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Quality management systems for municipal waste data

Best practices and recommendations

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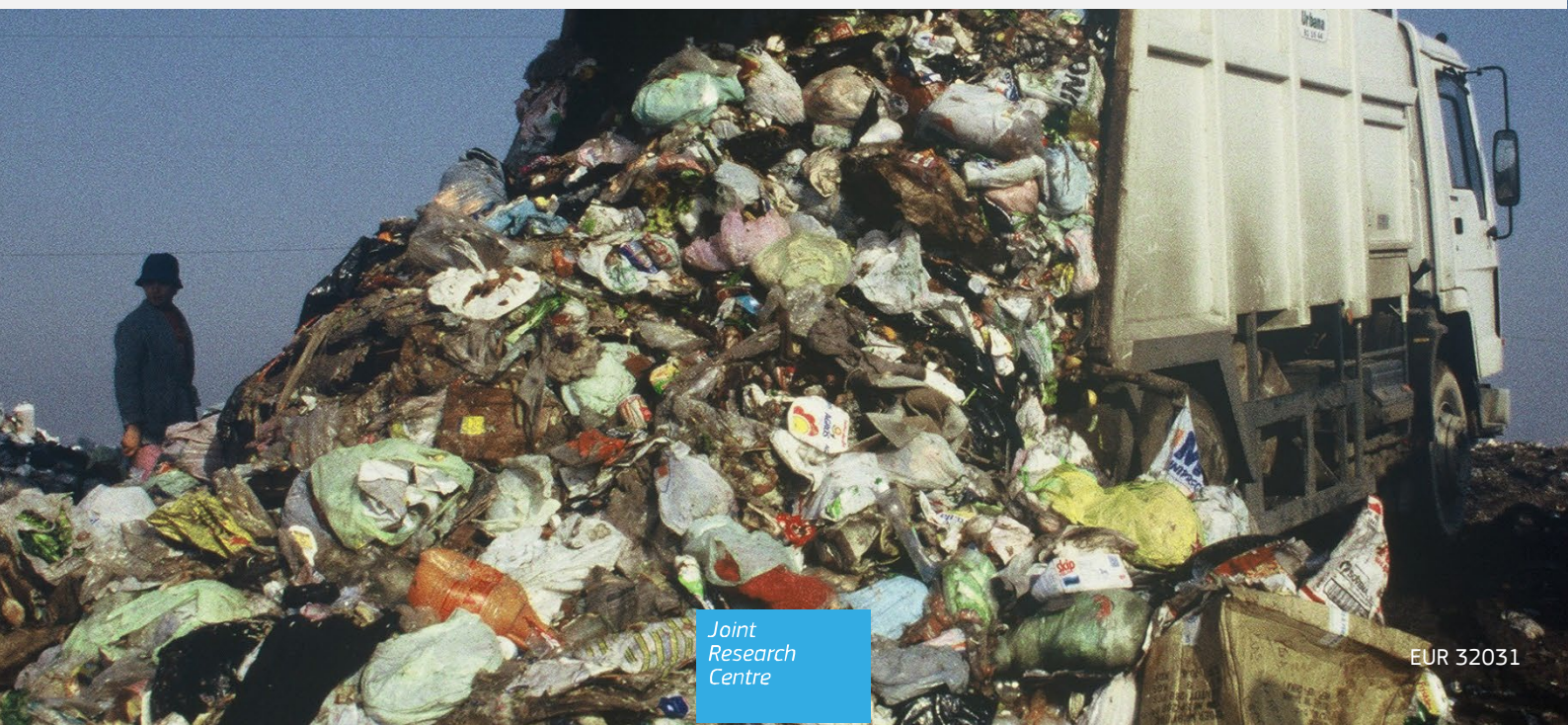

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Contents

Abstract

The aim of this study is to develop a proposal for an operational framework for a harmonised quality management system at EU level, with respect to the collection, reporting and publication of waste data as well as monitoring. To this end, a screening of the current situation in the EU-27 has been carried out, focusing particularly on data collection and reporting practices. This proposal builds upon the reporting obligations laid down in the Waste Framework Directive, the Packaging and Packaging Waste Directive and the Waste Statistics Regulation. Member States have the obligation to demonstrate compliance with EU recycling targets and are encouraged to establish a system for quality control and traceability of waste. The implementation of a harmonised quality management system can help Member States to track the progress of municipalities towards the attainment of the targets and to assess the impact of specific measures. It can facilitate comparability of data across Member States and better monitoring of the performance of waste management in the EU-27 and beyond. The availability of reliable and consistent waste data can ultimately support the development of new policy options under EU waste legislation.

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This report is issued as a scientific publication from the Joint Research Centre of the European Commission, and does not constitute legislation issued by the European Union. While it contains best practices to be pursued, these recommendations are not binding and, in the absence of legislative amendments, should not be construed as legal interpretation for current enforcement of EU waste legislation.

Executive summary

Within this study we examine the current practices for collection and reporting of waste data, including reporting obligations for Member States, methodologies and available standards for waste composition analysis and the indicators in use (or proposed in the literature) to assess the performance of waste management. Based on the findings, we propose an operational framework for the EU-wide harmonisation of quality management systems. The framework encompasses the proposal to establish electronic registries for waste, to amend the reporting obligations in place with additional requirements, including the reporting of waste management practices, to harmonise the methodology and frequency of waste composition analysis and to establish a monitoring system with specific key performance indicators to track the performance of Member States.

Policy context

The Waste Framework Directive (EU 2018/851, amending Directive 2008/98/EC) and the Packaging and Packaging Waste Directive (EU 2018/852, amending Directive 94/62/EC) lay down recycling targets for municipal waste and for packaging, respectively. Member States are required to demonstrate the attainment of the recycling targets, by reporting data on waste. As established in Article 9(5) of the Waste Framework Directive, Member States also have the obligation to assess the implementation of food waste prevention measures and to monitor the amount of food waste generated. Specific datasets for municipal waste, packaging waste and food waste are collected through the Eurostat-OECD joint questionnaire, the Eurostat questionnaire for packaging waste and the Eurostat questionnaire for food waste, respectively.

Data on generation and treatment of waste and on the available infrastructure are reported to Eurostat in compliance with the Waste Statistics Regulation ((EC) 2150/2002), which lays down reporting obligations on waste statistics. Relevant legal acts are Commission Regulation (EC) 782/2005, Commission Regulation (EC) 1445/2005 and Commission Regulation (EU) 849/2010 amending Regulation (EC) No 2150/2002.

However, the methodology for data collection and to some extent the granularity of data is determined by each Member State, hindering in many cases comparability both across countries and through time.

The establishment of a harmonised quality management system can help Member States to track the progress towards the attainment of specific targets and hence to verify compliance with relevant regulations. As mandated by Article 11a(3) of the Waste Framework Directive, Member States are required to establish a system for quality control and traceability of municipal waste, which may consist of electronic registries. However, at present Electronic Registries for Waste have not been implemented in all Member States.

Key conclusions

We propose a harmonised framework for quality management including the following measures:

- recording waste data and waste management practices in a national Electronic Registry for Waste;
- carrying out composition analyses of municipal waste, food waste and packaging waste with a given frequency;
- complementing the reporting obligations currently in force with two additional datasets on input and output of sorting;
- reporting waste management practices (especially on commingling[1] rules) and collection schemes;
- implementing a monitoring system at EU level with a set of Key Performance Indicators (KPIs) proposed within the report.

Related and future JRC work

This study is part of a series of studies carried out by the JRC for DG Environment that address, *inter alia*, sewage sludge management, end-of-waste criteria for plastic waste, the definition of recycling, recycling of waste batteries and different aspects in the separate collection of municipal waste. In relation to the latter (to

[1] Commingling means the collection of two or more waste streams (e.g. plastic and metals) in a single container and does not impede high-quality recycling or other recovery of waste, in line with the waste hierarchy (Directive (EU) 2018/851).

which this study relates), additional studies cover waste bin labelling harmonisation (Albizzati, Cristóbal, et al., 2023) and commingling practices (Albizzati & Tonini, 2023).

Quick guide

The report is structured as follows: in Chapter 1 the policy context is given and the rationale and scope of the study are described. Chapter 2 provides an overview of current practices for data collection, reporting and monitoring and the reporting obligations currently in place; it also provides best practices for impurity rates. In Chapter 3 a proposal for a harmonised operational framework is presented. Potential financial costs, socio-economic impacts and potential benefits are discussed in Chapter 4. In Chapter 5 an overview of the proposed measures is given, along with concluding remarks and final recommendations.

1 Introduction

1.1 Policy context and background

The Waste Framework Directive (EU 2018/851, amending Directive 2008/98/EC, henceforth WFD) and the Packaging and Packaging Waste Directive (EU 2018/852, amending Directive 94/62/EC, henceforth PPWD) lay down recycling targets for municipal waste[2] (MW) and for packaging waste (plastic, wood, ferrous metals, aluminium, glass and paper/cardboard), respectively. Member States (MS) are required to demonstrate the attainment of the recycling targets by reporting data on waste generation and treatment. As established in Article 9(5) of the WFD, Member States also have the obligation to assess the implementation of food waste prevention measures and to monitor the amount of food waste generated.

The Waste Statistics Regulation (2150/2002/EC) establishes a framework for the production of regular statistics on the generation, recovery and disposal of waste. The main objective of the statistics is to monitor the implementation of EU waste policies. Data can be collected by the Member States by means of surveys, administrative sources and statistical estimation procedures. Member States are required to transmit statistical results to Eurostat in an appropriate format. Hence, the collection and consolidation of data on waste falls under the responsibility of Eurostat.

Specific datasets for municipal waste, packaging waste and food waste are collected through the Eurostat-OECD joint questionnaire, the Eurostat questionnaire for packaging waste, and the Eurostat questionnaire for food waste, respectively. In order to improve the accuracy of data submitted by Member States, Eurostat has published guidance documents for the compilation and reporting of data on municipal waste (Eurostat, 2021a), on packaging waste (Eurostat, 2022c) and on food waste (Eurostat, 2022d). Those guidance documents are based on the reporting obligations and methodologies for reporting set out in Commission Implementing Decisions (EU) 2019/1004 for municipal waste, (EU) 2019/665 amending Decision 2005/270/EC for packaging and packaging waste and (EU) 2019/1597 for food waste.

One way to increase the traceability of waste at local level and facilitate the transmission of data to Eurostat is the implementation of digital tools to report and publish data, namely national Electronic Registries for Waste (ERW). The use of electronic registries is mandatory for hazardous waste, in accordance with Article 35(4) of the WFD, "*Member States shall set up an electronic registry or coordinated registries to record the data on hazardous waste referred to in paragraph 1 covering the entire geographical territory of the Member State concerned*". It is not mandatory but still recommended for other waste streams with recycling targets in place: "*Member States may establish such registries for other waste streams, in particular for those waste streams for which targets are set in legislative acts of the Union*".

Member States should implement waste management strategies[3] to improve the performance of the separate waste collection system and achieve the recycling targets. For a sound evaluation of the waste management system, it is crucial to establish a quality management system (QMS). As mandated by Article 11a(3) of the WFD, "*Member States shall establish an effective system of quality control and traceability of municipal waste to ensure that the conditions laid down in point (c) of paragraph 1 of this Article and in paragraph 2 of this Article are met. To ensure the reliability and accuracy of the data gathered on recycled waste, the system may consist of electronic registries set up pursuant to Article 35(4), technical specifications for the quality requirements of sorted waste, or average loss rates for sorted waste for various waste types and waste management practices respectively. Average loss rates shall only be used in cases where reliable data cannot be obtained otherwise and shall be calculated on the basis of the calculation rules established in the delegated act adopted pursuant to paragraph 10 of this Article*".

The QMS should be part of an integrated waste management strategy and be fully aligned with the regional, national and European legislative framework. The objectives of such a system may be periodically reviewed and updated to enable progress with waste collection and management. As stated by (Dri et al., 2018), a holistic QMS should take into account:

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[2] Throughout the report, 'municipal waste' is understood as defined in the WFD, Article 3(2b). (Unless otherwise stated, 'municipal solid waste' refers to municipal waste as defined therein.)

[3] cf. WFD article 28 "Waste Management Plans"

- current and future expected trends of waste streams for the territory; this will allow improvements in the waste management strategy in place;
- the waste hierarchy, prioritising measures accordingly;
- the obligations for setting up separate waste collection schemes for certain waste fractions, as specified in the WFD, e.g. separate collection of bio-waste from 2024 or textiles from 2025;
- commingling rules in place for the collection of waste fractions;
- collection schemes implemented in the municipalities (e.g. door-to-door, bring system, deposit refund schemes) for the different waste streams;
- economic instruments, such as pay-as-you-throw (PAYT), deployed in the waste management practices;
- the availability and capacity of waste sorting/treatment facilities and the type of actors in charge, e.g. external contractors or local authorities;
- best available practices or any other specific factor affecting waste management (e.g. the significant presence of tourists/commuters, specific economic activities, climate).

1.2 Rationale and objective of the study

The establishment of a harmonised quality management system can help Member States to track their progress towards the attainment of specific targets and hence to verify compliance with the regulations in force.

Data reporting and monitoring are crucial components of a quality management system, as they can facilitate feedback to different operators of the recycling value chain and can help to identify limiting factors in the separate waste collection systems in place. A quality management system can thus support the monitoring of implemented waste management strategies and the design of new strategies (Dri et al., 2018).

Today, the Eurostat waste database is the EU central hub for waste statistics, with the collection of waste data regulated by the Waste Statistics Regulation ((EC) 2150/2002); however, the methodology for data collection is to be established by each Member State (who may choose among different methods e.g. through surveys, administrative sources, statistical estimations or a combination thereof). At national level, waste data may, but doesn't have to, be collected and reported using electronic waste registries: 22 Member States are currently using such registries, but even then, the granularity of data differs among Member States.

Meanwhile, reporting obligations are in place for specific datasets, while others are transmitted to Eurostat on a voluntary basis. Based on the compiled metadata and on additional datasets declared by Member States on voluntary basis, Eurostat regularly updates various waste-related indicators (e.g. recycling rate of municipal waste and recycling rate of packaging waste). The key performance indicators by Eurostat allow tracking the progress of Member States towards the attainment of recycling targets. Nonetheless, the calibration of new strategies for waste management such as new collection schemes, require additional datasets (e.g. share of targeted materials and impurities in the collected waste, collection and sorting rates), not available in common statistics repositories. The above issues in data quality have been known and investigated for some time (Eunomia, 2017)

A harmonised QMS could therefore contribute to improving the quality and availability of waste data at EU level, by focusing on three dimensions of quality management: collection, reporting and monitoring. At EU level, a harmonised QMS can also contribute both to improving data communication between the different actors of the waste value chain and to improving the traceability of waste. It can ultimately enhance the comparability of data between Member States and facilitate a systematic optimisation of waste management strategies. In order to ensure data comparability, it is essential to set common terminologies and establish harmonised methodologies for the collection and reporting of data.

The aim of this study is therefore to:

- map the current situation in the EU, in terms of common practices in Member States for different dimensions of quality management in waste management;
- develop a proposal for an operational framework for a harmonised quality management system at EU level, including data collection, reporting, publication and monitoring;
- provide recommendations for waste authorities that devise and implement waste management strategies at local, regional or national level, and for waste operators.

1.3 Scope

1.3.1 Dimensions of quality management covered

With the aim of increasing the availability and reliability of waste data as well as knowledge of waste management practices implemented across the EU-27, this work proposes a harmonised framework for quality management, covering the following dimensions:

- **Data collection and publication**, including the use of electronic registries, to increase the traceability of data, enhance transparency and improve the quality of data reported to Eurostat.
- **Data collection and waste composition analysis**, proposing guidelines and a standardised methodology to be followed, as well as an appropriate frequency to perform a waste composition analysis.
- **Reporting of waste data and waste management practices**, proposing to revise the reporting obligations currently in force and complementing the reporting of waste data with reporting of collection schemes, commingling rules and economic incentives.
- **Control and monitoring**, proposing a set of Key Performance Indicators (KPIs), to track the progress of Member States and evaluate the effectiveness of waste management strategies.

1.3.2 Waste management phases and target authorities

The operational framework aims to cover all waste management phases, from generation to collection, sorting, and recycling, up to final disposal.

The framework builds upon the instructions and reporting obligations for municipal waste, packaging waste and food waste, as specified in Section 1.1. For every waste stream, the QMS should facilitate the data and information exchange between different actors, e.g. private operators (recyclers).

The operational framework is thus meant to be primarily targeted at waste authorities, which devise and implement waste management strategies at local, regional or national level, and waste operators who handle waste. The responsibility of implementing the QMS ultimately falls on the municipalities and Member States. The monitoring process is the responsibility of Eurostat. Its main objective is to track the progress of Member States towards compliance with the targets set in the waste legislation and more generally with specific EU policy objectives.

1.3.3 Waste fractions

As mentioned above, recycling targets for municipal waste and for packaging waste have been laid down in the WFD and in the PPWD, respectively. As indicated in the WFD: "*To ensure that preparing for re-use and recycling targets are based on reliable and comparable data and to enable a more effective monitoring of progress in attaining those targets, the definition of municipal waste in Directive 2008/98/EC should be in line with the definition used for statistical purposes by Eurostat and the Organisation for Economic Cooperation and Development (OECD), on the basis of which Member States have been reporting data for several years. Municipal waste is defined as waste from households and waste from other sources, such as retail, administration, education, health services, accommodation and food services, and other services and activities, which is similar in nature and composition to waste from households.*"

In this study we focus on municipal waste and we refer to the definition of municipal waste corresponding to the types of waste included in the List of Waste (LoW) established in Commission Decision 2014/955/EU (see Annex 1). Reporting obligations in place for **municipal waste**, **packaging waste** and **food waste** are accounted for.

The scope encompasses in particular two main waste stream categories within municipal waste, namely bio-waste and dry recyclables, but also takes into account the composition of residual waste. Bio-waste and dry recyclables (metal, glass, plastic and paper/cardboard) represent a large share of the total MW, namely 71% of the total MW in the EU-27 in 2018, as deduced from the data listed in **Table 1** (composition of municipal waste). Municipal waste includes waste generated from households and other sources which are similar in composition to waste from households.

Other waste streams like waste from electrical and electronic equipment (WEEE), batteries, and end-of-life vehicles (ELVs) are addressed by other EU policy instruments, i.e. the WEEE Directive, the Batteries Directive (now replaced by the Battery and Waste Battery Regulation, BWBR), and the ELV Directive, respectively, and are hence outside the scope.

Table 1. Municipal waste composition in the EU-27 in 2018.

Waste stream	**2018**
Metals	3%
Glass	5%
Plastic	13%
Paper and cardboard	14%
Bio-waste	36%
Wood	2%
Textiles	4%
Electrical and electronic equipment	2%
Batteries	0.1%
Bulky waste	3%
Mixed waste	13%
Other waste	4.9%
Total	**100%**

Bio-waste and dry recyclables are highlighted in green and represent 71% of the total. Source: (Albizzati & Tonini, 2023); Edjabou et al., 2021); EEA, 2023).

2 Overview of current practices for data collection, reporting and monitoring

This section gives an overview of the reporting obligations mandated by EU legislation, the databases for waste at EU level and national level, the methodologies for waste characterisation and the common indicators for waste monitoring.

2.1 Transmission of statistics

The European data centre for waste, under the responsibility of Eurostat (Eurostat, 2022b), represents the central hub for publishing data and information on waste.

The **Waste Statistics Regulation** ((EC) 2150/2002) (under the umbrella Regulation (EC) 223/2009 on European Statistics) lays down the requirements for transmission of statistics which form the basis of the waste database: waste data are to be submitted by the statistical authorities of each Member State to Eurostat. Relevant legal acts are:

- Commission Regulation (EC) 782/2005 setting out the format for the transmission of results on waste statistics;
- Commission Regulation (EC) 1445/2005 defining the proper quality evaluation criteria and the contents of the quality reports for waste statistics;
- Commission Regulation (EU) 849/2010 amending Regulation (EC) No 2150/2002 of the European Parliament and of the Council on waste statistics.

The Waste Statistics Regulation does not mandate a specific method to collect data: data can be collected through surveys, administrative sources, statistical estimations or a combination of those methods, following the manual on waste statistics (Eurostat, 2013). The specific methodology is to be established and handled by each Member State. Member States describe the selected methodologies in a quality report, to be submitted along with the data (European Commission, 2022), used as a basis to assess and compare the quality of the data submitted. Eurostat carries out a data validation process in cooperation with the Member States.

The electronic Dataflow Administration and Management Information System (eDAMIS) is the standard transmission tool used to submit the data and quality reports. National statistical offices have direct access to the tool. Ministries and environmental protection agencies can also request access or they can transmit the files to the statistical authorities (Eurostat, 2013).

In particular, the Waste Statistics Regulation mandates the transmission of the following datasets (Eurostat, 2013):

- generation of waste (18 NACE[4] economic sectors, households);
- treatment of waste (incineration, energy recovery, recycling, backfilling, landfilling, other disposal);
- number and capacity of disposal and recovery operations (incineration, energy recovery, recycling, backfilling, landfilling);
- coverage of waste collection scheme (population).

2.2 Reporting obligations

For **municipal waste**, the reporting obligations are based on the requirements laid down in the WFD as well as in Commission Implementing Decisions (EU) 2019/1004, (EU) 2019/1885 and (EU) 2011/753. Data are collected through the Eurostat spreadsheet questionnaire for municipal waste and the Eurostat-OECD joint questionnaire. A quality report must also be completed (Eurostat, 2021a). The following datasets shall be reported for municipal waste[5] (Eurostat, 2021a):

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[4] NACE is the acronym for "Nomenclature statistique des activités économiques dans la Communauté européenne" (statistical classification of economic activities in the European Community). Council Regulation (EEC) No 3037/90 on the statistical classification of economic activities in the European Community, as amended by Commission Regulation (EEC) No 761/93, imposes the use of a uniform classification with all Member States.

[5] Following the calculation rules laid down in Decision 2019/1004, and aligned with the wording of Article 11a of the WFD.

- waste generation (amount of municipal waste generated from households and other sources which are similar in composition to waste from households);
- separate collection (amount of municipal waste collected through separate waste collection at the initial point of collection);
- preparation for reuse and recycling (amount of municipal waste prepared for reuse or for recycling);
- recovery (amount of municipal waste subject to energy recovery or other recovery);
- disposal (amount of municipal waste sent to incineration without energy recovery, landfill or other disposal).

Member States have the obligation to additionally report:

- material breakdown;
- recycling rate;
- landfill rate.

As for generation and collection, based on the experience from the first MW reporting carried out in 2022, Eurostat and the JRC have observed that many Member States report the quantity of MW generated equal to the MW collected. This is not a consistent approach, but is nonetheless allowed by Commission Implementing Decision (EU) 2019/1004, specifically Annex V, wherever Member States do not have data available to estimate the generation (e.g. waste composition analyses). In Section 3.1.2 we propose a methodology (detailed in Annex 2) to estimate and report the quantity of MW generated when this is not readily available to the Member State.

For **packaging waste** the reporting obligations are laid down in the PPWD, following the reporting requirements in Commission Decision 2005/270/EC, last amended by Commission Implementing Decision (EU) 2019/665, which establishes the format for reporting. Data are reported using the Eurostat spreadsheet questionnaire for packaging waste. A quality report must be submitted along with the data. The following datasets shall be reported for packaging waste[6] (Eurostat, 2022c):

- waste generation (amount of packaging waste generated);
- recycling (amount of packaging waste recycled);
- repair of wooden packaging;
- recovery (amount of packaging waste subject to energy recovery or other recovery).

In the proposal for the PPW Regulation[7], new provisions to improve the monitoring and traceability of packaging flows have been included. Article 50(1) of the PPW Regulation proposal lays down requirements for Member States to report data on the implementation of the recycling targets, on the consumption of plastic carrier bags and on the separate collection rate of packaging covered by the obligation to establish deposit and return systems set out in Article 44(1) of the Regulation proposal. Article 50(2) lays down reporting obligations for the amounts of packaging placed on the market, the amounts of separately collected packaging waste, the recycling rates and the installed capacities for sorting and recycling.

According to Article 6c (d) of Commission Implementing Decision (EU) 2019/665, "*Where **biodegradable packaging** that is subject to aerobic or anaerobic treatment is included in the recycled amounts for the respective packaging material, the amount of biodegradable packaging in biodegradable waste shall be determined by performing regular composition analyses of the biodegradable waste entering those operations. Biodegradable packaging waste that is removed before, during or after the recycling operation shall not be included in the recycled amounts*".

For **food waste** the obligation to assess the implementation of food waste prevention measures and to monitor the amount of food waste is established in Article 9(5) of the WFD. The delegated act (EU) 2019/1597 establishes the methodology for reporting. On this legal basis, Member States have had the obligation to report data on food waste since 2020. Data are reported using the Eurostat spreadsheet questionnaire for food waste. A quality report must be submitted along with the data (Eurostat, 2022d). The following datasets shall be reported for food waste:

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[6] Following the calculation rules set, in particular in provisions of Article 6a of the PPWD as well as in new Articles 6a to 6d and Article 6f of Decision 2005/270/EC.

[7] https://environment.ec.europa.eu/publications/proposal-packaging-and-packaging-waste_en

- generation (amount of food waste generated);
- food waste prevention (food reused or recycled as feed, before becoming waste).

2.3 Eurostat Waste Database

The data collected are validated by Eurostat, which produces the waste statistics, published in the waste database (env_was). As shown in **Table 2**, in Eurostat's online database waste datasets are available for two main categories:

- waste generation and treatment (env_wasgt), including data on generation of waste, treatment of waste, as well as on recovery and disposal facilities;
- waste streams (env_wasst), including data about municipal waste, specific waste streams, trade and transboundary shipment of waste.

Data on waste generation is classified by source into household activities and into 18 business activities, following the statistical classification of economic activities in the European Community (NACE Rev. 2) (Eurostat, 2008) and by waste category, according to the European Waste Classification for Statistics (EWC-STAT) (Eurostat, 2010). This classification is linked to the European LoW (see Annex 1) and contains 51 waste categories, making a distinction between hazardous and non-hazardous waste. Data on waste treatment are classified into six treatment types (recycling, backfilling, incineration with energy recovery, other incineration, disposal on land and land treatment, other disposal) and in waste categories. It does not include pre-treatment activities (e.g. sorting). Data on disposal facilities follow a geographical classification by NUTS regions (Eurostat, 2021b). The reference period of the statistics is one calendar year.

Table 2. Eurostat Database on Waste (env_was)

Entries	**Datasets**
Waste generation and treatment (env_wasgt)	Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)
	Treatment of waste by waste category, hazardousness and waste management operations (env_wastrt)
	Management of waste excluding major mineral waste, by waste management operations (env_wasoper)
	Management of waste excluding major mineral waste, by waste management operations and waste flow (env_wasflow)
	Number and capacity of recovery and disposal facilities by NUTS regions (env_wasfac)
	Management of waste by waste management operations and type of material (env_wassd)
Waste streams (env_wasst)	Food waste and food waste prevention by NACE Rev. 2 activity (env_wasfw)
	Trade in waste by type of material and partner (env_wastrdmp)
	Packaging waste by waste management operations (env_waspac)
	Recycling rates of packaging waste for monitoring compliance with policy targets, by type of packaging (env_waspacr)
	Consumption of lightweight plastic carrier bags by their wall thickness (env_waspcp)
	Waste electrical and electronic equipment by waste management operations – open scope, 6 product categories (env_waseleeos)
	Waste electrical and electronic equipment by waste management operations (env_waselee)

	Sales and collection of portable batteries and accumulators[8] (env_waspb)
	Recycling of batteries and accumulators (env_wasbat)
	End-of-life vehicles by waste management operations (env_waselv)
	End-of-life vehicles – reuse, recycling and recovery (env_waselvt)
	Transboundary shipments of notified waste by partner, hazardousness and waste management operations (env_wasship)
	Municipal waste by waste management operations (env_wasmun)

Source: (Eurostat, 2022b)

2.4 National Electronic Registries for Waste

At national level, electronic registries can be used to collect and publish data on waste generation, management and disposal. At present, 22 Member States use electronic registries to manage waste data (Tuscano et al., 2022). **Table 3** provides an overview of current practices in Member States, using publicly available information as the basis, including reporting obligations and the implementation of Electronic Registries for Waste (ERW).

Table 3. Overview of current practices for reporting of waste data in the EU-27.

MS	**Electronic registries in place and legal background**	**Authorities managing ERW and entities with reporting obligations**	**Waste covered**
BE	Waste management is regulated by the three waste agencies based in the 3 regions: – Flanders (OVAM, 2023) – Brussels Capital (Brussels Environment, 2023) – Wallonia (Environment de Wallonie, 2023) Statistical reporting is undertaken by the 3 regional authorities separately. Reporting obligations are included in the Flemish 'VLAREMA regulation (2012)' (Chapter 7: Registering and reporting information on waste and materials) (VITO, 2023).	Managing authority: N/A Reporting obligations: Municipalities, local authorities, waste management bodies and waste collectors can declare the amount of household waste collected. Recyclers can declare the material input and output flows.	Household waste
BG	Bulgaria implemented a national waste information system (NISO) in 2021. Legal basis is provided by Ordinance No 1 of 4 June 2014 on the procedure and forms for providing information on waste activities and the procedure for keeping public registers (EEA BG, 2022).	Managing authority: N/A Reporting obligations: N/A	All
CZ	The Waste Management Information System ISOH was launched on 1 January 2009 to enforce the reporting obligations established in the Waste Act. ISOH is connected to the system of basic registers in accordance with the Act on Basic Registers No.	Managing authority: The ISOH platform is managed by the Ministry of Environment. Reporting obligations:	All

[8] NB the new battery and battery waste regulation (BWBR) eliminates the distinction between batteries and accumulators and introduces a new definition for 'batteries'.

	111/2009 Coll (ISOH CZ, 2022). ISOH is a comprehensive, detailed, regional, heterogeneous, modular and fully electronic information system. It supports the decision-making, control and statistical needs of the waste management of the Czech Republic. Data on waste production and management are available in detailed form to state administration authorities and in aggregated form to the public.	Producers and waste management facilities submit annual reports to relevant regional authorities, in charge of transmitting the data to the Ministry of Environment. – waste management facilities, – facilities that need a permit, – recyclers of ELVs and WEEE, – traders and brokers.	
DK	In Denmark, the Danish Waste Data System (ADS) is in place (EPA DK, 2022). It contains waste data and statistical reports on waste generation and treatment as well as data on recycling rates at municipal and national level.	<u>Managing authority:</u> N/A <u>Reporting obligations:</u> Enterprises and establishments collecting, transporting, receiving or importing waste for treatment must report to the Waste Data System. Businesses exporting waste for treatment to another facility or treating waste also have the obligation to report.	All
DE	The Ordinance on Waste Recovery and Disposal Records (Nachweisführung bei der Entsorgung von Abfällen - NachwV) entered into force in 2007. It specifies the provisions of the Circular Economy Act (Kreislaufwirtschaftsgesetz – KrWG) to keep registers and records on hazardous waste. In 2010 the electronic waste records procedure (elektronisches Abfallnachweisverfahren - eANV) (BMUV, 2007) was introduced. At present, a joint waste monitoring system (ASYS) is used to report hazardous waste in all 16 federal states. ASYS supports not only the collection, processing and evaluation of data, but also the automated monitoring and exchange of data between regions (ASYS, 2022). Using ASYS, the authorities can efficiently manage and process all necessary data from the eANV and thus monitor the proper disposal of hazardous waste.	<u>Managing authority:</u> Saxon State Office for Environment, Agriculture and Geology <u>Reporting obligations:</u> – waste disposers, – waste collectors, – waste transporters, and – waste producers.	Hazardous waste
EE	In Estonia, the 'Information system for environmental decisions (KOTKAS)' is in place. This ERW is a module of the "Information system for environmental decisions" (KOTKAS, 2022).	<u>Managing authority:</u> The Estonian Environmental Board and Municipalities that have a "Register of waste holders". <u>Reporting obligations:</u> – waste management companies, – waste producers, – producer responsibility organisations, – collectors/transporters of waste, – regional, local and municipal authorities.	All waste codes from LoW, plus additional subtypes of waste, e.g. metal waste managed by EPR (WEEE, batteries and accumulators, vehicles, tyres)
IE	No ERW if waste is handled within the national boundaries. TFS Guidelines help stakeholders comply with their obligations under the WSR (waste shipment regulation) (NTFSO, 2023).	<u>Managing authority:</u> The National TFS (trans-frontier shipment) Office at Dublin City Council is designated as the National Competent Authority for the export, import and transit of waste	-

		shipments. Reporting obligations: N/A	
EL	The obligation for the ERW is defined in 'Law 4819/2021: use of waste for energy production'. A national registry for waste collection and transport is in place. The registry was developed by the Hellenic ministry of environment and energy and addresses all companies and organisations (including local authorities) that generate waste (YPEKA, 2022). The registry is also connected to other public administration systems (i.e. TAXISnet, Diavgeia).	Managing authority: N/A Reporting obligations: Entities obliged to obtain an environmental permit, a collection and transport of hazardous waste permit or who collect and transport non-hazardous waste on a professional basis and municipal authorities have the obligation to report data to the Electronic Waste Register.	All waste codes from the LoW
ES	The electronic procedure to declare waste data via eSIR (E-SIR, 2022) for the transport of hazardous and non-hazardous waste destined for disposal and shipment of hazardous waste and residual waste destined for recovery is mandatory as of July 2021 (MITERD, 2020). At least three regions have adopted their own procedure to collect waste data: Andalusia (Junta de Andalucia, 2022), Catalonia (ARC, 2022) and Galicia (Xunta de Galicia, 2022). The electronic registry for waste management has been developed by the Spanish Ministry for Ecological Transition and Demographic Challenge. It includes the production and management register, the repository of shipments and the one of annual reports.	Managing authority: Spanish Ministry for Ecological Transition and Demographic Challenge or in some cases the regional government (e.g. in Andalusia, Catalonia and Galicia). Reporting obligations: The reporting obligations apply to waste operators responsible for transport and shipment of certain categories of waste.	All
FR	The decree n° 2021-321 (traceability of waste, excavated earth and sediments) lays down rules for the creation of a "national register of waste" (RNDTS, 2022). For hazardous waste, a "management system" to trace the process of issuing and managing waste tracking slips (BSD) must be created. This system is to be implemented through the Trackdéchets application (tele-service / electronic data interchange). An ordinance on recording and declaring data for household packaging waste and graphic paper has been in place since 2018 (Republic of France, 2023; SYDEREP, 2022).	Managing authority: N/A Reporting obligations: RNDTS (Registre National des Déchets, Terres Excavées et Sédiments): – operators of waste incinerators, – landfills for non-hazardous and non-inert waste, – facilities releasing waste from waste status. SYDEREP: Extended Producer Responsibility (EPR) scheme in France.	All
HR	The Environmental Pollution Register (ROO) is an information system established by the Ministry of Economy and Sustainable Development as a comprehensive IT and network-based solution, and consists of a database with an associated application for entry, verification, review, analysis and exchange of data and browsers that provide the public with direct access to data. The Environmental Pollution Register is a set of data on the sources, type, quantity, manner and place of release and/or transfer of pollutants into air, water and/or sea and soil and waste produced,	Managing authority: Croatian Ministry of Economy and Sustainable Development The ROO is managed by the Ministry of Economy and Sustainable Development. Data available for public consultation. Reporting obligations: N/A	All

	collected and treated. The database contains data from 4 800 operators and 10 600 organisational units from 2008 to 2018 calendar year (ROO, 2023).		
IT	A national registry for waste data was established in 2006 (ISPRA, 2006). Data include municipal waste (production, separate collection and management), special waste and national list of permits. Data are gathered and processed by the national division of the waste registry with the contribution of the regional and provincial divisions and all the public bodies holding information as well as through the national environmental declaration model. The registry is not electronic however. Electronic registries have been implemented at local level, like the one in place in Lombardy (ARPA, 2011), following LR 26/2003 and DGR 2513/2011.	Managing authority: N/A Reporting obligations: N/A	-
CY	Within the waste management strategy there are specific treatment options and targets for waste management (with focus on bio-waste and packaging waste). All operations in the waste management systems are monitored. No information on ERW available.	Managing authority: The Department of Environment of the Ministry of Agriculture, Rural Development and Environment is the competent waste management authority (EEA, 2023). Reporting obligations: N/A	-
LV	The Latvian Centre for Environment, Geology and Meteorology is in charge of collecting information on waste management and ensuring that the provisions on waste management are fulfilled. It also monitors the management of hazardous waste and waste shipments (EGM LV, 2023). An ERW is in place; however, no information is available in English.	Managing authority: Latvian Centre for Environment, Geology and Meteorology Reporting obligations: N/A	-
LT	Lithuania implemented an ERW within the Unified Product, Packaging and Waste Record Keeping Information System (GPAIS) (PPWIS, 2022) under the legal act on the approval of the accounting and reporting rules for the generation and management of waste (E-TAR LT, 2023).	Managing authority: N/A Reporting obligations: N/A	All
LU	Electronic registry under development.	Managing authority: N/A Reporting obligations: N/A	-
HU	A registration takes place at the 'Register of environmental pollution'. The purpose of this portal and web application is the collection, verification, analysis and exchange of data from the field of environmental protection (ROO, 2022). Electronic registries of waste (generation, collection, treatment) are available (OKIR, 2023)	Managing authority: N/A Reporting obligations: Organisations can declare waste data (generation, collection, recovery/disposal). Data are available for public consultation.	All

MT	Implementation of electronic registry planned.	Managing authority: N/A Reporting obligations: N/A	-
NL	In the Netherlands, waste needs to be reported to the National Waste Reporting system (landelijk meldpunt afvalstoffen, LMA) (LMA, 2022).	Managing authority: Rijkswaterstaat, the Ministry of infrastructure and water management, is the national reporting agency; therefore LMA is part of Rijkswaterstaat. Reporting obligations: Establishments receiving hazardous waste or establishments where hazardous waste generated at the establishment is directly disposed of or recovered have the obligation to report. The reporting obligations apply also to waste establishments falling under category 28.4 of Annex I C of the Environmental Law Decree. These include, for example, storage companies, transhipment companies, landfills and incineration plants.	All
AT	The reporting obligation was established in the Waste Management Law 2002 (Article 17). Affected authorities must submit an annual waste balance sheet for the previous calendar year. The statement must include type, quantity, origin and fate of waste. The required contents and structure of the electronic transmission is set in the Waste Balance Ordinance (497/2008). Data are submitted to the EDM Portal (FEA, 2022).	Managing authority: Federal Ministry of Climate Action Environment, Energy, Mobility, Innovation, and the Austrian Provincial Governors (Austrian Federal State Authorities). The Environment Agency of Austria is a processor of several parts of the EDM-System contracted to maintain the IT system. Reporting obligations: – operators of waste incineration plants, – landfill owners, – recyclers of ELVs, – producers of recycled construction material, – compost producers, – handlers of WEEE, – recyclers.	All
PL	The Database on Products and Packaging and Waste Management (BDO) is an electronic system established under the provisions of the Waste Act of 14 December 2012. An integral part of the BDO is the register of entities introducing products, packaged products in the market and authorities in charge of waste management, which was launched on 24 January 2018 (MOS PL, 2022).	Managing authority: N/A Reporting obligations: All entities listed in Articles 50(1) and 51(1) of the Polish Waste Act (2012) are subject to registration. Except: – entrepreneurs introducing products on the territory of the country, – operators recovering or recycling waste generated from products, – recovery facilities, – exporting and intra-community supply	All

		of waste generated from products in order to undergo recovery and recycling, – running ELV disassembly stations, – WEEE recovery facilities, – waste transporters, – waste dealers and waste brokers, as far as they are not subject to registration.	
PT	Integrated System for Electronic Registration of Waste (SIRER) in place (APA, 2020). The legal obligation to register in SIRER and report data derives from Articles 97 and 98 of Decree-Law 102-D/2020 of 10 December. The Ministerial Order 20/2022 of 5 January introduces the new SIRER Regulation.	Managing authority: Portuguese Environment Agency Reporting obligations: Producers, transporters, traders/brokers and waste treatment operators, provided that they are covered by the legal obligation. Entities responsible for municipal and multi-municipal systems for urban waste.	Municipal waste
RO	Environmental integrated system (Sistemul integrate de mediu, SIM) in place (ANPM, 2015).	Managing authority: Ministry of Environment, Water and Forests and the National Agency for Environmental Protection (ANPM). Reporting obligations: N/A	All
SI	Under the legislation in the field of waste management, persons liable are obliged to report annually. The Environmental Agency of the Republic of Slovenia also publishes data on waste management that were collected on the basis of received reports (Slovenian Environment Agency, 2023). The Environmental Agency of the Republic of Slovenia keeps different registers (recovery, disposal, collection, transport). The established registers are published annually in the Official Journal of the Republic of Slovenia.	Managing authority: Environmental Agency of the Republic of Slovenia. Reporting obligations: The reporting obligations apply to waste operators.	All
SK	The use of a national information system for waste management is based on Act no. 79/2015 on Waste. The waste management information system (ISOH) is used to monitor the fulfilment of national and international obligations. It provides basic statistical data for waste from generation up to disposal (ISOH SK, 2022). The Ministry of Environment implemented a new decree on registration and reporting obligations (LP/2022/791) (Slovak Republic, 2022).	Managing authority: N/A Reporting obligations: N/A	All
FI	The Centres for Economic Development, Transport and the Environment (ELY) are responsible for the regional implementation and development of tasks mandated from the central government. There are 15 ELY centres (ELY FI, 2022). Among other tasks, they are responsible for reporting and monitoring the state of the environment and promoting environmental protection. They have supervisory duties under the Environmental	Managing authority: Centres for Economic Development, Transport and the Environment Reporting obligations: N/A	-

	Protection Act, Water Act and the Waste Act (MEFI, 2023). Each region has an e-platform where companies can initiate a case and receive decisions. It includes services such as environmental permits and notifications (KEHA, 2022).		
SE	The information to be provided in the 'Waste Registry' is defined in the Waste Ordinance (Sveriges Riksdag, 2020) and the Swedish Environmental Protection Agency's regulations (NFS 2020: 5) (Swedish EPA, 2020). Reporting to a Waste Registry is possible via e-service or via API (a web service that enables two different systems to exchange). There is an online statistical system to manage waste statistics (Avfall Web) (Avfall Sverige, 2022). The goal is to provide support to waste operators in business planning and benchmarking.	Managing authority: The Swedish Environmental Protection Agency is responsible for reporting hazardous waste data. Reporting obligations: N/A	Hazardous waste

Source: Based on (Tuscano et al., 2022) and JRC in-house research.
'N/A' means no data found or publicly available.

2.5 Standards and methodologies for waste composition analysis

A common practice for collecting reliable and statistically sound data on waste composition is to carry out a waste composition analysis. A waste composition analysis is a methodology to determine the material composition of a mixed waste stream. An overview of the available standards and guidelines for waste composition analyses is given below.

Waste composition can be classified into physico-chemical composition (energy, ash content and elemental content) and physical composition (distribution of solid waste materials) (Edjabou et al., 2021). A physical composition analysis can reveal for instance which dry recyclable materials (metal, glass, plastic, paper and cardboard) have not been sorted at source.

To obtain an accurate physical composition, a waste characterisation is needed (Edjabou et al., 2021), including sampling and testing.

A standard for sampling and waste composition analysis is available in the EU: **EN 14899:2005** – Characterization of waste – Sampling of waste materials - Framework for the preparation and application of a Sampling Plan.

The standard has been further elaborated in five technical reports on exemplary approaches for sampling:

- **CEN/TR 15310-1:2006** – Part 1: Guidance on selection and application of criteria for sampling under various conditions;
- **CEN/TR 15310-2:2006** – Part 2: Guidance on sampling techniques;
- **CEN/TR 15310-3:2006** – Part 3: Guidance on procedures for sub-sampling in the field;
- **CEN/TR 15310-4:2006** – Part 4: Guidance on procedures for sample packaging, storage, preservation, transport and delivery;
- **CEN/TR 15310-5:2006** – Part 5: Guidance on the process of defining the sampling plan.

Furthermore, it is recommended to perform moisture content analyses along with compositional analyses for all streams (not only non-organic).

Member States can also develop their own national standards, guidelines based on national standards, or even ordinances for waste composition analysis. Some of them are listed in the following (non-exhaustive) **Table 4**.

Table 4. Standards, methodologies, technical reports, and guidelines for waste composition analysis available in the European territory (non-exhaustive list)

Country	**Standard / Legal reference / Guideline**
DE	A guideline is available in the federal state of Saxony, including general requirements for the characterisation of waste (Sachsen, 2014).
FR	A guideline has been in place since 2006 for household and similar waste. Sampling plans cover different stages, from collection (analysis of a defined mass of collected waste) to sorting (characterisation of a waste sample at the entrance of the sorting facility). National standards for waste composition analysis were adopted in 2009 (characterisation of separately collected waste at the sorting facility). Guidelines to implement the national characterisation method for waste are available (ADEME, 2007, 2014)
IT	Guidelines for waste composition analysis were proposed in 2000, before the implementation of the EN 14899 standard.
AT	In addition to the EN standards mentioned above, Austria developed its own standards and guidelines for the sorting of municipal but also separate collected waste. A 'Guideline for the performance of residual waste sorting analyses' (prepared by the Austrian Technical Working Group on Sorting Analyses considering the "Guidelines for the Statistical Evaluation of Sorting Analyses and Unit Weight Analyses" (Felsenstein & Spangl, 2017a; TWS, 2021) is in place. This guideline lays down 20 rules on minimum requirements to be met in the planning, performance and evaluation of residual waste sorting analyses. This should enable the comparability of the results of different sorting analyses (in terms of time and space). This guideline supplements or specifies the national standard ÖNORM S 2097 (Sorting analysis of waste. Parts 1-4) (OENORM, 2005). The ÖNORM S 2127 describes the "Basic characterisation of waste piles or solid waste from containers and transport vehicles" (OENORM, 2011). For paper packaging waste (Beigl et al., 2021) and bio-waste, guidelines on planning, performance, and evaluation were developed (Beigl et al., 2020).
PT	An Ordinance 851/2009 is in place, defining the 'Technical specifications on the characterisation of municipal waste' (MAOTDR, 2009).
FI	The Finnish Solid Waste Association has developed guidelines for mixed waste composition analysis (JLY, 2017). It contains a recommendation on the classification of the waste fractions, guidance on sampling and testing methods and recommendations for statistical analysis of the results.
Nordic countries	Two documents have been prepared within the Nordic Innovation Centre project "Development of Nordic generic horizontal standards for sampling" (NORDTEST, 2008): – Nordic horizontal standard for sampling (NT ENVIR 012); – Horizontal standard on selection of operational sampling standards for solids and liquids (NT ENVIR 013).
EU-wide	Within the project "FP5-EESD - Programme for research, technological development and demonstration on Energy, environment and sustainable development, 1998-2002", a methodological tool to enhance the precision and comparability of solid waste analysis data (S.W.A. - TOOL) was developed (European Commission, 2004). The methodology reported includes guidelines to carry out necessary pre-investigations, analysis design and planning, execution of waste analysis and evaluation of waste analysis. Those guidelines can be used as a basis for the development of methodologies to perform waste composition analyses. However, it is unclear to what extent this methodological approach is followed by the Member States

2.6 Common performance indicators for waste management

2.6.1 Eurostat waste-related indicators

Eurostat has devised three sets of indicators: EU Sustainable Development Goals (SDGs), Resource Efficiency Indicators (REI) and Circular Economy Indicators (CEI). Waste-related indicators are used by Eurostat as a means to track trends in waste generation in Member States. They measure progress towards specific EU policy objectives, such as the Circular Economy Action Plan (Eurostat, 2022a). The Key Performance Indicators (KPIs) related to waste are summarised in **Table 5**. Those indicators that are relevant in the context of this study are highlighted in green.

Table 5. KPIs related to waste monitored by Eurostat (Eurostat, 2022a)

Waste-related indicator	**Unit**	**Description**	**Data source**	**Publishing frequency**	**Associated with indicator set**
Generation of waste excluding major mineral wastes	kg/inhabitant	Amount of waste generated annually. Available for the EU and for individual countries. It covers non-hazardous and hazardous waste from all economic sectors and households (excluding mineral wastes and soil).	Waste Statistics Regulation	Every second year (reference year 2004)	SDGs, REI, CEI
Management of waste excluding major mineral wastes	%	It includes treatment rates for the treatment categories established in the Waste Statistics Regulation. Available for the EU and for individual countries. It covers non-hazardous and hazardous waste from all economic sectors and households (excluding mineral wastes and soil).	Waste Statistics Regulation; COMEXT (Eurostat, 2023) (for national import/export data, if no other data are available in the metadata)	Every second year (reference year 2010)	REI, CEI
Material prices for recyclates	€/tonne	Specific market prices of glass, paper and cardboard, and plastic and traded volume (import and export) of those materials.	COMEXT (Eurostat, 2023); Foreign Trade Statistics	Monthly (since 2004)	-
Municipal waste generation and treatment, by treatment method	kg/inhabitant	Amount of MW generated, amounts of MW recovered and disposed of by treatment method (material recycling, recycling through composting and digestion, energy recovery, incineration, landfill and other).	Data collected to comply with the requirements of the WFD	Every year (since 1995)	SDGs, REI, CEI
Recycling rate of e-waste	%	The overall e-waste recycling rate is the collection rate multiplied by the rate of recycling at the treatment facilities, and it is assumed that the total amount of collected e-waste is indeed sent to	Data collected under WEEE Directive 2012/19/EU	Every year (since 2008)	REI, CEI

		treatment / recycling facilities.			
Recycling rate of packaging waste by type of packaging	%	Share of recycled packaging waste in all generated packaging waste. Available for the EU and for individual countries.	Data collected under Packaging Directive 94/62/EC and Article 6b(1) of Decision 2005/270/EC	Every year (since 2000)	CEI
Recovery rate of construction and demolition waste	%	Ratio of construction and demolition waste which is prepared for reuse, recycled or subject to material recovery, divided by the construction and demolition waste treated as defined in Regulation (EC) No 2150/2002 on waste statistics.	Waste Statistics Regulation	Every 2 years (since 2010)	CEI

Source: (Eurostat, 2022a)
NB: Indicators relevant in the context of the present study are highlighted in green.

Of the two highlighted indicators, **municipal waste generation and treatment** measures the amount of waste generated and the way it is treated. The datasets used for this indicator are:

- generation of municipal waste per capita (source of data: Eurostat, based on the dataset env_wasmun collected via the joint questionnaire);
- recycling rate of municipal waste (source of data: Eurostat, based on data reported by statistical institutes or other competent authorities of each MS);
- recycling of bio-waste (source of data: Eurostat, based on the dataset env_wasmun collected via the Eurostat-OECD joint questionnaire);
- municipal waste by waste operations (source of data: Eurostat, based on data submitted by statistical institutes or other competent authorities of each MS).

The second relevant indicator, **recycling rate of packaging waste**, measures the share of recycled packaging waste in the total amount of packaging waste that is generated. The datasets used for this indicator are:

- recycling rates of packaging waste for monitoring compliance with policy targets (env_waspacr);
- packaging waste by waste operations (env_waspac).

The data provider for both datasets is Eurostat, based on the data reported by the Ministry of Environment of each MS, in compliance with the PPWD.

2.6.2 Indicators proposed in the JRC best environmental practice

In the JRC's report on best environmental management practices for the waste management sector (Dri et al., 2018), five environmental performance indicators were proposed (see **Table 6**) to assess the performance of waste management, with a focus on MW.

Table 6. Indicators proposed in the JRC Best Environmental Practices

Environmental performance indicator	**Unit**	**Description**
MW generation	kg/capita	*The indicator describes the amount of total MW generated within the territory administered by a local waste authority per year, in relation to the resident population.*
Amount of mixed MW collected	kg/capita	*The indicator describes the amount of mixed MW collected per capita per year. Its calculation takes into account the waste collected as non-source-separated mixed waste. Mixed MW contains all waste fractions for which no separate container or other collection system is available. In systems where most of the waste is segregated at source and collected separately, this is often referred to as "residual*

		waste".
Waste sent for energy recovery or disposal	kg/capita	*The indicator measures the annual amount of MW that is treated by either incineration with energy recovery and/or disposal operations, such as landfilling or incineration, without energy recovery.*
MW sent for disposal	kg/capita	*The indicator measures the annual amount of MW that is sent for disposal, such as landfill or incineration, without energy recovery (all disposal operations are defined in Annex I to the WFD).*
Capture rate of a specific waste stream	%	*The capture rate is the percentage of the estimated generation of a specific waste fraction that is collected separately. It provides insights into the efficiency (i.e. how efficient in intercepting the recyclables) of a separate collection system. The capture rate can be calculated for the separately collected fractions, e.g. plastic; metal; paper and cardboard; glass; commingled packaging; bio-waste.*

Source: (Dri et al., 2018)

2.6.3 KPIs for economic instruments in municipal waste management

This section reviews best practice KPIs for economic instruments in municipal waste management. Appropriate economic instruments encourage consumers and waste operators to act in accordance with the waste hierarchy and thus help to induce sound waste management practices. The hierarchy's highest priorities are prevention of waste and preparing for reuse. Therefore, an efficiently managed waste collection system is likely to include economic instruments targeted at increasing waste prevention and preparing for reuse before recycling, recovery and disposal. Given the varied settings across the 27 MS, in practice municipalities and waste operators employ a wide range of economic instruments.

Fees and charges and other economic incentives and disincentives were shown to reduce waste generation as well as increase separate waste collection (Albizzati, Antonopoulos, et al., 2023). The WFD encourages the application of differentiated fees and charges for waste disposal services to consumers that include the full cost of waste treatment and disposal, including environmental impacts.

A per-unit fee for mixed residual wastes, called pay-as-you-throw (PAYT), implements the polluter-pays-principle. When fees for mixed residual waste are higher than fees for sorted wastes, households tend to increase their sorting effort[9] (Cristóbal et al., 2022). Surcharges and quantity restrictions can "level the playing field" between the financial cost of landfill and incineration versus the financial cost of less polluting waste treatment options.

In addition, some financial economic instruments, which include fiscal measures, encourage reuse, or preparation for reuse and recycling. For example, fiscal incentives such as tax reductions, rebates, and exemptions for donation of products may divert these items away from waste disposal to reuse because citizens receive a financial benefit for the donations (Dobson, 2007). There is increasing interest in using fiscal measures to reduce food waste (Dhir et al., 2020; Mourad, 2016).

Food waste donation and redistribution may require compensation of transaction costs for collection, storage and transport (Spang et al., 2019). A 2015 report, "Review of EU legislation and policies with implications on food waste", summarised fiscal policy implications, stating that "taxation seems to be an area in which strategic changes could lead to effective food waste reduction measures" (Vittuari, 2015).

Other economic incentives facilitate markets for products diverted from waste disposal, for example subsidies for refurbishing used items and public procurement or lower Value Added Tax (VAT) for long-lived or used items (Hogg & Vergunst, 2011; Oosterhuis et al., 2009). Today, there are several financial and fiscal economic incentives and disincentives present in the EU, but a full discussion of these is beyond the scope of this report.

[9] although some households might choose to avoid mixed-waste charges by discarding residual waste in the recyclables stream, thereby increasing impurities in recyclables, this effect is marginal and more than compensated by the overall significant decrease in absolute amounts of mixed waste and improved recyclables collection.

Municipalities and waste operators can tailor the mix of financial incentives and disincentives to the local situation to achieve the best environmental outcome. Article 4 of the WFD states that "*MS shall make use of economic instruments and other measures to provide incentives for the application of the waste hierarchy, such as those indicated in Annex IVa or other appropriate instruments and measures*". Eight selected economic instruments from Annex IVa that are features of collection and treatment systems are shown in **Table 7**.

For the purposes of this report, the instruments are divided into four categories:

1. Fee-based instruments, such as taxes and other charges that are paid by users of waste disposal services to better reflect the full cost of waste treatment.
2. Fiscal incentives focused on consumer actions, for example to encourage donation of used items rather than throwing them away.
3. Product-focused instruments such as extended producer responsibility schemes and deposit refund systems that fund waste sorting by citizens and centralised sorting, collection and transport of specific types of wastes, for example recyclable packaging.
4. Management-focused instruments that aim to increase the operational efficiency of waste collection and treatment services.

The eight economic instruments identified in **Table 7** are acknowledged in the literature and in the WFD to be positively correlated to the overall goals of waste management systems; however, comprehensive data on how prevalent they are in the EU-27 are not currently available.

Table 7. Annex IVa of WFD 2018/851 lists economic instruments that are features of collection and treatment systems.

Fees paid by users of waste disposal services	**Financial / fiscal incentives to citizens**	**Product-focused incentives to citizens**	**Management-focused**
Charges and restrictions for the landfilling and incineration of waste which incentivise waste prevention and recycling, while keeping landfilling the least preferred waste management option	Fiscal/financial incentives for donation of products, in particular food	EPR schemes for various types of waste and measures to increase their effectiveness, cost efficiency and governance	Sound planning of investments in waste management infrastructure, including through Union funds
PAYT schemes that charge waste producers based on the actual amount of waste generated and provide incentives for separation at source of recyclable waste and for reduction of mixed waste	Use of fiscal/financial measures or other means to promote the uptake of products and materials that are prepared for reuse or recycled	DRS and other measures to encourage efficient collection of used products and materials	Phasing out of subsidies which are not consistent with the waste hierarchy

N.B. The three instruments highlighted in green are proposed in this report as KPIs of the QMS.

Empirical data that capture the prevalence of economic instruments in waste management in the 27 MS are not routinely collected through the existing joint Eurostat-OECD process (Eurostat, 2021a). As a result, these data are not available for monitoring, evaluation and benchmarking, which would help to better understand and, eventually, improve management of waste collection systems. Making these data available would increase the comparability of data between MS and help to pinpoint the influence of specific management practices on outcomes such as recycling targets and purity rates.

2.6.4 Best practices: impurity rates in the separately collected waste

High rates of impurities in the separately collected waste fractions will most likely result in higher rejection rates at the sorting facilities. For the collection phase, **impurity thresholds** for various waste streams have been proposed in the literature as summarised in **Table 8.** The listed thresholds can serve as a reference of best practices or benchmarks of excellence; they are however not meant to be proposed as binding targets.

Table 8. Impurity thresholds of certain separately collected waste streams as reported in the literature

Fractions	**Proposed impurity[10] benchmark values**	**Comments and references**
Separately collected **bio-waste**[11]	< 2 % Plastic contamination with liners and bags in food waste: from 1.3% to < 0.1% of food waste	For bio-waste, the type of collection system is important for the level of impurities. The best-practice case involves door-to-door collection with compostable bags. Impurities in bio-waste[12] should be below 2%, to ensure high-value processing in anaerobic digestion plants and production of high-quality compost. N.B. The maximum technical limit for impurities can be up to 10%, but this does not allow the production of quality compost. (CIC, 2017; Dri et al., 2018; Dubois et al., 2020; EEB, 2020; SEPA, 2019)
Separately collected **paper/cardboard**	< 3%	Up to 6-7% impurities is considered an unacceptable value in the current practices. The threshold established in the EN 643:2014 standard for non-targeted material for recycling is below 3%, depending on the paper grade. (CEPI, 2016; CITEO, 2019)
Separately collected **plastic packaging**	10%	Both the level of segregation of the plastic packaging waste (i.e. the way it is separated at source) and the collection scheme influence the impurity rates of plastic packaging considerably. For separately collected plastic waste, up to 10% impurities are in general terms considered acceptable. (Andreasi Bassi et al., 2020; UBA, 2018)
PET beverage bottles with DRS	< 5% (in PET post-consumer bales)	For PET bottles collected with DRS, impurities shall be below 5%. (Andreasi Bassi et al., 2020)
Separately collected **glass**	5%	For glass packaging waste, impurities should be less than 5%. (ASSOVETRO, 2016; European Environmental Bureau, 2022; FEVE, 2012)
Separately collected **metal**	11% (for the aluminium fraction) 16% (for the steel fraction)	For the metal fraction, impurities of 11% and 16% are considered acceptable for the aluminium and steel fractions, respectively (CITEO, 2019)

[10] Impurity can generally be defined as waste that is not targeted for separate or commingled collection by local authorities in charge of waste management, or waste management companies. Here the term impurity refers to the presence of non-targeted materials in a given waste stream.

[11] From 1 December 2019, the plastic limit for outputs was reduced to 8% of the PAS110 limit for digestates and 50% of the PAS100 limit for composts (SEPA, 2019).

[12] In the present report, impurities in bio-waste refer to all materials that are not suitable for composting.

3 Operational framework for a harmonised quality management system

In this chapter a detailed operational framework for an EU-wide harmonised quality management system is proposed as a policy measure to improve the quality and availability of waste data. The overarching goal is to improve waste management systems and enhance the quantity and quality of recycling at operational level.

The proposal encompasses different dimensions of the QMS and consists of a set of measures: implementing a national waste electronic registry; amending the existing reporting obligations, with complementary reporting of new datasets and of waste management practices; proposing a new methodology to calculate the amount of generated MW; carrying out waste composition analyses for different waste fractions at a specific frequency and following a standardised methodology; and deploying a monitoring system, with a specific set of KPIs.

This specific proposal follows the recommendations given in the JRC Best Environmental Management Practice for the Waste Management Sector by (Dri et al., 2018). It is based on an extensive literature review performed in-house at the JRC as well as on stakeholder consultations held on the broader topic of harmonisation of separate waste collection.

3.1 Data collection and reporting

3.1.1 Electronic Registries for Waste

In order to design effective waste management strategies, the availability of reliable statistical data for the main waste streams is crucial (Bel & Flanagan, 2020). As mentioned above, electronic registries for waste have been implemented in several Member States voluntarily. The availability of a national platform can enhance transparency along the waste value chain and can support national authorities in identifying areas for improvement (Bel & Flanagan, 2020).

Hence, it is proposed to **establish a national reporting system (i.e. an Electronic Registry for Waste)** to collect local data on waste. The structure of the ERW is to be designed with the ultimate goal of optimising the submission of waste data to Eurostat. Legal provisions to supply data may be necessary at national level to ensure the submission of the required information and data by private waste management operators.

3.1.2 Reporting obligations

Due to aggregation of waste streams along the recycling value chain (e.g. from different sources), it is challenging to track waste streams in each phase. This hinders the possibility of evaluating the actual performance of strategies implemented at a specific stage, e.g. in the collection (Bel & Flanagan, 2020). In order to address this issue, it is proposed to complement the reporting obligations and requirements on transmission of statistics currently in place with **additional reporting** of the following datasets:

- amount of separately collected waste entering sorting **(input of sorting)**, including impurities;
- amount of waste after sorting **(output of sorting)**.

The ratio of the above-mentioned waste amounts indicates the level of **rejects** in the sorting phase and thus gives an additional indication of the performance of the collection system.

Also, the first reporting exercise on MW has shown that many Member States report the quantity of MW collected equal to the quantity of MW generated. While this is a contradiction, it is nevertheless allowed by Commission Implementing Decision (EU) 2019/1004. In Annex 2 we propose a methodology to quantify the amount of MW generated starting from the amount of MW collected. We suggest that this methodology is used either by Member States themselves or Eurostat to report MW generation quantities in a consistent manner across all Member States.

In addition, the performance of waste management systems is influenced by internal and external factors. *Internal* factors are strategies (e.g. collection schemes) and instruments (e.g. economic incentives) (Albizzati, Antonopoulos, et al., 2023); *external* factors are mostly linked to the level of economic activities and territorial features (Dri et al., 2018).

External factors can be heterogeneous and difficult to systemise, but internal factors can and should be taken into account when assessing the performance of a waste management system. However, currently there is a lack of consistent data and knowledge on the waste management strategies implemented across the EU-27. Data have been collected on a voluntary basis by the European Environment Agency (EEA). There are no

mandatory obligations to report waste management practices. Nonetheless such data are needed for the design of appropriate waste management strategies and the evaluation of their effectiveness, and ultimately for informing the sound planning of investments in the waste management sector.

It is hence proposed to **complement the reporting obligations with reporting of waste management practices**, i.e. the waste collection scheme in place for each waste fraction and the commingling rules in place, as detailed below.

3.1.2.1 Reporting waste collection schemes and commingling rules

The impact of specific collection schemes (e.g. door-to-door, bring system, DRS for plastic bottles) for each waste fraction has been widely investigated (Albizzati, Antonopoulos, et al., 2023; BIPRO, 2015; Dri et al., 2018; Dubois et al., 2020). It has been demonstrated that some collection schemes are more effective than others in terms of increasing the recycling rates of waste fractions. Similarly, the commingled collection of specific waste fractions can offer environmental and economic benefits (Albizzati & Tonini, 2023). As it stands, neither collection schemes nor commingling rules are harmonised across the EU, and can differ even from one municipality to another within Member States. Collection of more detailed (national and regional) information on collection schemes and commingling practices would be beneficial to improve the *ex-post* assessment of the performance of MW management systems.

It is thus proposed to introduce **reporting obligations** for the following practices:

- the **scheme** (e.g. door-to-door, bring system, DRS) applied for the collection of each waste fraction within the scope (municipal waste from households and similar waste);
- the **commingling rules** applied (e.g. commingled collection of metal and plastic packaging).

For both, the reporting should contain information on how much of the collected (and thus of the generated) waste is collected via a certain type of collection scheme and a certain type of commingling rule. For instance, if some glass containers are collected through DRS and others through bring points, the respective amounts collected should be made clearly available.

3.2 Proposal for a harmonised methodology for waste composition analysis

Commission Implementing Decisions (EU) 2019/1004 and (EU) 2019/665 laying down rules for the calculation, verification and reporting of data for municipal waste and packaging and packaging waste, respectively, do not include a harmonised methodology for composition analysis of the mixed municipal waste and packaging waste streams. As mentioned in the previous chapter, there are different methodologies and standards available for carrying out composition analysis. This concerns, among others:

- the sampling point (from the collection vehicle or from collection containers);
- the sampling location and environment (population density, urban or regional areas);
- determination of the sample mass and the sample size (number of samples);
- the sample preparation (sieving); and
- the statistical evaluation of the results.

To ensure comparability across MS, it would be necessary to develop a harmonised standard or to indicate the use of one of the available standards.

3.2.1 Frequency of waste composition analysis

Harmonising the frequency with which a waste composition analysis needs to be undertaken is a further step to enhance comparability across Member States. A frequency of **6 years** is proposed here, in view of the following arguments and constraints:

- It takes time for newly implemented waste management measures, such as separate collection schemes for bio-waste, textiles or hazardous waste from households, to reach their full potential. The reason for this is that the population as well as municipalities and waste operators have to adapt to new collection schemes, and often improvements are necessary from the operators' side, even after the commissioning of new measures, to reach a satisfactory outcome.
- Municipal waste composition does not change rapidly over time, even though certain measures can have significant short-term impacts on specific fractions (e.g. implementation of mandatory deposit refund schemes (DRS) for plastic bottles and cans, as set out in the PPW Regulation proposal).

However, it must be taken into account that the removal of individual fractions, e.g. by a DRS, has hardly any effect on the composition of the residual waste, as the proportion of the DRS targeted fractions in the residual waste is low.

- Certain pieces of EU legislation on waste, such as for food waste (EU 2019/1597) or non-recycled plastics (EU 2023/595), set lower frequencies (4 or 5 years) for evaluating the amount of the above-mentioned wastes produced.
- Directive 2008/98/EC states that MS shall ensure that their competent authorities establish one or more waste management plans (Article 28)[13]. As reported in (EEA, 2016), 25 out of the 27 Member States have developed two or more national or regional waste management plans in the time period of 2001-2015. This means that, on average, Member States prepare a waste management plan at least every 7 years, for example BE (regional, 5 years), AT and NL (6 years, (BMK, 2022)), ES (7 years, (PEMAR, 2022)), PT (7 years, (PERSU, 2014), 10 years (PERSU, 2021), BG (8 years, (MEW, 2020)), CZ (10 years, (MZP, 2014)), and DK (13 years, (ME, 2020)). Also, municipalities develop their own waste management plans, with planning periods ranging between 6 and 10 years. It is reasonable to align the time intervals of the waste composition analyses with the time intervals of the waste management plans, as the findings of a waste composition analysis would then be used directly for the preparation of the plans.
- In the guidelines for mixed waste composition analysis developed by the Finnish Solid Waste Association, the frequency is 4 years (JLY, 2017).

It is additionally proposed to carry out at least **2 composition analyses within the reference year in different seasons**, considering that the composition of waste is influenced by temporal and economic factors, such as (European Commission, 2004; JLY, 2017):

- seasonal effects: changes can be observed in the municipal waste composition (e.g. higher ratio of bio-waste from gardening in spring/early summer, higher ratio of bio-waste in spring/summer due to the increased consumption of fruits);
- tourism: especially in regions with high tourism activity, the composition of waste can change significantly depending on the season.

3.2.2 Sampling plan at national level

In practice, municipal waste analyses are carried out by municipalities, cities, regions or possibly at federal states level. However, these data cannot simply be extrapolated to obtain estimates of the average waste composition at the national level. In order to obtain a valid estimate, coordination of these analyses is necessary at national level.

For statistically reliable results, a sufficient number of samples representative of the target statistical population must be analysed. Depending on the number of samples and targeted waste fractions, waste composition analyses are personnel- and time-intensive. As a consequence, thorough composition analyses tend to be rather expensive, hence an adequate sampling strategy shall be set, taking into account factors such as the season and population density covered by the analysis. The samples shall be divided into homogeneous parts to improve the reliability of data (European Commission, 2004; JLY, 2017).

A European standard for the characterisation of waste / sampling of waste material (EN 14899) is available, which has been further refined by five technical reports (CEN/TR 15310-1-5) (see Section 2.5). This standard defines minimum requirements on the programme, objective, sampling plan and report for the execution of a testing programme for waste characterisation.

Besides the standard with minimum requirements just mentioned, relevant parameters for statistically valid and subsequently comparable results of Member States have to be defined at EU level, including guidelines on for example:

- how to access samples (e.g. door-to-door, bring system);
- how to cover different income levels;
- how to cover different population densities;

[13] These plans have to include a comprehensive analysis of all waste streams, existing systems for collection, recovery and disposal, an assessment of the need for new facilities (in the framework of the EU-wide network required in Article 16).

- how to cover regions with different economic performance;
- which waste receptacles are considered (e.g. bags, 120 L or 240 L containers);
- required sample mass for sorting analyses and unit weight analyses (what is the targeted accuracy);
- the definition of the size of individual samples;
- the required amount and spatial distribution of single samples;
- a clear differentiation between household and commerce and industry; and
- how to consider the fact that municipal waste includes waste not stemming from households but similar in kind to household waste.

Samples that cannot be taken or sorted for reasons of work safety are to be discarded (e.g. danger due to hazardousness and sharpness). Containers should only not be taken into account for the analysis if the fill level is less than 20%. In both cases, new containers with a fill level >20% and no safety issues shall be used for sampling.

Besides a harmonised sampling and sorting plan, the harmonisation of methods to analyse and present the results is also key to enhancing the comparability of national waste composition analyses. In line with the proposal made by (JLY, 2017), it is recommended to carry out a statistical review of the results and present a confidence interval. Possible sources of errors (such as sampling problems, errors in processing the data) shall be clearly indicated.

3.2.3 Classification of waste fractions

A regular waste composition analysis can serve as a tool to monitor the effects of policy measures on the local waste management system. It is crucial to define the components of the waste to be recorded in the composition analysis.

The tables below propose a classification of the components (sub-fractions) of the waste streams to be analysed in the context of a waste composition analysis.

In **Table 9** a general proposal for the scope and categorisation of the waste composition analysis of municipal waste is given (26 waste fractions), based on guidelines and practical waste composition analyses performed in MS (Edjabou et al., 2021; Felsenstein & Spangl, 2017b; JLY, 2017; TWS, 2021). The breakdown corresponds to the sub-fractions to be identified in mixed or residual MW.

Table 10 provides a more detailed breakdown and proposed classification into waste sub-fractions to be analysed, for each of the main recyclable packaging waste fractions collected separately (paper and cardboard, plastics, glass, and metals), as well as wood.

Table 9. Proposal for waste sub-fractions to be analysed in (residual) municipal waste (26 sub-fractions)

Main waste fraction	Sub-fraction	Examples
Bio-waste	Non-preventable food waste	Fruit and vegetable peelings, coffee grounds incl. filter, tea bags, eggshells, bones
	Preventable food waste	Unopened food and beverages, whole bread, fruits or vegetables, cooked food leftovers, bitten/cut fruit and vegetables, loose pasta, beverages (leftovers) - only contents, packaging counts towards the respective packaging fraction
	Garden waste	Branches, twigs, leaves, grass, hay, fallen fruit, weeds, garden plants, cut flowers, houseplants (without pot), potting soil
	Biodegradable packaging[14]	Biodegradable packaging that is capable of undergoing physical, chemical, thermal or biological decomposition such that most of the finished compost ultimately decomposes into carbon dioxide, biomass and water, e.g. hemp, paper, biodegradable plastics such as PLA, cellulose, seaweed

[14] Products that when collected with bio-waste and treated with aerobic or anaerobic treatment have to be determined through regular composition analyses of the biodegradable waste since those quantities are included in the recycled amounts for the respective packaging material (according to Commission Implementing Decision (EU) 2019/665).

Paper and cardboard wastes	Paper and cardboard packaging	Wrapping paper, carrier bags, paper sacks (pastry, fruit), chocolate packaging, cigarette packets, cardboard boxes (e.g. shoes, detergent, boxes, rice), frozen food cartons, cardboard plates, paper plates, roll cores, e.g. for toilet paper / kitchen rolls, corrugated cardboard boxes
	Paper and cardboard non-packaging	Newspapers, advertising brochures, catalogues, books, calendars, instruction manuals, letters, notebooks, envelopes
Plastic wastes	Plastic packaging	All sorts of plastic beverage bottles incl. separately found closure, milk-, ketchup-, vinegar-, oil-bottles, bottles for cosmetics and detergents, canisters, tubes for cosmetics and detergents, tubs for margarine and dairy products, Styrofoam moulded parts, meat trays, packaging chips; plastic nets (fruit and vegetables)
	Plastic non-packaging	Toys, hoses, construction polystyrene, plastic tableware, toothbrushes, disposable razors, drinking straws, transparent sleeves, rubbish bags, large flowerpots, CDs (sleeves), agricultural foils
Glass wastes	Glass packaging	Beverage bottles: wine, beer, spirits bottles coloured/colourless; Canning jars, condensed milk bottles, vinegar and oil bottles, perfume bottles, medicine bottles
	Glass non-packaging	Window glass, glass plates from furniture / kitchen appliances (e.g. ceramic glass), mirror glass; drinking glasses, glass vases, glass tableware, candles, grave light glasses burnt off (only wax residues), laboratory glasses
Metallic wastes (Ferrous)	Ferrous metals containing packaging	Steel beverage cans, crown corks, food cans, empty paint cans, paint cans, screw caps, cleaning clothes hangers
	Ferrous metals containing non packaging	Screws, nails, sheet metal, tubes, fittings, metal tools (parts), metal appliances, wires, cutlery, crockery, tin toys, bicycle parts
Metallic wastes (Aluminium)	Aluminium packaging	Aluminium beverage cans, beverage screw caps, empty spray cans, aluminium lids, cat food bowls, mustard, mayonnaise tubes, disposable barbecue cups
	Aluminium non-packaging	Aluminium tableware, household aluminium foil, non-ferrous metals, sanitary fittings, tealight covers
Wood wastes	Wood packaging	Thermoformed and thermoglued wooden trays, wooden boxes (e.g. wine bottles, liquors), packaging whole and chips
	Wood non-packaging	Painted and coated wood, boards, handles, wooden toys, carvings, wooden skewers, ice-cream sticks, pressed, chipboard, wooden furniture, sawdust
Composites	Composite packaging	Combination of at least two different materials (e.g. beverage carton for milk products, trays for cut cheese/sausage)
Textile wastes	Textile	Clothing, bed and table linen, towels, curtains, blankets, cloth bags, carpets
	Shoes	Shoes, boots, sandals, slippers
WEEE, hazardous waste and batteries	WEEE	Electrical appliances (incl. the batteries), extension cables, cable reels, appliance cables, chargers, PCs, washing machines, dryers, air conditioners, electric cookers, flat screens, CRT screens, laptops, mobile phones, LCD photo frames, refrigerators and freezers, lamps (fluorescent tubes, energy-saving, sodium lamps, LED)
	Problematic materials/ hazardous waste	Medicines, paints, varnishes, solvents, acids, alkalis, engine oil, oil-contaminated waste, oil filters, spray cans and gas cartridges that have not been emptied, fire extinguishers, chemical residues, cleaning and cleaning agents (residues), asbestos products
	Batteries waste	Loose consumer batteries, button cells, (mobile phone) batteries, battery packs, starter batteries
Other waste	Inert materials	Bricks, cement, plaster, tiles, stones, ceramic tableware and vases, grit, small animal litter (mineral), ash
	Hygiene articles	Paper tissues, paper napkins, kitchen roll paper, paper rolls, cleaning tissues, wet wipes, paper towels; baby and adult nappies; women's hygiene articles (panty liners, pads, tampons), incontinence pads, cotton buds, cotton pads
	Other wastes	Leather belts or bags, tyres without rims, bicycle inner tubes, rubber seals, rubber mats, mats, toys and tools made of various materials, materials, stuffed animals, tyres with rims, hair, feathers, aluminium and plastic coffee capsules, dog excrement bags, animal carcasses, hoover bags with contents, cigarette butts, candle and wax remnants, mechanical light switches, wall sockets, lightbulbs,

		needles
	Sorting residues (not identifiable)	Unidentifiable residuals

Table 10 below proposes sub-fractions to be analysed in *each* of the separately collected recyclables streams. Where relevant, the corresponding recycling codes according to Commission Decision 97/129/EC[15] are mentioned.

NB: The sub-fractions proposed offer an intermediate level of detail, finer than the generic categories (e.g. "paper and cardboard") but not as detailed as the further sorting and corresponding grades which may be used in each value chain (e.g. in the case of paper and board, the grade classification of EN643[16] or other detailed industry nomenclature).

Table 10. Proposal for waste sub-fractions to be analysed from separately collected packaging waste streams (source: own elaboration)

Paper and cardboard packaging waste		**Recycling code**
Paper	Paper packaging	22
	Paper-non packaging	22
Carton and corrugated board	Carton and corrugated board packaging	20, 21
	Carton and corrugated board non-packaging	20, 21
Composite packaging containing paper or cardboard	Beverage cartons (paper/plastic/metal composite)	84
	Other paper/cardboard packaging coated with plastic or other material	80, 81, 82, 83, 85
Other (non-pulp) materials	Other valuables (e.g. other recyclable materials)	
	Municipal waste (non-recyclable)	
	Hazardous waste	
Plastic packaging waste		
Plastics	PET packaging	1
	HDPE packaging	2
	PVC packaging	3
	LDPE packaging	4
	PP packaging	5
	PS packaging (non-foam)	6
	Styrofoam packaging (XPS/EPS)	6
	Other plastic packaging	7
	Plastic non-packaging items	
Composite packaging containing plastics	Beverage cartons (paper/plastic/metal composite)	84
	Composite plastic packaging made of different kinds or layers of plastic	
	Other plastic-containing composite packaging	81, 92
Other (non-plastic)	Other (non-plastic) recyclable materials	

[15] Commission Decision of 28 January 1997 establishing the identification system for packaging materials pursuant to European Parliament and Council Directive 94/62/EC on packaging and packaging waste.

[16] CEN standard EN643:2014.

materials	Other valuables (e.g. reusable materials)	
	Municipal waste (non-recyclable)	
	Hazardous waste	
Glass packaging waste		
Glass	Clear glass packaging	70
	Green glass packaging	71
	Brown glass packaging	72
	Other coloured glass packaging	73, 74
	Glass-non packaging*	
Composite packaging containing glass	Glass-containing composite packaging	95, 96, 97, 98
Other (non-glass) materials	Lids and stoppers (metal)	40, 41
	Lids and stoppers (other materials)	
	Packaging made of inert materials (e.g. ceramics)	
	Other packaging materials	
	Other recyclable materials	
	Municipal waste (non-recyclable)	
	Hazardous waste	
Metallic packaging waste		
Metallic wastes (Ferrous)	Ferrous metal packaging	40
	Ferrous metal non-packaging items	40
Metallic wastes (Aluminium)	Aluminium packaging	41
	Aluminium non-packaging items	41
Composite packaging containing metals	Beverage cartons (paper/plastic/metal composite)	84
	Composite metal packaging made of different metals	
	Other metal-containing composite packaging	80, 82, 83, 85, 90, 91, 92
Other (non-metallic) materials	Other valuables (e.g. other recyclable materials)	
	Municipal waste (non-recyclable)	
	Hazardous waste	
Wood packaging waste		
Wood packaging	Painted or varnished wood	50
	Uncoated wood	50
Other materials	Other valuables (e.g. other recyclable materials)	
	Municipal waste (non-recyclable)	
	Hazardous waste	

* For glass it is assumed that many items will be smashed in collection, making the distinction between packaging and non-packaging more difficult. The latter category encompasses glass which cannot clearly be identified as originating from packaging,

3.3 Monitoring

A harmonised quality management system can be used as a tool for gathering data in Member States and to increase the traceability of waste streams and improve the comparability of data across the EU. However, the key potential of the QMS lies in the possibility to assess the performance of waste management practices.

In order to measure the effectiveness of existing waste management practices or plan those or new strategies, it is necessary to monitor the performance of the waste management system. Performance can be monitored within different phases of the value chain through Key Performance Indicators (KPIs), such as capture rates in the collection phase, sorting and rejection rates in the sorting phase, as well as recycling rates in the recycling phase (BIPRO, 2015).

Hence, it is proposed to **establish a monitoring system at EU level** with a specific set of KPIs (complementing the ones already in use), to be calculated and published by Eurostat.

3.3.1 Proposed KPIs

Based on stakeholder consultations and literature research, among others (Dri et al.,2018, ECN, 2022, Eurostat, 2022a, ITENE, 2018, SEPA, 2019, Wilson et al., 2015), we propose a set of **eight KPIs** (see **Table 11**) to monitor the performance of Member States' waste management (complementing the indicators already used by Eurostat, listed in **Table 5**). The frequency of publications should be established *ad hoc* for each KPI.

The first KPI we propose in the current framework is on the **type of collection** for dry recyclables and bio-waste, to measure the **amount of waste collected separately or commingled**. The source of data for the calculation is the data collected to fulfil the new reporting obligations proposed (see Section 3.1.2).

As recommended by Dri et al., 2018, we propose to include three environmental performance indicators, namely **capture rate**, **impurity rate** and **amount of bio-waste in residual waste**. The data source for the calculation of these KPIs is the data collected to fulfil the requirements on transmission of statistics and the reporting obligations currently in force (see Section 2.1 and Section 2.2).

If compostable plastic waste is collected and treated along with bio-waste, Member States should be able to calculate and report compostable plastic recycled quantities in the total plastic recycled quantities (Caro et al., 2023). Hence we propose a KPI to measure the **amount of biodegradable packaging in bio-waste**. Data can be retrieved from composition analyses performed to fulfil the obligations laid down in Article 6c (d) of Commission Implementing Decision (EU) 2019/665, as described in Section 2.2.

While there are several sources of data to determine the prevalence of economic instruments implemented in each Member State, they are not coordinated, and some are not conducted at regular intervals. In addition, the definition or level of detail of the data collected and reported differs across the EU, for example as follows:

- The EEA's Early Warning Assessment Report (EEA, 2023)[17] is a principal source of reliable data on taxes and/or bans on landfilling residual or biodegradable waste, taxes on municipal waste incineration and pay-as-you-throw (PAYT) systems. According to the current methodology, MS declare the percentage of population covered by PAYT. Reporting in terms of the percentage of waste generated in the QMS would provide valuable complementary information because it would correlate with the weight of wastes generated.
- Several independent research projects have generated reliable publicly available data on the economic instruments in use in Europe. However, the reporting frequency of these data is not predictable because it relies on the research interests of independent scientists and the scope of research grants. The definition of PAYT for data collection, for example, differs from project to project depending on the research goals. Also, researchers do not always have access to MS' quantitative data. They might use expert opinion to determine to what extent economic instruments are in use. Therefore, research project data are not routinised and are consulted only as part of *ad hoc* data collection efforts by the Commission and MS.

[17] Prepared three times in total with a distance of 5 years, as they are related to the early warning mechanism of the WFD, the PPWD and the Landfill Directive.

Evidently, the definition and/or level of detail of such collected and reported data differs across the EU. Improving the consistency and timeliness of such data would facilitate the monitoring of the current situation. The goal is to capture data on the economic incentives that promote waste prevention and expand separate collection schemes, while discouraging landfilling and incineration.

Therefore, we propose to introduce **KPIs for three types of economic incentives** in place in each Member State, including fee-based incentives (PAYT) and fiscal/financial incentives. Product-focused incentives (including DRS) are not included as they are already covered by other reporting obligations. In fact, in November 2022 the proposal for a revision of EU legislation on packaging and packaging waste included the mandate for MS to report the collection rate of packaging under mandatory deposit and return systems.[18] Assuming that both EPR and DRS reporting obligations are in place, no additional KPIs are needed at this time. Finally, management-focused economic instruments are not easily defined because they are varied and designed to fit local conditions and challenges; therefore, they are not suited to an EU-level KPI.

The **fee-based incentive KPI** measures the **percentage of generated waste that is subject to a PAYT scheme**. The proposed KPI for PAYT improves the consistency and compatibility of datasets by defining PAYT with the EEA's most recent definition: "*A PAYT system is a charging system for residual municipal waste management that is based on the polluter pays principle. This means that a household has to pay a fee for the collection and treatment of its residual waste based on the generated amount which is intended to provide an incentive to reduce the amount of residual waste produced. This fee can be designed in various ways, taking into account variable elements like container size, volume of sacks, frequency of collection, weight or a combination of these elements. When PAYT is applied, the fee for the residual waste per collected amount is higher than the fee(s) for the separately collected waste fractions, or these other fractions are collected free of charge.*" (Reichel et al., 2022).

There are two proposed best practice KPIs for **fiscal incentives**. The first KPI measures the **percentage of municipal waste generated that is eligible for fiscal incentives for donation of products**. This KPI captures practices shown to prevent waste. The second KPI is the **percentage that is eligible for fiscal and other financial incentives that promote the market for used products**.

Table 11. Summary of eight proposed KPIs for the operational framework

KPI	Unit	Description
Amount of waste collected separately or commingled by type of collection	kg/capita	The indicator measures the amount of waste (for dry recyclables and bio-waste) collected separately or commingled by type of collection scheme (e.g. door-to-door, bring system, DRS).
Capture rate of a specific waste stream	%	The indicator measures the share of waste collected separately relative to the total generated waste for a specific waste fraction. It quantifies the efficiency of the separate collection system (for dry recyclables and bio-waste).
Impurity rate of a specific waste stream	%	The indicator measures the share of non-targeted materials in the collected or sorted waste fraction.
Amount of bio-waste in residual waste	kg/capita	The indicator measures the amount of bio-waste present in residual waste, which is identified by a composition analysis.
Amount of biodegradable packaging in bio-waste	%	The indicator measures the amount of biodegradable packaging within the separately collected bio-waste fraction. The indicator intends to facilitate the calculation of the recycling rate for these materials (when treated along with the bio-waste, the recycled amounts will be registered for the respective packaging material).

[18] https://environment.ec.europa.eu/publications/proposal-packaging-and-packaging-waste_en

Percentage of generated waste that is subject to a PAYT scheme	%	The indicator measures the percentage of the total waste generated that is subject to a PAYT scheme[19]. The definition for PAYT is the same as the definition applied by the EEA in its forthcoming Early Warning Reports.
Percentage of generated waste that is eligible for fiscal incentives for donation of products	%	The indicator measures the share of generated waste (not waste fraction) that is eligible for fiscal incentives for donations of products, including but not limited to donated food products for example[20]. Fiscal incentives include tax deductions, tax rebates, adjustments to taxable income, etc.
Percentage of generated waste that is eligible for financial incentives (including fiscal incentives) to promote the uptake of products and materials	%	The indicator measures the share of waste that is generated that is eligible for financial incentives (including fiscal incentives) to promote the uptake of products and materials that are prepared for reuse or recycled[21].

[19] For example, a Member State has ten municipalities of the same size and population. Six of the ten municipalities generating 60% of the total generated waste charge citizens fees for collecting each bag of "residual" waste (less bags equal lower fees). Four of the ten municipalities generating 40% of the total generated waste charge residents an annual fee that does not change with the number of bags collected. In this case, the percentage of generated waste that is subject to a PAYT scheme is 60%.

[20] Example: 10 of 20 municipalities generate 80% of a MS' MW. These 10 offer local companies tax deductions for the value of donated products. The percentage of MW generated that is eligible for fiscal incentives for donation equals 80%.

[21] Example: 10 of 20 municipalities generate 80% of a MS' MW. These 10 each subsidise the purchase of used furniture from the municipality. The percentage of MW generated that is eligible for fiscal incentives equals 80%.

4 Potential financial costs, benefits, and socio-economic impacts

4.1 Potential financial costs

This report summarises best practices and proposes that these may form the basis for a potential regulatory proposal by the European Commission. Such a proposal would include a detailed analysis of costs and benefits according to the Better Regulation Guidelines and the Better Regulation Toolbox.[22] This section provides a preliminary and mostly qualitative discussion of the financial costs, socio-economic impacts and potential benefits for each of the best practices described above as they would impact MS. It discusses the costs and impacts from the perspective of different stakeholders: citizens, municipalities and operators, MS and the Commission; but without the detailed estimates that would be part of a regulatory proposal, as this is beyond the scope of the current work.

The best practices proposed in the operational framework outlined above are:

- establishing and managing a harmonised national Electronic Registry for Waste (ERW) in every MS;
- implementing a harmonised waste composition analyses every 6 years for every MS; and
- monitoring waste management practices biannually with KPIs (waste collection schemes and commingling rules and economic instruments).

The potential cost impacts of these best practices are explained below.

4.1.1 Cost of establishing and managing a national Electronic Registry for Waste

There are three categories of costs for establishing and managing an Electronic Registry for Waste. First, one-time investment costs for the design and development of an operational ERW system, including the software, distribution and updating. Second, one-time administrative costs for the labour required for project management and the cost of communicating guidance to users. Third, recurring administrative costs for the ongoing management of the ERW system, including data collection, management, and reporting.

As noted in Section 3.1, the majority of MS (22 of 27) have already implemented a WEEE registry. It is assumed that the majority of MS would rely on their existing architecture. In general, the net cost of establishing a new registry would be relatively low due to the existing knowledge in the field. Only five MS would need to adopt completely new practices. Alternatively, the Commission could develop a common registry, which would also draw from existing architectures and, therefore, would be expected to create lower costs, e.g. in comparison to developing a completely new ERW system for WEE.

4.1.2 Cost of conducting waste composition analyses

This best practice would be a new administrative activity for the purpose of cooperation with and inspection by public authorities, including maintenance of appropriate records. Potential costs associated with waste composition analysis depend on the following factors:

- The cost of waste composition studies is additional to the existing operations in all MS, although several MS have national guidelines, based on the EN standards for waste composition analysis, as mentioned above. This assumption must be made as long as no data are available on the number of times per year municipalities currently conduct composition studies.
- There are approximately 46 000 EU enterprises conducting waste collection, treatment, and disposal activities that will carry out two waste composition studies in the same year, every 6 years as described in Section 3.2.
- Operators/municipalities will use contracted services to conduct waste composition studies to produce the new data for the QMS reporting every 6 years. The average cost of a contracted service

[22] https://commission.europa.eu/law/law-making-process/planning-and-proposing-law/better-regulation/better-regulation-guidelines-and-toolbox_en

(in the fourth quarter of 2022) ranges between EUR 20 000 and EUR 70 000.[23] The estimates vary widely, depending upon the provider, region and potential travel costs.

- After training, ongoing administrative costs could be considered business-as-usual expenses.

4.1.3 Cost of implementing a monitoring system with specific KPIs

In general, the concept of a QMS is well understood and already implemented in several MS. In addition, MS already collect data for the joint Eurostat and OECD data call and for reporting according to Commission Implementing Decision 2019/1004 and food waste reporting. Therefore, all operational stakeholders have the means and capabilities to implement a QMS independently or in conjunction with the existing Eurostat annual data call.

The financial cost of implementing an EU-wide harmonised QMS depends on whether it is adopted as a stand-alone MS survey or incorporated into the existing MS surveys run by Eurostat. If the new QMS KPIs are complementary, Eurostat can incorporate the new KPIs at minimal cost with existing staff.

If the QMS KPIs are not complementary with existing Eurostat waste data collection surveys, a new survey would be needed. Eurostat would likely require 0.5 Full Time Equivalent (FTE) per year in initial costs for 2 years. Eurostat would help the MS to correctly collect the data and complete the required table. Good-quality data are expected at the end of the second year. These costs are considered administrative costs from one-time actions (launching the QMS). Indicatively, EU institutions' annual personnel costs for this activity are estimated at EUR 16 750 assuming an average annual adjusted salary for employees in the EU of EUR 33 500 per year, so a total cost of EUR 33 500.[24]

4.2 Potential benefits

The implementation of an **EU-wide harmonised framework for quality management** does not lead directly to environmental benefits. Nevertheless, in the long term it can indirectly affect the environmental performance of waste management systems, as it can facilitate a systematic optimisation of waste management strategies, leading to reduced waste generation and increased recycling rates, in line with the waste hierarchy.

The proposal to establish **national ERWs** can contribute to increased traceability of waste streams. The availability of national databases can facilitate the identification of problems in the waste management system, including the detection of irregular or illegal waste disposal practices. Better informed performance analyses can contribute to the optimisation of waste management strategies implemented in the municipalities. Improving the consistency and reliability of data gathered at local level also contributes to the quality of data reported by Member States to Eurostat. Public access to the ERW enhances transparency for operators and citizens.

The proposal to carry out **waste composition analyses** with a given frequency (6 years) can also support the evaluation of the performance of policy measures on the local waste management system. To date there is neither a harmonised methodology nor a given frequency to carry out waste composition analyses. The recommended frequency of 6 years and the reference to a specific methodology to be followed can allow comparability of data. Data from waste composition analyses can also be used to monitor the performance of local waste management systems.

The proposal to **report additional datasets** on the input and output of sorting can support the evaluation of the efficiency of collection and sorting and the design of optimisation strategies in these phases of the waste value chain. In a comparable manner, the proposal to additionally **report waste management practices** can help to close the data gap in the EU-27, as some of those data are currently reported only on a voluntary basis. Those data are crucial for the sound planning of investments in the waste management sector as well as for the design of appropriate waste management strategies and the evaluation of their effectiveness.

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[23] The estimated costs of EUR 20 000 to EUR 70 000 for composition analysis for one year (as of Q4 2022) are based on information from a call for tender, internet-based searches of providers, and personal communications from one MS currently conducting composition analysis.

[24] Based on the interview conducted with Oscar Gomez (Eurostat - Team Leader, Green deal, circular economy and waste statistics) on 9 November 2022 and on https://ec.europa.eu/eurostat/web/products-eurostat-news/w/ddn-20221219-3

Finally, the implementation of a **monitoring system**, or rather the complementing of the monitoring tool maintained by Eurostat with an additional set of new KPIs, can be used to track trends in the waste management systems of the Member States. The KPIs are to be calculated on the basis of the data submitted for compliance with the reporting obligations. The availability of harmonised and consistent waste data for each Member State can ultimately support the evaluation of new policy options at EU level.

4.3 Potential socio-economic impacts

Citizens. From the citizens' perspective, there are no significant socio-economic impacts expected as a result of a harmonised QMS being adopted for the EU. The implementation of a harmonised QMS system would be a marginal adjustment to business as usual for many waste management operators, municipalities and national institutions. The expected additional annual costs to citizens paying for waste collection services are deemed to be negligible. Therefore, no distributional impacts are expected.

Employment. The proposed harmonised QMS requirements are expected to be achievable with currently available employees in municipal and private waste management companies. The requirement for regular waste composition analysis might give rise to a small positive employment impact in this sector.

5 Conclusions and recommendations

Waste management operators, whether public (e.g. waste authorities) or private (e.g. utilities), at municipal, regional and national level can improve the performance of their waste management operations by adopting best practices and putting in place concrete elements of a Quality Management System.

The present study analysed the dimensions of quality management and state of the art in place in EU Member States, in order to propose best practices applicable at EU level to improve waste management practices, with a focus on data collection, reporting, monitoring and performance improvement.

The features of a proposed harmonised Quality Management System are summarised in **Table 12**.

Table 12. Proposed operational framework for a harmonised quality management system - overview

Dimension of the QMS	**Requirements proposed**	**Authority responsible and reporting obligations**
Collecting and managing waste data	Establish a **national Electronic Registry for Waste (ERW)** to collect waste data and waste management practices.	**Member State** responsible for establishing and managing the ERW. **Waste operators** (private or public) responsible for reporting waste data to the ERW.
Collecting data on waste composition	Carry out a **composition analysis** of **municipal waste**, **food waste** and **packaging waste** (frequency: every 6 years – 2 analyses within the reference year).	**Member State** responsible for implementing the harmonised EU-wide approach for waste composition analyses.
Reporting waste data and waste management practices	Adopt the methodology proposed to report both **generated** and **collected** waste. Complement the reporting obligations with two new datasets (**input of sorting; output of sorting**). Additional obligation to **report waste management practices**: – commingling rules; – collection schemes.	**Waste operators** (private or public) responsible for reporting data to municipalities or directly to the Member State. **Municipalities** responsible for reporting practices to the Member State. **Member State** responsible for gathering national waste data within the ERW and reporting them to Eurostat. **Eurostat** responsible for publishing data in the waste database.
Monitoring waste management systems	Implement a **monitoring system** at EU level with the proposed **KPIs**, including KPIs on economic incentives (see Table 11). Benchmark the **impurity rates** achieved in separately collected waste against best-practice levels.	**Eurostat** responsible for implementing the monitoring system, calculating and publishing KPIs for each Member State. KPIs can be used by **municipalities/Member States** (on a voluntary basis) to evaluate the effectiveness of specific strategies.

The proposed framework, proposed as voluntary, is envisaged as a harmonised approach that will support the diffusion of best-performing practices across the EU as well as facilitate consolidation and comparability of data from different sources. It could be envisaged as a mandatory approach taking into account relevant cost-benefit considerations.

Implementing the above recommendations and proposed best practices at the appropriate levels of the waste management value chain will support performance improvement and compliance with the general obligations of EU waste legislation, not only in terms of data quality and reporting obligations, but also in the attainment of waste policy objectives such as recycling targets. Ultimately, this framework also supports broader environmental and economic policy goals at national and EU level, accelerating the transition to a low-carbon, circular and resource-efficient economy.

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List of abbreviations

BWBR	Batteries and Waste Batteries Regulation (Regulation (EU) 2023/1542)
CEI	Circular Economy Indicators
DG	Directorate-General
DRS	Deposit Refund Scheme
eDAMIS	electronic Dataflow Administration and Management Information System
EEA	European Environment Agency
ELV	End-of-Life Vehicle
ELVD	End-of-Life Vehicle Directive (Directive 2000/53/EC)
EPR	Extended Producer Responsibility
ERW	Electronic Registry for Waste
EU	European Union
e-waste	see WEEE
EWC-STAT	European Waste Classification for Statistics
KPI	Key Performance Indicator
MBT	Mechanical Biological Treatment
LoW	List of Waste
MS	Member State
MW	Municipal Waste
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne
OECD	Organisation for Economic Co-operation and Development
PAYT	Pay-as-you-Throw
PPW	Packaging and Packaging Waste
PPWD/PPWR	Packaging and Packaging Waste Directive / Regulation
PRO	Producer Responsibility Organisation
QMS	Quality Management System
REI	Resource Efficiency Indicators
SDGs	Sustainable Development Goals
WEEE	Waste Electrical and Electronic Equipment; a.k.a. e-waste
WFD	Waste Framework Directive

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Annex 1. List of Waste

Table 13. Waste codes included in municipal waste from the list of waste established in Commission Decision 2014/955/EU

15	**WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTER MATERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED**
15 01	packaging (including separately collected municipal packaging waste)
15 01 01	paper and cardboard packaging
15 01 02	plastic packaging
15 01 03	wooden packaging
15 01 04	metallic packaging
15 01 05	composite packaging
15 01 06	mixed packaging
15 01 07	glass packaging
15 01 09	textile packaging
15 01 10*	packaging containing residues of or contaminated by hazardous substances
15 01 11*	metallic packaging containing a hazardous solid porous matrix (for example asbestos), including empty pressure containers
20	**MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS**
20 01	**separately collected fractions (except 15 01)**
20 01 01	paper and cardboard
20 01 02	Glass
20 01 08	biodegradable kitchen and canteen waste
20 01 10	Clothes
20 01 11	Textiles
20 01 13*	Solvents
20 01 14*	Acids
20 01 15*	Alkalines
20 01 17*	Photochemicals
20 01 19*	Pesticides
20 01 21*	fluorescent tubes and other mercury-containing waste
20 01 23*	discarded equipment containing chlorofluorocarbons
20 01 25	edible oil and fat
20 01 26*	oil and fat other than those mentioned in 20 01 25
20 01 27*	paint, inks, adhesives and resins containing hazardous substances
20 01 28	paint, inks, adhesives and resins other than those mentioned in 20 01 27

20 01 29*	detergents containing hazardous substances
20 01 30	detergents other than those mentioned in 20 01 29
20 01 31*	cytotoxic and cytostatic medicines
20 01 32	medicines other than those mentioned in 20 01 31
20 01 33*	batteries and accumulators included in 16 06 01, 16 06 02 or 16 06 03 and unsorted batteries and accumulators containing these batteries
20 01 34	batteries and accumulators other than those mentioned in 20 01 33
20 01 35*	discarded electrical and electronic equipment other than those mentioned in 20 01 21 and 20 01 23 containing hazardous components
20 01 36	discarded electrical and electronic equipment other than those mentioned in 20 01 21, 20 01 23 and 20 01 35
20 01 37*	wood containing hazardous substances
20 01 38	wood other than that mentioned in 20 01 37
20 01 39	Plastics
20 01 40	Metals
20 01 41	wastes from chimney sweeping
20 01 99	other fractions not otherwise specified
20 02	**garden and park wastes (including cemetery waste)**
20 02 01	biodegradable waste
20 02 03	other non-biodegradable wastes
20 03	**other municipal wastes**
20 03 01	mixed municipal waste
20 03 02	waste from markets
20 03 03	street-cleaning residues
20 03 07	bulky waste
20 03 99	municipal wastes not otherwise specified

Annex 2. A methodology to calculate generated municipal waste from collected amounts

1. Underlying data

Specific datasets for municipal waste are collected by Eurostat via a dedicated questionnaire that Member States (MS) need to compile following the guidelines provided in "Guidance for the compilation and reporting of data on municipal waste according to Commission Implementing Decisions 2019/1004/EC and 2019/1885/EC, and the Joint Questionnaire of Eurostat and OECD" (Eurostat, 2021a).

Member States are requested to provide a material breakdown of municipal waste (MW) that encompasses: metals, glass, plastic, paper and cardboard, bio-waste, bio-waste separated and recycled at source, wood, textiles, electrical and electronic equipment, batteries, bulky waste, mixed waste, and other. For these waste streams, MS are requested to state the amount of both generated waste and separately collected waste. Yet, as mentioned in Section 2.1 of this report, Eurostat and the JRC have observed that several MS report the quantity of **MW generated *equal* to the MW collected**, as this is allowed by Commission Implementing Decision (EU) 2019/1004 whenever MS do not have data available to estimate the generation.

***Collected* amounts of MW are known** to MS because they must track waste collection flows by law. What may not be known is the *generated waste*. To identify whether the MS reports actual generated amounts of MW, we use a threshold value that represents the maximum share of mixed waste in the total generated MW. We use the value of 25% because normally, in a compositional analysis of MW, the mixed (non-distinguishable) waste should not exceed 10-20%. When this threshold value is exceeded, it means that the data reported by the MS under 'Municipal waste generated' actually corresponds to *collected waste* and that 'mixed waste' actually corresponds to the *collected 'mixed waste'*. For these cases, we propose a methodology to estimate the amount of generated MW.

2. Methodology to estimate MW generation for MS reporting only collected MW

For the MS that report separately collected MW only, the step-wise methodology described in the following subsections needs to be applied to estimate the amount of generated MW per waste stream. For this purpose, the JRC has developed a spreadsheet calculator that is available upon request and/or can be made available (e.g. to ESTAT or Member States).

The methodology is illustrated in **Figure 1.A** below and in the following paragraphs, taking the example of the paper and cardboard (P&C) fraction as an illustrative recyclable fraction.

Figure 1.A. Representation of the methodology herein proposed to estimate MW generation

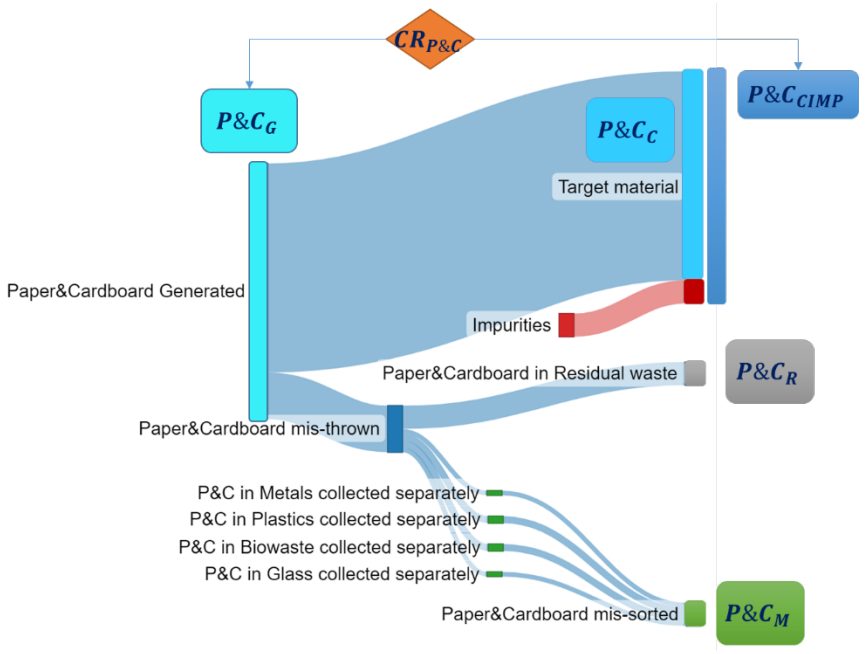

Figure 1.A.a: Waste flows - illustration with the Paper & Cardboard fraction

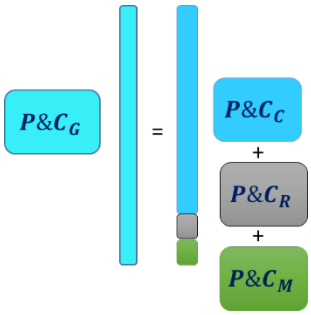

Figure 1.A.b: Waste generated vs. collected (see also Equation 2)

Note that the following acronyms are used in Figure 1.A above, and in the descriptions below: '$CR_{P\&C}$' collection rate of paper and cardboard; '$P\&C_C$' targeted waste paper and cardboard collected; '$P\&C_{CIMP}$' waste paper and cardboard collected inclusive of possible impurities; '$P\&C_G$' waste paper and cardboard generated; '$P\&C_M$' waste paper and cardboard mis-sorted; '$P\&C_R$' waste paper and cardboard in residual waste.

2.1 MW generated amount

The first step is to calculate the amount of MW generated per stream. The values reported to Eurostat refer to waste *collected* inclusive of possible impurities (*CIMP*) and, therefore, do not represent the *total generated* amount. Knowing the capture rates (*CR*) of a specific waste stream, it is possible to calculate the waste generated (*G*), as is illustrated in Equation 1 for the case of paper and cardboard waste (*P&C*). The capture rates (*CR*) are based on the information reported in the European Environment Agency's (EEA) Early Warning Assessment Report (Reichel et al., 2022).

Equation 1

$$CR_{P\&C} = {P\&C_{CIMP}}/{P\&C_G} \rightarrow P\&C_G = {P\&C_{CIMP}}/{CR_{P\&C}}$$

2.2 Collection scheme in place

The second step in the methodology is to identify the average collection scheme in place for the different waste streams and its coverage in a MS. While this may be based upon specific information, we based it on the information reported in the EEA's Early Warning Assessment Report (Reichel et al., 2022) and the results of this analysis are reported in Section 3.2 of (Albizzati, Cristóbal, et al., 2023).

2.3 Composition of the waste stream collected: share of targeted material and impurities

The third step is to estimate the material fraction composition of the collected waste streams in terms of impurities[25] and targeted material[26]. This is needed because the amounts reported under 'Separate collection' (in the Eurostat survey) for the different waste streams actually refer to the entirety of the separately collected waste stream, thus including both the targeted material (e.g. magazines in paper and cardboard waste) and possible impurities collected with it (e.g. plastic in paper and cardboard waste). The share of targeted materials and impurities depends on the collection scheme implemented. The collection scheme in place influences the share of targeted materials and impurities, but also the composition of the mixed waste stream, where large amounts of recyclables and bio-waste can be found due to mis-sortings[27]. The share of targeted material and impurities in the collected waste stream (% of targeted and impurities, which add up to 100%) can be based either on specific data or literature. We based it on the latter (e.g. out of the total paper and cardboard waste reported as collected, 90% is target and 10% impurities). All assumptions are reported in (Albizzati & Tonini, 2023).

2.4 Fractional material composition of the targeted material and impurities

The fourth step is to estimate the fractional composition of the targeted material (e.g. for paper and cardboard it would be the % of magazines, advertisements, corrugated boards, etc.) and of the impurities (e.g. for paper and cardboard the % of glass, metal, plastic, etc.; similarly for any other targeted waste stream). To this end, compositional analyses shall be used. While these should in principle be specific to the MS, for most of them they are lacking. To circumvent this lack of specific knowledge for each MS, we used the fractional composition analysis by (Edjabou et al., 2021) and we assumed it to be valid for all Member States. The study by (Edjabou et al., 2021) focuses on a handful of Danish municipalities with a defined collection scheme for each waste stream, for which it is possible to calculate the share of targeted materials and impurities. Furthermore, the study performed a detailed compositional analysis accounting for a total of 52 material fractions for both collected waste and mixed waste. With this information, step 3 can be performed. Notice

---

[25] **Impurity:** Waste that is not targeted for separate or commingled collection by local authorities in charge of waste management, or waste management companies. In the present framework, impurities include moisture content.

[26] **Targeted material:** The waste or mix of waste that is the objective target for separate or commingled collection defined by local authorities in charge of waste management, or waste management companies. Depending on the objectives of the waste collection system, a certain waste is targeted as it is sortable and recyclable and a market exists for the final secondary raw materials.

[27] **Mis-sortings:** The waste that is the objective target for separate or commingled collection defined by local authorities in charge of waste management, or waste management companies, which ends up in another waste stream (e.g. paper and cardboard waste ending up in the plastic waste stream, while it should end up in the paper and cardboard dedicated waste stream).

that one should be careful when handling commingling. If commingling is in place, e.g. plastic and metal, the presence of plastic waste in the metal waste stream should not be considered as an impurity in the methodology described herein.

2.5 Combining steps 1 to 4

By combining the MW generated in steps 2 to 4, it is possible to derive the quantity of targeted materials and impurities are found in, for example, separately collected paper and cardboard but also the mis-sortings of, for example, paper and cardboard in the separately collected plastic waste (or glass waste or metal waste or bio-waste, etc.). Yet, the quantification of how much, for example, paper and cardboard ends up in the mixed waste is still unknown. For this, the following step is necessary.

2.6 Composition of the mixed waste

The fifth step is to estimate the mixed waste composition. This can be defined using Equation 2. Indeed, taking into account the case of paper and cardboard waste, it is known how much paper and cardboard is generated in total ($P\&C_G$, applying Equation 1), the amount of targeted material separately collected ($P\&C_C$) and the amount of mis-sortings of paper and cardboard in separately collected bio-waste, plastic, glass, and metal ($P\&C_M$), while the only unknown value is the amount of paper and cardboard found in the mixed waste ($P\&C_R$) – see Figure 1.A.b. It is important to note that at this stage it has been assumed that the amounts reported to Eurostat of wood, textile, electrical and electronic equipment, batteries, and bulky waste are without impurities.

$$P\&C_G = P\&C_C + P\&C_M + P\&C_R \rightarrow \ P\&C_R = P\&C_G - P\&C_C - P\&C_M$$ Equation 2

By applying Equation 2 to each waste stream, the total amount of paper and cardboard, glass, metal, plastic, wood, textile, electrical and electronic equipment, batteries, and bio-waste ending up in the mixed waste can be quantified ($RES_{rec+bio}$). By using Equation 3, it is then possible to quantify the amount of *mixed waste* corresponding to the remaining material flows (e.g. animal excrements, sanitary products) (RES_{other}), as the total amount of mixed waste is known and corresponds to the data reported to Eurostat ($RES_{Eurostat}$).

$$RES_{other} = RES_{Eurostat} - RES_{rec+bio}$$ Equation 3

By implementing Equation 1 to Equation 3 it is **possible to allocate the recyclables reported under mixed waste to the corresponding waste stream and estimate the generated waste from collected amounts**.

3. Inconsistencies identified in the current MW dataset reported to Eurostat

3.1 Inconsistencies in the amount of bio-waste reported

A check on the amount of bio-waste generated was performed. Specifically, the amount of food waste generated by Member States was estimated in (Laurentiis & Caldeira, 2021) (with updates due to a minor revision of the model calculations). The amount of generated bio-waste is calculated by applying Equation 1. It was found that for Bulgaria, Estonia, Hungary and Slovenia either the amount of collected bio-waste reported to Eurostat or the capture rate reported to the European Environment Agency is wrong as the amount of food waste generated exceeds the amount of total bio-waste generated Table 14.

Table 14. Inconsistencies found in the reporting of bio-waste collected or bio-waste capture rates

Member State	Food waste generated [tonnes]	Total bio-waste generated [tonnes]
BG	672 149	171 485
EE	149 429	125 717
HU	1 014 492	962 011
SI	221 868	216 134

3.2 Inconsistencies in the amount of mixed waste reported

When implementing Equation 3 it was observed for a number of Member States that the amount of recyclables found in mixed waste exceeded the total amount of mixed waste reported to Eurostat (Table 15). This indicates that either the amount of mixed waste reported is underestimated or the capture rates are overestimated.

Table 15. Inconsistencies found in the reporting of mixed waste to Eurostat

Member State	Problem identified	Recyclables found in mixed waste [tonnes]	Mixed waste reported [tonnes]
HR	Capture rate is reported as 0% for metals (so we set it to 1% to be able to perform the calculations). Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	4 970 934	1 002 262
CY	No data have been reported to Eurostat		
DK	Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	2 015 226	1 637 469
FI	Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	1 577 475	1 509 605
EL	No data have been reported to Eurostat		
IE	No data have been reported to Eurostat		
LT	Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	794 584	535 029
PL	No data have been reported to Eurostat		
SK	Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	1 528 454	1 190 064
SI	Mixed waste reported is too low compared to what we estimate → Capture rates for recyclables are too high (?)	267 213	265 621
ES	No data have been reported to Eurostat		

Notice that, out of the 27 Member States, 7 were reporting both generated and collected amounts, 5 did not report any data to Eurostat, and out of the 15 for which the above-mentioned methodology was applied, 6 showed a problem with the amount of mixed waste (too low, or capture rates reported in the Early Warning Assessment Reports too high).

4. Further applications of the methodology to MS reporting both generated and separately collected MW

The step-wise methodology previously described can also be applied to those MS reporting both *generated* and *separately collected* MW in order to track how the different waste streams are partitioned during source segregation: how much is separately collected as an individual stream, how much is commingled, how much is mis-sorted, and how much is ending up in the mixed waste (residual).

When implementing the methodology for these Member States, one needs to assign (or approximate) the collection scheme[28] in place and its coverage to be able to track where the different waste streams end up. Notice that, in this case, capture rates are calculated following Equation 4 and not the ones reported to the EEA.

[28] The type of collection schemes in place across Member States in the EU-27 may be consulted at (Albizzati, Cristóbal, et al., 2023).

Equation 4

$$CR_{calculated} = {P\&C_{collected\ as\ reported\ to\ Eurostat}}\Big/{P\&C_{generated,as\ reported\ to\ Eurostat}}$$

Once the CR is calculated, the composition of a selected waste stream of the total MW collected can be further split in terms of the share of targeted material and impurities following the steps 2 to 4. Clearly, one can also estimate the amount of recyclables found in the mixed waste using Equation 2. The total amount of waste collected as mixed waste is obtained by summing up the amount of mixed waste reported as generated and the amount of recyclables ending up in the residual waste (Equation 5).

Equation 5

$$Mixed\ waste_{collected} = Mixed\ waste_{generated} - Recyclables_{in\ mixed\ waste}$$

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