d) and EC (2019b): Estonia's recycling rate of large household appliances (Category 1 WEEE) was used.	Estonia's recycling rate of large household appliances was the highest recycling rate achieved in Europe in 2017 in this category.

Source: Own development.
Note: The material composition of municipal waste is based on a sampling exercise conducted by Zero Waste Europe[52] and referenced in JRC (2018).

52 [52] See https://zerowasteeurope.eu/.

Table 0-3 WEEE material fractions and their recycling potential, as found in literature

Material fraction	Potential recycling rate	Source	Comments
Iron	95%	Deloitte (2017).	The report develops an 'optimised scenario', which realises more ambitious recovery targets for C&DW. For the scenario, the study calculated the potential recycling rate of metallic waste (including iron) with Eurofer (The European Steel Association). No explicit mention of collection rate of iron could be located.
Plastics	70%	Nordic Council of Ministers (2014).	The study looked at the collected quantities of plastic packaging (defined as packaging waste, bulky packaging waste and small plastic waste other than packaging, from households and other MSW sources) from MSW in Nordic countries, and compared the collection rates to the estimates of plastics placed on the market. For Sweden, the estimated plastic packaging placed on the market (excluding PET bottles) was 176,478 tonnes (2010), whilst 123,500 were collected (2010) by municipalities, therefore resulting in an approximate 70% collection rate.
Other	37%	*The make-up of this material fraction is unknown and no further information on its content could be found.* The current recycling rate of EEA-31 countries was used as a proxy.[53]	This remains an optimistic estimate.
Glass	77%	Dutch Waste Management Association (2015).	The study reports 546 kilotonnes of glass packaging being produced in the Netherlands, out of which 418 kilotonnes is collected (p. 4). This results in a collection rate of nearly 77%. In absence of data on glass waste found in WEEE and its collection potential, we used the same rate as for MSW.
Aluminium	97%	Green Alliance (2019). *This study refers to*	The report makes four proposals on how to achieve "near 100 percent recycling rate for aluminium packaging" (p. 1). They are as follows:

[53] This refers to the average of the recycling rates found in Figure 3-13.

Material fraction	Potential recycling rate	Source	Comments
		aluminium packaging.	• Improve deposit-return schemes (i.e. a well run DRS can collect 95% of cans for high quality recycling); • Improve kerbside services for aluminium products not dealt with through DRS; • Ensure best practice at sorting plants; • Recover the remainder from incinerator bottom ash. In absence of data on aluminium waste found in WEEE and its collection potential, we used the same rate as for MSW.
Copper	82%	European Copper Institute (2018).	In the “summary diagram of copper stocks and flows in the EU28”, there are 2,490 kt of copper content in end-of-life scrap, out of which 1,610 kt are collected for recycling and 430 kt are lost during separation. The focus of the present report is what is collected prior to separation, thus, the 430 kt have been added to the 1,610 kt. This results in a collection rate of nearly 82%.
Silver	55%	EC (2017b).	No data could be found on the potential (maximum) collection of silver, so the ‘end-of-life recycling input rate’ was used (as found on p. 384).
Gold	10%	EC (2017b).	No data could be found on the potential (maximum) collection of gold, so the ‘end-of-life recycling input rate’ was used (as found on p. 115).
Palladium	10%	UNEP (2011).	No data could be found on the potential (maximum) collection of palladium, so the ‘end-of-life recycling rate’ of palladium in electronics was used. This ranged from 5% to 10%, so the upper bound was used (as found in Table E1, p. 32).

Source: Own development.

Annex III Barriers related to 'processing'

Processing barriers to the recycling of C&DW

Legislative barriers

Regulatory aspects affecting processing concern either lack of policies or policies that do not work optimally for recycling. For example, several Member States lack both an End of Waste (EoW) criteria and sorting requirements for C&DW (Deloitte, 2016). Deloitte (2017) argue that low recovery rates could be the result of a lack of effective policies for the use of recycled materials and a lack of obligations for the use of recycled materials or recycled content in construction materials. In line with this, ETC/WMGE identify as barriers the fact that the standards usually only allow low replacement rates in low-grade concrete.

Technical barriers

There is a technical barrier in incorporating recycled waste into new products. For example, concrete waste into new concrete. As explained by the VEEP-project (2016), the most advanced concrete recycling technologies currently produce coarse (>4mm) recycled concrete aggregates by removing cement paste from the surface of the aggregates. However, the fine (0-4mm) fraction, which accounts for approximately 40% of the concrete waste, still faces technical barriers to be incorporated into new concrete and consequently, is often down-cycled (In addition there are other minor (e.g. glass) and emerging (e.g. mineral wool) C&DW materials, currently accounting for 0.7% of the total C&DW, but revealing growing rates. Emerging C&DW streams have not yet found technological and business solutions, and are mostly landfilled (Ibid.). The heterogeneity of C&DW, together with the potential presence of hazardous materials and lack of traceability (limited information on the origin and quality of waste materials) leads to large streams of C&DW being downcycled (ETC/WMGE, 2020). Even the highest performing countries seem to struggle with mixed C&DW materials and the presence of hazardous substances in C&DW (or the requirement to prove this) (Deloitte, 2016). Although 'selective demolition'[54] can in theory enhance the recovery of fractions for high-quality recycling, process related aspects such as time availability, space (especially in an urban environment) and structural safety in the dismantling / demolition work hinder it (ETC/WMGE, 2020). At present, inadequate source segregation is an important barrier (Deloitte, 2017). The main barriers to mineral wool recycling are ensuring the purity and steady availability of recycled mineral wool (Nordic Council of Ministers, 2019). Deloitte (2017) echoed this point, explaining that the proximity and spread of suitable recycling facilities close to sites where waste arises is important, as this is closely linked to the cost of transport.

Market and financial barriers

On the *market barriers,* several studies corroborate that the low cost of raw materials in combination with the low cost of landfill and the high treatment costs make recycling inefficient from a cost perspective (Galvez-Martos et al., 2018; Deloitte, 2017; ETC/WMGE 2020; JRC, 2018; BIO by Deloitte, 2016). This is due to necessary steps such as material screening and reprocessing as well as the high cost of specific sorting machines that constrain recycling on-site (Hamidreza Ghaffar, S. et al., 2020). BIO by Deloitte (2016) distinguishes between barriers in high and lower performing countries. Both in low and well performing countries market barriers concerning the low price of natural raw materials,

[54] The process of identifying hazardous materials (that have to be removed prior to demolition) to ensure high-quality (pure) material fractions are separated for recycling (or reuse)

the lack of trust in recycled materials and the small market for recycled materials (the market is unable to absorb the quantities of recycled waste) are found. Deloitte (2017) highlighted the low acceptability of secondary materials (or material containing recycled materials) by the construction industry. There is a notion that recycled aggregates have a lower performance as compared to virgin materials (JRC,2018, ETC/WMGE, 2020), for instance, concerning the production of concrete, and there are also concerns about the quality and potential presence of hazardous materials, such as asbestos (ETC/WMGE, 2020). Deloitte (2016) also noted that in the high performing countries, the potential of green public procurement in construction and public tenders still remains untapped in some cases (e.g. Estonia). As explained in ETC/WMGE (2020) 'selective demolition'[55] increases costs, as the process prolongs demolition time and therefore requires more labour. The same study explains that complex buildings increase costs for selective demolition and material separation.

Awareness and knowledge related barriers

Lastly, Deloitte (2017) states that there is a lack of *awareness*, understanding and competence by the industry across the EU, regarding what they should and could be doing to improve C&DW management and recycling. In a similar vein, Deloitte (2016) lists the lack of know-how of construction actors, and the lack of guidance and standards for recycled C&DW materials as barriers.

Processing barriers to the recycling of MSW

Legislative barriers

Oeko (2016) explain how national regulations can hinder recycling by imposing restrictions on the recycling industry. Examples of such legislative barriers affecting processing include the lack of end-of-waste criteria and bureaucratic barriers for recycling permits. Differences in national regulations, permits and registrations can halt the transfer of best practice or best available technology between Member States. Weaker norms outside the EU create incentives for economic operators to export waste for treatment, especially to Asia (European Parliament, 2015). This also links to illegal shipments (European Parliament, 2015) when treatment options outside of the EU are cheaper than building recycling plants in the EU.

Technical barriers

Although *technological barriers* are increasingly being overcome by technology developments in the recycling industry, waste collected as mixed cannot in principle be recycled or re-used to a significant degree and therefore its resource efficiency potential is lost (Oeko, 2016). As Oeko (2016) explains, the sorting of specific materials is particularly challenging as most existing sorting equipment cannot recognise black plastics, thus discarding the waste products altogether. Impurity levels in recyclable waste are also an important cause of the technical limits to recycling, as contamination sets an upper recycling limit. Since impurities often lead to down-cycling, lower quality products are generated from the recycling process. This downcycling in turn makes recyclables less economically attractive (reducing recycling levels). Impurities also lead to the need to add virgin material to products made from recyclable waste, thus reducing the overall recycling efficiency. As BiPRO and CRI (2015) explain, in warmer climates the quality of collected bio-waste might have started to degrade.

[55] The process of identifying hazardous materials (that have to be removed prior to demolition) to ensure high-quality (pure) material fractions are separated for recycling (or reuse).

Market and financial barriers

The health risks / implications of products containing recycled materials is an issue. A briefing for the European Parliament (2015) states, “one of the main barriers related to waste management is seen as promoting recycling while making sure consumers are protected from toxic substances which can be found in waste.” While the Waste Framework Directive promotes recycling through the waste hierarchy and binding targets, the REACH Regulation regulates chemicals contained in products (with the aim of protecting consumer health and the environment). Although REACH does not apply to waste, it applies to materials leaving the waste regime after recycling (reaching 'end-of-waste' status), with some exemptions from registration granted to recyclers. Recyclers have to determine whether the substances present in products they manufacture (including any impurities) have hazardous properties. They also need to search for relevant existing information and evaluate it. This requires carrying out checks and controls at various stages of the recycling process, as well as getting information about the raw material products, which may not be public or easily available. The need to meet these requirements results may drive up recycling costs (pushing recycling operations and use of secondary raw materials outside the EU and preventing higher recycling rates), which is an important *market barrier*.

Among the *market barriers* Oeko (2016) report the fact that returns on investment are highly influenced by the volatile prices of primary raw materials (e.g. metal prices), which can pose a financial barrier. This is related to the fact that the markets for recyclables can be unprofitable if the competing raw material prices are low enough. The immaturity of secondary material markets – except for established ones e.g. for glass and paper - is a significant barrier to further increasing recycling levels. If the value of recovered materials is low, it does not provide waste planners and operators with a sufficient incentive to engage and intensify recycling activities. Materials are subject to price volatility in the secondary materials markets, and it is therefore difficult to attract investors. Another barrier stems from the fact that energy recovery of waste (also called 'waste-to-energy') can in some cases compete with recycling as a waste treatment method (European Parliament, 2015a).

Setting up and maintaining waste plants and other infrastructure requires high investment and running costs, which can result in a long payback period (if incomes are not high enough) (Oeko, 2016). The European Parliament (2017) adds that developing waste management and treatment capacities that are economically and environmentally viable over the long term is a challenge, especially for EU countries with a lower GDP, such as Hungary, Slovakia, Latvia, Poland, Romania, Estonia, Bulgaria and Portugal.

Processing barriers to the recycling of WEEE

Legislative barriers

In terms of regulation, illicit e-waste trade (illegally exported waste) remains a barrier to recycling (European Commission, 2019c; Bakhiyi, B., 2018). Addressing illegal exports is a current priority, as waste-related crime has been recognised as an EU priority in the overall policy on organised crime for the period 2018-2020 (Europol, 2020). This has been prompted by the fact that illicit waste shipments outside the OECD still take place, despite all 28 EU Member States being signatories to the Basel Convention. A recent study by the Basel Action Network (2018) identified that despite having legal barriers to international waste dumping in place, 339 446 tonnes of hazardous electronic waste per year (approximately 4% of the total) is exported from the EU to developing countries, primarily in Africa.
In addition, WEEE is often treated under non-compliant conditions with other metal scrap (European Commission, 2019c).

Technical barriers

The properties of the waste are troublesome and health risks as a result of hazardous materials present in WEEE are often cited as barriers. Large household appliances (e.g. ovens, fridges, washing machines) currently make up over 40% of WEEE but this waste stream also includes large volumes of other equipment such as IT equipment (mainly computers), TVs (over two million discarded each year), small household appliances (e.g. kettles and hair dryers), electrical tools, digital watches, electronic toys and medical devices (Health & Safety Executive, 2020). Each of these products contains several materials in varying proportions. For example, an average TV contains 6% metal and 50% glass, whereas a cooker is 89% metal and only 6% glass. Other materials found include plastics, ceramics and precious metals. From this complex mix of product types and materials, some are hazardous (heavy metals such arsenic, cadmium, lead and mercury and certain flame retardants), posing a number of health risks for example, from exposure to substances released during processing (Health & Safety Executive, 2020; Bakhiyi, B., 2018; Kuehr, R.,2012). This links to market barriers, as many critical metals are not recycled because of the low volumes of these materials within electronic equipment and low market prices that do not cover recycling costs (Thiebaud et al., 2018). As such there is a lack of commercial-scale recycling technology for many critical metals and rare earth elements (Ibid.). That is exacerbated by technological developments trending towards gadgets that become smaller over time, resulting in an even lower weight of exotic materials that can be recovered per single appliance (NewInnoNet, 2016). Given the very low fraction of critical metals in WEEE, these barriers may not be considered priorities to act on based on volume, however they are significant when considering issues of value-added and material security, especially as the EU relies heavily on imports of many critical raw materials. When looking into plastics, the problems are different. Plastic processors require large quantities of recycled plastic, manufactured according to strictly controlled specifications and at a competitive price and the diversity of the raw material (plastics) complicates the recycling process, making it costly and affecting the quality of the end product (EP, 2018). As a consequence, the demand for recycled plastics is only 6% of demand in Europe (Ibid).

Market and financial barriers

Concerning market and finance related aspects, the barriers applying to plastic recycling are important for WEEE, as electronic equipment has an average plastics content of about 30% (EC, 2007). The main issues complicating plastic recycling are the quality and price of the recycled product, compared with their virgin alternative. The low price typically paid for plastic material (be it virgin or recycled) makes it difficult to justify the investment made during the recycling process (European Commission, 2019c). This results in much material being exported from Europe to places where cost structures (e.g. lower labour cost) make recycling more economically attractive (Ibid). Next to that, the high cost of legal treatment of waste – particularly in developed countries - that may contain hazardous materials sometimes drives illicit waste processing (despite transboundary movement of WEEE is restricted by the Basel Convention and ratified by most countries of the world) (Işıldar, A., 2018)

Awareness and knowledge related barriers

In terms of *awareness* and *knowledge* related barriers linked to processing of WEEE, Tansel (2017) identifies a lack of awareness and training on the safe handling and processing of materials during recovery at uncontrolled recycling operations as barriers.

Annex IV Enablers related to 'processing'

Enablers for C&DW recycling related to processing

Legislative enablers

Regulation is useful for ensuring that high(er) quality recyclables are generated. Quality protocols and certification schemes to establish controls on input materials and processes for instance, lead to higher quality recyclables (Deloitte, 2017). ETC/WMGE (2020) states that mandatory decontamination of construction waste, requiring the removal of hazardous materials can also lead to higher quality recyclables. The study also states that (mandatory) selective demolition, which is already mandatory in many member states, leads to higher quality recovery of materials. Other studies add that having in place EoW criteria (EC, 2018b; ECN, 2017) and/or quality certificates for recycled products (EC, 2018b) to encourage the uptake of products containing recycled material, encourage higher levels of recycling. Also requirements for at-source separation do (Deloitte, 2017).

Technical enablers

Deloitte (2017) state that a key to stimulating recycling of C&DW is ensuring that there are a good spread of recycling facilities, including facilities to deal with key material streams – e.g. inert, gypsum, wood, plastics etc. In addition to the presence of facilities, there are other technical enablers that allow for better material quality. For example, design for disassembly (ETC/WMGE, 2020) and the phasing-out of substances of concern in production processes and an improved tracking system could reduce the barriers for recycling (Deloitte, 2017). The importance of having traceability systems has also been highlighted by ETC/WMGE (2020).This is in line with the EU action plan, which states that the "promotion of non-toxic material cycles and better tracking of chemicals of concern in products will facilitate recycling and improve the uptake of secondary raw materials. Promoting selective demolition and sorting at source also help the separation of unwanted fractions from recyclable C&DW and improves quality (EC, 2018b; ETC/WMGE, 2020).

Market and financial enablers

ETC/WMGE (2020) stresses the importance of cooperation across the C&D value chain to enable recycling. For instance, to overcome the C&DW market / financial barriers, a large number of actors need to adopt design for disassembly to together create a larger market, effectively stimulating supply and demand. The study also states that cooperation between different stakeholders in the value chain, such as the 'green concrete deal' in The Netherlands, are useful. To ensure financial success, the study recommends identifying a market for material recovery prior to demolition. Lastly, the study notes that selective demolition tends to result in lower C&DW treatment costs and more employment due to the fact that it is more labour intensive.

Awareness and knowledge related enablers

Best practice guidelines and tools for C&DW management (Deloitte, 2017) and education on the circular economy at different levels in universities (ETC/WMGE, 2020) can help further recycling of C&DW. Overall, software/apps can be beneficial to help improve the inspection, tracking and reporting on levels of recycling and recovery (Deloitte, 2017).

Enablers for MSW recycling related to processing

Legislative enablers

Regulation can also help stimulate the market for recyclates, which as showed in the barriers section, face a problem of competitiveness. With regards to plastics, measures identified for these include: creating quality standards for secondary plastics, encouraging certification in order to increase the trust of both industry and consumers, introducing mandatory rules on minimum recycled content in certain products and encouraging member states to consider reducing VAT on recycled products (EP, 2018b).

Technical enablers

On the technica*l* side, The EC (2018b) mentions that municipalities should make sure that planned or existing treatment infrastructure matches the collection systems. Having an extensive technical infrastructure is also a prerequisite for high levels of recycling (BiPRO and CRI, 2015). For fractions such as plastics an essential enabler lies in product design. According to Plastics Recyclers Europe (2018) Plastics design should prioritise recyclability aspects, balancing these out with the other performance criteria (product safety, shelf life, marketing and branding, etc.) which currently rule. A product is considered recyclable if it meets the following conditions: The product is made with a plastic that is collected for recycling, has market value and/or is supported by a legislatively mandated program; The product is sorted and aggregated into defined streams for recycling processes; the product can be processed and reclaimed/recycled with commercial recycling processes; the recycled plastic becomes a raw material that is used in the production of new products.

Market and financial enablers

To overcome market / financial barriers, The EC (2018b) encourages cooperation between municipalities on infrastructure planning and/or service procurement to ensure scale efficiency and that the financial burden is shared. It also promotes the use of EU funds to develop adequate waste infrastructure for recycling.

Enablers for WEEE recycling related to processing

Legislative enablers

There are several legislative aspects that can enable recycling that mainly relate to enforcement. The EC (2018b) lists the following: considering the adoption of minimum quality standards for the treatment of WEEE and 'preparation for re-use' targets at national level (separate from the EU target); introducing (or intensifying) controls at all stages of the management chain; organising (unannounced) inspections targeting illegal or non-compliant activities; and taking action against unauthorised operators at all levels; and in the case of hazardous materials, enforcing the shared responsibility of waste producers and other chain operators for hazardous waste management.

Market and financial enablers

EERA (2018) provides a series of recommendations to help the economics of recycling and facilitate recycling of WEEE. Relating to processing, it firstly proposes establishing an "observatory" to monitor the operational costs of EU recyclers, with tailored cost intervals, on the basis of the first results highlighting typical cost ranges of compliance elements in the cited EERA (2018) study. The second recommendation is to define minimum operational costs for auditing and compliance to be excluded from price negotiations with compliance schemes (this should be the common basis, eventually indexed per country, of "non-negotiable costs"). Lastly, improving the reporting on collection and treatment is an essential economic requirement to have a level playing field. Specifically, when applying on a Member State level the ‘all-actors’ model or inclusion of ‘substantiated estimates’, these should also be accompanied with making the CENELEC EN 50625 (Collection, logistics & treatment requirements for WEEE) series of standards applicable for every operator to ensure proper treatment.

Awareness and knowledge related enablers

EC (2018) calls for developing and implementing mechanisms for exchanging product-related information relevant for recycling and preparation for re-use between producers and recyclers (e.g. I4R - Information for Recyclers - platform) as well as establishing a ‘preparation for re-use’ network of registered and authorised/certified operators at national level. The same report encourages Member States to create, publish, disseminate and use clear and harmonised guidance on waste classification and management (making use of the Commission’s technical guidance on the classification of waste), to facilitate the management of hazardous waste.

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