European Environment Agency

Tracking waste prevention progress —
A narrative-based waste prevention monitoring framework at the EU level

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European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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Acknowledgements

Authors

Sanna Due (EEA), Alexandra Wu, Jurate Miliute-Plepiene (IVL Swedish environment institute), Mona Arnold, Patrycja Slotte (VTT Technical research centre of Finland), Dirk Nelen (VITO)

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Key messages

- This report proposes a **new framework for monitoring waste prevention**. The framework consists of three clusters of indicators: the system where prevention is implemented, policy enablers focusing on waste prevention measures and waste prevention outcomes. Given that waste prevention occurs over time, this report seeks to assess longer term trends in waste prevention.

- This comprehensive monitoring framework allows a broader understanding of waste generation and prevention; however, the data collected were not sufficient for an in-depth analysis of waste prevention progress or for assessing the effectiveness of specific prevention measures. **For a deeper analysis, more specific data and information need to be collected across EU countries in a systematic and harmonised way**.

- Total waste (excluding major mineral waste) per capita in the 27 EU Member States (EU-27) increased by 1.45% from 2010 to 2020 ([1]), while overall economic growth — expressed in terms of per capita gross domestic product ([2]) — increased by 6%, **showing signs that relative, but not absolute, decoupling has been achieved between waste generation and economic growth**.

- To prevent waste generation, countries mainly focus on promoting sustainable consumption models, encouraging reuse and repair activities, and developing and supporting information campaigns to raise awareness. **However, although waste prevention programmes have been in place for almost 10 years in the EU, it remains difficult to establish a link between the introduction of waste prevention programmes and waste generation**.

- Although progress has been made in moving up the waste hierarchy, substantial additional efforts should be made to prevent waste generation, and more effective measures are likely to be needed for all types of waste. **This will require the strong implementation of circularity in the EU economy, designing out waste in new, long-lived and repairable products, and changing our consumption habits to less material-intensive activities**.

- **Almost all EU-27 countries have some sort of quantitative target (n=25) and quantitative indicators (n=22) related to waste prevention** (for all types of waste). However, the targets and indicators vary widely. Some targets and indicators are, for example, more related to waste management than to waste prevention.

- To improve and harmonise waste prevention monitoring, more efforts are needed to strengthen and standardise the measurement of waste prevention at country level. **The establishment of harmonised, specific indicators at the EU level to measure waste prevention could help with this**.

- Establishing **quantitative waste prevention targets at the EU level**, such as the legally binding food waste reduction target that is currently being developed, can also help in setting a direction and an objective for measurement and in strengthening obligations on waste prevention.

([1]) Data on waste generation including total waste (excluding major mineral wastes) presented in this report are based on data extracted in September 2022. The figures for 2020 may have been adjusted since then.
([2]) Gross domestic product is at chain-linked volumes at market prices.

Executive summary

Total waste (excluding major mineral waste) generated per capita in the 27 EU Member States (EU-27) increased by 1.45% from 2010 to 2020. The average European citizen generated about 517kg of municipal waste in 2020 ([3]). With one of the highest rates of waste production per capita in the world, the EU has been prioritising addressing its high levels of waste generation and improving waste management in society. According to the waste hierarchy, which is the EU's principle for the environmental ranking of waste management policies, waste prevention is the best policy option for waste management. The Waste Framework Directive (WFD), European Green Deal, circular economy action plan and zero pollution action plan define waste prevention as the main priority in waste management because it reduces or avoids the amount of waste generated in the first place. Waste prevention is also key to achieving a circular economy within the planetary boundaries because of its potential to reduce levels of resource use, increase recirculation of materials with longer lifespans and more sustainable products in the economy, and shift to non-material-based business models

Monitoring waste prevention progress is important to track the progress of efforts to reduce waste, but it is not currently a standard practice at the EU level, which makes assessing waste prevention performance in the EU very difficult.

Waste prevention monitoring is unique in that it is more than a simple matter of tracking whether waste generation has decreased. This is because the term prevention itself implies that a certain event or action has taken place, which leads to an impact on waste output. This means that a key aspect of waste prevention monitoring is to consider waste generation in the context of another metric, such as waste prevention effort or an economic metric (e.g. gross domestic product (GDP)), which is used to assess whether society is decoupling environmental impact from economic growth. Furthermore, waste prevention monitoring goes beyond the end-of-pipe mentality and can also consider resource use, material footprints and consumption levels for areas with high material intensity consumption, as well as value retention strategies that could reduce the consumption of material and products.

([3]) Based on data extracted since September 2022. Figures for 2020 may have been adjusted since then.

In 2018, the EEA was mandated to:

> … publish, every two years, a report containing a review of the progress made in the completion and implementation of waste prevention programmes (WPPs), including an assessment of the evolution as regards the prevention of waste generation for each Member State (MS) and for the Union as a whole, and as regards the decoupling of waste generation from economic growth and the transition towards a circular economy (EU, 2018a).

The ultimate goal of this report is to develop an indicator framework to monitor the progress of waste prevention at the level of the EU-27. It presents a framework based on carefully selected indicators for monitoring waste prevention efforts and progress at the EU level, in the context of policy measures, as reflected in the waste prevention programmes of Member States. The framework is aligned with the definition of waste prevention in the WFD and was developed with the priority of obtaining an operational framework that can be implemented as soon as possible and with limited administrative burden.

A narrative-based monitoring framework was developed to comprehensively consider the social, economic and environmental systems in which resources are consumed and waste is generated. In this sense, the framework consists of indicators in three clusters: **(1) the system context,** which describes the most relevant causal links between key socio-economic activities that generate waste and eventually lead to impacts on human health and the environment; **(2) policy enablers,** which focus on policy-related waste prevention measures that are or can be put in place with the explicit intention of impacting the chain of events identified in cluster 1, at any stage; and **(3) waste output,** which refers to the changes in waste generation, including waste output on the basis of economic development (e.g. waste generated per unit of GDP).

The indicator framework was used for the first time in this report. First, data were collected for each indicator at the EU-27 level. Then, the data were compiled and interpreted to identify any notable patterns. Lastly, the patterns and trends were compared between the clusters to identify any notable linkages between socio-economic trends, waste prevention efforts and actual waste output, or to determine whether observed trends in waste output could be influenced by other external factors not included in the indicator framework. In addition to analysing waste prevention, the indicators and method of analysis were also assessed.

The final indicator set is listed below.

Cluster 1: System context

1. **Population** (average population — total)
2. **GDP** (main GDP aggregates per capita, chain-linked volumes)
3. **Household final consumption expenditure** (final consumption expenditure of households by consumption purpose (COICOP 3 digit), chain-linked volumes)
4. **RMC** (material flow accounts in raw material equivalents and by final uses of products — modelling estimates)
5. **Value added from reuse, repair and recycling** (gross value added related to circular economy sectors, value added at factor cost (aggregated indicator as available on Eurostat))
6. **Turnover in repair sectors** (annual detailed enterprise statistics for repair services)

Cluster 2: Policy enablers

1. **Presence of each type of measure** in WFD Article 9, categorised by policy instrument type (number of Member States of all 27 Member States)
2. **Presence of targets** categorised by policy instrument (number of Member States of all 27 Member States)
3. **Presence of indicators** categorised by policy instrument (number of Member States of all 27 Member States)
4. **Development and evaluation of waste prevention programmes over time**
5. **For a specific waste stream**:
    a. Presence of each type of **measure** in WFD Article 9, categorised by policy instrument type (number of Member States of all 27 Member States)
    b. Presence of **targets** categorised by policy instrument (number of Member States of all 27 Member States)
    c. Presence of **indicators** categorised by policy instrument (number of Member States of all 27 Member States)

Cluster 3: Waste output

1. **Total waste** (excluding major mineral waste) generation (tonne per year, in total and per capita)
2. **Waste intensity** of net waste volume (without major mineral waste) (per GDP unit, kg per thousand euros per year)
3. **Municipal waste generation** (kg per capita per year)
4. **Residual municipal waste** (kg per capita and per cent of waste generated)
5. **Weight of reuse** (kg per capita, in total and per product category)
6. **GHG emissions from waste management** (GHG emissions by source sector for selected waste management categories)
7. **Substances of very high concern** in products placed on the market
8. **Food waste** (kg per capita)

Notes: COICOP, Classification of Individual Consumption by Purpose; GHG, greenhouse gas; RMC, raw material consumption.

Summary of key findings on waste prevention progress at the EU-27 level

Per capita total waste (excluding major mineral waste) generated increased by 1.45% from 2010 to 2020, while GDP increased by 6%, indicating that relative decoupling may be occurring between total waste (excluding major mineral waste) and economic growth.

However, both per capita total waste (excluding major mineral waste) and GDP decreased by about 4% each from 2018 to 2020. It is unclear whether the waste decrease was connected to the economic downturn due to measures introduced to manage the COVID-19 pandemic, given that a closer look at the types of waste comprising total waste (excluding major mineral waste) shows that the major proportion of the decrease is attributed to combustion waste from the energy sector, and this is most likely to be related to the decrease in use of solid fossil fuels rather than waste prevention measures (see Section 5.1.1 for a detailed explanation). However, further investigation is needed to understand the causes behind the waste trends observed.

In the waste prevention programmes of the EU-27 countries, the top three waste prevention measures are Article 9(d) 'Encourage reuse and repair activities' (average 44%), Article 9(a) 'Promote sustainable consumption models' (average 37%) and Article 9(g) 'Reduce the generation of food waste' (average 36%) (see Section 4.2 for a full explanation). Of these measures, voluntary initiatives or agreements are the most common type of instruments, followed by informative and regulatory instruments. However, no strong linkages can be established between the waste prevention measures and waste generation or socio-economic trends.

Overall, the waste hierarchy establishes a priority order, starting with prevention and moving to preparation for reuse, then to recycling and finally to energy recovery through to disposal, such as landfilling. This principle aims to encourage the options that deliver the best overall environmental outcome. Although progress has been made in moving up the waste hierarchy, substantial additional efforts are required for preventing waste generation, and more effective measures are likely to be needed on all types of waste. This is likely to require the strong implementation of circularity in the EU economy, designing out waste in new, long-lived and repairable products, and changing our consumption habits to less material-intensive consumption activities.

Summary of key reflections on the indicator framework

Overall, the data collected on the indicators were able to provide a 'big picture' understanding of the waste generation situation over the past decade; however, they were not sufficient for a comprehensive, in-depth analysis of waste prevention progress or for assessing all causes behind the waste generation trends observed. The reasons are as follows.

First, the lack of granularity on the total waste (excluding major mineral waste) indicator and lack of a good-quality (ideally quantifiable) indicator on the waste prevention measures — especially in terms of the magnitude of the waste prevention effort (e.g. budget for waste prevention programmes or measures) — were identified as key limitations in the indicator framework.

Second, given that there is no standardised structure for the content of waste prevention programmes, including a description of quantitative targets, indicators and measures, it was difficult to compare and analyse waste prevention measures between countries. Developing a common standard for the structure and content of waste prevention programmes would help to streamline the monitoring of the implementation of waste prevention measures.

Establishing standardised specific indicators to measure waste prevention will help to improve the monitoring of waste prevention. Setting EU-level waste prevention targets, such as the food waste reduction target that is currently being developed, can also help to set the direction and an objective for measurement and to strengthen obligations on waste prevention.

1 Introduction

The EU has high rates of waste generation per capita, with 517kg of waste generated per EU inhabitant in 2020 (Eurostat, 2022s). This waste must be managed to minimise the risk of negative impacts on human health, the environment and society. According to the waste hierarchy (the EU's principle for the environmental ranking of waste management policies), waste prevention is the preferred waste policy option because it reduces the amount of waste generated in the first place (Figure 1.1).

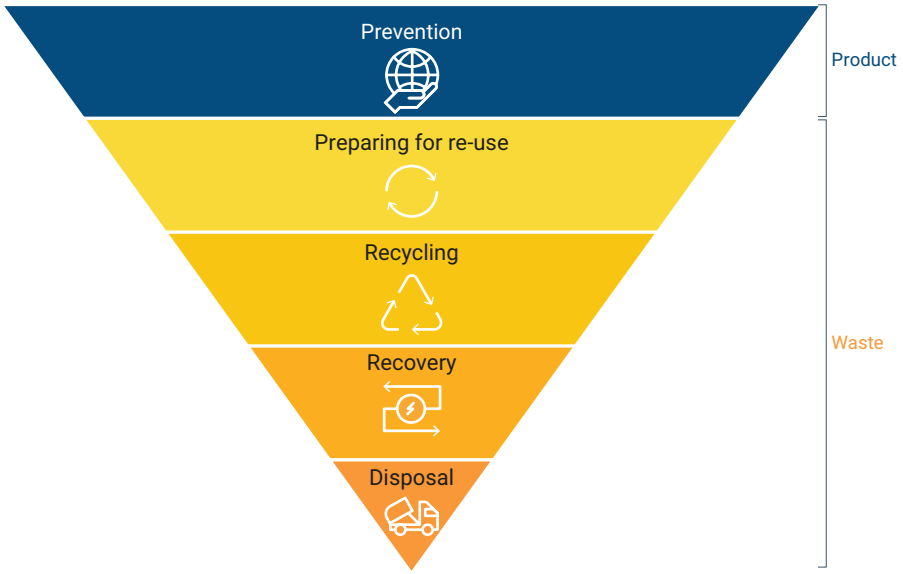
Waste prevention is also a key component of the transition to a circular economy because of its potential to reduce the negative environmental and social impacts associated with the production, distribution and consumption of new products, as well as its contribution to increasing resource efficiency. This can be done, for example, by reducing natural resource extraction and maximising the useful life of products and materials.

Most waste prevention programmes state the aim of **decoupling waste** generation from economic growth (EEA, 2014). Decoupling can be either absolute or relative. **Absolute decoupling** occurs when waste generation is stable or decreasing while the economy is growing. **Relative decoupling** occurs when the growth rate of waste generation is positive but less than the growth rate of the economy (Eurostat, 2023).

The ultimate goal of this report is to develop an indicator framework to monitor the progress of waste prevention at the level of the 27 EU Member States (EU-27).

In a previous EEA report on waste prevention (EEA, 2021), it was observed that waste generation is still increasing throughout Europe, for both total waste and key waste streams. A relative decoupling of waste generation from economic growth

Figure 1.1 **Waste hierarchy**



Source: European Commission (2023).

has been achieved in the EU as a whole and in individual countries, but there are no signs that overall waste reduction has been achieved in a growing economy (i.e. absolute decoupling). This means that, as the economy continues to grow, absolute waste generation remains on the rise.

Monitoring waste prevention is important to track the progress of waste reduction efforts, but it is not currently systematically carried out as a standard practice at the EU-27 level, which makes it very difficult to assess waste prevention performance in the EU.

However, measuring and monitoring waste prevention can be very difficult because, in essence, it is an attempt to measure what is **avoided or not generated** (Box 1.1). It has become clear that the approach to waste prevention monitoring needs to be improved by, for example, adopting a more comprehensive and systematic approach that reflects the socio-economic system in which waste generation occurs. This would allow us to consolidate the monitoring into a more cohesive narrative on waste prevention progress overall. Therefore, this report focuses on assessing the methods and indicators used for tracking the implementation of waste prevention policies and the status and progress of waste prevention at the EU level.

Box 1.1

What is waste prevention?

According to the Waste Framework Directive, waste prevention is defined as ' … measures taken before a substance, material or product has become waste, that reduce:

a. the **quantity of waste**, including through the **re-use** of products or the **extension of the life span** of products;
b. the **adverse impacts** of the generated waste on the environment and human health; or
c. the **content of hazardous substances** in materials and products.'

Waste prevention is at the heart of EU waste policy and links directly to the circular economy by avoiding the negative economic, environmental and societal impacts associated with the extraction and consumption of natural resources that, at the end of the product's lifecycle, are disposed of as waste. Waste prevention can occur as the result of the efficient and effective use of materials along the entire value chain, including reducing or minimising raw material use. This also includes effective efforts to educate the public and raise awareness.

Waste prevention monitoring is unique in that it is more than a simple matter of tracking whether per capita waste generation has decreased. This is because the term **prevention** itself implies that a certain event or action has not taken place, which purposely leads to an impact on waste output. This means that a key aspect of waste prevention monitoring is to consider waste generation **in the context of another metric**, for example an economic indicator (such as gross domestic product), which is used to assess whether society is decoupling environmental impact from economic growth, which is a key goal of the Waste Framework Directive.

Waste prevention monitoring supposes the adoption of a systems analysis perspective, which considers the interactions of socio-economic activities (i.e. a chain of causal links) that eventually lead to waste generation. In so doing, levers in the system to prevent and minimise waste can be identified, and the respective efforts and their effects on waste generation can be measured.

Box 1.2

What is the purpose of an indicator framework?

An indicator framework intends to provide an organised way of viewing data from different sources. It allows the presentation of these data in a way that facilitates interpretation and uncovers both the relevance and the connection between the different indicators.

An indicator framework can be used for monitoring programmes and policies, as a means of determining progress towards achieving their aims, under the assumption that the actions proposed in the programmes and policies will effectively contribute to the intended results.

A waste prevention monitoring framework uses carefully selected indicators that allow us to observe changes that can actually be attributed to measures and actions contained in Member State and EU-wide waste prevention programmes and policies.

The Driving forces, Pressures, States, Impacts and Responses (DPSIR) impact model, which is used by the EEA for integrated environmental assessment, allows the systems analysis required for waste prevention monitoring (EEA, 1999). The DPSIR model describes the network of causal links from **driving forces** (economic and human activities) that create **pressures** on the environment, resulting in changes to environmental **states** (i.e. state of soil, water, air, changes in physical, biological or chemical processes) and generating **impacts** (on ecosystems or human health). Based on this chain of events, **responses** (i.e. socio-political reactions to the changes and impacts) can be devised (German Environment Agency, 2019).

The purpose of this report is to develop and apply a framework based on carefully selected indicators for monitoring waste prevention efforts and progress in Europe. It should be noted that while there is no specific definition available (Box 1.2), for the purpose of this report waste prevention monitoring refers to monitoring the state of waste prevention in Europe in the context of policy — specifically the measures in the waste prevention programmes. While it is acknowledged that waste prevention overall includes more than the programmes, for the purpose of obtaining a feasible and operational framework, other aspects (such as initiatives by non-governmental organisations, companies and industries) are excluded from the scope of the report.

This report is divided into the following parts. Chapter 2 further describes the DPSIR concept and methodology behind the proposed monitoring framework, including the scope, assumptions and limitations. Chapter 3 presents the structure and details of the monitoring framework itself. Chapter 4 presents the data collected on the indicators. Chapter 5 provides an analysis and discussion of the indicator data, and ends with key messages on waste prevention monitoring and the indicator framework itself.

2 Methodology

In this chapter, the methodology used for developing the waste prevention monitoring framework is set out. It considers the following steps:

Step 1. **Development of a narrative-based framework** to support indicator selection based on the Driving forces, Pressures, States, Impacts and Responses (DPSIR) systems model. The framework was then populated with indicators. These indicators are organised into three distinct groups, referred to as 'clusters'. Each cluster represents an area that is core for framing waste prevention monitoring. Indicators were identified for the different clusters based on their assumed or expected contribution to explaining and revealing the overall narrative of waste prevention.

Step 2. **Mapping of the data** source and availability for each indicator identified.

Step 3. **Analysis of each indicator** based on the Relevance, Acceptance, Credibility, Ease and Robustness (RACER) criteria to obtain a final selection of high-quality operational indicators for the monitoring framework.

The details of each methodological step are provided, followed by some remarks on the scope and limitations of the methodology and resulting monitoring framework.

2.1 Step 1: Narrative-based framework

The framework for 'telling the story' of waste prevention progress in Europe considers the Bellagio Declaration (see Box 2.1), which is a set of principles on how to ensure that monitoring the transition to a circular economy captures all relevant aspects and involves all relevant parties. While it has mainly been applied to the circular economy, it is also relevant to waste prevention, given the close ties between waste prevention and circular economy.

The system that is subject to the development of a monitoring framework refers to the **economic system of production and consumption of material goods**, which, on the one hand, provides the functionalities demanded by society (such as nutrition, mobility, communication and transport) and, on the other hand, generates production waste and discarded products that eventually affect the environment. The DPSIR model describes the interactions between the environment and socio-economic activities observed within this system through a chain of causal links. When the causes and effects are understood within the model, then interventions can be devised to target specific points in the system.

Box 2.1

What is the Bellagio Declaration?

The Bellagio Declaration consists of a set of principles for monitoring the circular economy transition. It lays out the following seven elements:

1. Monitor the circular economy transition, holistically considering all relevant public and private initiatives across the economy.
2. Define indicator groups,— which should include indicators on material and waste flows, environmental footprints, and economic and social impacts, as well as policy, process and behaviour.
3. Follow indicator selection criteria — this refers to the RACER (Relevance, Acceptance, Credibility, Ease and Robustness) criteria for indicator selection (see Section 2.3).
4. Exploit a wide range of data and information sources — including official statistics, policy information and new data sources.
5. Ensure multilevel monitoring that captures changes across all levels of the economy.
6. Allow for measuring progress towards targets, which should help to assess progress towards relevant policy targets and objectives.
7. Ensure visibility and clarity, including communication methods that effectively inform policymakers, stakeholders and citizens.

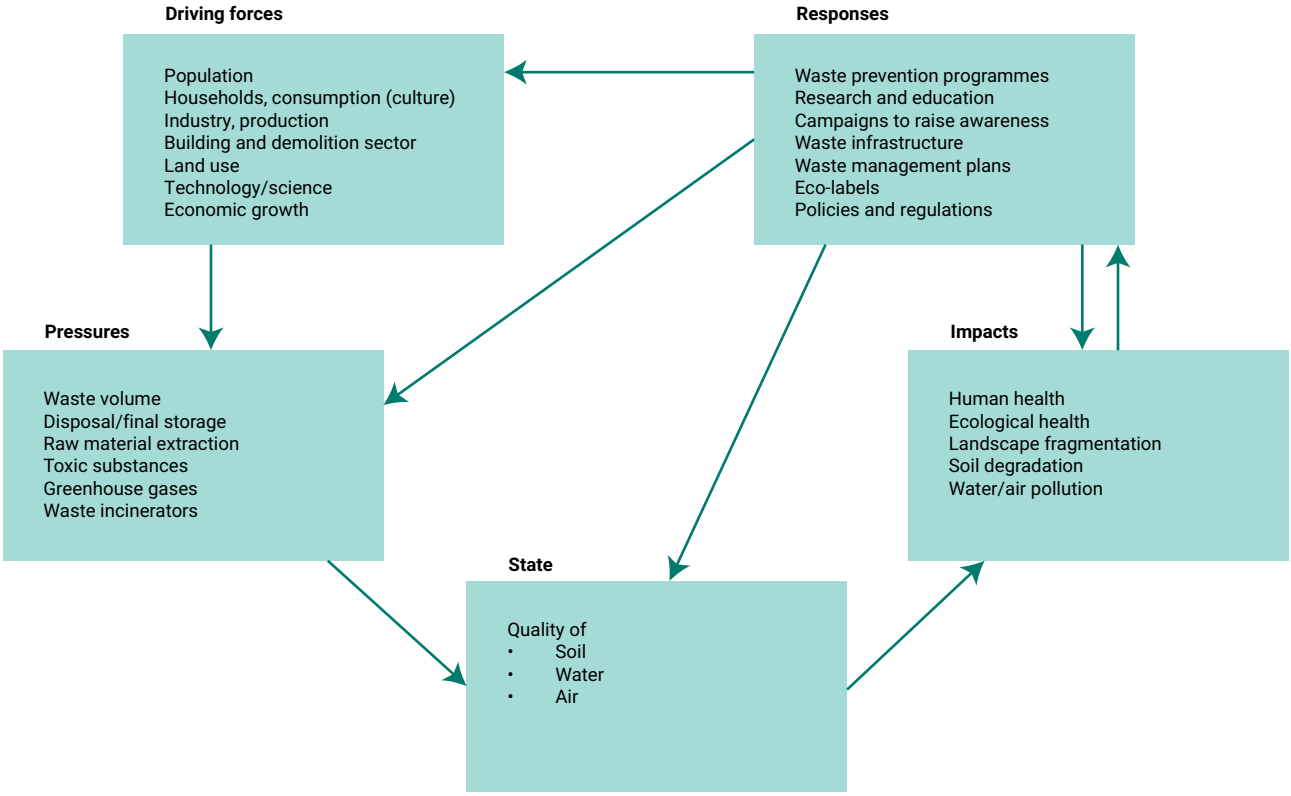
Source: EPA Network et al. (2020).

The DPSIR model was selected because it is already a readily used and integrated environmental assessment concept that specifically focuses on interactions between environment and socio-economic activities. As described by Wilts and Galinksi (2019), it:

> … allows indicators to be structured in terms of ecological quality and the resulting influence of policy decisions … The aim is to clearly differentiate waste prevention indicators according to their different approaches, distinguishing between driving forces, environmental impacts caused by them and their specific impacts, the state of individual environmental media and concrete measures aimed at preventing waste.

Figure 2.1 illustrates the DPSIR model as it is applied to waste prevention.

Figure 2.1 DPSIR model from the waste prevention perspective



Note: While impacts are relevant when analysing waste prevention in the DPSIR context, for the purpose of this report they are not included because the selection of indicators does not include the impact category (see Figure 2.2).

Source: Adapted from German Environment Agency (2019).

To consolidate the waste prevention monitoring into a cohesive narrative with respect to overall waste prevention in Europe, especially from a policy perspective (as embedded in the waste prevention programmes of Member States), the DPSIR model was adapted to a narrative-based framework consisting of three main cluster areas: (1) the system context, (2) policy enablers and (3) waste output. The linkages between the DPSIR model and the three proposed clusters are as follows (Figure 2.2):

- **Cluster 1: the system context** facilitates the identification of relevant causal links between key socio-economic parameters or activities and identified environmental pressures and changes to the environmental state that in turn eventually affect human health and the ecosystem. In the DPSIR model, the indicators in this cluster mainly cover the driving forces aspect.

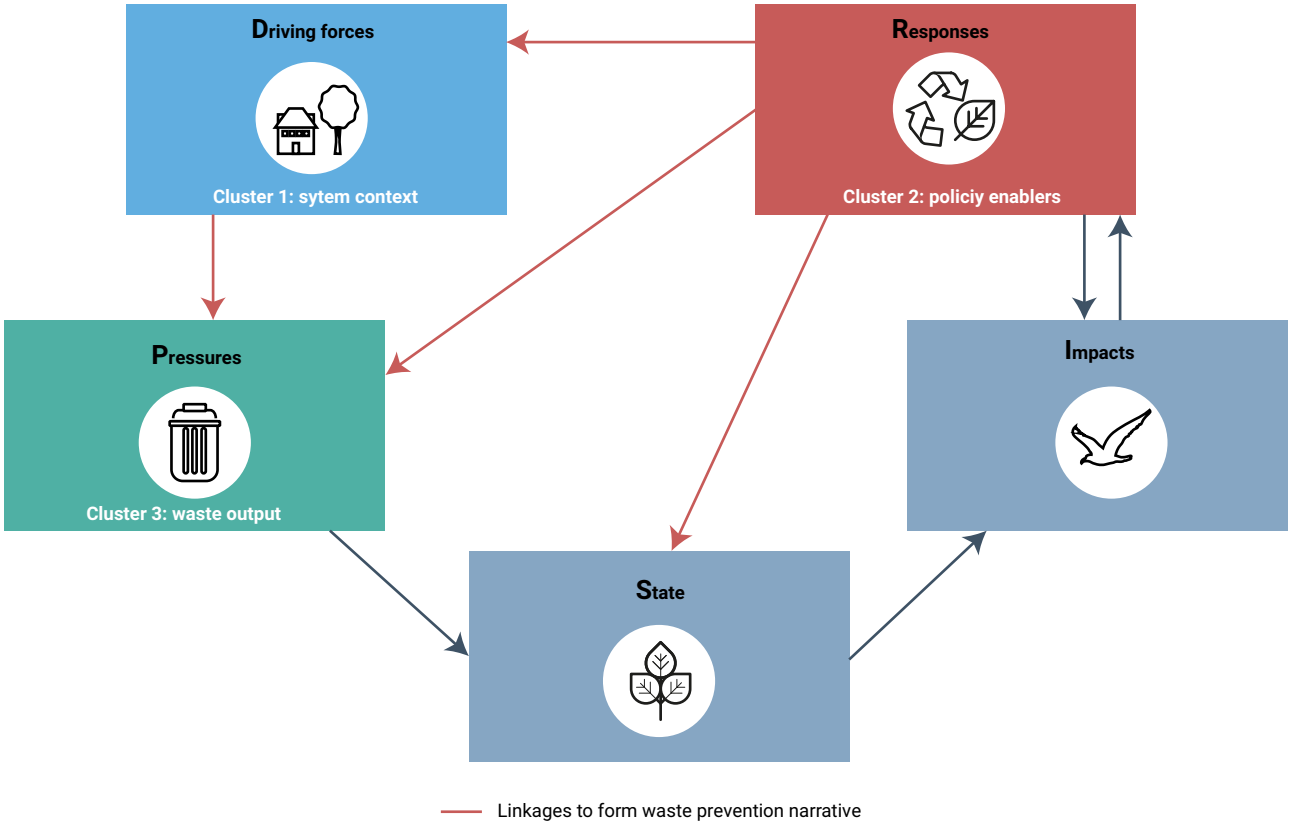
- **Cluster 2: policy enablers** focus on policy-driven waste prevention measures that are (or can be) put in place with the explicit intention of affecting the chain of events identified in cluster 1, at any stage. In the DPSIR model, this covers the responses aspect. While enablers of waste prevention can come in many forms (e.g. technological, social, cultural), for the purpose of this waste prevention monitoring framework, only waste prevention measures aligned with the list of measures in Article 9 of the Waste Framework Directive (WFD) are considered.

- **Cluster 3: waste output** refers to the changes in waste generation and key environmental impacts. This includes waste output and greenhouse gas (GHG) emissions from waste management. In the DPSIR model, this covers the pressures aspect. The indicators in this cluster are structured according to the definition of waste prevention in the WFD.

It should be noted that, while a connection can be established between policy responses and waste output, it does not indicate or necessarily provide a quantifiable measure of how much the response itself is contributing to the waste output observed, given that waste output can be influenced by measures taken in other policy domains as well as by diverse socio-economic and environmental factors (e.g. economic downturn/upturn, demographic change, warfare, natural disasters, social/cultural change). That is, an observed correlation between two factors does not necessarily show causation between those factors. However, the mere consideration of such connections will surely contribute to an improved understanding of the effects of response measures in the system.

The clusters were populated with relevant existing indicators based on their assumed or expected contribution to explaining and revealing the waste prevention narrative that is applicable to the production and consumption system under analysis. The selection of indicators was based on desk research of academic journal articles, publications and reports related to waste prevention monitoring and the methods used, in-depth interviews with EU country representatives on the design and experience of their own waste prevention monitoring programmes, and the authors' own analysis and elaboration.

Figure 2.2 **Linkage between the DPSIR model and the three-cluster narrative framework**



Source: EEA.

2.2 Step 2: Data availability mapping

In each of the three clusters, the availability of data was identified and mapped for each indicator. Given that the geographical scope of the monitoring framework is EU wide, priority was given to indicators that have data (1) available individually for each EU country (which can be aggregated to an EU-wide figure) and (2) aggregated at the EU level only. Indicators with data that are available at the national level for only some (but not all) EU countries were excluded. This consideration for prioritising data availability was based on the need to operationalise the monitoring framework as soon as possible. However, indicators with data that are expected to be available in the future were flagged for future incorporation into the framework.

2.3 Step 3: Indicator analysis and selection

Indicators are important for quantifying and describing developments to help improve the understanding of complex realities, trends and evolution over time (Watson et al., 2013). While there are no strict guidelines on indicator development, a widely used and accepted framework for analysing indicators is the RACER criteria, which assesses individual indicators on the following criteria (Watson et al., 2013; German Environment Agency, 2019):

- **relevance** to waste prevention goals or objectives;
- **acceptance** by targeted stakeholders, such as policymakers and academics;
- **credibility**, transparency and confidence in the indicator (i.e. the indicator is unmistakable, unambiguous and simple to interpret);
- **ease** in terms of both quantification and follow-up over time and communication with target groups;
- **robustness** in terms of data quality, scope and representativeness; ability to prevent manipulation and errors; and the quality of the database.

The RACER criteria were used to assess and calculate a final score (out of a maximum score of 3 ([4])) for each indicator in the three clusters. Stakeholder input was collected to assess the acceptance and credibility criteria of shortlisted indicators ([5]). Then, based on the results of the scoring and further reflection on the indicators, a final selection was made to obtain a set of operational indicators for the waste prevention monitoring framework. Full details of the RACER evaluation can be found in Annex 1.

([4]) A numerical score from 0 to 3 is allocated based on the scale of that criterion, where 3=extremely (RACER criterion), 2=very (RACER criterion), 1=somewhat (RACER criterion) and 0=not at all (RACER criterion). For example, a score of 3 for relevance means that the indicator is 'extremely relevant'. The scores for each criterion were then averaged to produce the final score.

([5]) The input from stakeholders came in the form of an Eionet workshop in June 2022 to which members of the Eionet group for circular economy and resource use were invited.

2.4 How the indicator framework was used

The general approach for analysing the data and discussing the progress of waste prevention when preparing the waste prevention reports was as follows:

- First, data were collected for each indicator of each cluster (at the EU level, focusing on the EU-27).
- Then, the data for each indicator were compiled and interpreted to identify any notable patterns (e.g. economic or population trends, common waste prevention measures taken by countries, waste generation changes).
- Lastly, the patterns and trends were compared between the clusters to identify any notable linkages between socio-economic trends, waste prevention efforts and actual waste output, or to determine whether observed trends in waste output could be influenced by other external factors not included in the indicator framework.

2.5 Scope and limitations

In this section, the scope and main limitations considered in developing the waste prevention monitoring framework are described.

2.5.1 Prioritising an effective operational framework

Ultimately, the prioritisation of indicators in the monitoring framework is meant to reflect the most important aspects of waste prevention (as verified by the RACER criteria analysis) and data availability at the EU-27 level. This is to ensure that the proposed monitoring framework is operational and feasible to implement, while also maximising coverage and comprehensiveness to draw meaningful conclusions about the status of waste prevention in Europe.

2.5.2 Assessing policy effectiveness

The biggest challenge is in the ability to attribute observed changes in waste output volumes to specific or a combination of waste prevention measures, which is the essence of assessing policy effectiveness. The potential linkage between one or multiple measures and their effect can also vary depending on the measure(s) themselves. For example, the effect of an informative measure and its contribution to waste reduction is much less straightforward to determine than a tax regulation or product ban.

This is because waste generation occurs in a complex system where a diversity of socio-economic trends, human activities and environmental impacts are interconnected, and therefore it is challenging to isolate the impact of a single aspect of the system on waste output. Waste generation is also deeply affected by the economics of a country, such as consumer expenditure and gross domestic product (Chertow, 2008). Low-income countries tend to have lower per capita waste generation figures, independent of the presence or effectiveness of waste prevention policies.

Although, from this line of reasoning, one can question whether the establishment of waste prevention programmes (reflecting the waste prevention measures) actually leads to a reduction in waste output or decoupling from economic growth, the question can be formulated in the other direction: that is, it also cannot be discerned based on the knowledge and methods available whether waste output volumes would be higher in the absence of waste prevention programmes. In short, it is not feasible to assess with great certainty the contribution of waste prevention programmes to waste reduction or economic decoupling.

Such conclusions have also been reached in similar work by Watson et al. (2013), Yano and Sakai (2016) and Wilts et al. (2019). For example, the literature review of waste prevention monitoring indicators conducted by Yano and Sakai (2016) found that most indicators can measure a possible outcome of prevention but not the prevention itself. That is, a causal link between prevention and policy cannot be proven by the indicators because improvements in decoupling waste generation and material productivity can be caused by many factors (e.g. macroeconomic, demographic and cultural factors). One major challenge is that waste prevention indicators and targets in themselves cannot provide the causal relationship with the waste prevention behaviour of those that generate the waste (Yano and Sakai, 2016). Nonetheless, it remains valuable to compare and assess these factors to gain an understanding of the extent and types of waste prevention efforts implemented and of their potential contribution to waste generation outcomes.

Lastly, the goal of developing the indicator framework on waste prevention is to provide an organised, simple and concise way to present data obtained from different sources and to uncover connections between indicators when applied to the economic system of production and consumption of material goods (i.e. the interpretation of the indicators to assess progress towards prevention goals at the EU level). A longer term follow-up of indicators would also enable monitoring and, additionally, by revealing multiple relationships, facilitate the isolation of direct impacts from individual policy measures.

2.5.3 Assessing policy efficiency

It should be noted that the approach developed in this monitoring framework does not consider policy efficiency, which is determined based on the resources used or needed to implement the waste prevention effort itself. The main reason for this is that data on the budgets or resources used for measures in EU countries are typically not widely available or easily accessible, or they are difficult to collect. Therefore, it was decided to keep the efficiency aspect outside the scope of this report.

3 Waste prevention monitoring framework

3.1 Cluster 1: System context

The system being assessed in waste prevention monitoring is the economic system of production and consumption of material goods, which, on the one hand, provides the functionalities demanded by society and, on the other hand, generates waste that eventually affects the environment. Therefore, the focus of this first cluster is to monitor the key social and economic parameters in the system that drive the consumption of resources that eventually generate waste.

Climate change, biodiversity loss and changes in the chemical composition of the atmosphere, oceans and soils, among others, are threats to the environment, the supply of resources and ultimately human health. The primary drivers for human activities are those that are directly dependent on the environment itself (i.e. the need for shelter, water and food). Secondary drivers are related to demographic, socio-economic and technological developments, for example the need for mobility and culture and a wish for entertainment. These secondary drivers shape changes in lifestyle, consumption and production patterns (Kristensen, 2004; EEA, 2015, 2019a; German Environment Agency, 2019).

A synthesis of global and European megatrends, emerging trends and wild cards (i.e. unlikely but potentially disruptive future developments) was presented in a recent report on drivers of change with relevance to Europe's environment and sustainability (EEA, 2019a). The trends and drivers give context to the system of production and consumption of material goods and ultimately to waste generation. The main trend categories mentioned in the report are (1) the growing, urbanising and migrating global population; (2) worldwide climate change and environmental degradation; (3) increasing scarcity of and global competition for resources; (4) accelerating technological change and convergence; (5) power shifts in the global economy and geopolitical landscape; and (6) diversifying values, lifestyles and governance approaches.

Nevertheless, it must be noted that the main factors affecting waste generation are related to demographics and economic performance. Population growth together with investments in human capital boost the global economic output but also imply a growing demand for water, food, energy, minerals and land, resulting in resource depletion and negative impact on the environment caused by increasing waste generation, among other factors. Waste prevention is regarded as the most efficient way to improve resource efficiency and to reduce the environmental impact of waste. Waste prevention implies actions to save resources from being used unnecessarily and reduces the consumption of energy, water and other resources associated with production, transport or storage of goods (EEA, 2015; EU, 2018b; Messner et al., 2020).

The influence of demographics on waste generation is broader than simply the linear dependency of waste generation on population growth. For example, the correlation of demographics with food waste generation was studied by Cerciello et al. (2019). Their results showed that food waste increased with higher population density and consumption levels (positive correlation), while it decreased with a higher share of women, elderly people, immigrants and unemployed people in the population (negative correlation).

Box 3.1

Tourism and waste

Tourism is another factor influencing waste generation (Obersteiner et al., 2021) the contribution of tourism to (municipal. Within the EU Horizon 2020-funded project 'URBANWASTE — Urban strategies for waste management in tourist cities', eco-innovative waste prevention and management strategies were implemented in 10 pilot cities with high levels of tourism. All pilot measures of waste prevention and treatment (e.g. food waste prevention, reductions in single-use plastic) achieved savings in greenhouse gas emissions compared with the situation before implementation of the measure. For example, the installation of public drinking water fountains was a measure with high potential to reduce the carbon footprint of tourism because tourists were encouraged to refill their drinking bottles, thus reducing plastic bottle waste.

Waste generation also depends on factors such as specific expenditure types, the share of expenditure types by income, household size, lifestyle habits or consumption patterns and to a lesser degree on broad economic developments. Therefore, cultural aspects are underlying factors in waste generation, and this points to the complexity of waste generation trends and how they are difficult to change in the short run (Cerciello et al., 2019; EEA, 2021).

To break the link between economic growth and the negative environmental impacts associated with the generation of waste (e.g. see Box 3.1), the Waste Framework Directive (WFD; (EU) 2018/851) stipulates that appropriate waste prevention measures are applied, including measures that encourage the design, manufacturing and use of products that are resource-efficient, durable, repairable, reusable and upgradable; promote and support sustainable production and consumption models; reduce generation of waste; reduce the content of hazardous substances in materials and products; and promote reuse. To ensure a uniform measurement of the overall progress in the implementation of waste prevention measures, common indicators and targets are required.

Indicators are useful to measure and monitor the socio-economic system's relevant background parameters that provide and describe the context in which prevention measures will be implemented. The context parameters can be grouped into five main categories (as listed below); however, for the purpose of the waste prevention monitoring framework, only indicators describing the nature of consumers (group 1), values of production and consumption (group 2) and circular use of resources (group 3) were chosen and listed in Table 3.1.

The parameters to describe the system context can be grouped as:

1. number and nature of producers and consumers;
2. volumes and values of production and consumption;
3. volumes and values of circular resource use, e.g. quantity of secondary raw materials used in production per year (German Environment Agency, 2019), circular material use rate (Eurostat, 2020a);
4. hazardous substances use, e.g. total amount of hazardous substances used in production processes and products; overall effects on the environment and human health (German Environment Agency, 2019) ([6]);

([6]) This report identifies that an indicator framework on the system context of waste prevention should ideally include parameters related to hazardous substances; however, this can be challenging because a large amount of production takes place outside the EU and new substances are constantly entering the market.

5. degree of provision of particular societal functionalities, e.g. number of vehicles (EEA, 2019a), number and economic value of research and development innovation projects related to waste prevention and sustainable consumption implemented annually (German Environment Agency, 2019).

3.1.1 Selected indicators

Based on the scoring of the RACER evaluation, the final selection of indicators is listed in Table 3.1. This is based on the top-scoring indicators, with the exception of the raw material consumption (RMC) indicator, which was included despite a lower score because it is the only available indicator relating to material consumption that performed relatively well in the RACER evaluation.

Table 3.1 Selected indicators for cluster 1: system context

Indicator	Description and rationale	Data source	RACER evaluation
Driving forces			
1. Number and nature of producers and consumers			
Population (average population — total) (EEA, 2019a)	Related to waste generation; indicates demand for resources. It can be used as a standalone demographic indicator or as an auxiliary indicator to derive indicators per capita. Data are updated annually. It is expressed as population on 1 January (following recommended definition of 'usually resident population') or as average population (i.e. the arithmetic mean of the population on 1 January of 2 consecutive years) (Eurostat, 2019; European Commission and Eurostat, 2015). The average population is used in the calculation of other indicators.	**Eurostat** online data code: DEMO_GIND (average population — total). Link to data source ([a]) Link to metadata ([b])	Total score: 2.9. To be used as an auxiliary indicator to calculate 'per capita' figures and to monitor trends in waste generation in time series relative to other variables, such as population growth.
2. Volumes and values of production and consumption			
GDP (EEA, 2019a)	Economic growth indicator connected to waste generation and relevant for monitoring of decoupling of economic growth and waste generation. It is an indicator to monitor a nation's economic situation. It can be used as a standalone indicator or as an auxiliary indicator to derive indicators per unit of GDP. Data are updated annually. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Expressing GDP in purchasing power standards eliminates differences in price levels between countries, and calculations on a per head basis allow the comparison of economies significantly different in absolute size (Eurostat, 2022j).	**Eurostat** online data code: NAMA_10_PC (main GDP aggregates per capita, chain-linked volumes), (B1GQ). Link to data source ([c]) Link to metadata ([d])	Total score: 2.8. To be used as an auxiliary indicator to calculate indicators' 'per unit of GDP', and to monitor trends in time series on decoupling of economic growth and waste generation.

Table 3.1 Selected indicators for cluster 1: system context (cont.)

Indicator	Description and rationale	Data source	RACER evaluation
	Driving forces		
	2. Volumes and values of production and consumption		
	Definition of GDP at market prices is given in Eurostat's metadata file for annual national account (nama10) (Eurostat, 2021a). GDP at market prices is defined as the result of the production activity of resident producer units.		
Household final consumption expenditure by composition	Indicator of consumption patterns and type of waste generated. Waste generation depends more on specific expenditure types and the share of expenditure types by income. Household consumption expenditure can be classified by consumption purpose according to COICOP (Eurostat, 2021a). This indicator consists of the following COICOP consumption categories as sub indicators: (1) total consumption, (2) food and non-alcoholic beverages, (3) alcoholic beverages, tobacco and narcotics, (4) clothing and footwear, (5) housing, water, electricity, gas and other fuels, (6) furnishings, household equipment and routine household maintenance, (7) health, (8) transport, (9) communications, (10) recreation and culture, (11) education, (12) restaurants and hotels and (13) miscellaneous goods and services.	**Eurostat** online data code: NAMA_10_CO3_P3 (final consumption expenditure of households by consumption purpose (COICOP 3 digit), chain-linked volumes). Link to data source ([e]) Link to metadata ([d])	Total score: 2.8. To be used as a standalone indicator to monitor purpose-specific consumption patterns and therefore waste generation trends.
RMC (Wilts et al., 2019)	Indicator for efficient use of resources. It is part of the EU SDGs indicator set and is used to monitor progress towards SDG 12 on ensuring sustainable consumption and production patterns. As a material footprint indicator, RMC represents the total amount of extracted raw materials needed to produce the goods and services consumed, irrespective of where in the world the material extraction took place. Foreign resource consumption is calculated referring to raw material equivalents. Data are updated annually. Data are presented for all EU Member States plus Switzerland (Eurostat, 2022o). Although RMC is able to better capture the actual total use of materials, RMC data sets contain only modelling estimates (Eurostat, 2022c). This indicator combines RMC data from multiple data sources (see column to the right), and presents a selection of the highest per capita RMC categories.	**Eurostat** online data code: ENV_AC_RME (material flow accounts in raw material equivalents — modelling estimates). Link to data source ([f]) Link to metadata ([g]) **Eurostat** online data code: SDG_12_21 (RMC). Link to data source ([h]) Link to metadata ([g]) **Eurostat** online data code: ENV_AC_RMEFD (material flow accounts in raw material equivalents by final uses of products — modelling estimates). Link to data source ([i]) Link to metadata ([i])	Total score: 1.9. To include in tonnes per capita per material type (biomass, metal ores, non-metallic minerals, fossil fuel energy materials/carriers). Another possibility, more relevant for waste prevention, is to use raw material equivalents by final use of products.

Table 3.1 Selected indicators for cluster 1: system context (cont.)

Indicator	Description and rationale	Data source	RACER evaluation
	3. Volumes and values of circular resource use		
Value added from reuse, repair and recycling	Gross value added related to circular economy sectors (cei_cie010) (specific to recycling, repair and reuse sectors). An indicator for resource use efficiency. Most available repair and reuse data refer to a limited set of specific products, limiting their use in a generic prevention indicator set. This indicator can be used to infer measures taken in the recycling, repair and reuse sectors (Eurostat, 2020b).	**Eurostat** online data code: cei_cie010 (gross value added related to circular economy sectors, value added at factor cost). Link to data source ([k]) Link to metadata ([l])	Total score: 1.3. To be used because no other reuse and repair indicators are currently available from robust EU-level data sources.
Turnover in repair sectors	Complementing the indicator on value added from circular economy sectors, which includes recycling, this would provide further insight on the value of repair alone in comparison with reuse and repair sectors. This indicator consists of a set of sub indicators consisting of repair sectors as follows: (1) repair of communication equipment, (2) repair of computers and peripheral equipment, (3) repair of consumer electronics, (4) repair of footwear and leather goods, (5) repair of furniture and home furnishings, (6) repair of household appliances and home and garden equipment, (7) repair of other personal and household goods, and (8) repair of watches, clocks and jewellery.	**Eurostat** online data code: SBS_NA_1A_SE_R2 (annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95)). Link to data source ([m]) Link to metadata ([n])	Total score: 1.4. To be used because no other reuse and repair indicators are currently available from robust EU-level data sources. Furthermore, not all sectors involving repair can be included due to data limitations.

Notes: Full details on the RACER evaluation can be found in Annex 1.

([a]) https://ec.europa.eu/eurostat/databrowser/view/demo_gind/default/table?lang=en

([b]) https://ec.europa.eu/eurostat/cache/metadata/en/demo_gind_esms.htm

([c] https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_PC__custom_2982865/default/table?lang=en

([d]) https://ec.europa.eu/eurostat/cache/metadata/en/nama10_esms.htm

([e]) https://ec.europa.eu/eurostat/databrowser/view/NAMA_10_CO3_P3__custom_2983237/default/table?lang=en

([f]) https://ec.europa.eu/eurostat/databrowser/view/env_ac_rme/default/table?lang=en

([g]) https://ec.europa.eu/eurostat/cache/metadata/en/sdg_12_21_esmsip2.htm

([i]) https://ec.europa.eu/eurostat/databrowser/view/env_ac_rmefd/default/table?lang=en

([j]) https://ec.europa.eu/eurostat/cache/metadata/en/env_ac_rme_esms.htm

([k]) https://ec.europa.eu/eurostat/databrowser/view/CEI_CIE010/default/table?lang=en

([l]) https://ec.europa.eu/eurostat/cache/metadata/en/cei_cie010_esmsip2.htm

([m]) https://ec.europa.eu/eurostat/databrowser/view/SBS_NA_1A_SE_R2/default/table?lang=en

([n]) https://ec.europa.eu/eurostat/cache/metadata/en/sbs_esms.htm

COICOP, Classification of Individual Consumption by Purpose

GDP, gross domestic product

NACE, Nomenclature of Economic Activities

SDG, Sustainable Development Goal.

Source: EEA compilation.

3.2 Cluster 2: Policy enablers

The focus of this cluster is to monitor waste prevention measures (namely in the form of policies) as enablers of change. The corresponding indicators seek to align closely with the waste prevention measures in the WFD.

The waste hierarchy in the WFD (Article 4) is applied to prioritise waste management efforts, with waste prevention as the most favoured option, followed by preparation for reuse, recycling or other recovery (e.g. energy recovery), and disposal as the least favoured waste management option (if the more preferrable option also delivers the best overall environmental outcome). Specifically, on the prevention of waste, Article 9 provides a framework of waste prevention measures (Box 3.2).

Box 3.2

Framework of waste prevention measures from Waste Framework Directive Article 9

a. Promote and support **sustainable consumption** models.
b. Encourage the design, manufacturing and use of products that are **resource-efficient, durable** (including in terms of life span and absence of planned obsolescence), **repairable, reusable and upgradable**.
c. Target products containing critical raw materials to prevent those materials from becoming waste.
d. Encourage the reuse of products and the setting up of systems promoting **repair** and **reuse activities**, including, in particular, electrical and electronic equipment, textiles and furniture, and packaging and construction materials and products.
e. Encourage, as appropriate, and without prejudice to intellectual property rights, the **availability of spare parts, instruction manuals, technical information** or other instruments, equipment or software enabling the repair and reuse of products without compromising their quality and safety.
f. **Reduce waste generation** in processes related to industrial production, extraction of minerals, manufacturing, construction and demolition, considering the **best available techniques**.
g. **Reduce the generation of food waste** in primary production, in processing and manufacturing, in retail and other areas of food distribution, in restaurants and food services, and in households as a contribution to the United Nations Sustainable Development Goal to reduce global food waste at the retail and consumer levels by 50% per capita and to reduce food losses along production and supply chains by 2030.
h. Encourage **food donation** and other redistribution for human consumption, prioritising human use over animal feed and the reprocessing of food into non-food products.
i. Promote a **reduction in the content of hazardous substances** in materials and products, without prejudice to harmonised legal requirements concerning those materials and products laid down at EU level, and ensure that any supplier of an article as defined in point 33 of Article 3 of Regulation (EC) No 1907/2006 of the European Parliament and of the Council provides the information pursuant to Article 33(1) of that regulation to the European Chemicals Agency as from 5 January 2021.
j. Reduce the generation of waste, in particular waste that is not suitable for reuse or recycling.
k. **Identify** products that are **the main sources of littering**, notably in natural and marine environments, and **take appropriate measures to prevent and reduce litter** from such products. Where Member States decide to implement this obligation through market restrictions, they are to ensure that such restrictions are proportionate and non-discriminatory.
l. **Aim to halt the generation of marine litter** as a contribution towards the United Nations Sustainable Development Goal to prevent and significantly reduce marine pollution of all kinds.
m. Develop and support **information campaigns to raise awareness** about waste prevention and littering.

Source: WFD (EU, 2018a).

Based on the waste prevention measures described above, indicators for this cluster on policy enablers were identified. For each indicator, a short description and justification/rationale are given. The data sources for all indicators were the waste prevention programmes.

For the indicator category **WFD Article 9 completeness**, multiple rounds of tracking these indicators will allow the analysis of policy focus and trends and how they evolve over time.

3.2.1 Selected indicators

A RACER evaluation was conducted on the indicators in this cluster. Despite the low score for some indicators, all were included because no other indicators were available to track the progress of waste prevention policy measures in EU Member States (for reporting at the EU level) with a reasonable amount of time and resources. Therefore, the evaluation of this cluster was based more on obtaining an operational set of indicators (Table 3.2).

Table 3.2 Selected indicators for cluster 2: policy enablers

Indicator	Description and rationale	Data source	RACER evaluation
WFD Article 9 completeness			
Presence of each type of **measure** in Article 9, categorised by a policy instrument's (1) regulatory, (2) market based, (3) voluntary agreement and (4) information. Expressed as the proportion of EU Member States that have the measure.	A requirement in the WFD is for Member States to have these measures as a minimum. Categorisation of policy instruments builds on the report: Progress towards preventing waste in Europe – the case of textile waste prevention (EEA, 2021). Putting all indicators together, it will be possible to assess the balance of measures within and between Member States, and distinguish any geographical differences or trends.	WPPs.	Total score: 1.8. While this indicator has a lower overall score, it should nonetheless be included because it is the most direct indicator available to reflect waste prevention measures in Member States.
Presence of **targets,** expressed as the proportion of EU Member States that have the target.			Total score: 2.2. No further comment.
Presence of **indicators,** expressed as the proportion of EU Member States that have the indicator.			Total score: 2.2. No further comment.
Evolution of WPPs over time			
Development and evaluation of WPPs over time ([a]).	To track the development of WPPs in EU Member States. Furthermore, Article 30 of the WFD states that WPPs should be evaluated every 6 years and revised as appropriate.	WPP evaluation reports published on Member State public authority websites.	Total score: 2.4. No further comment.
Waste stream focus			
Presence of each type of **measure** in Article 9 as relevant to the selected waste stream, categorised by policy instrument: (1) regulatory, (2) market based, (3) voluntary agreement and (4) informative. Expressed as the proportion of EU Member States that have the measure.	To monitor any trends or changes on the focus of waste streams over time.	WPPs.	Total score: 1.8. While this indicator has a lower overall score, it should nonetheless be included because it is the most direct indicator available to reflect waste prevention measures in Member States.

Table 3.2 Selected indicators for cluster 2: policy enablers (cont.)

Indicator	Description and rationale	Data source	RACER evaluation
	Waste stream focus		
The waste stream will be selected for each waste prevention report in consultation with the EEA and considering hotspot issues and policy trends at the time of preparing the reports. Total waste should always be included as a default. For the 2023 report, food waste is selected.	To monitor any trends or changes on the focus of waste streams over time.	WPPs.	Total score: 1.8. While this indicator has a lower overall score, it should nonetheless be included because it is the most direct indicator available to reflect waste prevention measures in Member States.
Presence of **targets** categorised by policy instrument (see above) as relevant to the selected waste stream. Expressed as the proportion of EU Member States that have the target.			Total score: 2.2. No further comment.
The presence of **indicators** categorised by policy instrument (see above) as relevant to the selected waste stream. Expressed as the proportion of EU Member States that have the indicator.			Total score: 2.2. No further comment.

Notes: Full details on the RACER evaluation can be found in Annex 1.

([a]) It is advised that data collection on this indicator should be as standardised and structured as possible. This can be done, for example, by distributing a short questionnaire to waste prevention contacts in the EU-27 to collect information on the names, dates of introduction and duration of each WPP version that is available, as well as whether or not the WPPs have been evaluated, and when.

WPP, waste prevention programme.

Source: EEA compilation.

For indicators related to Article 9 completeness, a matrix is used to collect and present data on the presence or absence of measures by type of policy instrument, for each type of measure. Table 3.3 summarises the definitions of the types of policy instruments used to categorise the measures.

Table 3.3 Definitions of policy instruments used to categorise waste prevention measures

Type of policy instrument	Description
Regulatory	Covers waste prevention measures that actors are obliged to implement by law. This includes bans, restrictions and other requirements or obligations. For example, Romania launched a ban on landfilling food waste from wholesale, retail and distribution sectors from January 2023 onwards. Austria banned single-use plastic bags in January 2020, following the implementation of the EU Single-use Plastics Directive.
Market based	Market-based or economic instruments aim to set economic incentives for changes in consumption or production patterns by making less waste-intensive alternatives more attractive. This type of instrument involves tax regulations, subsidies, the introduction of fees and other waste management operations so that 'waste-light' products or services become more competitive. Green public procurement is also included, as it can increase the power of public procurers as buyers on the market.
Voluntary initiatives or agreements	Refer to actions taken by both governmental and non-governmental stakeholders that are not legally binding/obligatory, as well as voluntary agreements among stakeholders that do not necessarily require a political decision-making process but rather require negotiations. This broad category also includes research and pilot initiatives, establishment of reuse centres and networks, and other projects.
Informative	Relate to communication campaigns, educational and training activities, and awareness-raising materials for consumers, businesses or other target audiences. The underlying assumption is that better access to information will change consumer habits or nudge companies towards taking up cost-saving opportunities.
EPR	Includes the establishment of EPR schemes, whether legally binding at EU level (i.e. WEEE, ELVs and batteries) or voluntary, as well as activities that affect the core strategy and operation of the EPR schemes. This reflects EPR activities that are additional to existing legally binding EPR schemes as required by EU directives and regulations. Initiatives that are related to the EPR schemes but do not directly affect the core operation are excluded (e.g. a communication activity targeted at EPR actors, which would instead be classified as an informative instrument).

Notes: ELV, end-of-life vehicle; EPR, extended producer responsibility; WEEE, waste electrical and electronic equipment.

Source: EEA compilation based on EEA (2021).

3.3 Cluster 3: Waste output

3.3.1 Description of the cluster and the methodology used

This cluster concerns both output- and impact-related indicators, which measure either waste or material streams or their corresponding impacts on the environment and human health, stemming from waste prevention.

Specifically, the selection of indicators within the cluster 'output/impact indicators' was carried out in three steps. First, a long list of indicators was compiled from previous larger review studies (German Environment Agency, 2019; Wilts et al., 2019). 'In addition, we carried out a search of the most recent literature, and indicators were identified through EU Member State profiles on waste prevention, from interviews with country experts and from the EU circular economy monitoring framework (Eurostat, 2022q). Next, the initial list of indicators was too long to apply a RACER evaluation. Therefore, the list was shortened based on the following considerations: (1) relevance to the cluster group (output/impact indicators); (2) focus on total waste; (3) relevance to the waste prevention conceptual definition (i.e. how well the list covers all subcategories by prevention definition (see below)); and (4) relevance for use at the EU level. The list of screened indicators, their description, the rationale for inclusion and the preliminary assessment of data availability are presented in Table 3.4. Annex 1 contains the list of indicators before RACER scoring. Finally, the indicators were subjected to RACER evaluation to select the final set of operational indicators.

The waste prevention definition was used to categorise indicators into those addressing:

1. waste quantities;
2. reuse of products;
3. impacts of waste;
4. the content of hazardous substances in materials and products as defined by the WFD (see Box 1.1); and
5. the waste stream.

3.3.2 Selected indicators

The selected indicators are presented in Table 3.4.

Table 3.4 Selected indicators for cluster 3: waste output

Indicator	Description and rationale	Data sources
	1. Waste quantity related, including decoupling	
Total waste (excluding major mineral waste) generation, tonnes per year (in total and per capita).	Data on generation of waste (excluding major mineral waste) covers hazardous and non-hazardous waste from all economic sectors and households, including secondary waste from waste treatment([a]). Mineral waste is excluded in many studies, as it varies widely across the EU Member States. It was deemed that excluding the flow improves the comparability across the EU Member States. Monitoring the total waste generation is essential for understanding the progress towards waste prevention. The indicator was also previously used by EEA and in many other studies.	**Eurostat** online data code: ENV_WASGEN TOT_X_MIN, waste category — total waste excluding major mineral wastes (or kg/capita). Link to data source ([b]) Link to metadata ([c]) Frequency every 2 years (reported by Member States every 2 years, covers all EU Member States).
Waste intensity of net waste volume (without major mineral waste) per GDP unit, kg per thousand euro per year.	Same as above but expressed per unit of GDP. This is a decoupling indicator that has been used before by EEA (e.g. EEA, 2021). The indicator has good data availability and is part of Eurostat's circular economy monitoring framework.	**Eurostat** online data code: CEI_PC032. Generation of waste (excluding major mineral wastes) per GDP unit. According to Eurostat 'The indicator is defined as all waste generated in a country (in mass unit), excluding major mineral wastes, per GDP unit (in euro, chain linked volumes (2010)). The ratio is expressed in kg per thousand euro. Link to data source ([d]) Link to metadata ([e]) Eurostat: part of Eurostat's circular economy monitoring framework, frequency every 2 years. (The data are based on total waste (above) available every 2 years and GDP available every year.)

Table 3.4 Selected indicators for cluster 3: waste output (cont.)

Indicator	Description and rationale	Data sources
	1. Waste quantity related, including decoupling	
Municipal waste generation (kg per capita per year).	The indicator measures waste collected by or on behalf of municipal authorities. The waste is to a large extent generated by households but includes similar waste from other sources, such as offices, small-scale commerce or public institutions. Since the reference year 2020 (reported in 2021), there were changes in the definition of 'municipal waste' as per Directive (EU) 2018/851 (EU, 2018b): almost all waste collected from households (both mixed and sorted), including similar waste from other sources, are considered municipal waste but excluding C&D, production, agriculture, forestry, fishing, septic tanks, sewage sludge and end-of-life vehicles. The indicator is used in countries' profiles, is widely used in countries' prevention programmes, is part of Eurostat's circular economy monitoring framework and has also been used in many other studies. The indicator has very good data availability and data are comprehensible. Consideration of municipal waste instead of other waste (e.g. industrial waste) is advantageous because municipal waste reflects changes in consumption patterns, as well as the performance of waste prevention where actions and the involvement of citizens is most relevant.	**Eurostat** online data code: CEI_PC031. Link to data source ([f]) Link to metadata ([g]) Eurostat: part of Eurostat's circular economy monitoring framework, with annual updates (typically updated in March) (Eurostat, 2021d).
Municipal residual waste, kg per capita and percentage of waste generated.	Municipal residual waste — unsorted waste, including residues of sorting processes. There is no legal definition at the EU level, but a definition has been developed by the EEA (EEA, 2022c). It is important to distinguish waste prevention from waste disposal prevention. Waste disposal prevention is beneficial in that it contributes significantly to the circular economy. It is therefore valuable that the waste hierarchy prefers waste management options that maximally prevent disposal, such as recycling and preparing for reuse. Recycling prevents the disposal of waste that the system has failed to prevent, and therefore this indicator on residual municipal waste is relevant. The EU's WFD also sets the target to recycle and/or prepare for reuse at least 60% of municipal waste by 2030. There is also a non-binding commitment at the EU level to reduce the amounts of residual municipal waste by half. The latter is based on the EU's circular economy action plan and the zero pollution action plan. The reference year is not defined, but the EEA selected 2020, since it refers to the years when the plan was adopted (EEA, 2022c). Both targets could be addressed by combining increasing recycling rates and reducing waste generation (EEA, 2022b).	**Eurostat** online data code: env_wasmun. Link to data source([h]) Link to metadata([i]) Disposal — landfill and other (D1-D7, D12)+(disposal — incineration (D10) and recovery — energy recovery (R1)).
	2. Indicators addressing reuse	
Weight of reuse, kg per capita in total or per waste stream (e.g. waste C&D, textiles, EEE, furniture). Data will be available from 2023.	The actual reuse in kg per capita, and per kg per material category. '…'reuse' means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.' (WFD, Article 2(13)) (EU, 2008). As reuse is considered one of the prevention strategies in the WFD, it is very relevant to have it among waste prevention indicators.	Weight of reuse, kg per capita in total or per waste stream (e.g. waste C&D, textiles, EEE, furniture). Starting from 2023, data will be reported by the EU Member States to Eurostat, including total reuse and reuse by product streams, such as C&D, textiles, EEE, furniture and other items. Frequency every 3 years. Note: Data are not available for the 2023 report, but the indicator should be usable after 2023.

Table 3.4 Selected indicators for cluster 3: waste output (cont.)

Indicator	Description and rationale	Data sources
	There is some criticism about using the quantity of reuse as an indicator, as it does not clearly reflect whether change is a result of a decrease in consumption or an increase in prevention. However, a series of different reuse models have been proposed (Żaneta et al., 2021), each of which might require a different approach to allow the reuse to be quantified. Other indicators or a set of indicators such as service lifespans and number of effective uses (e.g. wears for clothing), as proposed by Klepp et al. (2020) and Okumura (2022), could be considered for future updates of the waste prevention framework.	
	3. Impact indicators	
GHGs from waste management (EEA, 2019a)	This data set includes data on GHG emissions inventory, as reported to the EEA. The data are published once a year for the year *t*-2. The purpose of waste prevention is to reduce the adverse impacts of the generated waste on the environment and human health. This indicator shows GHGs from waste management and points to how GHGs can be avoided with waste prevention measures.	**Eurostat** online data code: ENV_AIR_GGE. Link to data source (i) Link to metadata (k) (GHG emissions by source sector for the following waste management categories: (CRF5A) solid waste disposal, (CRF5B) biological treatment of solid waste, and (CRF 5C) incineration and open burning of waste.)
	4. Hazardous content indicators	
SVHCs in products placed on the market (based on the SCIP database) (not yet a clear nominator)	Statistics on the consumption of chemicals are available from Eurostat annually (as the total weight of hazardous substances used in production process and products). These data are hard to interpret, as the weights of all substances are added into one figure. However, the level of hazard depends also on concentrations, exposure, level of hazards, the type of chemicals and other factors. As per WFD requirements, the European Chemicals Agency develops a database of articles containing SVHCs from the Candidate List under REACH (called SCIP database). As of January 2021, companies producing, importing or supplying articles containing substances from the candidate list have to submit information about these articles to the SCIP database. The SCIP database could potentially be used in the coming years as the source for the waste prevention indicator related to the content of hazardous substances in materials. At the time of writing this report, it is not yet clear whether this indicator is suitable. However, this can be determined when good-quality data become available in the future. It is therefore included in this list as a potentially suitable indicator, but further investigation is needed. When developing the final indicator, focus should also be put on soil use and related chemical use, including feed and food production, as well as the implementation of national action plans for POPs.	

Table 3.4 Selected indicators for cluster 3: waste output (cont.)

Indicator	Description and rationale	Data sources
5. Waste stream indicators (as addition to total and municipal waste quantity indicators): the framework includes multiple waste streams that support occasional thematic assessments (i.e. specific waste stream(s) can be selected for inclusion as deemed necessary)		
Food waste generation per capita (best available indicator) (German Environment Agency, 2019).	Food waste is a highly relevant waste stream to consider, as the WFD indicates that measures taken by EU countries should contribute to UN SDG 12.3 to reduce food waste by 50% by 2030 (EU, 2018a). As called for by the farm to fork strategy, the Commission will propose legally binding targets to reduce food waste across the EU, by Q2 2023, defined against a baseline (2020) for EU food waste levels set following the first EU-wide monitoring of food waste levels. An EU standard definition of avoidable food waste is not yet available. However, if and when such a definition is developed, and data are collected at the EU level, this could potentially be a suitable indicator related to food waste. According to the EU's guidance on food waste reporting, Member States can submit certain data on a voluntary basis, such as the levels of edible food waste, donated food and surplus food. If such data become available at the EU level in the future, then it may be suitable to develop an indicator covering these aspects.	**Eurostat** online code: ENV_WASFW. Link to data source ([l]) Link to metadata ([m]) (Food waste and food waste prevention by NACE Rev. 2 activity — tonnes of fresh mass, kg per capita.) Note: This indicator was selected for the 2023 report.

Notes:
([a]) Definition of 'generation of waste excluding major mineral wastes': the indicator covers hazardous (haz) and non-hazardous (nhaz) waste from all economic sectors and from households, including waste from waste treatment (secondary waste) but excluding major mineral waste, i.e. the total waste generated except the following waste categories: (a) mineral waste from construction and demolition (EWC-Stat 12.1); (b) other mineral wastes (EWC-Stat 12.2, 12.3, 12.5); (c) soils (EWC-Stat 12.6); (d) dredging spoils (EWC-Stat 12.7). Although completely or partly mineral, the indicator explicitly includes combustion wastes (EWC-Stat 12.4) and mineral wastes from waste treatment and stabilised wastes (EWC-Stat 12.8 to 13)' (Schrör, undated).

([b]) https://ec.europa.eu/eurostat/databrowser/view/ENV_WASGEN/default/table?lang=en&category=env.env_was.env_wasgt

([c]) https://ec.europa.eu/eurostat/cache/metadata/en/env_wasgt_esms.htm

([d]) https://ec.europa.eu/eurostat/databrowser/view/cei_pc032/default/table?lang=en

([e]) https://ec.europa.eu/eurostat/cache/metadata/en/cei_pc032_esmsip2.htm

([f]) https://ec.europa.eu/eurostat/databrowser/view/cei_pc031/default/table?lang=en

([g]) https://ec.europa.eu/eurostat/cache/metadata/en/cei_pc031_esmsip2.htm

([h]) https://ec.europa.eu/eurostat/databrowser/view/ENV_WASMUN/default/table?lang=en

([i]) https://ec.europa.eu/eurostat/cache/metadata/en/env_wasmun_esms.htm

([l]) https://ec.europa.eu/eurostat/databrowser/view/env_air_gge/default/table?lang=en

([k]) https://ec.europa.eu/eurostat/cache/metadata/en/env_air_gge_esms.htm

([l]) https://ec.europa.eu/eurostat/databrowser/view/ENV_WASFW/default/table?lang=en

([m]) https://ec.europa.eu/eurostat/cache/metadata/en/env_wasfw_esms.htm

C&D, construction and demolition

EEE, electrical and electronic equipment

GHG, greenhouse gas

NACE, Nomenclature of Economic Activities

POP, persistent organic pollutant

SVHC, substance of very high concern

REACH, Regulation on registration, evaluation, authorisation and restriction of chemicals

SCIP database, database of information on substances of concern

SDG, Sustainable Development Goal.

Source: EEA compilation.

4 Results of indicator data

It should be noted that all data presented in this report, including those from Eurostat, are based on data extracted in September 2022.

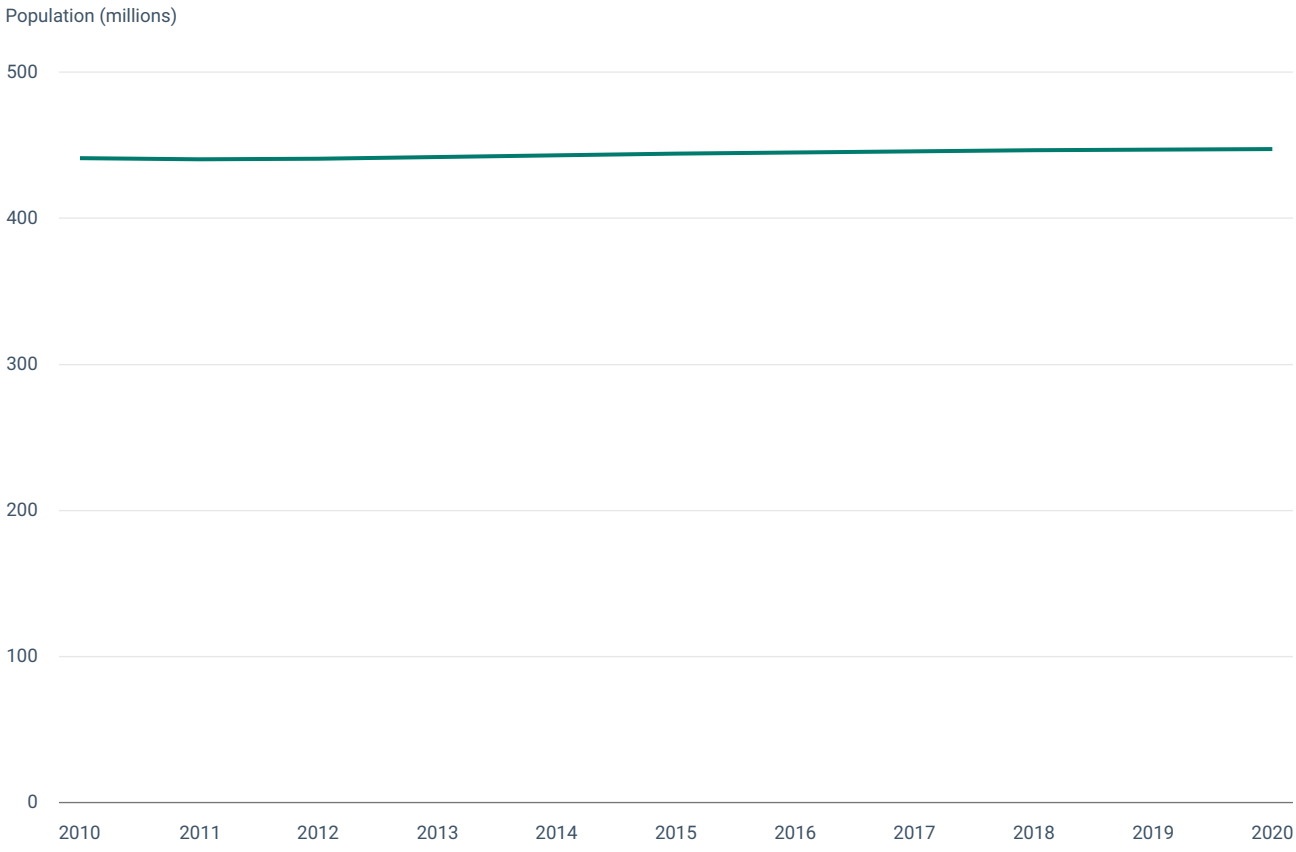
4.1 System context

This section presents data on cluster 1 indicators. Conceptually, indicators such as population, gross domestic product (GDP), household consumption expenditure and raw material consumption (RMC) are likely to be associated with waste generation, while an increase in the value added by the repair, reuse and recycling sector and turnover of repair sectors should be associated with a decrease in waste generation. However, as will be shown in Chapter 5, the relationships between waste prevention and socio-economic trends/demographics can be much more nuanced.

4.1.1 Population

The population of the EU-27 remained rather constant between 2010 and 2020, with only a small increase of 1.4%: a change from around 441 million in 2010 to around 447 million in 2020 (Figure 4.1).

Figure 4.1 Population of EU-27, 2010-2020

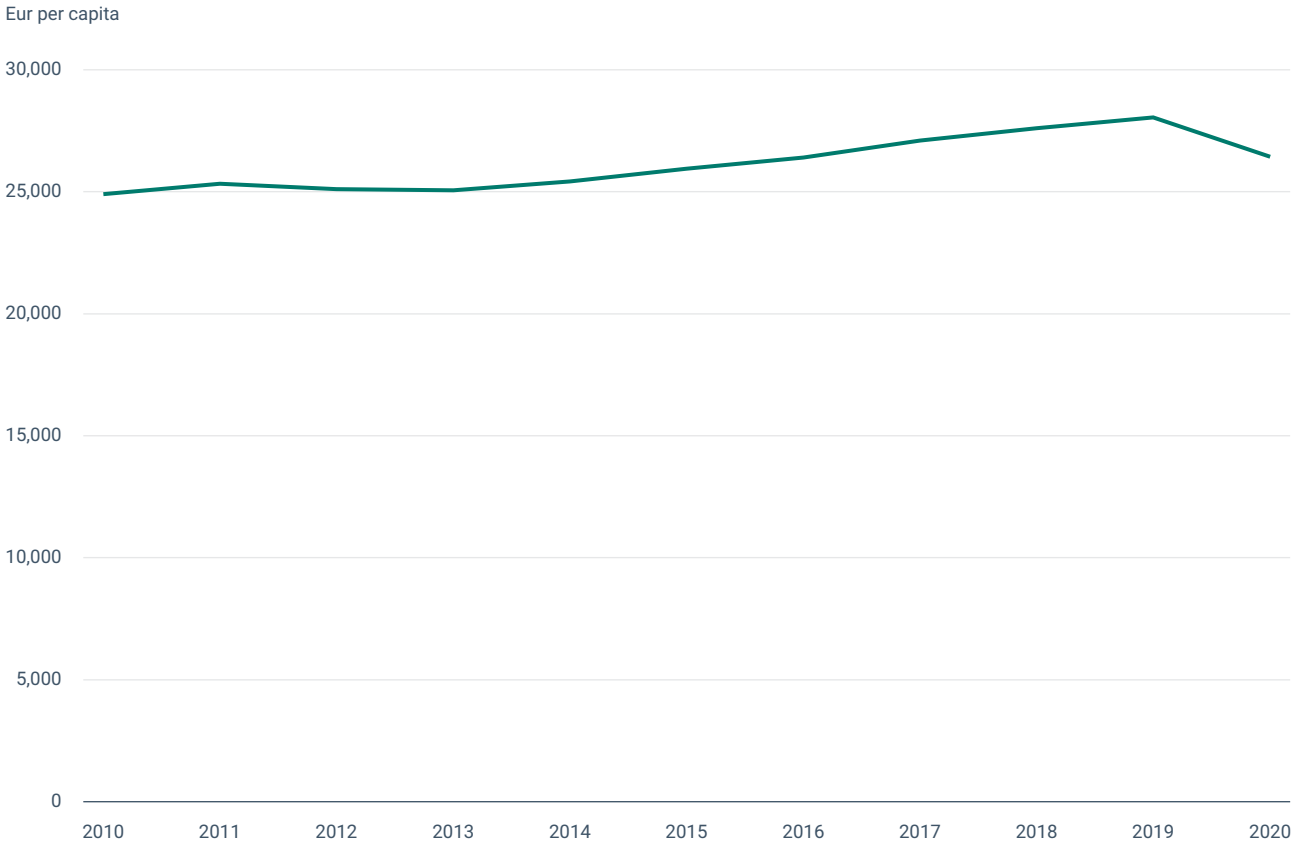


Source: Eurostat (2019).

4.1.2 Gross domestic product

The GDP of the EU-27 at market prices expressed as chain-linked volumes (2010) to exclude the effect of inflation increased between 2010 and 2019 by 12.6%; a change from EUR 24,900 per capita in 2010 to EUR 28,040 per capita in 2019. However, because of the onset of the COVID-19 pandemic early 2020, and the subsequent lockdowns in most of the EU Member States, GDP dropped by 5.7% that year (Figure 4.2).

Figure 4.2 GDP at market prices, 2010-2020



Source: Eurostat (2019).

4.1.3 Household final consumption expenditure by composition

Household consumption expenditure can be classified by consumption purpose according to COICOP (Classification of Individual Consumption by Purpose). Household final consumption expenditure in the EU-27, shown in Figure 4.3, is expressed in chain-linked volumes (2010) to exclude the effect of inflation. The total final consumption expenditure of households increased between 2010 and 2020 by 2.1%; however, between 2010 and 2019 it increased by 10.9%. The drop of 7.9% between 2019 and 2020 can be attributed to the COVID-19 pandemic.

The main categories contributing to the final consumption expenditure of households in 2010 and in 2020 (>10% of total final expenditure of households) were 'Housing, water, electricity, gas and other fuels', 'Food and non-alcoholic beverages', 'Transport', and 'Miscellaneous goods and services'.

Between 2010 and 2020 the final expenditure of households mainly dropped for 'Restaurants and hotels' (-26%) and 'Clothing and footwear' (-7%). Restrictions related to the COVID-19 pandemic are most probably the main reason for these declines because between 2010 and 2019 the expenditure in both of these categories increased by 18.3% and 11.9%, respectively. In both time periods (i.e. 2010-2019 and 2010-2020), the highest increase in household expenditure was for 'Communications' and in both cases it was at the level of approximately 30%; however, this category makes only a minor contribution to the total final expenditure of households.

Due to restrictions related to COVID-19, the final expenditure of households mainly increased for 'Food and non-alcoholic beverages', with an increase of 3.1% between 2019 and 2020, while at the same time a drop of 37.5% was observed in the 'Restaurants and hotels' category.

4.1.4 Raw material consumption

RMC represents the total amount of extracted raw materials needed to produce the goods and services consumed, irrespective of where in the world the material extraction took place. In Figure 4.4 the overall RMC per capita in the EU-27 is shown together with the main product groups with the highest RMC. Since 2010, RMC dropped by 7.5%; however, since 2012, RMC has remained rather stable at the level of approximately 14 tonnes per capita. In 2020, it dropped by approximately 6% compared with 2019, from 14.5 tonnes per capita in 2019 to 13.7 tonnes per capita in 2020.

The main driver for material extraction is the construction sector, with approximately 30% of RMC belonging to the 'Construction and construction works' group. The second group with the highest RMC, at the level of approximately 11-12% RMC between 2010 and 2020, is 'Food, beverages, and tobacco products'.

Figure 4.3 **Final consumption expenditure of households by purpose (COICOP 3 digit), 2010-2020**

Source: Eurostat (2012e).

Figure 4.4 Raw material equivalents by final uses of products, 2010-2020

Source: Eurostat, 2022m.

4.1.5 Gross value added related to circular economy sectors

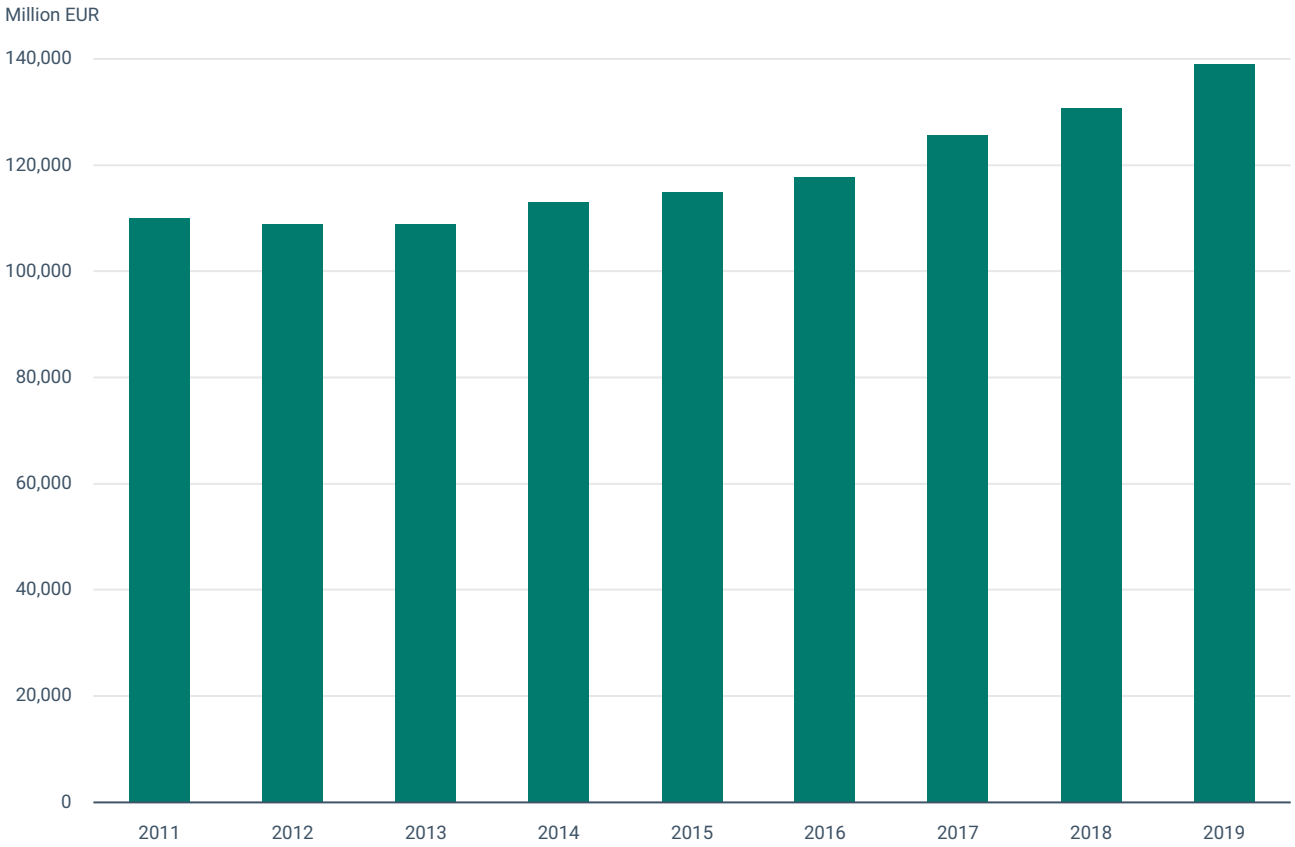
The gross value added of circular economy sectors at the EU level (covering repair, reuse and recycling) increased by approximately 26% from 2011 to 2019. The sectors covered by this indicator can be found on Eurostat ([7]) (Figure 4.5).

([7]) https://ec.europa.eu/eurostat/documents/8105938/8465062/cei_cie010_esmsip_NACE-codes.pdf

4.1.6 Repair sectors only

The value of turnover in the repair sector was relatively steady at around EUR17,000 million from 2011 to 2015 and then increased rapidly to around EUR23,000 million in 2017, before dropping back down to 2016 levels in 2019.

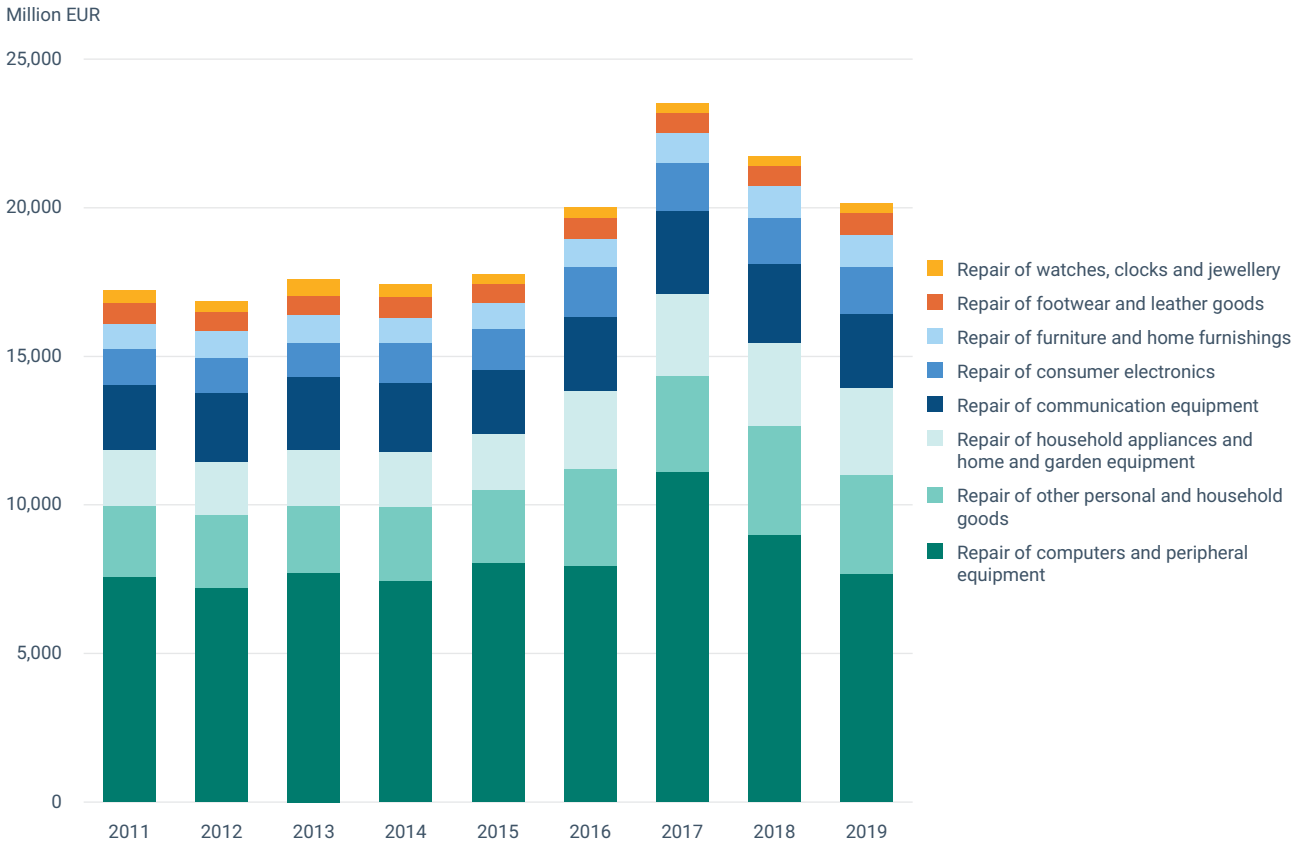
Figure 4.5 Gross value added by circular economy sectors, 2011-2019



Source: Eurostat (2020b).

Nonetheless, it should be noted that not all product sectors where repair is possible are included in the data set (because of data limitations) (Figure 4.6).

Figure 4.6 Turnover of the repair sector (EUR million), 2011-2019



Source: Eurostat (2020a).

4.2 Policy enablers

4.2.1 Prevention measures for non-specific waste streams, targets and indicators

Table 4.1 shows the percentage of EU-27 countries that include in their waste prevention programmes Waste Framework Directive (WFD) Article 9 measures, further categorised by specific types of policy instrument: (1) regulatory, (2) market based, (3) voluntary agreement, (4) informative and (5) extended producer responsibility (EPR). For example, for the measure on **sustainable consumption models** (Article 9(a)), 93% of EU-27 countries have mentioned measures of this type (irrespective of policy instrument) in their waste prevention programmes. Meanwhile, 22% of EU-27 countries have regulatory instruments for the same measure. The blue shading represents the frequency that a policy instrument is used for a particular measure in EU-27 countries. The darker the colour, the larger the number of countries that have a particular policy instrument for the respective measure. Similarly, green shading indicates the frequency of a measure addressed in waste prevention programmes for any policy instrument.

Across all measures in Article 9, the most common type of policy instrument is voluntary initiatives or agreements, which is perhaps not surprising considering that the category covers a broad range of measures. This is followed by informative and regulatory instruments, and then market-based and EPR instruments.

The top three Article 9 measures that appear most frequently in the waste prevention programmes of EU-27 countries are Article 9(a) 'Sustainable consumption models' (93%), Article 9(d) 'Encourage reuse and repair activities' (93%), and Article 9(m) 'Develop and support information campaigns to raise awareness' (93%). Of these measures, voluntary

initiatives or agreements are again the most common type of instrument, followed by informative and regulatory instruments.

Table 4.1 **Proportion of EU-27 countries that include in their waste prevention programmes WFD Article 9 measures, further categorised by specific policy instrument types; proportion of EU-27 countries that include quantitative targets and indicators in their waste prevention programmes**

Measures, targets and indicators	Any policy instrument (%)	Type of policy instrument (%)[a]				
		Regulatory	Market based	Voluntary initiatives or agreements	Informative	EPR
Total waste						
Article 9 measures (paraphrased)						
[a] Sustainable consumption models	93	22	41	63	56	4
[b] Encourage resource efficiency, durability, repairability, reusability and upgradability	85	15	11	74	26	11
[c] Target products containing critical raw materials	52	19	0	44	22	4
[d] Encourage reuse and repair activities	93	22	48	85	56	7
[e] Encourage availability of spare parts, instruction manuals and technical information	56	22	0	26	26	0
[f] Reduce waste generation in processes related to industrial production, mineral extraction, manufacturing and construction	81	30	30	63	37	0
[g] Reduce the generation of food waste	89	44	4	85	44	0
[h] Encourage food donation and other redistribution	70	15	7	52	19	0
[i] Promote the reduction of the content of hazardous substances in materials and products	63	30	4	52	15	0
[j] Reduce the generation of waste, in particular waste that is not suitable for preparing for reuse or recycling	63	19	15	41	19	4
[k] Identify products that are the main sources of littering; take appropriate measures to prevent and reduce litter from such products	67	44	15	56	4	7
[l] Aim to halt the generation of marine litter	56	22	4	41	19	0
[m] Develop and support information campaigns to raise awareness	93	0	0	7	93	0
Quantitative targets in WPPs	25 countries of EU-27					
Indicators in WPPs	22 countries of EU-27					

Notes: Blue shading represents the frequency that a policy instrument is used for a particular measure in EU-27 countries. The darker the colour, the larger the number of countries that have a particular policy instrument for the respective measure. Green shading indicates the frequency of a measure addressed in WPPs for any policy instrument.

[a] See Table 3.3 for a description of each type of policy instrument.

WPP, waste prevention programme.

Source: WPPs of EU-27 countries (more information in the waste prevention country profiles of EU countries).

Lastly, most countries have quantitative targets in their waste prevention programmes (25 countries) and indicators (22 countries).

4.2.2 Evolution of waste prevention programmes over time

During data collection in this first round of implementing the indicator framework, it was found that there is no standardised format for the data provided in Member States' waste prevention programmes or on government ministry websites informing on the outcome of the evaluation of a programme or on the improvements or modifications suggested or to be considered in a subsequent programme. Therefore, the data collected were not sufficient to show the status of evaluation. Suggestions for improving the data collection approach were added to the indicator framework ([8]).

4.2.3 Food waste prevention measures, targets and indicators

As for the generic waste prevention measures, Table 4.2 indicates the percentage of Member States with measures in place specifically aiming to prevent food waste, categorised by the type of policy instrument. Also for measures targeting food waste prevention, voluntary initiatives or agreements are the most commonly proposed type of instrument (e.g. food donation initiatives, pilot projects and studies), followed by informative instruments (e.g. communication campaigns and educational initiatives), then regulatory instruments (e.g. regulations and bans to divert food waste from landfill) and then market-based instruments (e.g. tax reductions for food donations, public procurement measures). No food waste measures were found in relation to EPR, most likely due to irrelevance (i.e. take-back measure are much less feasible for food waste than for other wastes, such as waste electrical and electronic equipment (WEEE) or packaging). Lastly, the proportions of countries with quantitative targets and indicators on food waste are relatively low compared with the proportions of countries with quantitative targets and indicators on total waste, with 15 countries for both quantitative targets and indicators.

Table 4.2 Proportion of EU-27 countries with measures according to WFD Article 9, as well as targets and indicators, for food waste

Measures, targets and indicators	Any policy instrument (%)	Type of policy instrument (%)				
		Regulatory	Market based	Voluntary initiatives or agreements	Informative	EPR
Article 9 measures number (7) and (8), plus additional measures, averaged	61	39	15	65	56	0
Quantitative targets	15 EU countries					
Indicators	15 EU countries					

Source: Waste prevention programmes of EU-27 countries.

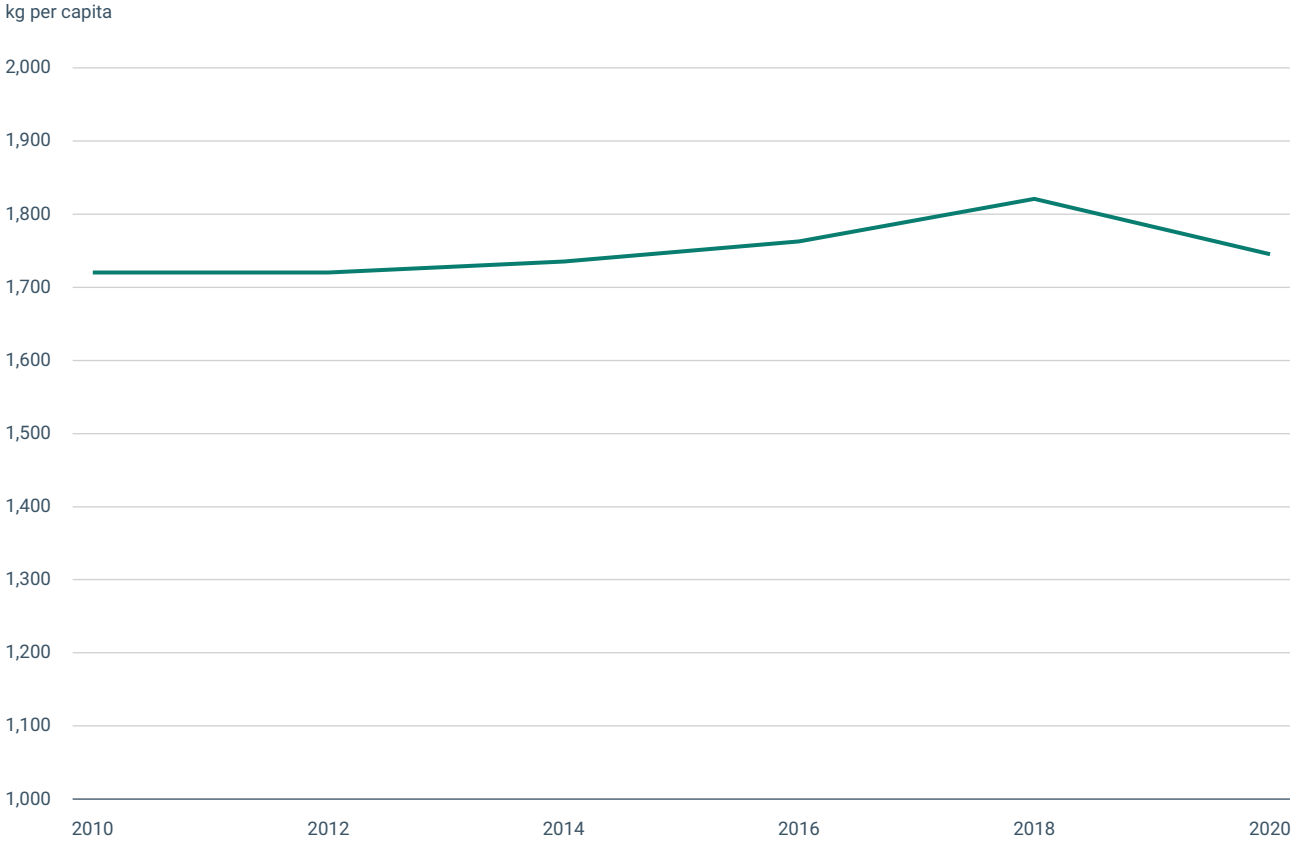
([8]) It is advised that data collection on this indicator should be as standardised and structured as possible. This can be done, for example, by distributing a short questionnaire to waste prevention contacts in the EU-27 to collect information on the names, dates of introduction and duration of each WPP version that is available, as well as whether or not the WPPs have been evaluated, and when.

4.3 Waste output

4.3.1 Total waste (excluding major mineral waste) generation

In 2020, 780.7 million tonnes or 1,745kg per capita of total waste, excluding major mineral waste, was generated in the EU-27. Waste generation in the EU (excluding major mineral waste) has been steadily increasing by 7.2% during 2012-2018, followed by a rather sharp decline in 2020 to a level below that of 2016. The same trend can be observed when adjusted to per capita (Figure 4.7).

Figure 4.7 Total waste, excluding major mineral waste, generation per capita in the EU-27, 2010-2020



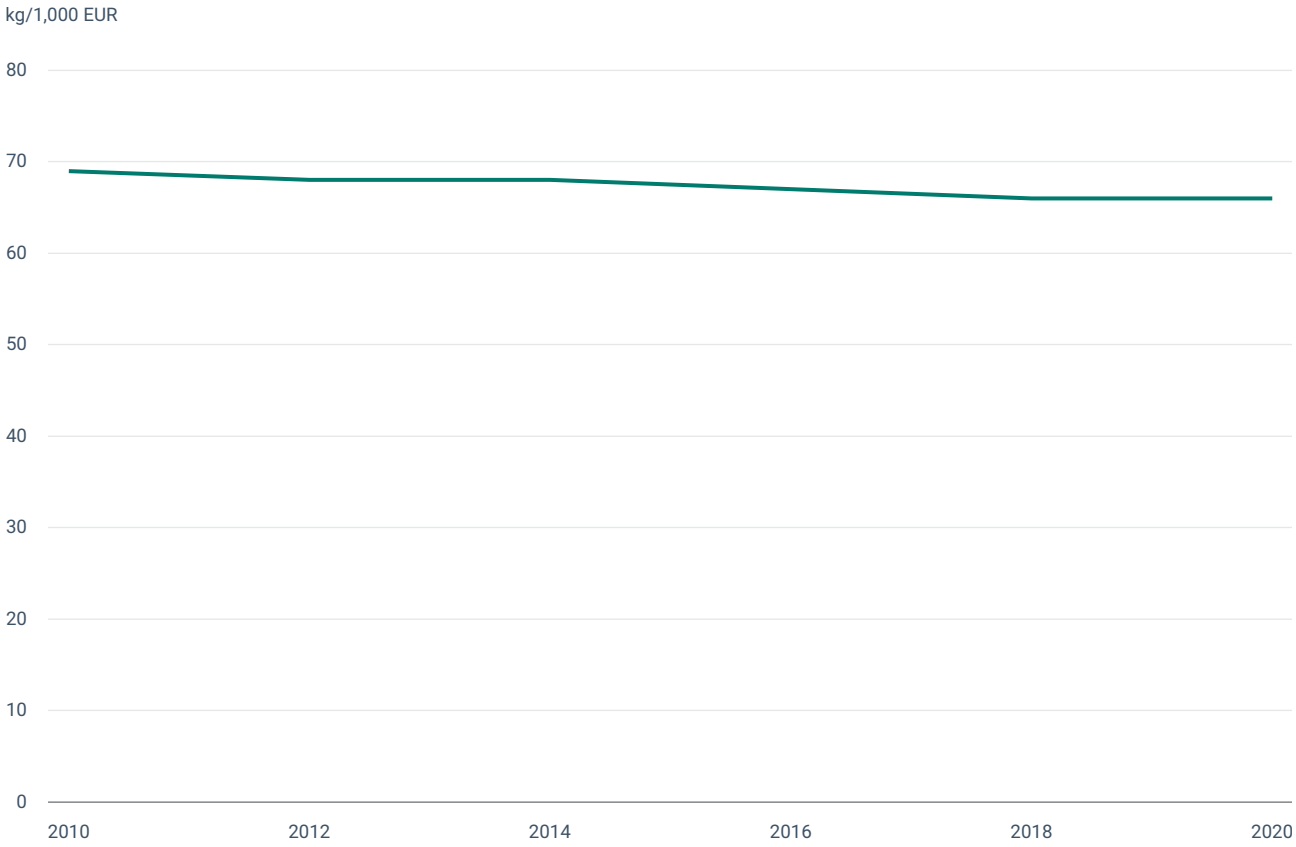
Note: Data for total waste (excluding major mineral waste) in the odd years are linearly extrapolated.

Source: Eurostat (2022f).

4.3.2 Waste intensity of net waste volume (excluding major mineral waste)

Waste intensity expresses waste generation per unit of GDP. It reflects the 'eco-efficiency' of an economy by measuring the link between waste generation and economic activity. The indicator can partly reflect the structure of the economy, when less waste-intensive sectors (e.g. services) replace more material-intensive activities (e.g. manufacturing). During 2010-2020, the waste intensity of the EU-27 decreased from 69kg to 66kg per EUR 1,000 GDP (Figure 4.8).

Figure 4.8 Waste intensity indicator: total waste generation excluding major mineral waste (kg) per GDP unit in the EU-27, 2010-2020



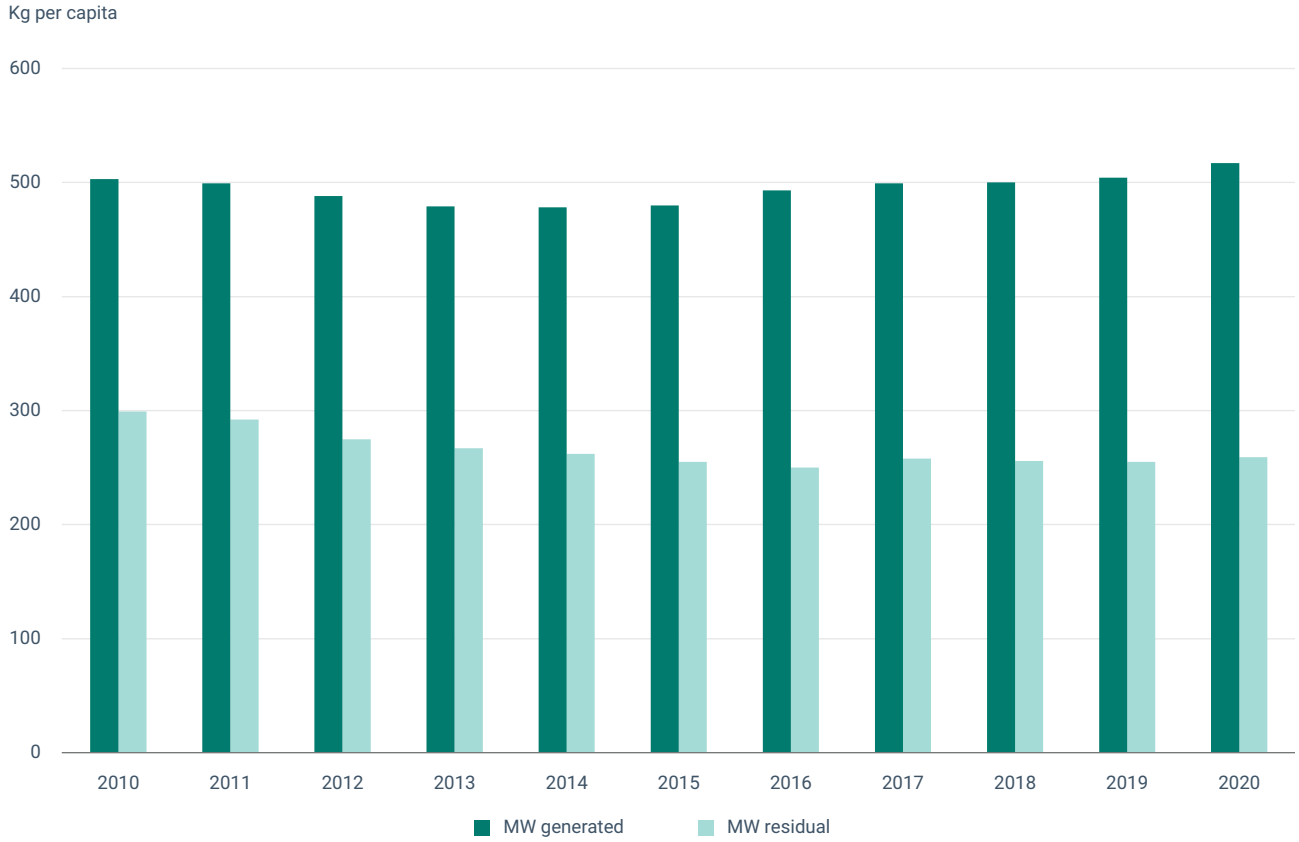
Note: Data for total waste (excluding major mineral waste) in the odd years are linearly extrapolated.

Source: Eurostat (2022g).

4.3.3 Municipal waste generation and residual municipal waste

In 2020, the per capita generation of municipal waste and residual municipal waste was 517kg and 259kg, respectively, but dynamic trends are somewhat different. The generation of municipal waste remains rather stable, despite a small decrease during 2010-2014 and an increase in 2015-2020 (Figure 4.9). The total increase between 2010 and 2020 was only 3%. A significant decrease is observed for residual municipal waste, which decreased by 13% between 2010 and 2020. The share (percentage) of municipal residual waste in the total amount of municipal waste generated has fallen by around 9% in the past 10 years. The greatest decrease was observed between 2010 and 2016 (-8 percentage points), but it remained rather stable after 2016. It should be noted that the 2020 data, which refer to the first year of the COVID-19 pandemic, may also be influenced by Member States applying the revised definition of municipal waste adopted in the WFD in 2018.

Figure 4.9 **Municipal waste and residual municipal waste per capita, and percentage of waste generated per total municipal waste in the EU-27, 2010-2020**



Source: Eurostat online data code: ENV_WASMUN. Residual municipal waste calculated based on Eurostat data on treatment (Disposal — incineration (D10) and recovery — energy recovery (R1))+(Disposal — landfill and other (D1-D7, D12)).

4.3.4 Weight of reuse

Data on product and component reuse are not yet available. Member States are expected to report the first statistics in 2023.

4.3.5 Substances of very high concern in products placed on the market (based on SCIP database)

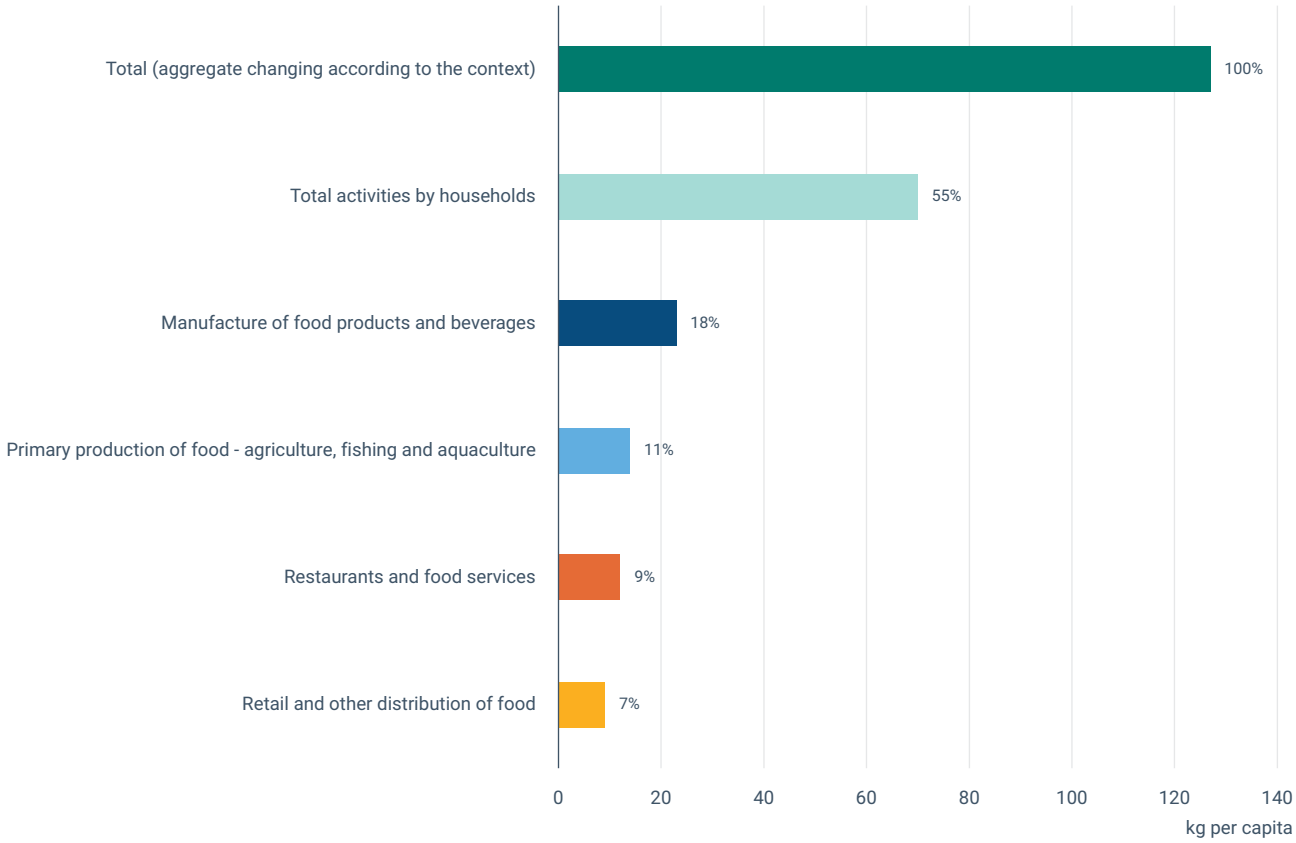
The database of information on substances of concern (SCIP database) could potentially be used in the coming years as the source for the waste prevention indicator related to the content of hazardous substances in materials. However, this was not feasible at the time of writing this report.

4.3.6 Food waste generation

2020 is the reference year of the first dedicated monitoring of the amount of food waste from different sectors, including households, at the EU level. The data are missing for some Member States, but, according to the Eurostat estimate, almost 57 million tonnes or 127kg per capita of food waste was generated in 2020 in the EU. Even if it is only 7% of the total waste (excluding major mineral waste), it

is estimated that food waste accounts for 6% of total EU greenhouse gas (GHG) emissions in addition to the unnecessary burden it places on limited natural land and water resources (European Commission, 2022b). Therefore, the environmental benefits of preventing food waste remain significant (Figure 4.10).

Figure 4.10 **Food waste generation (kg per capita) for each sector and as part of the total (%) in the EU-27, 2020**



Source: Eurostat online data code: ENV_WASFW.

4.3.7 Greenhouse gas emissions in waste management

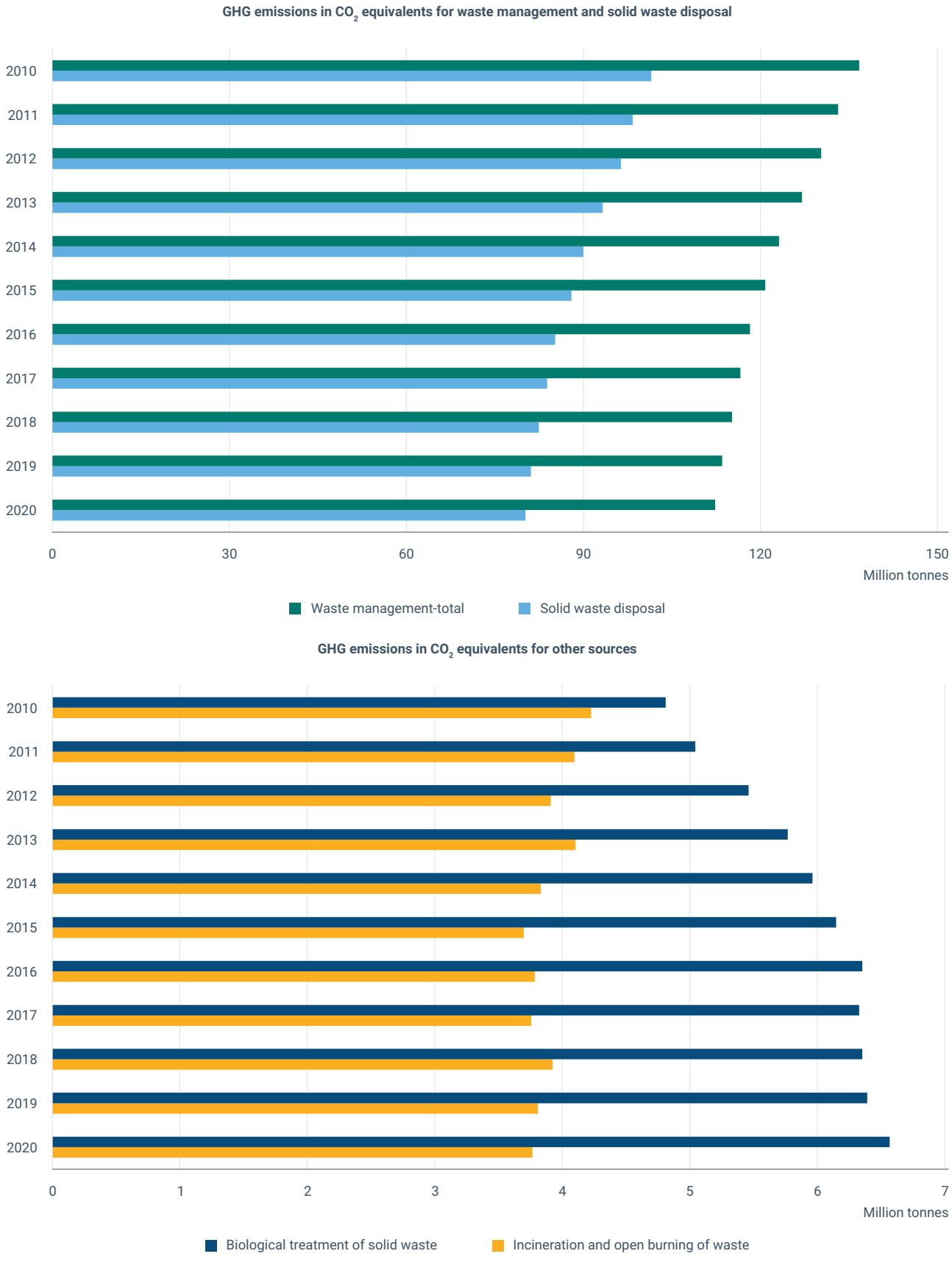
The reduction in the environmental impact of generated waste can be followed with GHG emissions from the waste management sector. The indicator is composed of four sub-indicators, namely (1) GHG emissions (million tonnes of CO_2 equivalent) from total waste management, (2) solid waste disposal, (3) biological treatment of solid waste and (4) incineration and open burning of waste. Other forms of recycling, backfilling and energy recovery are not included in this indicator. Waste incineration without energy recovery accounts for only about 7% of all incinerated waste (calculation based on Eurostat (2022r)).

GHG emissions from waste management in the EU-27 decreased from 137 million tonnes in 2010 to 112 million tonnes in 2020. This mainly corresponds to GHG emissions when waste is landfilled and does not indicate that less waste is being generated. Implementation of waste prevention measures can lead to significant savings in GHG emissions.

GHG emissions from biological treatment increased from 4.8 million tonnes in 2010 to 6.6 million tonnes in 2020, reflecting an increase in the recycling of biodegradable waste. Emissions from biological treatment include GHG emissions from waste composting and from anaerobic digestion at biogas facilities.

Emissions from waste incineration decreased by 11% between 2010 and 2020 and have remained stable at 3.8 million tonnes since 2014. Data on incineration include only facilities without energy recovery and do not include GHG emissions from waste-to-energy facilities. Treatment of total waste with energy recovery is increasing in the EU-27 (by 47% since 2010, (Eurostat, 2022r)), and the GHG emissions originating from that type of waste treatment are not reported in the waste management category but instead under 'Energy'. The waste generated has the highest environmental impact when landfilled due to methane emissions, but the adverse impact on the environment and human health related to CO_2 emissions cannot be neglected (Figure 4.11).

Figure 4.11 GHG emissions in the waste management sector



Note: The data on biological treatment and incineration are on a much lower scale than those for the other waste treatment methods. The data were plotted on separate scales to allow greater resolution of the trends of these two indicators.

Source: Eurostat (2022h).

5 Analysis and discussion of progress in waste prevention

As described in Section 2.1, the analysis of EU-level progress on waste prevention is based on a narrative framework that covers the socio-economic system underlying waste generation. Therefore, the analysis and discussion are carried out by connecting the data and information collected on the waste situation and environmental impact (indicators from cluster 3: waste output) in the contexts of Member States' current socio-economic situations and the observed past trends (cluster 1: system context), and the implementation of specific policy instruments intended to fulfil the purpose of the different measures suggested to prevent waste (cluster 2: policy enablers). Furthermore, the data from the system context and policy enablers are discussed in relation to each other, given that waste prevention measures can also affect the socio-economic system, such as by shifting consumption and expenditure behaviour. Therefore, the analysis approach aims to address the linkages between the drivers, pressures and responses of the DPSIR (Driving forces, Pressures, States, Impacts and Responses) framework to reveal the waste prevention narrative.

5.1 System context and waste output (clusters 1 and 3)

5.1.1 Waste, population and gross domestic product

Figure 5.1 presents indexed changes in the indicators on waste generation in comparison with population and gross domestic product (GDP).

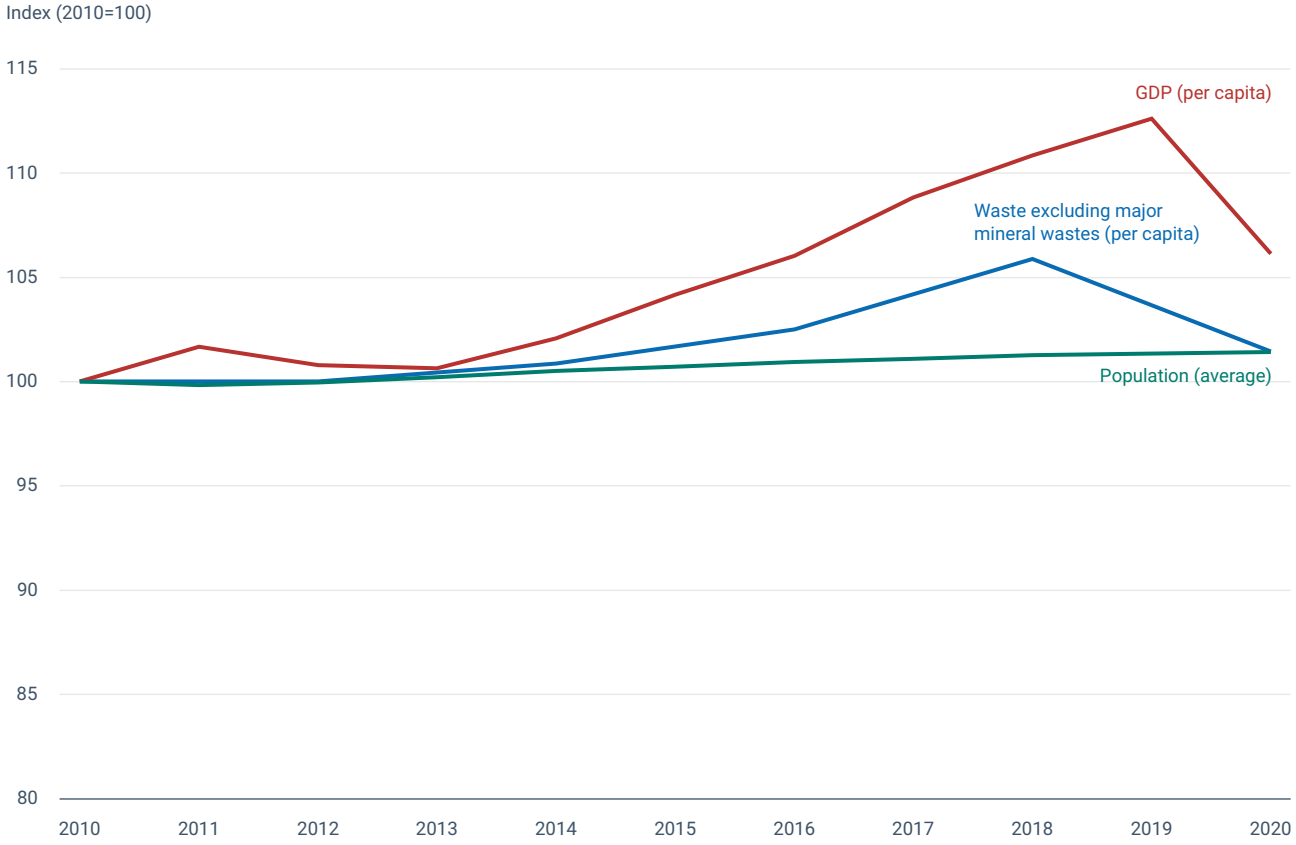
As mentioned in Section 4.3.2, waste intensity (based on total waste excluding major mineral waste) decreased by about 4% from 2010 to 2020. This indicates that waste generation lags behind the rate of economic growth, a sign of either relative decoupling (Box 5.1) or structural changes in the economy (e.g. due to the outsourcing of industry-based activities outside the EU).

Both per capita total waste (excluding major mineral waste) and GDP decreased by about 4% each from 2018 to 2020. It is unclear whether the decrease in waste is specifically due to the economic downturn caused by the measures introduced to manage the COVID-19 pandemic, given that a closer look at the types of waste comprising total waste (excluding major mineral waste) shows that a major proportion of the decrease is attributed to combustion waste from the energy sector, and this is most likely to be related to the decreased use of solid fossil fuels rather than to waste prevention measures.

Explaining the above in detail, between 2018 and 2020, the per capita total waste (excluding major mineral waste) decreased by 76kg (from 1,821kg to 1,745kg). Looking at the waste streams that make up the indicator, it was found that the biggest contributing waste stream was per capita combustion waste, which decreased by 79kg (from 253kg to 174kg), comprising around 30% of the decrease in total waste (excluding major mineral waste). The percentage change was lower for other waste streams.

Looking at per capita waste generation by sectors, again the largest decrease was in the electricity sector, with a decrease of 40% or 68kg per capita (from 170kg to 102kg per capita). In other sectors the variations were much smaller at a range of 1-8%. For instance, waste from the manufacturing sector decreased by 21kg per capita or by 5% compared with 2018 (which could also be related to the COVID-19 pandemic).

Figure 5.1 **Change indexed to 2010 for cluster 1 and cluster 3 indicators: total waste (excluding major mineral waste), population and GDP for the EU-27, 2010-2020**



Note: Data for total waste (excluding major mineral waste) in the odd years are linearly extrapolated.

Source: EEA compilation based on Eurostat data presented in Chapter 4.

All in all, the decrease in total waste (excluding mineral waste) in 2020 seems to be more related to the reduction in waste from the electricity sector than from other sectors. Comparing the data on combustion waste by EU countries, the decrease in combustion waste aligns with the decrease in the use of solid fossil fuels by country. It is unclear whether the reduction in solid fossil fuel use is strongly connected to the COVID-19 pandemic, as a constant decrease between 2011 and 2019 can be seen, with a much more pronounced decrease from 2019 to 2020.

Box 5.1

Types of decoupling

There are three types of decoupling:

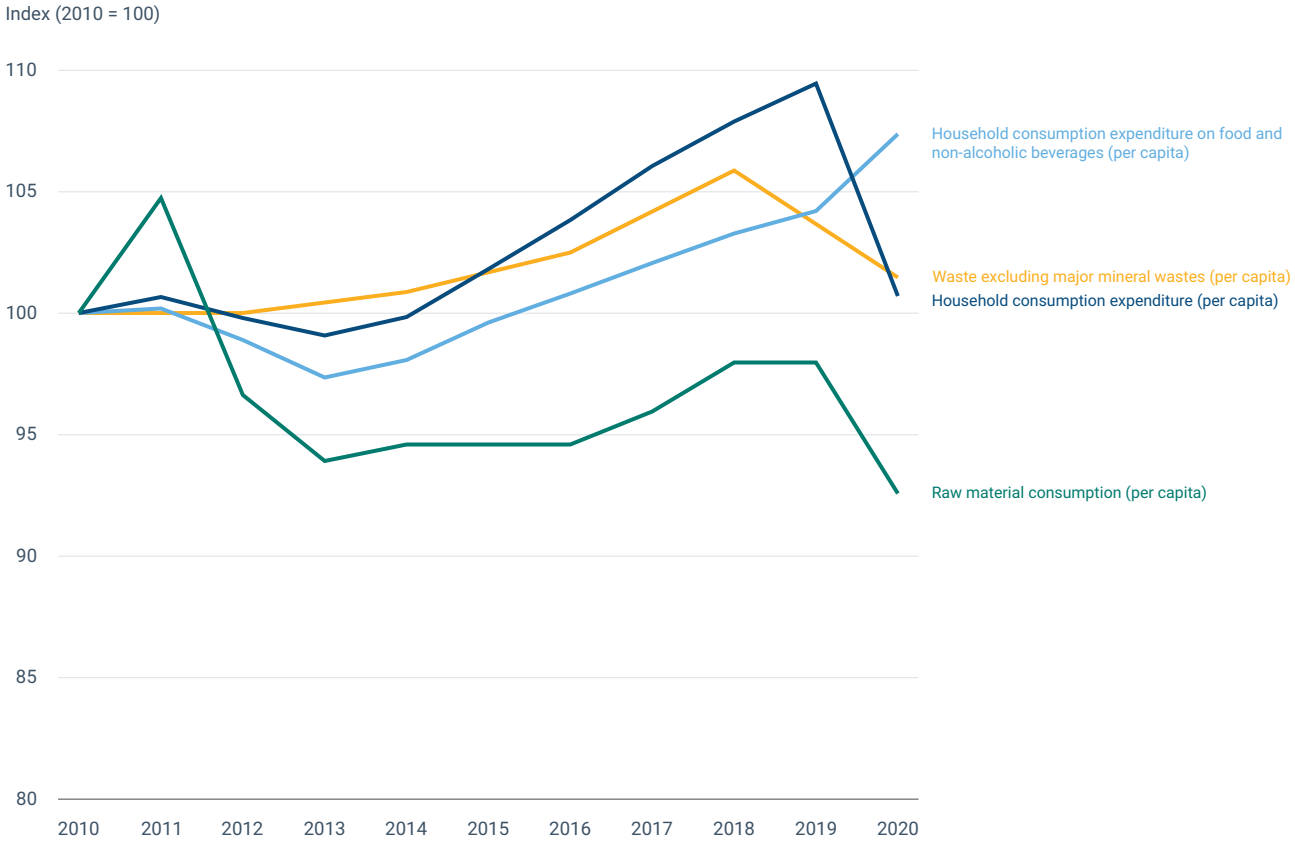
1. An absolute decoupling, when waste generation is decreasing despite the growth of economy.
2. A relative decoupling, when waste generation is increasing, but at a slower pace than the economic growth.
3. No decoupling, when waste generation is increasing similarly or faster than the economy.

Source: EEA (2021).

5.1.2 Waste and consumption

Figure 5.2 presents changes indexed to 2010 in the indicators on waste generation in comparison with consumption indicators, namely household consumption expenditure and raw material consumption (RMC).

Figure 5.2 **Changes indexed to 2010 for cluster 1 and cluster 3 indicators: total waste (excluding major mineral waste), final household consumption expenditure, final household consumption expenditure on food and non-alcoholic beverages, total RMC for the EU-27, 2010-2020**



Note: Data for total waste (excluding major mineral waste) in the odd years are linearly extrapolated.

Source: EEA compilation based on Eurostat data presented in Chapter 4.

Two trends can be observed. First, RMC per capita follows trends in final household consumption expenditure and GDP, but this is due mainly to the consumption of fuels and transport, which have limited relevance to waste prevention. Second, the trends in municipal waste generation follow trends in household expenses on food and non-alcoholic beverages. It should be noted that RMC includes materials extracted to produce the goods and services consumed, irrespective of where in the world the material extraction took place, while the amount of generated waste refers to waste generated in the EU-27.

Per capita household consumption expenditure on 'food, beverages, and tobacco products' is the second main driver of material extraction (after construction), and contributed approximately 11-12% of the RMC between 2010 and 2020, which corresponds with the final consumption expenditure of households, as 'food and non-alcoholic beverages' in 2020 reached 14% of total household expenses. In addition, in the same year, per capita food waste from households was estimated at around 70kg, which is around 13% of total municipal waste per capita, at 517kg.

To reduce generation of waste (excluding major mineral wastes) more effort should be put into preventing municipal waste generation and food waste generation in addition to all other waste types. This is likely to require the strong implementation of circularity in the EU economy, designing out waste in new, long-lived and repairable products, and changing our consumption habits to less material-intensive activities. Awareness-raising campaigns aimed at highlighting the costs and environmental impacts of food waste are a potential waste prevention measure. As indicated by Messner et al. (2020) society and economy. In response to that challenge, a plethora of initiatives addressing food waste have formed in recent years. These initiatives focus on aspects such as the efficiency of resource use, reduction of supply chain food waste, food donations and rescue, consumer behaviour, and above all, innovative ways to add value to food surplus and waste. What many initiatives have in common is that they mainly deal with food waste once it exists rather than preventing it from occurring in the first place, which might thwart efforts to increase long-term food systems sustainability. The idea of food waste prevention itself is beset by several conceptual paradoxes: it is considered the most preferred method to manage waste — which it was supposed to prevent in the first place, and it is an ambiguous ecological behaviour lacking the tangible characteristics of waste composting or recycling (i.e. prevention by its nature is invisible, to prevent waste generation, overproduction and overconsumption need to be addressed, as any efforts to constrain supply must be complemented by a change in social and cultural practices and values. More guidance can also be found in an EEA briefing on changing consumption behaviour for circularity (EEA, 2022a).

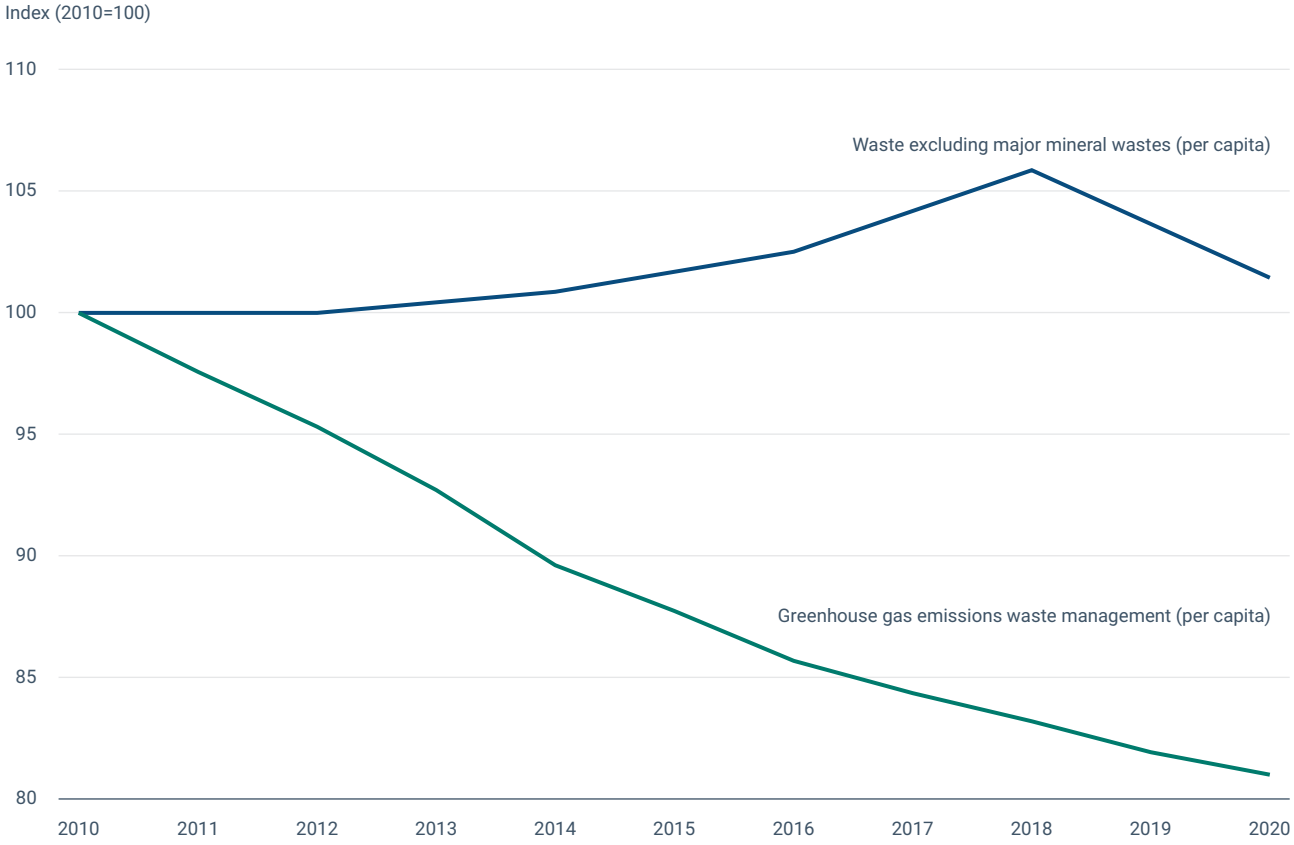
5.1.3 Municipal residual waste and municipal waste

Between 2010 and 2020 municipal waste increased by almost 3%, while municipal residual waste decreased by around 12%. Both municipal waste and municipal residual waste decreased from 2010 until 2015 when municipal waste started to increase. Municipal residual waste continued to decrease until 2016 before it increased somewhat in 2017 and then stabilised until 2020. The stabilisation of municipal residual waste in recent years is largely due to a similar-paced increase in both recycling rates and the amount of waste generated (EEA, 2022b). This means that the decrease in municipal residual waste in relation to municipal waste is attributed more to recycling and less to waste prevention efforts, as municipal residual waste has been increasing steadily from 2014 to 2020.

5.1.4 Greenhouse gas emissions

Figure 5.3 presents changes in the indicators on waste generation in comparison with greenhouse gas (GHG) emissions from the waste management sector, while Figure 5.4 presents data on volumes of waste treated, broken down by waste treatment methods. The purpose of these figures is to provide insight on the types of waste treatment activities that lead to GHG emissions.

Figure 5.3 **Change indexed to year 2010 for cluster 1 and cluster 3 indicators: total waste (excluding major mineral wastes) and GHG from waste management for the EU-27, 2010-2020**



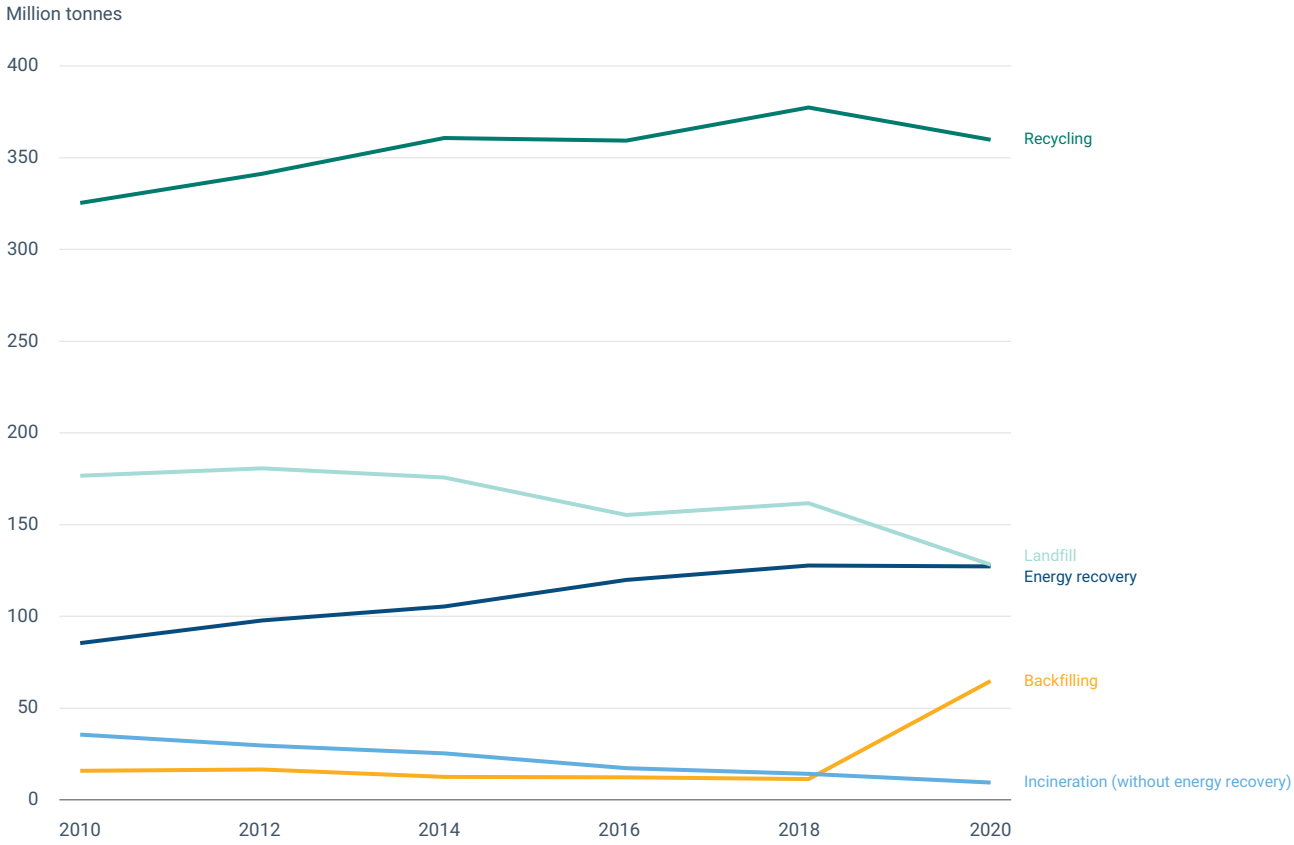
Note: Data for total waste (excluding major mineral waste) in the odd years are linearly extrapolated.

Source: EEA compilation based on Eurostat data presented in Chapter 4.

To move towards a climate-neutral economy a target to cut 55% of GHG emissions (from 1990 levels) by 2030 was proposed by the Commission in 2020 (European Commission, 2022). The majority of GHG emissions in the EU-27 originate from the energy sector, at the level of 2,488Mt of CO_2 equivalent (CO_2e) in 2020 (Eurostat, 2022i). GHG emissions from waste management, which were at the level of 112Mt CO_2e in 2020, comprise only a small part of the total GHG emissions in the EU-27, but GHG emissions from waste-to-energy activities are not reported under waste management. Nonetheless, even if waste is sent to incineration with energy recovery, it would not constitute waste prevention.

The decline in GHG emissions from waste treatment, seen in Figure 5.3, is mainly due to reduced landfilling and a shift in waste treatment and not to a reduction in the waste generated. As shown in Figure 5.4, a transition from landfilling towards energy and material recovery has taken place, indicating that waste management strategies are moving up the waste hierarchy but not to the level of waste prevention. It must be stressed that waste prevention is regarded as the most efficient way to improve resource efficiency and to reduce the environmental impact associated with waste generation. For example, Scherhaufer et al. (2018) including the impact from food waste management based on available data at the European level. The impacts are calculated for the Global Warming Potential, the Acidification Potential and the Eutrophication Potential using a bottom-up approach using more than 134 existing LCA studies on nine representative products (apple, tomato, potato, bread, milk, beef, pork, chicken, white fish reported that the global warming potential of food waste was about 186MtCO_2e, with the majority of the food waste-related impacts generated by emissions in the production step, underlining the importance of food waste prevention.

Figure 5.4 **Total waste (excluding major mineral waste) treatment by waste treatment type for the EU-27, 2010-2020**



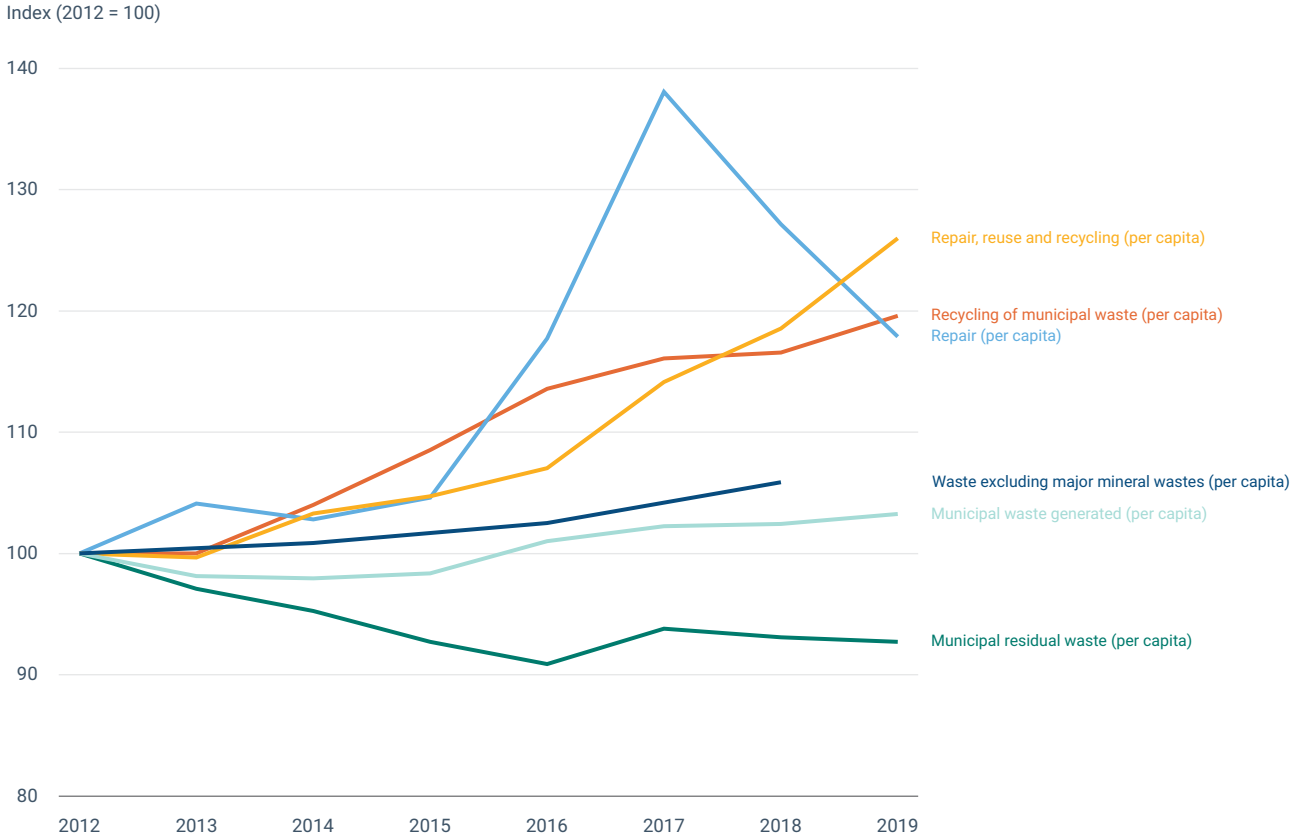
Source: EEA compilation based on Eurostat data (Eurostat data code: ENV_WASTRT).

If waste prevention efforts are effective, waste generation will decrease and less waste will be directed to waste management (i.e. landfilling, waste combustion and recycling). Recycling is an important part of the circular economy, as it keeps the resources used in the economy for as long as possible. However, waste prevention measures can potentially make an even bigger contribution to transforming unsustainable systems of production and consumption.

5.1.5 Reuse and repair

Figure 5.5 presents percentage changes in the indicators on waste generation in comparison with reuse, repair and recycling. As mentioned in Chapter 4, the indicator on the 'value added by repair, reuse and recycling' is an aggregated indicator and so it is not feasible to isolate the individual aspects of repair and reuse. Therefore, this indicator is discussed in comparison with relevant indicators, such as the turnover of repair and volume of recycling indicators, to try to understand the state of repair and reuse overall, especially in the context of waste generation.

Figure 5.5 **Percentage change from reference year 2012 for cluster 1 and cluster 3 indicators: total waste, municipal waste, residual municipal waste with value added in repair, reuse and recycling and turnover in repair sectors, EU-27, 2012-2019**



Note: Data are presented for 2012-2019 only, according to the time series of repair/reuse/recycling indicator data. Changes in waste generation and recycling indicators are based on waste volumes, while changes in repair and reuse indicators are based on financial units.

Source: EEA compilation based on Eurostat data presented in Chapter 4.

The value added by repair, reuse and recycling increased steadily by 26% from 2012 to 2019, while the turnover of repair sectors increased sharply by 33% from 2015 to 2017 and then fell by 20% in 2019. Nonetheless, the turnover of the repair sector still shows a net increase of 18% over the whole period.

The rapid increase and decrease in turnover in repair sectors does not seem to affect or be affected by municipal waste and municipal residual waste trends. However, a steady increase can be observed in municipal waste recycling volumes and the value added by repair, reuse and recycling. In 2020, an average of 517kg of municipal waste was generated per capita, of which 251kg (48%) was recycled.

It can be perceived that the majority of the values are composed of recycling; however, this cannot be determined based on the data available, considering that, for example, the Nomenclature of Economic Activities (NACE) codes considered for the recycling sector also include 'Retail sale of second-hand goods in stores' (European Commission, undated). Often, material recycling companies are considered in the NACE code category that refers to the corresponding manufacturing/industrial sector or to the recycled product category (e.g. glass, paper, metal), such as NACE code 17120 for paper recycling and 24100 for steel

recycling. Therefore, this indicator could be refined in the future to improve the fit for waste prevention purposes by excluding the following NACE categories currently considered in recycling:

- E 38.11 Collection of non-hazardous waste;
- E 38.12 Collection of hazardous waste;
- E 38.31 Dismantling of wrecks;
- E 38.32 Recovery of sorted materials;
- G 46.77 Wholesale of waste and scrap.

It should also be noted that the Waste Framework Directive (WFD) Article 9 measure to encourage reuse and repair activities (Art. 9(d)) is the second most common measure in the EU, with 93% of the EU-27 mentioning this measure (of any policy instrument) at least once in their waste prevention programmes. This could potentially be reflected in the overall increase in the turnover of repair sectors from 2012 to 2019, but does not explain the rapid decrease from 2017 onwards. It should be noted, however, that the indicator on Article 9 measures in waste prevention programmes reflect only the status of current versions of waste prevention programmes, the duration of which varies across EU countries.

5.1.6 Food waste

Given the lack of data on a time series, it was determined that food waste prevention could not be assessed in this report, but this can be carried out in the future when data on a longer time series are available. Nonetheless, based on the data collected, over half of food waste arises from households, accounting for 70kg per capita. The remainder is generated upstream of the supply chain in primary production/ agriculture and in manufacturing, retail and food services, for example. Waste prevention potential is best described as avoidable and unavoidable waste, where avoidable describes the part of food waste that could be eaten and thus prevented if the food was managed differently (e.g. consumed in time, better stored, packaged appropriately). It is voluntary for the Member States to report the ratio between avoidable and unavoidable food waste; however, those data are not yet available from Eurostat.

5.2 Policy enablers on system context and waste output (cluster 2 with clusters 1 and 3)

In this section, the indicator data of cluster 2 (policy enablers) are discussed in the context of clusters 1 (system context) and 3 (waste output). First, the most common measures found in waste prevention programmes are discussed. Then, less common measures or measures that are not found in the waste prevention programmes are discussed. Lastly, the limitations of cluster 2 data are reflected on and elaborated.

5.2.1 Common waste prevention measures and policy instruments found in waste prevention programmes

The most common measure found in the waste prevention programmes of EU-27 countries is 'Encouraging reuse and repair' (Art. 9(d)). This is addressed in

Section 5.1.5). 'Promoting sustainable consumption models' (Art. 9(a)) is the second most common measure, where voluntary initiatives or agreements are the most common policy instrument. The effect of this is expected to be seen in the reduction in RMC; however, given that the indicators collected in cluster 2 are not on a time series, it is not possible to assess the effect of this measure on RMC itself. Sustainable consumption could also be potentially reflected in waste and GDP decoupling, given that the economic value of consumption would continue to increase while waste generation would decrease.

The third most common measure is 'Reducing the generation of food waste' (Art. 9(g)); however, it was not feasible to assess the effect of measures or progress on food waste generation due to the lack of data on a time series, availability and comparability on both clusters.

5.2.2 Waste prevention measures that are rarely or not found in waste prevention programmes

Across the waste prevention programmes of the EU-27, not all types of policy instruments are applied for each measure listed in Article 9 of the WFD. For example, for the measure 'Reduce the generation of food waste' (Art. 9(g)), 85% of EU-27 waste prevention programmes mentioned the use of voluntary initiatives or agreements, while only 4% mentioned the use of market-based instruments.

When a particular policy instrument is applied in less than 10% of EU-27 countries' waste prevention programmes, this is defined as a 'gap' for the purpose of this report section. However, the presence of a gap does not necessarily indicate an area that requires an improvement in waste prevention because certain policy instruments may not be applicable to certain measures. For example, there were no such gaps for all regulatory measures except 'Developing and supporting information campaigns to raise awareness' (Art. 9(m)), but such a measure is likely to be much less suitable than other measures.

Market-based instruments are rarely applied to fulfil the purposes of measures such as 'Targeting products with critical raw materials' (Art. 9(c)), 'Encouraging the availability of spare parts' (Art. 9(d)), 'Reducing food waste generation' (Art. 9(g)), 'Encouraging food donation' (Art. 9(h)), 'Promoting the reduction of hazardous content' (Art. 9(i)) and 'Halting the generation of marine litter' (Art. 9(l)). This potentially indicates actual gaps in waste prevention or gaps in describing all relevant measures in the waste prevention programmes, as economic instruments such as fees, taxes and subsidies should be feasible and effective for these measures.

For informative instruments, only one gap was found in the measure of 'Identifying products that are the main sources of littering and take appropriate measures to prevent and reduce litter from such products' (Art. 9(k)). One can imagine that communication and awareness-raising activities on littering complement other measures in reducing littering, and therefore this could also be a potential gap in waste prevention measures.

No conclusions can be drawn on the coverage of measures for EPR instruments.

5.2.3 Limitations in cluster 2 data in general

As mentioned in Section 2.5, while this report describes observable trends, gaps and correlations in waste prevention measures and seeks to provide some

explanation behind them, it should be noted that none of the above discussions can be linked to specific waste output trends. It was not possible to observe clear linkages between these two clusters based on the data collected or to develop concrete conclusions that measures in the waste prevention programmes of EU-27 countries indeed lead to the waste trends observed.

One of the main gaps in the method is the lack of good-quality (ideally quantifiable) indicators on waste prevention measures. Given that the format, structure and content of waste prevention programme documents are not standardised across EU countries, the level of interpretation of the descriptions of waste prevention measures can vary widely. It is likely that waste prevention measures were in place before the waste prevention programmes were established, and that a given waste prevention programme does not include all waste prevention measures (e.g. when one measure is generally described as a package of smaller measures) or that not all the measures described in a waste prevention programme are in fact implemented or financed. Therefore, this approach provides a certain degree of approximation of the number and types of measures planned in the waste prevention programmes, but it does not reflect the magnitude of the waste prevention effort. Such an indicator is needed to compare with waste output data to (1) analyse the effectiveness of the implementation of policy instruments that target the prevention of waste along the list of identified measures (i.e. assessing the prevention potential of measures and instruments), and (2) compare the efficiency of measures and instruments in doing so (i.e. the effort and cost per tonne of prevented waste). Therefore, a more quantified indicator such as the budget of the waste prevention programmes may be a more suitable indicator for the future, although it may be difficult to obtain such data at the national level.

5.3 Key messages and reflections on analysing EU-level waste prevention progress

5.3.1 On waste prevention

- Total waste (excluding major mineral waste) in the EU-27 increased by 1.45% per capita from 2010 to 2020, while overall economic growth — expressed in terms of per capita GDP (chain-linked volumes at market prices) — increased by 6%, showing signs that relative decoupling may be occurring between total waste (excluding major mineral waste) and economic growth.

- However, both per capita total waste (excluding major mineral waste) and GDP decreased by 4% each from 2018 to 2020. It is unclear whether the waste decrease was connected to economic downturn due to measures introduced to manage the COVID-19 pandemic, given that a closer look at the types of waste comprising total waste (excluding major mineral waste) shows that a major proportion of the decrease is attributed to combustion waste from the energy sector, and this is most likely related to the decreased use of solid fossil fuels rather than waste prevention measures. Further investigation would be helpful to better understand the causes behind the observed waste trends in these years.

- Municipal residual waste has decreased from 2010 to 2020, but this is likely to be due to recycling rather than waste prevention efforts, as can also be seen in the increase in municipal waste generation during the same period.

- GHG emissions from waste management also decreased from 2010 to 2020, most likely due to improved waste treatment methods that have moved up the waste management hierarchy, such as combustion with energy recovery and recycling, and a decline in landfilling. However, these do not constitute waste prevention measures.

- When it comes to waste prevention measures, the waste prevention programmes of the EU-27 mainly focus on sustainable consumption models, encouraging reuse and repair activities and developing and supporting information campaigns to raise awareness (all of which are mentioned in 93% of the waste prevention programmes of the EU-27). However, it was not possible to identify concrete connections between the measures and the data on waste generation and socio-economic trends.

- Although waste prevention programmes have been established for almost 10 years, it is difficult to prove a link between the introduction of the programmes and an effect on waste generation.

- Although progress has been made in moving up the waste hierarchy, substantial additional efforts should be put into preventing waste generation, and more effective measures are likely to be needed for all types of waste. This is likely to require the strong implementation of circularity in the EU economy, designing out waste in new, long-lived and repairable products, and changing our production and consumption habits to less material-intensive activities.

5.3.2 On the indicator framework

- Overall, the data collected on the indicators were able to provide a 'big picture' understanding of the waste generation situation over the past decade, but they were not sufficient to allow a comprehensive, in-depth analysis of waste prevention progress or assess all the causes behind the waste generation trends observed.

- One major limitation in the indicator framework is that the use of total waste (excluding major mineral waste) significantly lacks granularity and hence the ability to dissect and trace back the types of waste contributing to the changes in total waste. Some effort was made at a later stage of the study to investigate types of waste, which pointed to a decrease in the use of solid fuels in combustion waste as the biggest contributor to the total decrease in waste; however, greater effort should be made in the future to analyse waste types. It is recommended that the total waste (excluding major mineral wastes) be elaborated with sub-indicators on types of waste.

- The second biggest limitation in the indicator framework is a lack of a good-quality (ideally quantifiable) indicator on waste prevention measures, as explained in detail in Section 5.2.3. Relying solely on the waste prevention measures as described or mentioned in waste prevention programme documents significantly lacks robustness (i.e. in the quality of data and its scope and representativeness as well as in the ability to prevent errors/manipulation of the database), as there is no certainty that the measures set out were indeed implemented and to what extent. In addition, the methods used in this study did not assess the quality and strength of the waste prevention measures.

- The potential for monitoring the implementation of by-product regulations and their impact on waste prevention could be considered in the future (particularly for the prevention of construction waste).

- Given that there is no standardised structure for the content of waste prevention programmes, including the description of quantitative targets, indicators and measures, it was difficult to compare and analyse the waste prevention measures between countries. Developing a common standard on the structure and content of waste prevention programmes can help to streamline the design and implementation of waste prevention measures. Elements of good practice can be seen, for example in the waste prevention programme of Spain, which includes for each priority waste type a list of waste prevention measures mapped against

strategic areas (e.g. reduction of waste amounts, reuse/extension of useful life, reducing hazardousness and environmental impact). Relevant actors are also identified for each measure, although the measures are not connected to specific targets and indicators to monitor them. Another example is in the waste prevention programme of Luxembourg, which has a table outlining specific quantitative and qualitative objectives and a list of measures for each type of waste. However, no indicators on the monitoring of efforts is included in the tables.

- Also related to waste prevention indicators, it may be useful in the future to first assess which type of instruments are expected to be most relevant or impactful to fulfil the purpose of a listed WFD Article 9 measure. This could, for example, be presented in a table with traffic light colours. The purpose would be to use this as a guide to assess whether the gaps observed in the policy instruments for given measures exist because they would be irrelevant or are an area where waste prevention efforts could be strengthened. For example, such a guide could be used to demonstrate that informative policy instruments are most useful for and applicable to Article 9(m) 'Develop and support information campaigns to raise awareness', while the opposite would be the case for regulatory instruments.

- Another limitation is with regard to indicators on consumption (i.e. household final consumption and RMC). It should be remembered that waste prevention does not aim to reduce EU final consumption, rather it relates to the decrease in waste intensity of per capita consumption. For example, communication, transport and energy consumption (electricity, gas and other fuels) represent a high share of the total expenditure and are extremely relevant for climate change, but they are not waste intensive and are therefore reasonably rarely targeted by the waste prevention measures of Member States. Therefore, future efforts could consider excluding low-waste or low-material intensity consumption areas from the household consumption indicator set (currently consisting of 13 sub-categories), and including only those from high-waste or high-material intensity consumption areas, such as food and beverages. Further analysis is needed to identify this.

- Similar to RMC, indicators referring to product groups that are not targeted by waste prevention programmes and waste prevention measures, such as 'products of agriculture, hunting and related services' and 'electricity, gas, steam and air conditioning', should be excluded. Further analysis is needed to identify the sectors to exclude.

- Related to consumption is the economic profits of waste prevention. Theoretically, the decreased consumption associated with waste prevention can result in economic benefits (which could then be spent elsewhere). It may be useful to explore whether other data can be used to develop an indicator on this.

- For the comparison between municipal residual waste and municipal waste, future analysis could consider presenting these data in terms of the percentage of municipal residual waste in total municipal waste, instead of municipal residual waste in absolute terms. This would allow a better analysis of whether prevention should give greater priority to the waste that currently is sent to recycling (municipal waste) or to the fractions that represent more weight within the residual municipal waste.

- While the municipal residual waste indicator can be seen as relevant to waste prevention because it can provide an indication of the treatment of waste that the system was unable to prevent, it can also be seen as weak because it is much more focused on preventing waste disposal rather than waste prevention itself. Therefore, future work to build on this waste prevention monitoring report could consider the removal of the residual municipal waste indicator entirely to shift the focus more clearly on to preventing waste generation.

- GHG emissions from the waste management indicator were initially selected to provide an indication of the adverse impacts of waste generated on the environment. However, the resulting data do not cover other relevant aspects, such as collection, waste processing, export to treatment facilities or incineration for waste-to-energy activities. Therefore, at the moment, this indicator does not represent the full GHG emissions of waste and needs further improvement and development.

- In the indicator 'value added by repair, reuse and recycling', it was difficult to fully distinguish the values between the three areas. Therefore, this indicator could be refined in the future to improve the fit for waste prevention purposes, by further investigating the sectors that comprise the recycling sector. This is likely to require the exclusion of the following NACE categories that are currently considered as part of recycling:

  – E 38.11 Collection of non-hazardous waste;

  – E 38.12 Collection of hazardous waste;

  – E 38.31 Dismantling of wrecks;

  – E 38.32 Recovery of sorted materials;

  – G 46.77 Wholesale of waste and scrap.

- On its own, the indicator 'turnover in repair sectors' can also be seen as being weak for evaluating repair activities, given the differences in prices and salaries across the EU, which has a direct impact on the amount of turnover. One possible improvement is to adjust the indicator to measure GDP from the repair sector as a share of total GDP for one country so that the indicator can be standardised and data compared between countries. However, the availability of data on factors such as the share of GDP from repair and on repair at the national level is unknown.

- To improve waste prevention monitoring, more efforts are needed to strengthen the measurement of waste prevention implementation at the country level. The establishment of standardised specific indicators to measure waste prevention can help with this. Setting EU-level waste prevention targets, like the legally binding target for reducing food waste that currently is being developed, can also help to set a basis for measurement and to strengthen countries' obligations on waste prevention.

Abbreviations

Abbreviation	Name
CO_2e	Carbon dioxide equivalent
DPSIR	Driving forces, Pressures, States, Impacts and Responses
EEA	European Environment Agency
EU	European Union
EU-27	27 EU Member States
GDP	Gross domestic product
GHG	Greenhouse gas
RACER	Relevance, Acceptance, Credibility, Ease and Robustness
RMC	Raw material consumption
WEEE	Waste electrical and electronic equipment
WFD	Waste Framework Directive
WPP	Waste prevention programme

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Annex 1 All indicators and RACER evaluation results

Cluster 1: System context

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
Driving forces				
1. Number and nature of producers and consumers				
Population (average population — total) (EEA, 2019a)	Related to waste generation; indicates demand for resources.	Can be used as a standalone demographic indicator or as an auxiliary indicator to derive indicators per capita. Data are updated annually. Is expressed as the **population on 1 January** (following recommended definition of 'usually resident population') or as the **average population** (i.e. the arithmetic mean of the population on 1 January of 2 consecutive years) (Eurostat, 2019) (European Commission and Eurostat, 2015). The average population is used in the calculation of other indicators such as GHG emissions per capita.	**Eurostat** online data code: DEMO_GIND (average population). **Eurostat** online data code: TPS00001 (population on 1 January). Link to data source Link to metadata	**Total score: 2.9.** To be used as an auxiliary indicator to calculate 'per capita' figures and to monitor trends in waste generation in time series relative to other variables, such as population growth. 1. Relevance: 3.0. Changes in population will be reflected in the demand for resources and thereafter waste generation. 2. Accepted: 3.0. The average population number is used in the calculation of relative indicators such as waste generation per capita. There are no roles and responsibilities of waste prevention stakeholders for the indicator. 3. Credible: 2.8. Population figures in EU Member States are credible for non-experts, unambiguous and easy to interpret. Impact of migration and the concept of legal residence might be more difficult to interpret. 4. Easy: 3.0. Data are available online and are continuously updated. 5. Robust: 2.8. Information is transmitted to Eurostat by the National Statistical Institutes. Some difficulties in the estimation of emigrants are reported (Eurostat, 2019).

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		1. Number and nature of producers and consumers		
Urban population (degree of urbanisation, percentage of total population) (EEA, 2019a)	Related to urbanisation trends and better access to waste preventing measures, and also to possible higher waste generation (e.g. food); urban versus rural consumption patterns.	The World Bank's (2020) definition of **urban population** is based on information provided by national statistical offices. Aggregation of urban and rural population may not add up to total population because of different country coverages. Data are updated annually (World Bank, 2020). Eurostat uses the degree of urbanisation (**DEGURBA**) as a classification to determine the character of an area (Eurostat, 2022b). A new methodology for classification of degree of urbanisation has been recently published (OECD et al., 2021). The percentage of population living in cities, suburbs and towns, and in rural areas, is shown. The degree of urbanisation classification could be also used as an auxiliary indicator to derive, for example municipal waste generation per degree of urbanisation (i.e. in cities, in towns and suburbs, and in rural area); however, data are not available. Data by degree of urbanisation are presently available for the following statistical domains: labour market, education, living conditions, welfare and tourism (Eurostat, 2022b).	**World Bank** staff estimates are based on the United Nations Population Division's World Urbanization Prospects: 2018 Revision. Data for the EU aggregate are available (World Bank, 2020). **Eurostat** online data code: ILC_LVHO01 (distribution of population by degree of urbanisation, dwelling type and income group — EU-SILC survey); percentage of population in (1) cities (DEG1), (2) towns and suburbs (DEG2), (3) rural areas (DEG3). Specifically, we use Degree of urbanisation — (DEG1) Cities. Link to data source Link to meta data	**Total score: 2.5**. To be used as an auxiliary indicator to calculate the urban areas' 'per capita' figures to monitor trends in waste generation in time series relative to other variables, such as urban population growth, and to monitor differences as compared with Member State-wide trends. For example, food waste has been shown to be affected by higher population density (Cerciello et al., 2019). 1. Relevance: 1.5. Municipal waste composition and weight could be different in urbanised areas and so progress in waste prevention might differ too. 2. Accepted: 3.0. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). There are no roles and responsibilities of waste prevention stakeholders for the indicator. 3. Credible: 3.0. Urban area population figures in EU Member States are credible for non-experts, unambiguous and easy to interpret. Definitions and maps are available via Eurostat (Eurostat, 2022b). 4. Easy: 2.5. Data are available online and are continuously updated. However, delays in the delivery of the information may occur. The indicators based on the EU-SILC survey are published in Eurostat from 1 to 1.5 years after the collection year. 5. Robust: 2.5. Data are available from World Bank and from Eurostat. World Bank estimates urban population based on information provided by national statistical offices, but differences in country definitions of urban and rural areas are present. Eurostat uses degree of urbanisation (DEGURBA) and a new methodology for classification of degree of urbanisation has been recently published.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		1. Number and nature of producers and consumers		
Number of households (total number of private households) (German Environment Agency, 2019) (Wilts et al., 2019)	Prevention is closely linked to complex consumption patterns and changes (e.g. in the average size of households or changes in the industrial structure of an economy), which can influence the generation of waste (Wilts et al., 2019).	**Number of households** can be used as a standalone indicator or as an auxiliary indicator to derive indicators per household. Data are updated annually. The data collection 'LFS — specific topics, household statistics' covers a range of statistics on the number, characteristics and typologies of households, based on the EU LFS. Data collection also encompasses some labour market indicators broken down by household composition (Eurostat, 2022l). **Average size of a household** is collected as part of the EU-SILC survey: Eurostat online data code: ILC_LVPH01.	**Eurostat** online data code: LFST_HHNHTYCH (number of private households by household composition, number of children and age of youngest child (1,000)). **Eurostat** online data code: LFST_HHNHWHTC (number of private households by household composition, number of children and working status within households (1,000)). Link to data source Link to metadata	**Total score: 2.8.** To include as an auxiliary indicator to calculate indicators 'per household' or to monitor trends in waste generation in time series relative to other variables, such as average size of households. For the latter, a combination with the 'total population' indicator is required. 1. Relevance: 3.0. Prevention is closely linked to complex consumption patterns and changes (e.g. in the average size of households and therefore in the number of households), which can influence the generation of waste. 2. Accepted: 3.0. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). There are no roles and responsibilities of waste prevention stakeholders for the indicator. 3. Credible: 3.0. Number of private household figures in EU Member States are credible for non-experts, unambiguous and easy to interpret. 4. Easy: 2.5. Data are available online and are continuously updated approximately 6 months after the end of the reference period. Break in time series for 2021. 5. Robust: 2.5. Data collection is based on the EU LFS. Methodology was revised in 2021.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		2. Volumes and values of production and consumption		
GDP (GDP at market prices) (EEA, 2019a)	The economic growth indicator is connected to waste generation and is relevant for monitoring the decoupling of economic growth and waste generation.	It is an indicator to monitor a nation´s economic situation. It can be used as a standalone indicator or as an auxiliary indicator to derive indicators per GDP unit. Data are updated annually. It reflects the total value of all goods and services produced less the value of goods and services used for intermediate consumption in their production. Expressing GDP in PPS eliminates differences in price levels between countries, and calculations on a per head basis allows for the comparison of economies significantly different in absolute size (Eurostat, 2022j). Definition of GDP at market prices is given in Eurostat's metadata file for annual national account (nama10) (Eurostat, 2021a). GDP at market prices is defined as the result of the production activity of resident producer units.	**Eurostat** online data code: TEC00001 (GDP at market prices). **Eurostat** online data code: NAMA_10_PC (main GDP aggregates per capita), (B1GQ) GDP at market prices. Link to data source Link to metadata	**Total score: 2.8.** To include as an auxiliary indicator to calculate indicators 'per GDP unit', and to monitor trends in time series on decoupling of economic growth and waste generation. 1. Relevance: 3.0. GDP is required for determining the decoupling of waste generation from economic growth. 2. Accepted: 2.8. Indicator is commonly used by policymakers, statistical agencies and academia. There might be an effect of waste prevention on GDP, derived from the changing of habits and consumption patterns, as well as from discouraging consumption and promoting economic activities linked to, for example, repair, remanufacturing. It is possible, however, that the roles and responsibilities of waste prevention stakeholders with respect to GDP are judged to be insignificant or, at best, marginal. 3. Credible: 2.0. Methodology is transparent. There may be a difference between the European aggregate and the appropriate sum of national data between updates. The concept of GDP, and the corresponding terminology and taxonomy, might be difficult to interpret by non-experts. 4. Easy: 3.0. Data are available online and are continuously updated (i.e. Member State's annual main aggregates are generally transmitted at t+2 and t+9 months). 5. Robust: 3.0. Quality is assured by strict application of ESA 2010 concepts and by thorough validation of the data delivered by countries.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		2. Volumes and values of production and consumption		
Household final consumption expenditure by composition (Eurostat, 2019, 2019, 2020a, 2020b, 2021a–g, 2022a–l)	Indicator of consumption patterns; type of generated waste. Waste generation depends more on specific expenditure types and the share of expenditure types by income.	Household consumption expenditure can be classified by consumption purpose according to the COICOP classification (Eurostat, 2021a).	**Eurostat** online data code: NAMA_10_CO3_P3 (final consumption expenditure of households by consumption purpose (COICOP 3 digit)). Link to data source Link to metadata	**Total score: 2.8.** To include as a standalone indicator to monitor purpose specific consumption patterns and therefore waste generation trends. 1. Relevance: 3.0. It allows waste amounts based on consumption to be predicted. 2. Accepted: 2.8. There might be an effect of waste prevention on household final consumption expenditure, derived from the changing of habits and consumption patterns, as well as from discouraging consumption and promoting economic activities linked to, for example, repair and remanufacturing. It is possible, however, that roles and responsibilities of waste prevention stakeholders with respect to household expenditure are judged to be insignificant or, at best, marginal. 3. Credible: 3.0. Household expenditure figures in EU Member States are credible for non-experts, unambiguous and easy to interpret. 4. Easy: 2.0. Data are available online and are continuously updated; however, detailed breakdowns of main consumption purposes have a delay of over 1 year. 5. Robust: 3.0. Quality is assured by strict application of ESA 2010 concepts and by thorough validation of the data delivered by countries.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		2. Volumes and values of production and consumption		
DMC (Wilts et al., 2019)	Indicator for efficient use of resources.	DMC is the main indicator for measuring the amount of materials used in an economy. It is a part of the **Resource Efficiency Scoreboard**. It is used to monitor progress towards a resource-efficient Europe. Data are updated annually. For calculation of **DMC per capita** the average population is used (Eurostat, 2022d). It measures the total amount of materials directly used by an economy and is defined as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports and minus all physical exports. It takes into account all solid, gaseous and liquid materials, except for air and water. Water included in products is included (Eurostat, 2017; Bourguignon, 2018). DMC excludes the raw materials extracted in non-EU countries and embedded in imported goods. However, it is available for all EU Member States and has a long time series (EEA, 2019b). To monitor the changes in production and consumption patterns, **DMC per material type**(e.g. biomass, metal ores, non-metallic minerals, fossil energy materials/carriers) can be monitored.	**Eurostat** online data code: ENV_AC_MFA (material flow accounts) Link to data source Link to metadata	**Total score: 1.8.** Not to include as it is recommended to include RMC. 1. Relevance: 2.0. Waste prevention is to encourage resource-efficient design, manufacturing and use of products. However, DMC excludes the raw materials extracted in non-EU countries and embedded in imported goods. 2. Accepted: 1.0. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). 3. Credible: 1.5. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022) 4. Easy: 2.0. Indicator data are available online and are updated at regular intervals; however, new data points are disseminated within 2 years after the reference year. 5. Robust: 2.5. Economy-wide material flow accounts are compiled from a wide range of data sources. The overall accuracy is considered good. Validation procedures, estimation of missing statistical data (gap-filling) and quality reporting are in place.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		2. Volumes and values of production and consumption		
RMC (Wilts et al., 2019)	Indicator for efficient use of resources.	It is a part of the **EU SDG indicator set** and is used to monitor progress towards SDG 12 on ensuring sustainable consumption and production patterns. As a material footprint indicator, RMC represents the total amount of extracted raw materials needed to produce the goods and services consumed, irrespective of where in the world the material extraction took place. Foreign resource consumption is calculated referring to raw material equivalents. Data are updated annually. Data are presented for all EU Member States plus Switzerland (Eurostat, 2022o). Although RMC is able to better capture the actual total use of materials, RMC data sets contain modelling estimates only.	**Eurostat** online data code: ENV_AC_RME (Material flow accounts in raw material equivalents — modelling estimates) Link to data source **Eurostat** online data code: SDG_12_21 (RMC) Link to data source **Eurostat** online data code: ENV_AC_RMEFD. Link to data source Link to metadata	**Total score: 1.9.** To include in tonnes per capita per material type (biomass, metal ores, non-metallic minerals, fossil energy materials/carriers). Another possibility, and what seems now maybe more relevant for waste prevention, is to use raw material equivalents by final uses of products. To be decided during the compilation of data for the actual reporting of waste prevention progress (if the indicator becomes selected) to get a truer sense of what is reasonable when taken in context with the data of other indicators. 1. Relevance: 3.0. Waste prevention is to encourage resource-efficient design, manufacturing and use of products. 2. Accepted: 1.0. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). There might be an effect of waste prevention on RMC, derived from the changing of habits and consumption patterns, as well as from discouraging consumption and promoting economic activities linked to, for example, repair and remanufacturing. It is possible, however, that roles and responsibilities of waste prevention stakeholders with respect to RMC are judged to be insignificant or, at best, marginal. 3. Credible: 1.0. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). The concept of RMC is difficult to explain to non-experts, somewhat ambiguous and interpretation is challenging, even for experts. 4. Easy: 2.0. Indicator data are available online and are updated yearly; however, new data points are disseminated within 2 years after the reference year. 5. Robust: 2.5. The estimates produced by Eurostat use harmonised methodologies; however, some countries are using their own estimation models.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
Driving forces				
2. Volumes and values of production and consumption				
Resource productivity: GDP/DMC (Yano and Sakai, 2016) (Wilts et al., 2019)	Monitors sustainable production and consumption models and resource efficiency.	Is an indicator for resource efficiency, and is a part of **the EU SDGs indicator set**. It is updated annually. Various units are employed for the data set 'resource productivity' (env_ac_rp), depending on which type of GDP (current price or volume figures) has been used for calculating the ratio: 'Euro per kilogram' (GDP in current prices), 'PPS per kilogram' (GDP in current prices expressed in PPS), 'Euro 2015-based chain-linked volumes per kilogram' (GDP in chain-linked volumes normalised to 2015 prices) and 'Index, 2000=100' (based on GDP in chain-linked volumes normalised to 2000 prices) (Eurostat, 2021e). A potential **weakness of using DMC** in a resource productivity indicator is that DMC excludes the raw materials extracted in non-EU countries and embedded in imported goods. RMC is an alternative to DMC as a resource productivity indicator (EEA, 2019b).	**Eurostat** online data code: ENV_AC_RP (resource productivity) Link to data source	**Total score: 1.3.** Not to include, as it is recommended to include RMC. 1. Relevance: 2.0. Waste prevention is to encourage resource-efficient design, manufacturing and use of products. However, DMC excludes the raw materials extracted in non-EU countries and embedded in imported goods. 2. Accepted: 0.5. Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). 3. Credible: 0.0. No score given. Based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). 4. Easy: 2.0. Indicator data are available online and are updated at regular intervals; however, new data points for DMC are disseminated within 2 years after the reference year. 5. Robust: 2.0. Economy-wide material flow accounts are compiled from a wide range of data sources. The overall accuracy is considered good. Validation procedures, estimation of missing statistical data (gap-filling) and quality reporting are in place.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		2. Volumes and values of production and consumption		
Primary energy consumption (in million tonnes of oil equivalent) (EEA, 2019a)	Efficient use of resources; if waste generation is prevented then the energy that would have been used for the production, storage or transport of goods that became waste is reduced.	The indicator is part of the **EU SDGs indicator set**. The indicator is updated annually. The indicator measures the total energy needs of a country excluding all non-energy use of energy carriers (e.g. used for producing chemicals). It covers the energy consumption by end users (Eurostat, 2022n). There are **EU energy consumption targets** for 2020 and 2030 (Article 3 of Directive 2012/27/EU): **2020 energy consumption** has to be no more than 1,483 Mtoe of primary energy or no more than 1,086 Mtoe of final energy. **2030 energy consumption** has to be no more than 1,273 Mtoe of primary energy and/or no more than 956 Mtoe of final energy (Eurostat, 2021c).	**Eurostat** online data code: SDG_07_10 (primary energy consumption). Link to data source **Eurostat** online data code: NRG_IND_EFF (includes primary and final energy consumption and corresponding distance to 2020 and 2030 targets). Link to data source Link to metadata Probably includes only [PEC2020-2030] primary energy consumption (Europe 2020-2030), expressed as Mtoe	**Total score: 2.1.** Could be included as supplementary information to RMC. 1. Relevance: 1.0. Waste prevention is to encourage resource-efficient design, manufacturing and use of products. 2. Accepted: 3.0. Indicator is commonly used by policymakers, statistical agencies and academia. There might be an effect of waste prevention on primary energy consumption, derived from the changing of habits and consumption patterns, as well as from discouraging consumption and promoting economic activities linked to, for example, repair and remanufacturing. It is possible, however, that roles and responsibilities of waste prevention stakeholders with respect to primary energy consumption are judged to be insignificant or, at best, marginal. 3. Credible: 2.0. The correlation between the indicator and prevention is not clear. Primary energy consumption figures in EU Member States are credible for non-experts, unambiguous and relatively easy to interpret when the underlying concepts 'oil equivalents' and 'primary' are sufficiently understood. 4. Easy: 2.0. Indicator data are available online and are updated at regular intervals; however, new data points are published 13 months after the reference year. 5. Robust: 2.5. Eurostat carries out quality tests, mainly on the coherency of the provided information.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
Driving forces				
2. Volumes and values of production and consumption				
Water use (EEA, 2019a)	Waste prevention implies actions to save resources from being used unnecessarily. If waste generation is prevented, then water that would have been used to produce goods that would become waste is saved.	This is part of the **EU SDGs indicator set**. The indicator is updated every 2 years with annual data (Eurostat, 2021f). The indicator is a measure of **total fresh water use as a percentage of the renewable freshwater resources** (groundwater and surface water) at a given time and place. It quantifies how much water is abstracted and how much water is returned after use to the environment. The difference between water abstraction and return is regarded as water use and illustrates the pressure on renewable freshwater resources due to water demand (Eurostat, 2021f). The indicator is a result of **estimations** by EEA based on data from the WISE SoE — Water Quantity database (WISE 3) and other open sources (JRC, Eurostat, OECD, FAO), including gap-filling methods (Eurostat, 2021f).	**Eurostat** online data code: SDG_06_60 (WEI+) Link to data source	**Total score: 1.6.** Not to include as the relevance to waste prevention is not straightforward. 1. Relevance: 1.0. Waste prevention is to encourage resource-efficient design, manufacturing and use of products. 2. Accepted: 2.7 . Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). 3. Credible: 1.0 . Scoring based on stakeholder feedback at the Waste Prevention Workshop (7 June 2022). The correlation between the indicator and prevention is not clear. 4. Easy: 1.0 . Indicator data are available online and is updated at regular intervals, however, new data points are disseminated within 3 years after the reference year. 5. Robust: 2.5 — The indicator is a result of estimations by EEA based on data from the WISE SoE — Water Quantity database (WISE 3) and other open sources (JRC, Eurostat, OECD, FAO), including gap-filling methods.
3. Volumes and values of circular resource use				
Value added from reuse, repair and recycling	An indicator for resource use efficiency.	'Private investments, jobs and gross value added related to circular economy sectors (cei_cie010)' (specific to recycling, repair and reuse sectors). Available repair and reuse data usually refer to a limited set of specific products, limiting their use in a generic prevention indicator set. This indicator can be used to infer measures taken in the recycling, repair and reuse sectors; however, it is likely that the majority of the values are associated with recycling (Eurostat, 2020b).	**Eurostat** online data code: cei_cie010. Link to data source	**Total score: 1.3.** To include, as no other reuse and repair indicators from robust EU-level data sources are available at the moment. 1. Relevance: 2.0 . Waste prevention is to encourage resource-efficient use of products. However, the inclusion of recycling reduces the relevance to waste prevention, as prevention stops before the recycling stage. 2. Accepted: 0.0. No score collected from stakeholder feedback. 3. Credible: 0.0. No score collected from stakeholder feedback. 4. Easy: 2.0 . Indicator data are available online and are updated at regular intervals. 5. Robust: 2.5 . The estimates produced by Eurostat use harmonised methodologies.

Indicator	Relevance to waste prevention	Description	Data source	RACER evaluation
		Driving forces		
		3. Volumes and values of circular resource use		
Turnover in repair sectors	An indicator for resource use efficiency.	Complementing the indicator on value added from circular economy sectors, which includes recycling, this would provide further insight on the value of repair alone in comparison with reuse and repair sectors.	**Eurostat** online data code: SBS_NA_1A_SE_R2**.** Link to data source	**Total score: 1.4.** To include, as no other reuse and repair indicators from robust EU-level data sources are available at the moment. 1. Relevance: 2.5 . Waste prevention is to encourage resource efficient use of products. 2. Accepted: 0.0. No score collected from stakeholder feedback. 3. Credible: 0.0. No score collected from stakeholder feedback. 4. Easy: 2.0 . Indicator data are available online and are updated at regular intervals. 5. Robust: 2.5 . The estimates produced by Eurostat use harmonised methodologies.
		Pressures		
Total annual emissions of GHGs (EEA, 2019a)	Monitoring of production and consumption patterns; resource efficiency.	The indicator is part of the **Resource Efficiency Scoreboard**. It is measured in **tonnes of CO_2 equivalent per capita** (total national emissions of the so called 'Kyoto basket' of GHGs). Data from EU Member States are collected yearly (as part of the reporting under the United Nations Framework Convention on Climate Change) (Eurostat, 2022i). A target to cut 55% of GHG emissions (from 1990 levels) by 2030 was proposed by the European Commission in 2020 (European Commission, 2022).	**Eurostat** online data code: ENV_AIR_GGE (GHG emissions by source sector for the following waste management categories: (CRF5A) solid waste disposal, (CRF5B) biological treatment of solid waste and (CRF5C) incineration and open burning of waste). Link to data source Link to metadata	**Total score: 2.6 .** To include tonnes of CO_2 equivalent per capita per sector, especially in waste management, to present decreased waste management GHG emissions as an effect of decreased waste volumes as a consequence of waste prevention. 1. Relevance: 2.5 . Waste prevention is to encourage resource-efficient design, manufacturing and use of products. High relevance for waste management sector. 2. Accepted: 2.8. There might be an effect of waste prevention on waste management emissions, derived from the decreased volumes of waste to be managed. It is unlikely that roles and responsibilities of waste prevention stakeholders with respect to primary energy consumption are found to be insignificant. 3. Credible: 2.5 . The correlation between waste management sector GHG and waste prevention is evident and credible for non-experts, although somewhat ambiguous and challenging to interpret. 4. Easy: 2.0 . EEA publishes data 18 months after the reference year. 5. Robust: 3.0 . Comparability across countries is considered good.

Notes: COICOP, Classification of Individual Consumption by Purpose; DMC, domestic material consumption; EU-SILC, EU Statistics on Income and Living Conditions; FAO, Food and Agriculture Organization of the United Nations; JRC, Joint Research Centre; LFS, Labour Force Survey; Mtoe, million tonnes of oil equivalent; OECD, Organisation for Economic Co-operation and Development; PPS, purchasing power standards; SDG, Sustainable Development Goal; WEI+, water exploitation index, plus; WISE, Water Information System for Europe.

Cluster 2: Policy enablers

Indicator	Description and rationale	Data source	RACER evaluation
		WFD Article 9 completeness	
Presence of each type of **measure** in Article 9, categorised by policy instrument: (1) regulatory, (2) market based, (3) voluntary agreement and (4) informative. Expressed as the proportion of EU Member States that have the measure.	A requirement in the WFD is for Member States to have these measures as a minimum. Categorisation of policy instruments builds on the report: Progress towards preventing waste in Europe – the case of textile waste prevention (EEA, 2021). Putting all indicators together, it will be possible to assess the balance of measures within and between Member States, and distinguish any geographical differences or trends.	WPPs	**Total score: 1.8.** While this indicator has a lower overall score, it should nonetheless be included because it is the most direct indicator available to reflect waste prevention measures in Member States. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 1.5. A country's waste prevention measures are not typically comprehensively stated in their WPPs. 5. Robust: 1.5. Since WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify waste prevention measures per type of policy instrument.
Presence of **targets** categorised by policy instrument (see above). Expressed as the proportion of EU Member States that have the target.			**Total score: 2.2.** No further comment. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 2.0. Country WPPs do tend to have waste prevention targets (often more so than a list of measures), although they can be rather generalised or vague. 5. Robust: 1.5. As WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify waste prevention targets per type of policy instrument.

Indicator	Description and rationale	Data source	RACER evaluation
		WFD Article 9 completeness	
Presence of **indicators** categorised by policy instrument (see above). Expressed as the proportion of EU Member States that have the indicator.			**Total score: 2.2.** No further comment. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 2.0. Not all WPPs include waste prevention indicators and the quality varies. 5. Robust: 1.5. Data quality and availability on waste prevention indicators in WPPs can be rather limited. As WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify WPP indicators per type of policy instrument.
Evolution of WPPs over time			
Number of countries that have evaluated their WPP at least once within the last 6-year period.	To track the development of WPPs in EU Member States. Furthermore, Article 30 of the WFD states that WPPs should be evaluated every 6 years and revised as appropriate.	WPPs and WPP evaluation reports published on Member State public authority websites.	**Total score: 2.4.** No further comment. 1. Relevance: 3.0. Direct relevance to WFD requirements. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 1.5. WPP evaluation reports and the corresponding dates might be difficult to track and retrieve. 5. Robust: 3.0. The only possible answers are yes, a particular Member State evaluated its WPP at least once within the last 6-year period, or no.

Indicator	Description and rationale	Data source	RACER evaluation
		Waste stream focus	
Presence of each type of **measure** in Article 9 as relevant to the selected waste stream, categorised by policy instrument: (1) regulatory, (2) market based, (3) voluntary agreement and (4) informative. Expressed as the proportion of EU Member States that have measures on the following: – food waste; – construction and demolition waste; – WEEE; – textile waste; – plastic waste; – manufacturing waste; – household/municipal waste; – hazardous waste. The waste stream will be selected for each waste prevention report in consultation with the EEA and considering hotspot issues and policy trends at the time of preparing the reports. Total waste should always be included as a default. For the 2023 report, food waste is selected.	To monitor any trends or changes on the focus of waste streams over time.	WPPs.	**Total score: 1.8.** While this indicator has a lower overall score, it should nonetheless be included because it is the most direct indicator available to reflect waste prevention measures in Member States. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 1.5. A country's waste prevention measures are not typically comprehensively stated in their WPPs. 5. Robust: 1.5. As WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify waste prevention measures per type of policy instrument.

Indicator	Description and rationale	Data source	RACER evaluation
		Waste stream focus	
Presence of **targets** categorised by policy instrument (see above) as relevant to the selected waste stream. Expressed as the proportion of EU Member States that have the target.			**Total score: 2.2.** No further comment. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 2.0. Country WPPs do tend to have waste prevention targets (often more so than a list of measures), although they can be rather generalised or vague. 5. Robust: 1.5. As WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify waste prevention targets per type of policy instrument.
Presence of **indicators** categorised by policy instrument (see above) as relevant to the selected waste stream. Expressed as the proportion of EU Member States that have the indicator.			**Total score: 2.2.** No further comment. 1. Relevance: 3.0. Direct relevance to waste prevention objectives. 2. Accepted: 3.0. The WFD is applicable to and has been accepted by all public authority stakeholders that have transposed the WFD into national legislation and are responsible for their national WPP. 3. Credible: 3.0. The indicator is credible for non-experts, unambiguous, easy to interpret, simple and robust. 4. Easy: 2.0. Not all WPPs include waste prevention indicators and the quality varies. 5. Robust: 1.5. Data quality and availability on waste prevention indicators in WPPs can be rather limited. As WPP documents are not standardised, it might, in some cases, be challenging and not straightforward to classify WPP indicators per type of policy instrument.

Cluster 3: Waste output

Indicator	Description	Data source	RACER evaluation	
1. Waste quantity related, including decoupling				
Total waste (excluding major mineral waste) generation, **tonne** per year (in total and per capita).	Data on generation of waste (excluding major mineral waste) covers hazardous and non-hazardous waste from all economic sectors and households, including secondary waste from waste treatment, but mostly excluding major mineral waste ([a]). Mineral waste is excluded in many studies, as it varies widely across the EU Member States. It was deemed that excluding the flow improves the comparability across the EU Member States.	**Eurostat** online data code: env_wasgen (TOT_X_MIN, waste category — total waste excluding major mineral wastes (or kg per capita)). Link to data source Link to metadata Frequency every 2 years (reported by Member States every 2 years, covers all EU Member States, next reference year 2020, probably available in autumn 2022).	Monitoring total waste generation is essential for understanding the progress towards waste prevention. The indicator has been used by EEA and in many other studies. The indicator is credible for non-experts, unambiguous, and easy to understand and interpret.	**Total score: 2.8.** 1. Relevance: 3. 2. Accepted: 2. 3. Credible: 3. 4. Easy: 3. 5. Robust: 3.
Waste intensity of net waste volume (without major mineral waste) per GDP unit, kg per thousand EUR per year.	Same as above but expressed per unit of GDP.	**Eurostat** online data code: cei_pc032. Generation of waste excluding major mineral wastes per GDP unit. 'The indicator is defined as all waste generated in a country (in mass unit), excluding major mineral wastes, per GDP unit (in euro, chain linked volumes (2010)). The ratio is expressed in kg per thousand EUR' (Eurostat, 2022g). Link to data source Eurostat: part of Eurostat's circular economy monitoring framework, frequency every 2 years. (The data are based on total waste (above) available every 2 years and GDP available every year.)	This is a decoupling indicator that has been used before by EEA (e.g. EEA, 2021). The indicator has good data availability and is part of Eurostat's circular economy monitoring framework. The indicator is quite credible for non-experts, unambiguous, and easy to understand and interpret.	**Total score: 2.9.** 1. Relevance: 3. 2. Accepted: 3. 3. Credible: 2.7. 4. Easy: 3. 5. Robust: 3.

Indicator	Description	Data source	RACER evaluation	
		1. Waste quantity related, including decoupling		
Municipal waste generation (kg per capita per year).	The indicator measures waste collected by or on behalf of municipal authorities. The waste is to a large extent generated by households, but includes similar waste from other sources, such as offices, small-scale commerce or public institutions. Since the reference year 2020 (reported in 2021), there were changes in the definition of 'municipal waste' as per EU Directive 2018/851 (EC, 2018): almost all waste collected from households (both mixed and sorted), including similar waste from other sources, are considered as municipal waste, but excluding C&D, production, agriculture, forestry, fishing, septic tanks, sewage sludge and end-of-life vehicles.	**Eurostat** online data code: cei_pc031. Link to data source **Eurostat** online data code: env_wasmun. Link to data source Eurostat: part of Eurostat's circular economy monitoring framework, with annual updates (typically updated in March) (Eurostat, 2021d).	The indicator is used in countries' profiles, is widely used in countries' prevention programmes, is part of Eurostat's circular economy monitoring framework and has also been used in many other studies. The indicator has very good data availability and is comprehensible. Consideration of municipal waste instead of other waste (e.g. industrial waste) is advantageous because municipal waste reflects changes in consumption patterns as well as the performance of waste prevention where actions and the involvement of citizens is most relevant.	**Total score: 3.** 1. Relevance: 3. 2. Accepted: 3. 3. Credible: 3. 4. Easy: 3. 5. Robust: 3.
Residual municipal waste, percentage of municipal waste generated.	Municipal residual waste — unsorted waste not suitable for recycling/ reuse, including residues of sorting processes. There is no legal definition at the EU level, but a definition is developed by the EEA (EEA, 2022c).	**Eurostat**: Disposal incineration (D10) + disposal — landfill and other (D1-D7, D12) + disposal — incineration (D10) and recovery — energy recovery. Link to data source	The EU's WFD sets the target to recycle and/or reuse at least 60% of municipal waste by 2030. There is also a non-binding commitment at the EU level to reduce the amounts of residual municipal waste by half. The latter is based on the EU's Circular Economy Action Plan and the Zero Pollution Action Plan. The reference year is not defined, but EEA selected 2020, as it refers to the years when the plan was adopted (EEA, 2022c). The quantities of residual municipal waste across the EU have remained relatively stable over the past years, largely due to a similar-paced increase in both recycling rates and the amount of generated waste (EEA, 2022b). Both targets could be addressed by combining increasing recycling rates and reducing waste generation (EEA, 2022b). Thus, indicator 'municipal residual waste per capita' can partly reflect the contribution of both recycling and prevention to achieve the targets. However, municipal residual waste includes materials that could have been prepared for reuse, and while many countries recover materials from municipal residual waste neither activity is considered as waste prevention.	**Total score: 2.5.** 1. Relevance: 1.5. 2. Accepted: 2. 3. Credible: 3. 4. Easy: 3. 5. Robust: 3.

Indicator	Description	Data source	RACER evaluation	
1. Waste quantity related, including decoupling				
Household waste generation intensity, (weight per household expenditure).	Total amount of household waste generated per measure of household expenditure (time delimited).	**Eurostat** online data code: TEN00110 (for waste from household sector) and NAMA_10_CO3_P3 (consumption expenditure). Waste generated by households (EP-HH) by year and waste category (EWC-Stat 4). Link to data source Data on household waste can refer to: – household waste from the household sector (Eurostat frequency every 2 years); – share of municipal waste from households (Eurostat frequency — annual reports by Member States, although the percentage of household waste in municipal waste is voluntary to report); – final consumption expenditures of households (Eurostat, 2022e).	Decoupling indicator. Relevance to select household waste similar to municipal waste, as above. Removed as a redundant indicator to the previous indicators.	**Total score: 3.** Total score: 3. 1. Relevance: 3. 2. Accepted: 3. 3. Credible: 3. 4. Easy: 3. 5. Robust: 3.
2. Extended life spans related indicators				
(1) Average technical useful life of all products placed on the market, weighted for specific environmental impacts (German Environment Agency, 2019) (unclear nominators). (2) Initial useful life of selected products (e.g. WEEE) (German Environment Agency, 2019). (3) Average use time of consumer durable goods (Yano and Sakai, 2016).	The first useful lifetime refers to product use by its first user and includes time it takes in private household (i.e. 1) for a percentage of product category placed on the market in year X to be disposed of (i.e. 2) or passed on to a second user (i.e. 3) (German Environment Agency, 2019). However, practically, such an indicator does not consider the storage time in households, and therefore the actual lifetime of products should encompass the storage time (measure 'lost opportunity') (ETC/WMGE, 2020; Miliute-Plepiene, 2021).	No systematised and workable data available at the EU level.	Increasing the service life of products is an essential part of waste prevention. This can be achieved by different means, especially policy measures that support, for example, eco-design, product refurbishing, repair, reuse, awareness raising for households. Indicators measuring the technical useful lifespan of products versus the lifetime affected by consumer behaviour are useful to support policy interventions. However, systemised and workable data are not available at the EU level and so no operational indicators are proposed to be included in the framework at his stage.	

Indicator	Description	Data source	RACER evaluation	
		3. Indicators addressing reuse		
GHGs from waste management 2(EEA, 2019a).	This data set includes data on GHG emissions inventory, as reported to the EEA. The data are published once a year for the year t-2.	Waste prevention is to reduce the adverse impacts of the generated waste on the environment and human health. This indicator shows GHGs from waste management to point at GHGs that can be avoided with waste prevention measures. (Eurostat, 2022i).	To include tonnes of CO_2 equivalent per sector, especially in waste management, to present decreased waste management GHG emissions as an effect of decreased waste volumes as a consequence of waste prevention.	**Total score: 2.6.**
(1) Total effects on the environment and on human health caused by the amount of waste generated (German Environment Agency, 2019). (2) GHG emissions associated with total waste or waste stream (e.g. food waste) (Yano and Sakai, 2016).	The effects could be measured in either normalised form or by selected impact category(-ies) or emissions (e.g. GHG emissions).	No data are available for both indicators.	The importance to consider the environmental effects of waste prevention is emphasised by several scholars (e.g. Yano and Sakai, 2016) and is part of **the** waste prevention definition. The bulk of environmental impact studies usually focus on the impacts of different waste treatment methods (usually recycling versus other treatment methods in the waste hierarchy). In 'traditional' LCA studies, the system boundary is often assumed to begin after waste generation. It is the so-called 'zero burden' assumption, which in effect treats waste as 'having no prior environmental burdens' (Yano and Sakai, 2016). Besides the 'zero burden' approach when assessing waste prevention (i.e. when waste prevention equals no effects of waste treatment), the effects could also be evaluated by tracing back the upstream emissions, before waste generation, including lifecycle stages of products affected by waste prevention (Yano and Sakai, 2016). Therefore, waste prevention might bring significant environmental credits. However, assessing waste prevention has methodological challenges due to lack of data and time-consuming efforts. Assessments of the total effects of waste prevention are very much lacking on both the EU and the Member State levels (Laurent et al., 2014a, 2014b), with little prospects for developing operational indicators at the EU level at the current stage.	

Indicator	Description	Data source	RACER evaluation	
		4. Impact indicators		
Weight of reuse, kg per capita in total and per waste stream (e.g. waste C&D, textiles, EEE, furniture). Data will be available from 2023.	The actual reuse in kg per capita, and per kg per material category. ' … 'reuse' means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived.' (WFD, Article 2 (13)) (EU, 2008).	Weight of reuse, kg per capita in total or per waste stream (e.g. waste C&D, textiles, EEE, furniture). Starting from 2023, data will be reported by the EU Member States to Eurostat, including total reuse and reuse by product streams, such as C&D, textiles, EEE, furniture and other items. Frequency every 3 years. Note: Not available for the 2023 report, but the indicator should be usable after 2023.	As reuse is considered as one of the prevention strategies in the WFD, it is very relevant to have it among waste prevention indicators. There is some criticism about using the quantity of reuse as an indicator, as it does not clearly reflect if change is a result of a decrease in consumption or an increase in prevention. However, a series of different reuse models have been proposed (Žaneta et al., 2021), each of which might require a different approach for allowing the reuse being quantified. Other indicators or a set of indicators for example service lifespans and number of effective uses (e.g. wears for clothing), as proposed in Klepp et al. (2020) and Okomura (2022), could be considered for the future updates of the waste prevention framework.	**Total score: 2.2.** 1. Relevance: 3. 2. Accepted: 2. 3. Credible: 1. 4. Easy: 2. 5. Robust: 3.
Preparation for reuse of municipal waste.	'Preparing for reuse' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be reused without any other pre-processing (WFD, Article 2 (16)) (EU, 2008).	**Eurostat** online data code (env_wasmun). Link to data source Very few Member States report these data and it is not possible to collect EU-wide data at the moment. Note: This indicator is not feasible to include for the 2023 report. This indicator could be included when data are widely available across EU Member States.	Relevant flow to include (same rationale as for municipal waste generation). Targets for municipal waste management include recycling and reuse. However, only a few Member States report preparations for reuse (as this is voluntary). Therefore, it is not possible to have this as an operational indicator for the 2022 progress report. The indicator might be reconsidered if data for all Member States become available.	**Total score: 1.9.** 1. Relevance: 3. 2. Accepted: 2.4. 3. Credible: 1. 4. Easy: 0. 5. Robust: 3.

Indicator	Description	Data source	RACER evaluation	
		4. Impact indicators		
Share of reusable packaging placed on the market (%).	Share of reusable packaging in of all packaging.	The provision of the necessary information required to calculate the share of reusable sales packaging is obligatory for Member States from the reference year 2020 and onwards, and the first report is due by 30 June 2022 (Eurostat, 2022k). Note: This indicator is not feasible to include for the 2023 report. This indicator could be included when data are widely available across EU Member States. Currently only available as market data with copyright and to be reproduced under license.	Relevant waste stream as the EU Directive 2018/852 (EC, 2018), amending Directive 94/62/EC on packaging and packaging waste, directs Member States to increase the share of reusable packaging placed on the market. The indicator removed because it is a stream-specific indicator.	**Total score: 1.7.** 1. Relevance: 1. 2. Accepted: 1.7. 3. Credible: 3. 4. Easy: 0. 5. Robust: 3.
WEEE prepared for reuse (kg per capita).	'Preparing for reuse' means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be reused without any other pre-processing (WFD, Article 2 (16)) (EU, 2008).	**Eurostat** online data code (for WEEE): ENV_WASELEE. WEEE by waste management operations: preparing for reuse online data code: ENV_WASELEE Link to data source	Relevant waste stream due to its hazardous content and significant lifecycle impacts in comparison with other streams per weight and potentially large 'environmental credits' from reuse and preparation for reuse (Miliute-Plepiene, 2021). The indicator was removed as a stream-specific indicator.	**Total score: 1.9.** 1. Relevance: 2. 2. Accepted: 0.3. 3. Credible: 1. 4. Easy: 3. 5. Robust: 3.
		5. Hazardous content indicators		
Total weight of hazardous substances used in production process and products (German Environment Agency, 2019; Eurostat, 2022q) in tonnes or per capita.	The input indicator measures the volume of aggregated consumption of toxic chemicals. The indicator used in the EU SDG set has notation in weight (tonnes). Three categories are available from Eurostat: (1) chemicals used in general (including non-hazardous); (2) hazardous for health; and (3) hazardous for environment.	Eurostat online data code: SDG_12_10. Consumption of chemicals by hazardousness — EU aggregate. Link to data source Statistics on the consumption of chemicals by different level of hazard are available from Eurostat annually; data are also available aggregated at the EU level, but there are no individual EU Member State data (Eurostat, 2021b).	Could be used to derive an overall effect on the environment and human health. Is considered by some studies as a better indicator than the quantity of hazardous waste (German Environment Agency, 2019; Wilts et al., 2019). The indicator is the part of the EU SDG indicator set. Even if evaluated, owing to difficulties to interpret (i.e. difficulties faced in other EEA projects), the indicator has been finally removed from the final framework.	**Total score: 2.2.** 1. Relevance: 3. 2. Accepted: 3. 3. Credible: 1. 4. Easy: 1. 5. Robust: 3.

Indicator	Description	Data source	RACER evaluation	
		5. Hazardous content indicators		
Total quantity of hazardous waste (excluding major mineral waste).	In literature, as nominators are used (e.g. percentage of total waste stream, kg per capita or per GDP unit, or as total waste quantity (weight) in absolute terms).	**Eurostat** online data code: sdg_12_50. Link to data source Frequency every 2 years. Indicator is the part of the EU SDG indicator set (Eurostat, 2022p). EEA total annual E-PRTR-reported quantity of hazardous and non-hazardous waste transfers (excluding data for the waste sector) and annual gross value added for industrial activities are available at https://www.eea.europa.eu/data-and-maps/daviz/total-annual-e-prtr-reported#tab-chart_2 and https://www.eea.europa.eu/data-and-maps/data/industrial-reporting-under-the-industrial-6	The waste data are mainly available on separately collected hazardous waste. Total quantity of hazardous waste is also part of the EU SDG indicator set. Note: Even if the ban on mixing hazardous and non-hazardous waste exists (according to Article 18 of the WFD), the indicator might show only improved separate collection of hazardous waste if hazardous content in mixed waste is not considered. Therefore, this might be misleading when monitoring prevention. Therefore, it is worth considering the content of hazardous substances in mixed waste in the future (e.g. using compositional studies). However, data are not available to collect at the EU level.	**Total score: 1.8.** 1. Relevance: 1. 2. Accepted: 1. 3. Credible: 1. 4. Easy: 3. 5. Robust: 3.
		6. Other indicators		
As an addition to waste quantity and impact indicators: (1) Circular material use rate, recycling rate of all waste (excluding major mineral waste), municipal waste (%) (Eurostat, 2020a) or per waste streams. (2) Recycling rate of total and/or municipal waste (%).	Circularity rate or circular material use rate measures the share of material recovered and fed back into the economy versus overall material use. Overall material use rate is calculated by summing up the aggregated DMC and circular use rate. The circular use of materials is approximated by the amount of waste recycled domestically plus imported waste minus exported waste destined for recovery abroad. Recycled rate measures the share of waste recycled and waste generated.	(1) Circular material use rate: **Eurostat** online data code: sdg_12_41 (for municipal waste). Link to data source (2) Recycling rate of total waste: **Eurostat** online data code: CEI_WM010 (for recycling rate of all waste excluding major mineral waste). Link to data source	The circular material use rate including recycling rate are considered among circular economy indicators for measuring the progress in the circular economy within and outside the EU (Yano and Sakai, 2016; Eurostat, 2022q). Indirectly, recycling could also be considered as part of prevention, as the use of circular materials is supposed to decrease the extraction of virgin resources, waste quantities and environmental effects. The approach is often used in LCA studies of recycling. Similar to the circular economy-based approaches, landfill diversion rate as an indicator of waste prevention has been suggested (Messner et al., 2020). According to WFD, neither recycling nor landfilling is directly considered as prevention, and therefore they are not included as operational indicators in measuring the progress of waste prevention.	**Total score: 1.4.** 1. Relevance: 1. 2. Accepted: 1. 3. Credible: 1. 4. Easy: 1. 5. Robust: 3. **Total score: 1.6.** 1. Relevance: 1. 2. Accepted: 1. 3. Credible: 1. 4. Easy: 2. 5. Robust: 3.

Indicator	Description	Data source	RACER evaluation	
7. Waste stream indicators (as addition to total and municipal waste quantity indicators)				
(1) Food waste (e.g. amount of avoidable food waste per capita (no data yet) or food waste generation per capita (best available indicator)) (German Environment Agency, 2019)		Data will be available in autumn 2022. Note: This indicator was selected for the 2023 report.	Very relevant waste stream to consider, as aspirational targets for food waste reduction by 50% by 2030 are set by WFD (EU, 2018a).	**Total score: 2.3.** 1. Relevance: 3. 2. Accepted: 3. 3. Credible: 1.5. 4. Easy: 1. 5. Robust: 3.
(2) Construction and demolition waste (kg per capita).		Eurostat online code: ENV_WASGEN. Economic activity – construction. Link to data source	C&D is one of the largest waste streams by weight and has a high potential for waste reuse. The target is 70% recovery, recycling and preparation for reuse according to WFD.	
(3) Packaging waste (kg per capita).		Eurostat online data code: ENV_WASPAC. Link to data source	High potential for waste prevention, with good data availability via EPR systems of the EU Member States.	
(4) WEEE (generation (collection) per capita).		Eurostat online data code: ENV_WASELEEOS. Link to data source	Highly relevant due to its hazardous content and high lifecycle environmental impacts in comparison with other waste stream per weight.	
(5) Annual consumption of lightweight plastic carrier bags.		Eurostat online code: ENV_WASPCB. Link to data source	High potential for waste prevention, with existing targets for waste prevention and data availability, but very small weight shares in relation to other waste streams.	

Notes: [a] Definition of 'generation of waste excluding major mineral wastes': the indicator covers hazardous (haz) and non-hazardous (nhaz) waste from all economic sectors and from households, including waste from waste treatment (secondary waste) but excluding major mineral waste, i.e. the total waste generated except the following waste categories: (1) mineral waste from construction and demolition (EWC-Stat 12.1); (2) other mineral wastes (EWC-Stat 12.2, 12.3, 12.5); (3) soils (EWC-Stat 12.6); (4) dredging spoils (EWC-Stat 12.7). Although completely or partly mineral, the indicator explicitly includes combustion wastes (EWC-Stat 12.4) and mineral wastes from waste treatment and stabilised wastes (EWC-Stat 12.8 to 13)' (Schrör, undated).

C&D, construction and demolition

DMC, domestic material consumption

E-PRTR, European Pollutant Release and Transfer Register

EWC, European Waste Classification

LCA, lifecycle assessment

SDG, Sustainable Development Goal

European Environment Agency

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European Environment Agency

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark
Tel.: +45 33 36 71 00
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

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