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Harmonised labelling of waste receptacles with matching product labels

Potential policy measure and assessment of impacts

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Contents

Abstract

Separate collection of waste is an enabler for the recovery of valuable materials which can be recycled or otherwise valorised. However, it relies on adequate sorting by individuals, which can be facilitated by relevant information provided on the product packaging (on-pack labelling), and on the receptacles used for waste collection.

Waste from packaging represents up to 40% of municipal solid waste and can drive the improvement in collection of recyclable materials. Meanwhile, as EU deadlines for separate collection targets close in, Member States are implementing various schemes designed to assist sorting, including labelling on products and bins. This often results in a multiplication of labels to be displayed in different jurisdictions, increasing costs for producers and increasing the risk of confusion for consumers.

Harmonised labels to be displayed on product packaging, with matching labels on waste receptacles indicating where those should be disposed of, would address these issues and yield economic and environmental benefits.

The analysis presented herein assesses the environmental and socioeconomic impacts of introducing such a harmonised labelling in the EU over the coming years.

Results suggest that this measure would generate a net benefit as compared to a business-as-usual scenario. It would be expected to yield overall socio-economic benefits, and improvements in environmental performance in all cases considered.

Foreword and caveat

This report was prepared upon request from the Directorate-General for the Environment (DG ENV) of the European Commission to analyse the impacts of potential measures to harmonise labelling on product packaging (on-pack labelling) and waste receptacles, with a view to clarifying sorting instructions and ultimately increasing the quantity and quality of recyclable materials collected.

The analysis is based on a number of assumptions and modelling hypotheses which are presented within the report, or stem from existing or proposed regulations. The results presented should in no way be interpreted as pre-empting or anticipating the formulation of future regulatory proposals, which will be developed, proposed, discussed and adopted in the future, in particular regarding the scope, timeline and mandates of the potential measures envisaged herein.

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Executive summary

Policy context

EU waste policy aims to contribute to the circular economy by extracting high-quality resources from waste disposal. The European Green Deal aims to promote growth by transitioning to a modern, resource-efficient, and competitive economy. Several EU waste laws are being reviewed as part of this transition.

The Waste Framework Directive (WFD) is the EU's legal framework for treating and managing waste in the EU. It introduces in particular the waste hierarchy, an order of preference for waste management, and calls for Member States to put in place separate collection of waste, to ultimately improve the quantity and quality of recycling.

In addition, EU rules on packaging and packaging waste cover both packaging design and packaging waste management. They aim to deal with the environmental issues raised by increasing quantities of packaging waste and to remove barriers to the internal market – potentially caused by EU countries adopting different rules on packaging design.

As part of the European Green Deal, and the Circular Economy Action Plan, the EU is revising rules on packaging (currently laid out by the PPWD). In compliance with Better Regulation guidelines, an Impact Assessment of the measures envisaged under a potential revision of the packaging legislation is being prepared.

Research question

The present study contributes to this effort by analysing the impacts of a proposed measure to harmonise the labelling of waste receptacles to specify which types of waste they can collect; this measure is envisaged in combination with requirements for producers to label packaging (on-pack labelling) with matching symbols. The assessment of the impacts of new labelling requirements on packaging has been carried out by (Eunomia and COWI, 2022) in a separate supporting study.

Approach and methodology

We make assumptions regarding the parameters of the proposed measure, regarding the targeted waste receptacles, general characteristics of the labels, response of sorting behaviour to labelling, and timeline of implementation. These assumptions were informed by literature reviews and stakeholder feedback, and are consistent with the elements of the revised legislative proposal under consideration at the time of the study. Two main scenarios for introduction (sub-measures) are investigated, corresponding to different implementation schedules.

As a basis, an estimation of the cohort of waste receptacles targeted by the proposed measure is provided and cross-checked through a variety of literature and industry sources.

The environmental impact assessment is carried out through Life-Cycle Assessment (LCA) across a broad range of environmental impacts. The economic assessment, based on Cost Benefit Analysis (CBA) and Societal Life Cycle Costing (LCC) examines direct and indirect costs to affected stakeholders. Global socio-economic impacts are then evaluated and discussed.

Main findings and conclusions

The results suggest that the financial costs associated with the implementation of a harmonised EU labelling scheme for waste receptacles, matched to product packaging labels, are more than compensated by the expected lower costs of waste management and reduced environmental externalities. This result is contingent on the assumption that the labelling scheme induces a 2% increase in the capture rates and 12% increase in the purity rates of the separately collected waste streams, which appears to be a conservative assumption in light of related analyses found in the (albeit limited) literature. As a sensitivity analysis shows, the positive sign of the net social benefits is preserved even if a lesser improvement in the capture rate (only 1%) is assumed.

Without the benefits associated with the reduction of external costs, the financial costs implied by the measure would be higher than the savings obtained from the improved MSW management. The latter notably consists of reduced costs for the management of residual waste, e.g., collection, landfilling, and incineration.

As a complement, the harmonisation of labels on waste containers/bins should be started *before* product harmonised packaging labels are rolled out, in order to prepare waste management systems and citizens for the change. This is the case because the effort needed for waste management entities to change labels on containers/bins is estimated to be lower than that needed for the packaging industry, but the adaptation time for citizens to such change is long, supporting an earlier rollout on bins. In any case, the transition should be accompanied by appropriate sorting instructions and awareness campaigns to maximise the benefits of the measure, as regularly emphasised in stakeholder consultations and in the literature.

Related and future JRC work

This work was elaborated by the JRC project team working on the potential harmonisation of Separate Waste Collection in the EU. Evidence collected for that project, through stakeholder consultation and desk-based research, supported the research conducted in the current project on labelling of waste receptacles.

Background and introduction

Policy context

EU waste policy aims to contribute to the circular economy by extracting high-quality resources from current waste disposal to landfill or incineration as much as possible. The European Green Deal aims to promote growth by transitioning to a modern, resource-efficient, and competitive economy. Several EU waste laws are being reviewed as part of this transition.

The Waste Framework Directive (WFD) is the EU's legal framework for treating and managing waste in the EU. It introduces an order of preference for waste management called the "waste hierarchy". To implement the waste hierarchy in practice, it calls for Member States to put in place separate collection of waste, allowing waste to be further processed in accordance with the waste hierarchy as much as possible, and in particular to improve the quantity and quality of recycling.

Figure 1: European Commission Waste Hierarchy[1]

Certain categories of waste require specific approaches. Therefore, in addition to the overarching legal framework, the EU has many laws to address different types of waste. In particular, EU rules on packaging and packaging waste cover both packaging design and packaging waste management. They aim to deal with the increasing quantities of packaging waste, which cause environmental problems. They also aim to remove barriers to the internal market – potentially caused by EU countries adopting different rules on packaging design.

The Packaging and Packaging Waste Directive (PPWD), in place since 1994, contains measures to prevent the generation of packaging waste, and to promote the re-use, recycling and other forms of recovery of packaging waste, instead of disposal. It also establishes producer responsibility and sets targets for recycling by materials.

Objective of the study

As part of the European Green Deal, and the Circular Economy Action Plan, the EU is revising rules on Packaging (currently laid out by the PPWD). In compliance with Better Regulation guidelines, an Impact Assessment is being prepared of the measures envisaged under a potential revision of the Packaging legislation. The assessment of the impacts of new labelling requirements on packaging, notably on producers, has been carried out in a separate supporting study carried out by (Eunomia and COWI, 2022).

The present study contributes to this effort by analysing the impacts of a proposed measure to harmonise the labelling of waste receptacles to specify which types of waste they can collect; this measure is envisaged in combination with requirements on producers to label packaging (on-pack labelling) with matching instructions.

Please note that the assessment of the impacts of labelling requirements on packaging, notably on producers, has been carried out in a separate supporting study carried out by (Eunomia and COWI, 2022).

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[1] Source: Waste Framework Directive webpage at https://environment.ec.europa.eu/topics/waste-and-recycling/waste-framework-directive_en

1. Rationale for waste identification: intervention logic

1.1 What is the problem? Low recycling of MSW

Waste recycling is a general objective of the EU's Waste Framework Directive and Circular Economy Action Plan. However, from an environmental perspective, the current rate of recycling of Municipal Solid Waste (MSW) is lower than desired in large parts of the EU 27 because of economic barriers (EEA, 2020) and inefficient collection systems. Separate waste collection (SWC) of MSW has clearly been identified as a positive driver of more and higher quality recycling (according to evidence gathered in-house[2]). It diverts recyclable materials from the residual or mixed municipal solid waste and therefore reduces the irretrievable loss of valuable resources to landfilling and incineration of waste (Dehoust et al., 2010).

While certain advanced waste management systems can collect some waste streams together (commingling) and rely on centralised sorting, these still rely on separation at source for key waste fractions (e.g., biowaste and many packaging items) and issues remain with the output of these processes[3]. Improved separation at source will generally deliver improved environmental outcomes (i.e. increase the quality of waste processing, drive towards improved waste hierarchy objectives and help achieve recycling targets) and is pursued by a large majority of countries; while sorting plants for mixed MSW may be a useful complement to SWC and to further push recycling targets, especially for some materials like plastics and aluminium.

Efficient municipal SWC relies on correct waste sorting at source by households and businesses that use municipal waste management systems.[4] The importance of citizens' cooperation is widely acknowledged (Briguglio, 2016; Geiger et al., 2019). Currently observed capture rates (i.e., how much of all separately collectable waste is deposited in the appropriate separate collection receptacle) and misthrow rates vary considerably between different collection systems (COLLECTORS, 2020c; Seyring et al., 2015), suggesting that significant efficiency gains are possible if best practices are adopted more widely throughout the EU[5].

1.2 Problem driver: Lacking or confusing information on sorting

To correctly sort their waste, consumers need to feel both motivated and competent, as well as supported by an environment that provides them with adequate information and opportunities to sort waste correctly (Reijonen et al., 2021). While SW collection schemes have been in place in most EU Member States (MS) for several decades, evidence shows that a considerable level of confusion persists among citizens with regard to correct sorting behaviour.[6] For instance, the combination of inappropriate and heterogeneous colours and/or shape of waste containers and bins discourages citizens' engagement and results in lower recycling rates (Tonglet et al., 2004). Even when labels on products and waste receptacles are used to assist sorting, they can create confusion when not properly coordinated between producers and waste collectors, when producers are required or allowed to display several uncoordinated labels or when different producer groups establish their own labels (RECOUP, 2019; UNEP, 2020)

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[2] "Development of an EU harmonised model for separate municipal waste collection and related policy support – literature based analysis report'- JRC report, to be published.

[3] Plants currently in operation achieve similar purity levels as conventional sorting with input from separate collection systems (Eule, 2016). However, to avoid the presence of substances that might be harmful even at low concentrations, the use of certain recovered materials derived from such a mixed MSW stream is restricted, even when the purity grades are in line with technical criteria. E.g., the EU Norm on Paper and Board explicitly excludes the use of recovered paper and cardboard when it is not sourced from separate collection (EU-Norm, 2014), and likewise the regulation on the exclusion of plastics extracted from mixed MSW for the use in food contact packaging (EC, 2021).

[4] SWC relies on appropriate waste sorting that includes the actions of (1) distinguishing recyclables from non-recyclables, (2) preparing recyclables for collection (e.g., washing and squeezing), (3) throwing recyclables in the right bin, and (4) bringing recyclables to the nearest drop-off or collection point (Varotto & Spagnolli, 2017).

[5] See for instance Dri et al., 2018 (Best Environmental Management Practice for the Waste Management Sector)

[6] (WRAP, 2016) reported the results of a UK survey (part of the EU at the time of the study and with waste collection systems typical of situations across the EU), indicating that 73% of respondents claimed to be uncertain about appropriate disposal practices for at least one or two materials; and 46% of all householders tended to dispose wrong items in the bin because they were confused if they can be recycled or not.

1.3 Consequences of not addressing the problem: loss of secondary raw materials, Single Market fragmentation

While EPR policies have triggered high recycling rates -- for paper and cardboard packaging (82 %), steel packaging (83 %) and glass packaging (78 %) -- rates are considerably lower for plastic packaging (42 %) and aluminium packaging (around 50 %) (EUROSTAT, 2022)[7]. In addition, due to the application of a change in the EU calculation rules (EU 2019/1004), observed recycling rates will further decrease (Antonopoulos et al., 2021; Obermeier and Lehmann, 2019).

The first consequence of not addressing the low recycling rates of these packaging materials is a loss of resources which could serve as a source of secondary raw materials for European industry, thereby slowing the transition to a circular economy. For example, high recycling rates for paper have allowed that 55 % of the total annual paper and cardboard production in 17 EU MS + UK (CEPI member countries: (CEPI, 2022)) is produced from recycled material. In the case of glass beverage-container production, the average batch contains around 50 % recycled content (FEVE, 2022). Such a high share of recyclates reduces the need for virgin raw material, energy and other auxiliary materials in the manufacturing processes, which in turn leads to a reduction in negative environmental impacts (Dupriez, 2017; Ferrara & De Feo, 2021; GPI, 2010).

The second consequence would be to expose the EU Single Market to a risk of fragmentation and inefficiency. As MS are undertaking efforts to become more circular and increase recycling, it is likely that they will address confusing or lacking sorting information themselves, with national labelling systems, both on waste receptacles and on packaging. In fact, most MS have already adopted such systems on waste receptacles, generally in an uncoordinated manner; the Nordic pictogram initiative is one exception with multinational coordination. If producers become obliged to manufacture different packaging with country-specific sorting information, the result would be a considerable Single Market barrier with an ensuing additional cost burden for firms and, eventually, EU citizens.

1.4 Rationale for harmonised labelling: helping citizens and business to sort waste and avoid excess costs

To effectively provide information to citizens and thereby facilitate improved waste sorting, different ways and formats are possible, e.g., guidelines on how to sort waste, information on the available waste collection infrastructure and on where to bring specific types of waste (Rhodes et al., 2014). Information can be distributed in print, digitally, through awareness raising events, by proximity advisors etc. However, it might not be remembered or at hand in the very moment of sorting and disposing of the waste, which gives rise to the use of identifiers or markings – here generally denominated as *label* – on the product and / or the waste container or bag. Labels can consist of symbols or pictures, colours, text (description or message), other visual signals, or a combination of the above.

Labels for products and waste bins help to identify the right bin for each type of waste, thereby making sorting more convenient (in practice other information might also be present, e.g., on how to prepare recyclables). To the extent that citizens misthrow or do not sort waste because they do not know how to identify the correct bin for disposal, or it takes them more time than they are willing to spend, such a measure can lead to improved sorting by increasing citizens' capabilities and opportunities (Ölander & Thøgersen, 1995). The literature generally associates positive impacts on waste sorting with labelling (Amir Kavei & Savoldi, 2021) and, consequently, on SWC rates and quality (COLLECTORS, 2020b, 2020a; Leeabai et al., 2021; WRAP, 2016). However, the effectiveness of labelling rests, in the first place, on citizens' general willingness to sort their waste.[8]

The clearest sorting guidance to citizens consists of two matching labels, one on the waste item and one the waste receptacle. This approach is implemented already in several MS, including Denmark, Sweden, and Finland (Nordic Council of Ministers, 2021). However, the uncoordinated introduction of such systems risks undermining the integrity of the Single Market and to cause an unnecessary cost burden on business (as discussed before). In response, an EU harmonised labelling of packaging is currently considered as part of the revision of the PPWD. To achieve the full benefits of such a labelling system for packaging, it is indispensable to complement it with matching information on waste receptacles.

7 Data based on old calculation method. Applying the new calculation rules (EU 2019/1004) will result in lower recycling rates.

8 For this reason, new labelling systems are typically implemented in conjunction with consumer awareness campaigns and possibly other reforms of the collection system. Therefore, it is not possible to have an isolated estimate of the pure effect of labelling on sorting performance and recycling rates.

While coloured bins and containers are used in many MSs to guide waste sorting, relying only on colour has clear limitations, most of all that it is not self-explanatory, but also that its flexibility to adapt to new and more detailed classifications of recyclables is limited (e.g., sorting into finer sub-fractions).[9] Recently favoured approaches therefore rely on pictograms for product labelling and the identification of the corresponding waste streams. When designed to be understandable without text (or with optional text), the use of pictograms on bins and waste containers does not require translation and is to a wide extent self-explanatory and thus seen as more effective than introducing bin colouring schemes (EEB, 2020).

Following this reasoning, Italy in 2017 not only harmonised colours but introduced a labelling system on bins, with voluntary matching symbols on packages (UNI, 2017); since then, some Scandinavian countries (Denmark, Finland, Iceland, Norway, Sweden), have introduced a comprehensive labelling system based on harmonised pictograms (with primarily symbols and, optionally, colours and text). These pictograms are placed on the packaging, and the same pictogram is displayed on the waste container, bin, or bag. This creates a strong visual link that is helping households to correctly sort their waste (Dansk Affaldsforening, 2022).

Building on the positive experience of those countries who have introduced standardised, matching labelling schemes on products and waste receptacles (Nordic Council of Ministers, 2021), the proposed measure therefore aims to reap the benefits of harmonising this approach to improve sorting (and ultimately increase recycling) while streamlining the internal market for packaging.

1.5 Stakeholder feedback

A kick-off workshop was held on 19th May 2021 to present stakeholders the upcoming JRC work on the topic of 'Separate waste collection of municipal waste: Development of a harmonised EU model'. Among other questions, stakeholders were asked about the most suitable way of harmonising the identification of bins/containers/bags.

From 29 items of feedback received after the workshop on 19th May 2021, 10 stakeholders replied directly to the different identification options for bins/containers/bags. Nine of the 10 stakeholders support the implementation of labels on receptacles, in combination with labels on packaging as the most appropriate identification approach for citizens. In comparison, the disproportionate effort and cost of changing the colour of the collection receptacle was mentioned by stakeholders several times. However, the harmonised labelling in combination with the harmonised colouring of receptacles was also supported by some stakeholders. It is worth mentioning that the Danish pictogram approach was explicitly mentioned as a suitable approach for EU-wide labelling by 4 of the 9 feedback inputs on this aspect.

A follow-up workshop was held on the 8th March 2022 to present to stakeholders the upcoming JRC work from the sub-group 3 focused on the topic of 'Separate waste collection of municipal waste: citizen involvement and behavioural aspects". Among other questions, stakeholders were asked about the possible harmonisation of bin colours at EU level, and how the introduction of EU-wide harmonised pictograms on available bins influence citizens' behaviour. In line with the results from the kick-off workshop, from the 13 feedbacks, half of the stakeholders agreed that harmonising the bin colour is not a priority and that it could be an expensive, time consuming and waste generating activity, without much effect on consumers' behaviour. Only some of them (3 out of 13) considered that measure necessary and effective. Concerning the harmonised pictograms, a majority (10 out of 13) expressed that harmonising pictograms at EU level would have a positive effect on consumers' behaviour for separate waste collection, some of them (6 out of 13) making explicit that this would only occur if the symbols on bins are coupled with the introduction of the same symbols on products. Only one stakeholder expressed that pictograms are neither important nor efficient for the consumer behaviour on waste sorting.

9 In addition, since many MS have long-standing colours for certain waste fractions, with differences between MS, adoption to a new set of harmonised colours might incur considerable adjustment costs and require a long adaptation time before becoming effective. Nevertheless, it could be considered as a long-term objective.

2. Scoping and definition of policy measures

DG ENV is preparing a legislative proposal for the PPW Directive. This proposal envisages harmonised labelling of packaging materials on products. The present document formulates and assesses a complementary proposal for labelling waste collection containers, to allow consumers a straightforward identification of the correct waste container for packaging and an overall improvement to separate waste collection.

As explained in the IA submitted with the initial proposal for a PPWD revision, the measure "Labelling criteria to facilitate consumers´ sorting (advanced Nordic pictograms system)" (M27c-y) is based on the assumption that also waste bins or bags will be labelled with the same symbols as the packaging (p.41f, boldface added):

"This measure will help address consumer confusion as to where to dispose of their waste packaging and will allow for harmonisation of consumer sorting across the Member States. The inspiration is taken from the pictogram system, which is already being successfully implemented in Denmark and introduced in Sweden, Finland, and Norway and projected for the Baltic countries. Material composition (rather than "recyclability") will be labelled. Exemptions to the use of the symbols on some specific packaging categories will be allowed to avoid adverse environmental consequences. This measure will prevent Member States from mandating their own consumer-facing packaging sorting instructions or labelling systems and thus preserve the integrity of the single market. This system of approved symbols will be an on-pack requirement, thus visible as a direct prompt to the consumer at point of disposal; the same symbols will be attached to waste bins or bags allowing for a simple identification of where to place packaging waste".

2.1 Scope

Waste receptacles

Separate waste collection (SWC) begins at the household level, where waste is segregated in different fractions, according to the local SWC scheme and commingling rules. Within the household, waste is collected in single or multi-compartments bins (the latter is a common practice in Scandinavian countries) or in specific bags (e.g. in Italy plastic packaging is collected in semi-transparent bags).

When it comes to disposal, depending on the collection scheme, the consumer carries the segregated waste either to home bins (door-to-door collection for single-family houses), to shared bins (kerbside collection for multi-flat buildings) or to street containers (drop-off/bring scheme). Home bins are placed at the property boundary of the single-family house. Shared bins are placed in back yards or waste rooms of multi-flat houses and are used only by inhabitants of that building. Street containers are placed at specific locations, subject to the local waste collection network, and can be placed either above ground or underground under specific circumstances (e.g., historical city centres). They can have different shapes and sizes, depending on the fraction to be collected and the frequency of collection, respectively.

The term receptacles used in this report encompasses bags, bins and containers.

There is a great variety of receptacles used across Member States. Waste containers are designed following the ISO 13030 and EN 13071 standards. Typical volumes of waste receptacles used in the EU can be summarised as follows (data retrieved from stakeholders for Germany; see Annex 3), information from leaflets/websites of municipalities (LIPASAM, 2022), catalogues of providers of bins/containers (Sartori Ambiente, 2022; SULO, 2022) and from literature (Iriarte et al., 2009; Rives et al., 2010)):

- Bags (door-to-door collection)
    - Dry recyclables: 30 – 50 L
    - Bio-waste: 10 – 30 L
    - Residual waste: 30 L
- Bins (door-to-door/kerbside collection)
    - Home bins: 35 - 360 L
    - Shared bins: 550 - 2500 L
- Containers (drop-off schemes)
    - Street containers: 1100 - 2300 L
    - Underground containers/tanks: 2500 - 5000 L
    - CAS containers: 2300 – 3400 L

Labelling of waste receptacles

Labelling of waste receptacles refers to a visual sign or pictogram, which may include complementary text elements and/or colours, displayed on or near the waste receptacle.

Dedicated bags used in door-to-door collection schemes can be differentiated by colour and may include text and symbol labels. As bags can be easily manufactured and distributed to the citizens through existing channels, the economic impact connected to (re-)labelling of bags is considered marginal and is not included in the present analysis.

Along with bin colours, labelling of waste containers and bins (mostly with pictograms) is being implemented across different Member States as a mean to increase consumers' engagement in SWC.

Pictograms on receptacles can be stand-alone, providing already great support for the citizens when it comes to waste disposal. Nonetheless, ideally the labelling system on the containers/bins shall be paired with a matching system on products. This practice is however neither widespread nor harmonised in the EU, not even at national level.

The exception is the Nordic Countries (DK, FI, ISL, NO, SE), which have already implemented the Nordic Pictogram system, following a comprehensive labelling approach both on the products (voluntary) and on the containers (in general, mandatory).

Labelling of Packaging

Product labelling refers to text, colour and symbols placed directly on the packaging of a product.

Article 8 of the PPWD states that "packaging shall indicate for the purposes of its identification and classification by the industry concerned the nature of the packaging material(s) used on the basis of Commission Decision 97/129/EC. Those labels are targeted to the waste operators and, despite being harmonised, their use is still voluntary.

Article 13 in the PPWD requires Member States to provide consumers with additional information on the disposal of the packaging material. However, labels with pictograms addressed to consumers are not harmonised across Member States and are not common practice yet.

Examples and best practices across Member States are provided below in Chapter 3.1.

Waste streams and fractions

Labels are assumed to be introduced on packaging products, which can correspond to any of the main broad waste fractions within MSW according to the WFD: dry recyclables (i.e.: paper and cardboard; plastics; metal; and glass); biowaste; and mixed (residual) waste (e.g. composite materials, in some cases ceramics).

Labels will therefore be introduced for all these waste fractions, at a minimum.

Nonetheless, as pointed out below in 2.2, the proposed system will have to be compatible with finer distinctions of sub-fractions within these categories (typically: for glass, different glass colours; for paper & card: paper separate from cardboard; for biowaste: food waste separate from garden waste, etc.)

2.2 Features of labels to be assessed (products / waste receptacles)

Characteristics to be determined in legal text

In this study, it is assumed that the revised PPWD (and associated legislation) shall mandate the use of:

- EU-wide harmonised labels on packaging;
- EU-wide harmonised pictograms for waste receptacles for all standard waste fractions (dry recyclables, residual waste and bio-waste);
- Matching labelling systems on waste receptacles and products.

The pictograms to be applied on waste containers and bins shall include a clear and harmonised symbol representing the waste fraction to be deposited in the bin. The symbol may be paired with a matching text indicating the waste fraction in the local language of the Member State. The pictogram system may also contain a complementary text, including the description of the sub-fractions to be deposited, as well as e.g. instructions on preparing the waste (washing, reducing volume).

As it has been widely accredited that colour has a great visual impact for consumers, labels on waste bins receptacles shall follow a specific and EU-wide harmonised colour scheme, developed to be as close as possible to the current practices in the Member States (e.g., yellow label for plastic waste, etc.). This would not involve changes to the colours of the receptacles themselves.

Labels shall be designed in a way that flexibility towards future changes in the waste management system, for instance regarding commingling rules, can be ensured.

On the product side, there are more limitations when it comes to integrating the label, considering that the packaging is already designed with specific characteristics (e.g., size and colour). Hence labels shall be designed in a way that they can be easily accommodated to existing packaging design (e.g., mono-chromatic symbol of the waste fraction).

Characteristics to be determined in implementing act / further legislation

Specific features of the labels to be applied on products and waste receptacles will be determined in an implementing act or other secondary legislation.

The specifications to be developed shall include the actual design and features of the labels, taking into account the generic features established in the PPWD and the minimum requirements for labelling, and including elements such as:

- pictures / logos / symbols shape and outline
- size specifications (e.g., minimum size for each medium)
- colour specifications and contrast
- use of complementary text, abbreviations and language-specific elements
- location on the medium (packaging and waste receptacles) and visibility (e.g., on the lid, on the front of the container…).

Secondary legislation will also establish the fineness of the distinctions between waste fractions and the nomenclature to be used to designate waste fractions. For instance, it is anticipated that the high-level distinction used here (dry recyclables i.e. paper / metal / plastics / glass + bio-waste + residual) will be refined to accommodate sorting and collection systems which distinguish further within fractions (e.g., clear glass / coloured glass or clear glass / brown glass / green glass…). This nomenclature shall take into account existing definitions at EU level such as those established (among others) in the Waste Framework Directive, the Waste Statistics Regulation and Commission Decision 97/129/EC.

As part of an ongoing project to be carried out by JRC, an in-depth literature review on consumers' perception of sorting practices and the effectiveness of behavioural interventions to influence sorting behaviour will be carried out. It is envisaged that the proposed labelling specifications would be tested with targeted groups of consumers. The outcome of that project, along with possible further work on labelling, will support the drafting of the implementing act.

As a complement, in order to avoid confusion, the policy measure should also make clear that the only pictograms or symbols for recycling instructions to be placed on product packaging are the new EU harmonised pictograms (as these function in conjunction with the mirrored pictograms on waste containers/bins/bags) and excluding other potentially confusing symbols. In addition to the new EU harmonised pictograms on containers/bins, municipalities may retain other labels that provide different and additional information as long as the EU harmonised pictograms are not obscured or made redundant.

2.3 Parameters of proposed policy measures

The proposed policy measure (and its two variants) is described in detail in section 3.3.

In particular, the measure shall define the following elements:

- To whom the law is applicable (packaging producers, Member States, municipalities, waste management organisations…);

- The level of constraint: which elements are voluntary or mandatory, e.g., the presence of a label or, if a label is in use, that it shall be the EU harmonised one;
- The level of specificity (e.g., level of detail in defining waste fractions)
- The timeline for introduction (transition phase, etc.)

3. Assessment of the current status and business-as-usual scenario

This section describes the current usage of labels on waste receptacles in EU MS, including whether these are matched to labels on products. It also discusses the likely future evolution of the current situation, in order to compare proposed measures against a common 'business-as-usual' baseline. Assumptions for this baseline encompass different dimensions, which will be analysed one by one:

- what is expected for the evolution of MS policies with respect to labelling,
- what is expected in terms of the physical generation and management of municipal solid waste (MSW),
- what is the stock of waste receptacles employed in the EU in 2025, the assumed starting year for the implementation of the harmonised EU labelling (EU-wide implementation can take 3 or 4 years, but the number of receptacles does not significantly change from one year to the next).

3.1 Labelling practices for waste receptacles and products

MS are following multiple approaches of how pictograms, labels, colour schemes and similar measures are used to facilitate waste sorting. Concerning colours, all MS have assigned bin colours to the different waste fractions, but those colours are country-specific and have not been harmonised across the EU. For example, for the plastics fraction the most used colour for the bin is yellow (16 countries out of 27), but some countries use blue (e.g., Malta, Greece, Cyprus), or orange (e.g., the Netherlands); for the glass fraction, green is the most widely used colour (19 countries out of 27), but also yellow (e.g., the Netherlands) or brown (e.g., Malta) are in use.

The use of pictograms on bins/containers for identifying the waste fractions to be disposed of is a widely used practice across MS, but again not harmonised. Only 6 MS do not make use of pictograms, indicating only the fraction name on the coloured bin/container. The current situation is summarised in Figure 2 below.

Most pictograms correspond to images or icons of representative products that should be deposited in that bin. Others include some form of more elaborate sorting instructions and may include information on the products that should not be deposited in that bin (e.g., Portugal). This information may be printed directly on the label or accessible through a QR code.

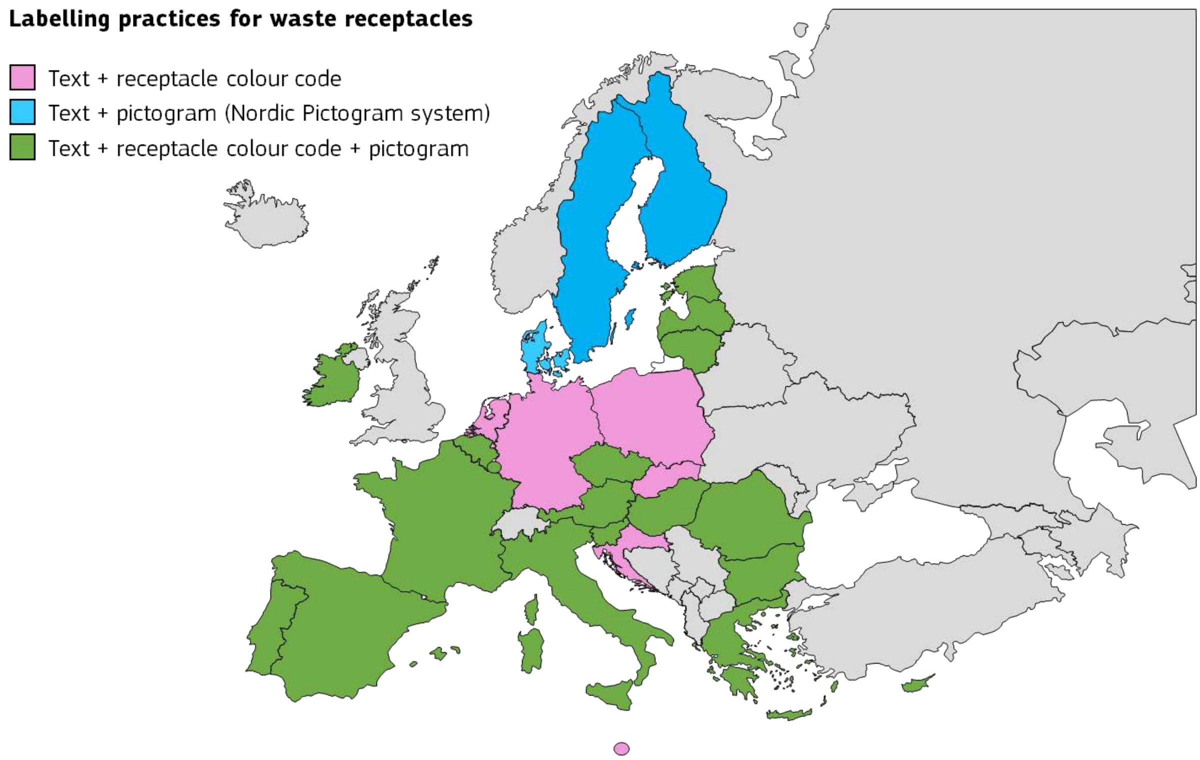

Figure 2: Mapping of existing labelling practices for waste receptacles within the EU

Product label schemes that provide citizens information on the correct waste disposal have been adopted at different levels within the EU (see Figure 3). France and Italy have imposed obligations for environmental labelling of packaging including instructions for disposal starting in 2022 and 2023, respectively. In France (CITEO, 2022) the mandatory harmonised label must include: the Triman sorting logo, the text/image block, the packaging components (text and/or pictogram), and the target stream (at least a pictogram). Similarly, in Italy (CONAI, 2022) the label must include information about the packaging disposal according to the material stream (e.g., plastic, glass) as well as the short text that calls for separate collection and following municipal guidelines. The regulation also recommends including information on the correct preparation of waste (e.g., emptying the package).

Apart from France and Italy, the remaining MS do not have specific legislation in place, but several voluntary schemes are present across the EU, usually promoted by national waste associations and EPR organizations. The most representative system is the "Nordic Pictogram" employed in the Scandinavian countries (Denmark, Sweden, and Finland[10] in the EU; as well as Norway). It encompasses almost 100 pictograms for different waste types consisting each of three components (symbol, colour and fraction name), which can be used by municipalities and companies to label containers in recycling centres and recycling stations, residential and municipal waste containers, and for labelling packaging (Nordic Council of Ministers, 2021). The colour code of this system is given to the pictogram itself, while the bin/containers are black. The pictogram creates a visual link between the packaging and the waste bin/container. It is also under consideration in the Baltic countries (i.e., Estonia, Latvia, and Lithuania).

Other countries present voluntary schemes promoted by the EPR organization related to The Green Dot, which only focuses on the colour of the bin (i.e., Spain (Ecoembes, 2022b) and Cyprus (Green-dot-Cyprus, 2022)), or can include on top a pictogram (i.e., Lithuania (PTO, 2022)), or the material and specific information on the correct separation (i.e., Portugal (Pontoverde, 2022)), or even an extended version including packaging element, icon and fraction name (i.e., Belgium and the Netherlands (FostPlus, 2022)). Besides, in the Netherlands, the Institute for Sustainable Packaging (KIDV) (KIDV, 2021) promotes the use of pictograms in black and white that helps the consumer to sort the packaging waste based on the material and the bin where it should be placed. In addition, the Ministry of Infrastructure and Water Management of the Netherlands has developed its own set of logos for waste separation based on colours and pictograms (initially not intended to be printed on products) (KIDV, 2021). The *On-pack recycling label* (OPRL) scheme, designed by a UK organisation and recognised by the UN Environment Programme as a best practice (UNEP, 2020), has developed packaging labels for reuse and recycling. Labels of this scheme are placed on the packaging of a wide range of products, such as soft drink caps, bread bags, plastic toiletry bottles etc. Recently, the OPRL has released new refill labels for specific packaging materials that were designed to be reused up to 10 times without posing a risk to the consumer (e.g., hand-soap bottle). In Ireland, similarly to UK, there is a voluntary system, promoted by an EPR organization (Repak, 2022), based on directional labels (i.e., providing information on the action to be performed by the citizen indicating if the product is widely recycled, need to be checked, or not yet recycled).

Finally, in some countries such as Austria and Germany, there are some marginal initiatives with more partial coverage, driven by associations and retailers (such as Aldi) (DVI, 2022) that place labels on their own products instructing the consumer to separate materials and indicating the correct bin colour for disposal. More product labelling schemes might exist in other MS, but for the sake of conciseness the cited examples are a sufficient illustration of the current situation.

[10] The system was launched in 2017 in Denmark, in 2020 in Sweden, and it is planned for Finland in 2022.

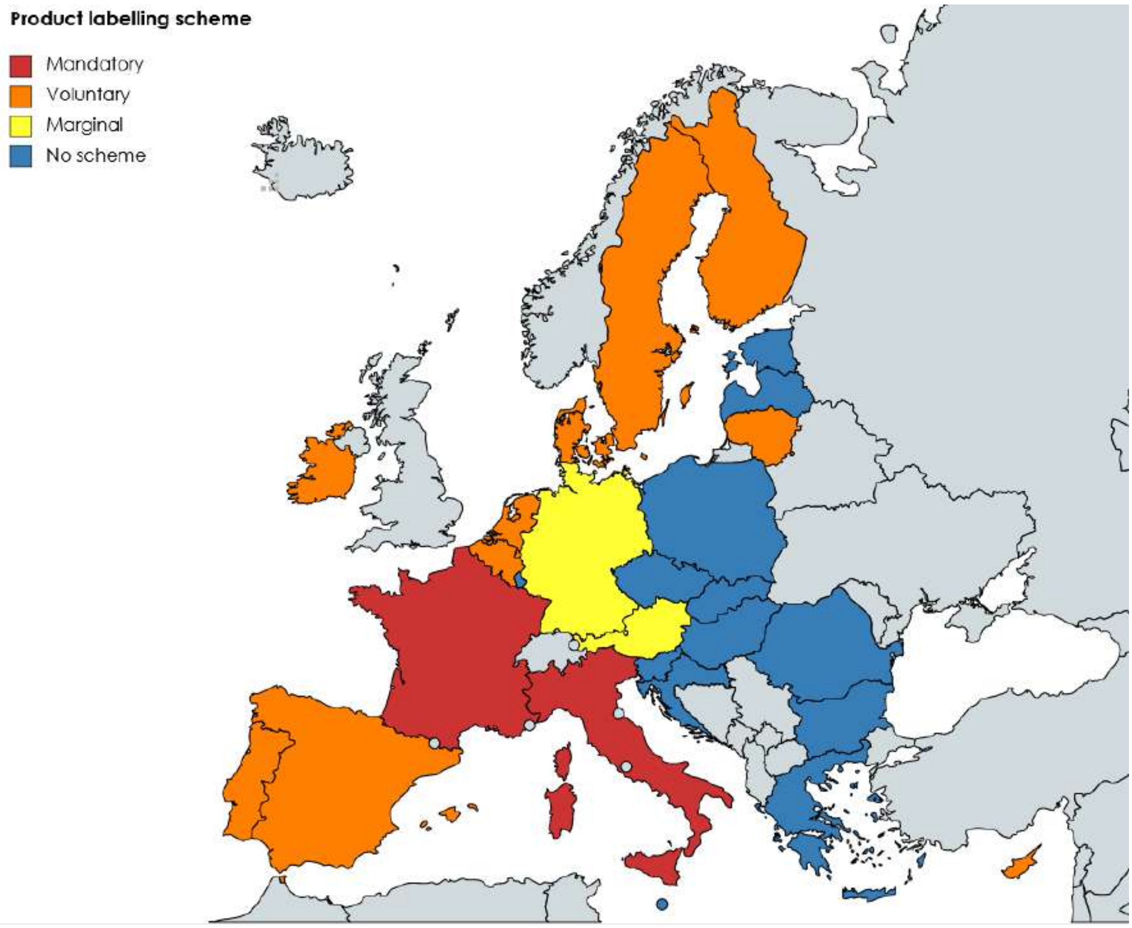

Figure 3: Mapping of existing product labelling schemes within the EU. JRC own elaboration, based on various sources.

The examples show that MS, in order to achieve recycling targets, are implementing labelling schemes on packaging (on-pack labelling) and waste receptacles in different and uncoordinated ways. From the two mandatory schemes in France and Italy, it can be concluded that certain features of the developed labels are common, yet they are far from being harmonised, and the match between labels on products and waste receptacles is mostly done by means of colour coding and textual waste collection guidelines. The waste management and packaging sector, anticipating the possibility of mandatory schemes, has come up with voluntary schemes that differ from country to country. This leads to a fragmentation on the labelling systems across the EU that might lead to confusion on the citizens' side and to lower recycling rates, and most importantly creates a considerable Single Market barrier with additional cost burdens for firms and, eventually, citizens. So far, the only system covering more than one MS and proposing a direct visual link between the packaging and the waste receptacle is the Nordic Pictogram system.

In sum, the analysis of the current situation suggests that without an EU regulatory intervention, MS will continue to develop their own waste receptacle and product labelling schemes, without convergence towards a potentially more efficient harmonised system. The only scheme with such an objective is the Nordic Pictogram system embraced by several northern EU countries.

3.2 Baseline (Business-as-usual development) of MSW generation and collection

Main assumptions and methodologies supporting the baseline projection

The baseline is based on data of MSW generation and management for EU-27 Member States reported for year 2018. It is an extrapolation of the *status quo* up until 2030[11], assuming no further policy changes. The

[11] further results up to 2040 are reported in Annex 8

impact of the policy options will be analysed based on the assumption that they will not become effective before year 2024.

The amounts of waste generated for each Member State (MS) is based on data assembled by Eurostat (both *env_wasgen* and *env_wasmun* series) and data collected by the European Environment Agency in its latest Early Warning Reports (EWRs) for 2019. The collected amounts and capture rates (also known as collection rates) of paper and cardboard, glass, metal, plastic, bio-waste, textile waste, wood waste and undifferentiated waste were based on the EWRs as these represent the most up-to-date data available. As for the other waste flows (i.e. chemical and medical waste, rubber waste, waste containing PCB, discarded equipment, batteries and accumulators, bulky waste, and construction and demolition waste) collected amounts were based on *env_wasgen* statistics for each Member State by selecting "Households" among the NACE activities. Within the list of NACE activities, it is possible to select "Services (except wholesale of waste and scrap)". This represents both services generating waste similar in composition to the one of households, but also other services, such as aviation, that do not contribute to MSW and, therefore, cannot be considered. Consequently, the total amount of MSW generated by services (Total MSW_S) in a specific MS was calculated as the difference between the total amount of MSW generated by the MS (Total $MSW_{env,wasmun}$) and the total amount of MSW generated by households in the MS (Total $MSW_{env,wasgen,HH}$) (Equation 1).

$$Total\ MSW_S = Total\ MSW_{env,wasmun} - Total\ MSW_{env,wasgen,HH}$$

Equation 1

The total amount of MSW generated by services was then disaggregated assuming that its composition is the same as that of household waste as they are assumed to be similar in composition. As an example, if for households it was found that paper and cardboard waste contributed by 18% to the total amount of MSW generated, the same share was assumed for services. Notice that according to (EUROSTAT, 2010) bulky waste is included in the undifferentiated waste. To calculate the share of bulky waste on the total generated MSW, the statistics reported by (ISPRA, 2021) were used (specifically, by considering the statistics reported in Figure 2.7 for the total and the segregated amounts of MSW in Italy, and Table 2.8 for bulky waste collected). Based on this we estimated a percent of bulky waste in the MSW equal to 2.70%. Note that the share of bulky waste on the total generated MSW for Italy was extrapolated to all MSs, as specific information on this waste stream is not available for each individual country.

It is important to note that the waste streams refer to separately collected waste, including the targeted material (e.g., magazines in paper and cardboard waste) and possible impurities (e.g., plastic in paper and cardboard waste). The share of targeted materials and impurities depends on the collection scheme implemented. Based on the EWRs, it was possible to define for each MS the most common collection schemes (i.e. whether separate or commingled collection is implemented for paper and cardboard, plastic, glass, metal, beverage cartons, and bio-waste in the MS; see Annex 1) and to estimate the corresponding shares of targeted materials and impurities based on information retrieved from literature (e.g. out of the total paper and cardboard waste reported as collected, purity rate is 90% and 10% are impurities).

The collection scheme in place influences the share of targeted materials and impurities in separately collected waste, but also the composition of the undifferentiated waste stream, where great amounts of recyclables and bio-waste can be found due to misplacements. In order to identify what and how much of targeted materials, impurities and misplacements can be found in the different streams, compositional analyses are required but are currently lacking.

To our knowledge, one of the few recent studies that performed a detailed compositional analysis, accounting for 52 material fractions of collected waste and undifferentiated waste, is the one of (Edjabou et al., 2021). The study by Edjabou et al. (2021) focuses on a handful of Danish municipalities with a defined collection scheme and for which it is possible to calculate the share of targeted materials, impurities and misplacements. Based on the information provided in Edjabou et al. (2021), it was possible to identify the composition of the targeted materials and impurities. For more details on the material fractions included and the collection schemes considered in the study, please refer to the original publication. It is important to note that the shares of targeted materials and impurities change according to the collection scheme implemented in a MS, while the fractional composition of the two is kept constant across MS.

Further, the paper of Edjabou et al. (2021) reports the compositional analysis of undifferentiated waste; however, this depends on the collection scheme employed and, therefore, needs to be defined for each MS. The values reported in Eurostat under the *env_wasgen* statistics and the collected amounts reported in the EWRs refer to waste collected inclusive of possible impurities (CIMP) and, therefore, do not represent the total generated amount. However, knowing the capture rates (CR) of a specific waste stream and per MS (Annex 2), it is possible to calculate the waste generated (G), as it is illustrated in Equation 2 for the case of paper and cardboard waste (P&C).

$$CR_{P\&C} = P\&C_{CIMP}/P\&C_G \rightarrow P\&C_G = P\&C_{CIMP}/CR_{P\&C}$$ *Equation 2*

Further, by combining the Eurostat and EEA data, together with the information on the collection schemes in a MS and the disaggregation of the waste streams into targeted materials and misplacements, it is possible to define how much of targeted materials and impurities are found in, for example, separately collected paper and cardboard, but also the misplacements of, for example, paper and cardboard in the separately collected plastic waste. Yet, the quantification of how much, for example, paper and cardboard ends up in the residual waste is still unknown. This can be defined using Equation 3. Indeed, considering the case of paper and cardboard waste, it is known how much of paper and cardboard is generated in total ($P\&C_G$, applying Equation 2), the amount of targeted material separately collected ($P\&C_C$) and the amount of misplacements of paper and cardboard in separately collected bio-waste, plastic, glass, and metal ($P\&C_M$), while the only unknown value is the amount of paper and cardboard found in the residual undifferentiated waste ($P\&C_R$). It is important to note that at this stage it has been assumed that the amounts reported of rubber waste, wood waste, textile waste, discarded equipment, batteries and accumulators waste, bulky waste, ceramics, and construction and demolition waste are *without* impurities.

$$P\&C_G = P\&C_C + P\&C_M + P\&C_R \rightarrow P\&C_R = P\&C_G - P\&C_C - P\&C_M$$ *Equation 3*

By applying Equation 3 to each waste stream, the total amount of paper and cardboard waste, glass waste, metal waste, rubber waste, plastic waste, wood waste, textile waste, discarded equipment, batteries and accumulators waste, bio-waste, bulky waste, ceramics, and construction and demolition waste ending up in the undifferentiated waste can be quantified ($RES_{rec+bio}$). By using Equation 4 it is then possible to quantify the amount of undifferentiated waste corresponding to other non-recyclable material flows (e.g. animal excrements, sanitary products, etc.) (RES_{other}), as the total amount of undifferentiated waste is known and corresponds to the (re-elaborated) data (RES_{Total}).

$$RES_{other} = RES_{Total} - RES_{rec+bio}$$ *Equation 4*

Issues when implementing the methodology for estimating waste generation

In Eurostat, for some MS, it is recorded that the waste collected is zero for specific waste streams. Applying Equation 2 would lead to a waste generation equal to zero, despite possibly having some mass ending up as misplacements in other waste streams or in the residual waste stream (following our methodology as explained above). When this occurred (for Cyprus, Poland, Portugal, and Malta), the waste generation was calculated as reported in Equation 5, where paper and cardboard waste is provided as an example.

$$P\&C_G = P\&C_R + P\&C_M$$ *Equation 5*

Another issue was related to capture rates. The capture rates utilised were mainly based on the information provided in the EEA's assessments in support of the Early Warning Report (EWR). However, in some cases, using the capture rates of the EWRs led to negative results when calculating the amounts of other non-recyclable fractions with Equation 4. Therefore, capture rates had to be changed according to the hierarchy presented in Figure 4.

Figure 4: Hierarchy of choices for modifying the capture rates when negative results are obtained owing to data inconsistencies.

If the capture rates reported in the EWRs lead to negative results when calculating Equation 5, then data retrieved from the literature were utilised. These were selected based on the collection scheme employed in a specific MS and waste stream. If the results of Equation 5 were negative, then information related to the capital of the MS reported in (Seyring et al., 2015) was used instead. If this, again, lead to negative results, the average capture rate of EU27 was employed. As last option, the capture rates were changed manually until the mass balance was closed.

Finally, in the EWRs of Poland and Romania, no information was provided on the capture rates of neither dry recyclables nor bio-waste. For Poland, a description of the most common collection scheme in place was provided in the report. Based on this and on literature, it was possible to assign capture and impurity rates for paper and cardboard waste, metal waste, glass waste, and bio-waste, while for plastic waste criteria 3 of the hierarchy shown in Figure 4 was applied. Notice that collected wood waste for 2018 was set to zero as it led to negative results and the data recorded for the previous years was zero tonnes. For Romania, information on capture rates for the most common collection schemes in place was provided in the EEA's assessments. Capture rates for paper and cardboard waste, metal waste, glass waste, and plastic waste were set by utilising criteria 3 (i.e., information retrieved from (Seyring et al., 2015)) of the hierarchy in Figure 4 in combination with criteria 5. Finally, with respect to bio-waste, no quantitative information was available neither in the EWRs nor in (Seyring et al., 2015). In the EWRs it is only stated that a low percentage of citizens are covered by separate collection of bio-waste. Therefore, it was decided to set Romania's capture rate of bio-waste equal to the lowest found among all MSs, i.e., Greece.

Waste generation, collection and treatment projections

Future total waste generation data are estimated with a linear econometric model. The model is calibrated on Eurostat's reported GDP, population, and generated waste data for each MS between 1995 and 2050. The model uses Eurostat's projected GDP and population data, for yeas 2021 to 2050 from the EU Reference Scenario 2020 (European Commission, 2022b).

The projected total amounts of waste were disaggregated into the specific waste streams based on the estimated composition of year 2018 for each MS. The estimation of the development of the shares of packaging waste generation is based on projections from (Eunomia and COWI, 2022), while the other waste streams are decreased proportionally. The collection rates of paper and cardboard, plastic, glass and metal were projected by applying an increases derived from projections of recycling rates for dry recyclables provided by (Eunomia and COWI, 2022). It is assumed that when recycling rates increase/decrease the collection rates should proportionally increase/decrease. Note that the collection rate for bio-waste was assumed to be constant from 2018 to 2040. Table 1 provides an overview of the generated municipal solid waste in EU27 for year 2025.

Table 1: Waste generated in EU27 in year 2025 (as example). Notice that beverage cartons and ceramics are assumed not to be separately collected.

Waste stream	Generated [M tonne]	Collected [M tonne]
Chemical and medical waste	0.3	0.3
Metal waste	9.1	3.5
Glass waste	17	11
Paper and cardboard waste	37	22
Rubber waste	0.2	0.2
Plastic waste	25	10
Wood waste	16	14
Textile waste	6.1	2.2
Waste containing PCB	0	0
Discarded equipment	8.1	3.1
Batteries and accumulators waste	0.3	0.14
Bio-waste	73	34
Undifferentiated waste	19	114
Beverage cartons	2.2	-
Bulky waste	6.2	6.2
Ceramics	0.6	-
Construction and demolition	6.7	6.7
Total	227	227

As for waste treatment and recycling, it was assumed that recycling of dry recyclables would increase according to the percentage increases estimated by (Eunomia and COWI, 2022), bio-waste recycling would remain constant (note that the share of composting, anaerobic digestion, and anaerobic digestion followed by composting is assumed to be constant and is based on the statistics of (ECN, 2019)), while the share of residual waste going to landfilling and incineration is projected to 2040 with a logarithmic regression based on the historical trends reported for the variable *env_wasmun* in Eurostat. Finally, it is considered that from 2026 on, incineration is subject to the ETS system.

Quantification of waste receptacles

To estimate the number of receptacles used in the EU27 in 2025, which will be the second year of implementation in the policy options and the earliest year that would be affected by an EU labelling policy, the point of departure is the total annual waste generation of each waste stream subject to separate collection. To take into account waste that does not enter the regular municipal collection (Deposit Refund Schemes), Equation 6 to Equation 8 are applied. The waste streams included in this calculation are reported in Table 1.

For each individual MS we use the following parameters: waste generated by households (corrected by subtracting the portion captured via DRS; Equation 7), number of households (distinguishing between multi- and single-family houses), collection frequency, bulk density of the waste stream and type of containers used (i.e. volume of 35L, 770L, 1100L, etc.). The type and number of waste streams typically collected separately in each MS is estimated based on the EWRs, where a qualitative description of the collection systems in place in each MS is available. However, given the qualitative form of this information, a simplification was made by assuming for each MS a reference type of collection system (see Annex 1).

$$N° \; receptacles \; with \; volume \; i \; for \; waste \; stream \; j = \frac{W_{j,collected\ receptacle} \cdot HH \cdot share\ receptacle_{\ i}}{\rho_j \cdot Vreceptacle_i \cdot collection\ frequency_j} \; [receptacle\ with\ vol\ i]$$

Equation 6

$$W_{j,collected\ receptacle} = W_{j,collected} - W_{j,generated} \cdot share\ to\ DRS_j \; \left[\frac{kg}{ab}/yr\right]$$

Equation 7

Where

$W_{j,collected\ receptacle}$: waste stream *j* as collected by households after subtracting DRS (kg/household/yr)

Collection frequency: number of emptying per year for waste stream *j* (emptying/yr)

HH: total households in the MS (number)

ρ_j: bulk density of the waste stream *j* (kg/L)

Share receptacle$_i$: share of households served with a specific receptacle volume *i* (e.g. 35L) (%)

$V_{container}$: receptacle vol *i*, empty (i.e. volume available after each emptying) (L·emptying/receptacle). For the calculation, the lower value from the bandwidth of receptacle volume was considered (e.g. 35 L for the containers with a volume of 35-50L).

$W_{j,collected}$: waste stream *j* collected (kg/household/yr)

$W_{j,generated}$: waste stream *j* generated (kg/household/yr)

Share to DRS$_j$: share of the waste stream *j* captured via DRS (kg/household/yr)

The share of waste captured by DRS was estimated for glass, PET bottle, HDPE bottle, aluminium cans and steel cans, based on the product between the capture rate reported by stakeholders (% of generated *j*; see Annex 2) in each MS and the share of each product to be returned via DRS in the waste stream *j*.[12] The frequency of collection was assumed as 52 times/yr for all streams, except for residual waste and biowaste in southern EU Member States (Croatia, Greece, Italy, Malta, Portugal, Spain), and for countries with specific

[12] Glass bottle: 89% of glass waste stream; PET bottles: 12% of plastic waste stream, HDPE bottles: 5% of plastic waste stream; aluminium cans: 13% of metal waste stream; steel cans: 6% of metal waste stream; following Riber et al., 2009

information on the frequency of collection (Austria, Slovenia), for which the frequency of biowaste and residual waste collection was raised to 104 times/yr.

The share of households served with receptacles of a given volume (parameter *Share receptacle*) is based on real data available for Germany (VKU, 2020). Using this, we distinguish between receptacles for single-family (bags, 35-60L up to 240-360L; see Annex 1) and multi-family (550-770L, 1100L and 2500L; see Annex 3). The volume distribution for all comingled streams, single stream plastic and metal waste was assumed equal to that of light weight packaging waste (LWP; Annex 3). As receptacle volumes for single stream glass waste was not available in the German data, the same distribution as for residual waste was assumed. The resulting total distribution of volumes was then extrapolated to all MS, taking into account the specific shares of single- and multi-family households in each MS (Equation 8).

As for the remaining parameter used in the calculation: the number of households, single- and multi-family houses for each of the 27 MS was retrieved from EUROSTAT (Eurostat, 2022) and based on the data for year 2019, which was the last year available. The figures for the EU27 MS populations were taken from the projections for year 2025. The bulk density of the waste streams was estimated based on the figures reported in Lagerkvist et al., (2010).[13]

$$share\ receptacle_i = SF_{MS} \cdot share\ receptacle_{i,SF} + MF_{MS} \cdot share\ receptacle_{i,MF}$$

Equation 8

Where:

SF_{MS}:	share of single-family households in the MS (%)
MF_{MS}:	share of multi-family households in the MS (%)
$share\ receptacle_{i,\ MF}$:	share of receptacle *i* in multi-family MF households (%)
$share\ receptacle_{i,\ SF}$:	share of receptacle *i* in single-family SF households (%)

The total sum of receptacles required for the specific waste stream *j* in each MS equals (Equation 9):

$$No\ receptacles\ for\ waste\ stream\ j = \sum_i No\ receptacles\ with\ volume\ i\ \ [sum\ of\ receptacles\ for\ waste\ stream\ j]$$

Equation 9

Finally, the total sum of receptacles across all waste streams in each MS comes down to (Equation 10):

$$No\ receptacles\ for\ all\ waste\ streams\ in\ each\ MS = \sum_j No\ receptacles\ for\ waste\ stream\ j\ \ [sum\ of\ receptacles\ for\ all\ waste\ streams]$$

Equation 10

The resulting number of receptacles used across all 27 MS is reported in Table 2. Note that both the total number of containers/bins reported in the table as well as the total number of containers/bins for packaging waste exclude waste collection bags.[14]

We finally estimated a range of min-max variation around the computed values by varying selected parameters such as the relative shares of receptacles of different volumes and the collection frequency. Specifically, we performed calculations by i) assuming 240L containers/bins for single-family and 1100L for multi-family; ii) assuming 110L containers/bins for single family and 1100L for multi-family; iii) assuming a collection frequency for biowaste and residual waste for all MS equal to 52 times/year and for dry recyclables 26 times/year instead of 52 times (i.e. once every second week; any stream, comingled or single). These three individual sensitivity analyses yielded the min-max range reported in Table 2.

[13] In kg/m^3: residual waste 120, biowaste 315, glass 360, metal 55, paper and cardboard 200, plastic 85, paper and cardboard/beverage cartons 200, metal/plastic 85, metal/plastic/beverage cartons 85, metal/plastic/paper/beverage cartons 143, metal/plastic/paper/beverage cartons/glass 223, other 223.

[14] As said before, given that bags can be very cheaply manufactured and distributed to citizens, the economic impact associated with the labelling of bags is considered to be negligible, and hence ignored in the impact analysis.

Table 2: Estimated number of waste containers for MSW collection in EU27, in million units. BC: beverage carton waste; BW: biowaste; CAS: containers for waste fractions metal, plastic, paper and cardboard, plastic, glass, and biowaste at civic amenity sites (CAS); GL: glass waste; M: metal waste; PC: paper and cardboard waste; PL: plastic waste; OT: other waste; RES: residual waste. The total number for EU27 does not include bags. The number of waste containers for packaging waste is calculated as the sum of all containers (excluding bags) minus RES, OT, and CAS.

	RES	PC&BC	M&PL	M&PL&BC	M&PC&PL&BC	M&PC&PL&BC&GL	BW	GL	PA	PL	M	OT	CAS
Total bags	0.00	0.00	0.91	5.14	5.32	0.00	0.00	0.00	0.03	0.49	1.31	0.00	0.00
Total containers/bins 35-50 L	1.17	0.00	0.00	0.00	0.00	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.00
Total containers/bins 60-80 L	29.07	0.00	0.00	0.00	0.00	0.10	2.05	1.13	0.02	0.00	0.00	0.00	0.00
Total containers/bins 110-120 L	27.87	0.10	0.07	0.42	0.43	0.10	3.54	1.08	0.84	0.04	0.11	0.00	0.00
Total containers/bins 240-360 L	12.21	0.28	0.22	1.25	1.30	0.04	1.81	0.47	2.40	0.12	0.32	0.00	0.00
Total containers/bins 550-770 L	1.57	0.01	0.01	0.06	0.03	0.01	0.03	0.07	0.07	0.00	0.01	0.00	0.00
Total containers/bins 1100 L	4.45	0.07	0.09	0.61	0.25	0.03	0.03	0.19	0.57	0.03	0.09	0.00	0.00
Total containers/bins 2500 L	0.26	0.00	0.00	0.01	0.00	0.00	0.30	0.01	0.01	0.00	0.00	0.52	0.11
Total containers/bin per waste stream	76.59	0.47	0.39	2.35	2.00	0.29	7.83	3.00	3.91	0.20	0.53	0.52	0.11
Total containers/bins													98.19 (55.81-111.85)
Total containers/bins for packaging waste													13.25 (12.37-26.39)

Plausibility check of estimated number of EU waste receptacles

Various plausibility checks were performed to compare the number of container/bins quantified by JRC with publicly available data from extended producer responsibility schemes and municipalities (e.g., Vienna). The check was on the one hand performed by comparing the estimated number of container/bins for individual packaging fractions with real data available for selected countries, and on the other hand by deriving an alternative estimate for the EU-wide number of container/bins for all packaging fractions.

The Portuguese EPR scheme Ponto Verde publishes detailed data on the number of civic amenity sites (CAS) and container/bins for dry recyclables collection for each municipality in Portugal (e.g., paper and cardboard, lightweight packaging, glass: Ponto Verde, 2022). Based on this data, the 25% and 75% percentile and median number of containers/bins were calculated for Portugal. As listed in *Table 3*, the number of bins estimated by JRC are closely in line with the numbers of bins derived from the report of Ponto Verde.

Table 3: Number of waste receptacles (excluding bags) in Portugal, estimated based on data published by Ponto Verde (2022), and – in the last column – comparison with the JRC main estimate.

Type of packaging waste	Portuguese EPR scheme			JRC model
	Number of bins (25 % percentile)	Number of bins (75 % percentile)	Number of bins (median)	Number of bins JRC (calculation)
paper & cardboard	36,181	60,807	40,446	57,100
lightweight packaging (plastic, metal, beverage carton)	8,508	123,342	40,446	58,200
glass	10,679	152,427	51,188	67,700

With respect to CAS, in Portugal there are 30.000 – 45.000 inhabitants per CAS. In comparison, JRC assumes a somewhat lower ration of 20,000 inhabitants per CAS.

Due to different collection approaches across the EU27, the numbers reported by EPR schemes (AGR, 2017; Ecoembes, 2022a; Ecovidrio, 2022; Green Dot, 2022; SloPak, 2022) will generally differ from the number of bins calculated by the JRC. But Table 4 clearly shows that the estimates of the JRC model are of the same order of magnitude as the reported number of bins for collection in the different EPR schemes. For countries in which the collection of dry recyclables is mainly performed by bring systems (e.g., Slovenia), the JRC calculation overestimates the number of bins. The reason for this is that the JRC calculation is based on the assumption that in particular single-family households are provided with small containers for each fraction. However, this is not the case in Slovenia, where even collection for single-family households is organised by means of bring systems and thus with larger but fewer bins/containers.

Table 4: Comparison of number of waste receptacles actually used in EPR schemes and estimated by JRC.

Type of packaging waste	EPR scheme (country)	Number of bins (EPR scheme)	Number of bins (JRC model)
paper & cardboard	Ecoembes (ES)	220,233	232,700
	SloPak (SI)	12,109	77,100
light weight packaging (plastic, metal, beverage carton)	Ecoembes (ES)	404,701	366,600
	SloPak (SI)	12.109	36,200
glass	AGR (AT)	68,000	64,670
	Ecovidrio (ES)	230,000	157,600
	Green Dot (DE)	300,000	551,100
	SloPak (SI)	12,109	15,300

For three countries, namely Portugal, Spain and Slovenia, full data on the number of bins for all dry recyclables is available. That enables an extrapolation of container/bin numbers from each of these countries to the EU27 aggregate. The results are:

- Portugal: 5.74 million containers/bins (from 4.85 to 8.43 million containers)

- Spain: 8.07 million containers/bins
- Slovenia: 8.25 million containers/bins
- JRC main estimate: 13.25 million containers/bins (from 12.39 to 26.39 million containers/bins)

The extrapolation exercise suggests that the JRC calculation may overestimate the actual numbers of bins/container for EU27. One reason for the difference is that the collection of dry recyclables in the three countries considered is mainly organised by a bring collection system. However, the JRC calculation methodology applies the same container/bin distribution to every country. Therefore, container-intensive door-to-door collection is also being assumed for countries that hardly use this collection approach. This results in an overestimation of container/bins.

Finally, the City of Vienna (1.9 Mio. Inhabitants, high population density (4,660 inh./km²), 10 % single family houses) has published the total numbers of container/bin used in 2018 for residual waste, biowaste and dry recyclables collection (442,655 container/bins, (VKU, 2020)). Extrapolation of these parameters to EU27 results in 102.7 Mio container/bins, compared to 98.19 Mio container/bins from the JRC main estimate.

3.3 Definition of the proposed measure: harmonised system of pictograms on waste receptacles (advanced Nordic Pictogram system)

The assessed policy measure is an EU-wide mandatory use of a harmonised system of Nordic pictogram style labels that indicates the waste types that are to be disposed of in each container/bin (of various sizes) and in bags. This measure is analysed against the backdrop of the Commission's currently elaborated revision of the PPWD, which contemplates a mandatory pictogram labelling on packaging, indicating into which bin the packaging should be placed for correct waste sorting. For the analysis presented here it is assumed that matching labels on product packaging are implemented.

The cost and benefits of harmonised pictograms on EU waste receptacles are assessed for two variants, or *sub-measures*, of implementation, which only differ in terms of their timing. An overview of the timeline for both variants is shown in Figure 5. Both sub-measures 1 and 2 assume that the initiative enters into force in year 2024. In the first year, the harmonised label is developed by a European Institution[15] along with the new pictograms to be placed on products. The label development includes stakeholder consultation and testing the new pictogram labels.

Sub-measures 1 and 2 assume that municipalities begin placing the new harmonised labels on all receptacles (containers, bins and bags) for packaging waste fractions, such as glass and plastic, as well as residual waste in the second year, i.e., starting in 2025. Pictograms are assumed to be used for all waste fractions because packaging is collected by material categories. The material categories collected also encompass non-packaging waste items and residual waste. Sub-measure 1 assumes the full transition to take four years in total, 2024 to 2028. Sub-measure 1 assumes that it takes municipalities three years to replace existing labels or add the new harmonised pictogram labels to all existing waste containers for packaging materials and residual waste. Under Sub-measure 1, municipalities label approximately one-third of total containers per year.

Sub-measure 2 assumes the full transition takes five years in total 2024-2029. Sub-measure 2 assumes that it takes municipalities four years to replace existing labels or add the new harmonised pictogram labels to all existing waste containers/bins for packaging materials and residual waste. Under Sub-measure 2, municipalities label approximately one-fourth of containers/bins per year.

[15] These activities could be coordinated by a European Institution, e.g., the European Commission itself or one of its Agencies.

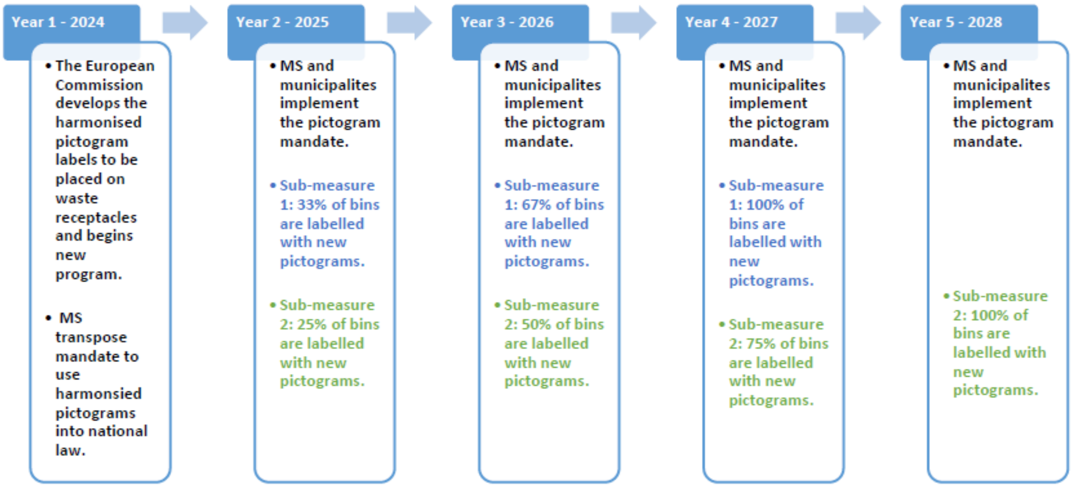

Figure 5: Timeline of Implementation Sub-measures for new EU Harmonised Pictograms for Waste Containers

Key assumptions on the expected effects on waste sorting

The introduction of a new harmonised labelling scheme at EU level is expected to generally improve citizens' capacity to correctly sort waste, i.e., to increase capture rates and purities in the separately collected waste fractions. However, depending on the current labelling and collection practice of each MS, the potential for improvement is not the same (see mapping shown in Figures 2 and 3). For modelling purposes, the following assumptions are made:

- For those countries with mandatory schemes of matched product-receptacle labels (i.e., France and Italy), it is assumed that all products are labelled and give sufficient information to citizens on how to properly dispose of the waste. Thus, it is assumed that the change towards a new harmonised labelling system does neither enhance nor diminish the sorting effectiveness.
- For those countries with voluntary schemes in place (e.g., those with Nordic Pictograms), since there is no comprehensive information available on the quantity of products that are currently covered, it is assumed that the existing labelling scheme is already a good and well-functioning practice, and that therefore the same assumption of 'no improvement' as in the case of mandatory scheme is made. This is a conservative assumption, made to avoid an overestimation of the measure's benefits.
- For those countries with no scheme in place, it is assumed that a new labelling system will improve the sorting effectiveness since it will be easier for citizens to separate and sort their waste correctly. For those countries with marginal schemes in place (i.e., Austria and Germany), it is assumed that the number of products covered by them is reduced (also because the revision of the PPWD envisages removal of confusing labelling), and thus the same assumption as for countries without scheme is made.

From experiments and experiences reported in the literature, it can be concluded that stringent communication and sorting instructions result in more waste being separately collected and higher purity of separated waste fractions, even though the exact quantification of the effect is difficult. Some studies in the literature have estimated the impact of sorting instructions on separate collection in general, including with labels using pictograms, but not specifically only for the latter. For the sake of simplicity, JRC analysis assumes that the effect on sorting of labels on waste receptacles will be similar to that of any other form of written sorting instructions provided to citizens.

It is important to acknowledge that the isolated impact of the labelling measure is practically impossible to obtain, since labelling is generally implemented in combination with other measures such as communication campaigns, provision of new bins or bags and complementary regulation such as changes of waste fees and taxes. Thus, for the purpose of this analysis, JRC relies on scientific/technical studies on the effectiveness of sorting instructions on different waste fractions (see Table 5), as well as on informal evidence from Denmark regarding its experience with the Nordic pictograms (personal communication DG ENV, 2022).

As mentioned before, the impact of labels on waste sorting is measured in two ways. First, through their effect on the capture rate for each waste fraction. And second, through their effect on the increase of targeted material within the collected fraction (sometimes calculated from the reported reduction of impurities in the collected fraction or the misthrow ratio). For the former, seven studies assessing the impact of clarifying sorting instructions have been identified as relevant data sources, five of them referring exclusively to the bio-waste fraction and two of them to dry recyclables or all fractions. Based on the reported data, it is conservatively assumed that the measure under study leads to an increase of the capture rate equal to 2% for food waste (being the minimum of the reported range: 2-45%[16]) and 2% for dry recyclables (being the minimum of the reported range: 2-8%[17]). For the purity rate of the targeted fractions, it is assumed that misthrows decrease, and the share of targeted materials collected in total increases by 12% (being the minimum of the range reported 12% - 20%) for all material fractions. It must be acknowledged that this assumption for the purity rate of dry recyclables is based on data from food waste studies.

Table 5: Evidence on the impact on waste sorting from providing citizens with better information, e.g., with information campaigns and labels.

Measure	Country	Parameter affected	Quantification (%)	Waste fraction	Reference
Awareness campaigns (including adding the pictograms)	DK	Sorting efficiency	+ 2 (estimated)	All	(personal communication, DG ENV, 2022)
Use of stickers as visual prompt	UK	Capture rate	+ 21	Food waste	(Shearer et al., 2017)
Change in sorting instructions	FR	Collection rate	+ 8	Dry recyclables	(Zero Waste Europe, 2018)
Awareness campaigns	IE	Capture rate	+ 45	Organic waste	(SligoCountyCouncil, 2018)
		Share of target materials	+ 17.5		
Information sticker on trash cans	SE	Capture rate	+ 19.8	Food waste	(Rousta et al., 2015)
		Share of target materials	+ 11.7		
Information campaign	ES	Separation rate	+ 3.9	Bio-waste	(Gallardo et al., 2021)
		Share of target materials	+ 17.8		
Information stickers and information campaigns	SE	Capture rate	+ 15	Food waste	(Rousta et al., 2016)
		Share of target materials	+ 20		

Another important assumption made, based on the literature reviewed, is that the effects of the measure on waste sorting effectiveness occur with no delay in time (i.e., right after the measure is implemented), and that they are perpetual. In Gallardo et al. (2021) and Shearer et al. (2017), it was shown that the effects from the measures were already observable after 5-6 months, even if other studies measured the results in the time lapse of years.

To conclude the section, we provide summary tables of our key assumptions. For each Member State and waste stream, we show our assumed capture and purity rates under the baseline and the labelling policy assumption (year 2027 was chosen for this illustration). For 12 MS that already have a mandatory or voluntary matched labelling scheme in place, there is no change. For the remaining 15 MS the capture rates increase with labelling (Table 6), following the assumptions described earlier (2% increase). Likewise, only for those same 15 MS do we assume an increase of the purity levels vary (12% increase) (Table 7).

Table 6: Capture rates (in percent) assumed for the baseline (B) and the scenario in which labels are implemented (L). Data refers to year 2027 (arbitrarily chosen for illustrative purposes).

	Paper and cardboard		Glass		Metal		Plastic		Bio-waste	
	B	L	B	L	B	L	B	L	B	L
Austria	85.3	87.0	65.0	66.3	76.8	78.3	93.1	95.0	80.0	81.6
Belgium	73.0	73.0	78.9	78.9	56.5	56.5	27.6	27.6	67.0	67.0
Bulgaria	27.8	28.4	45.6	46.5	43.4	44.3	22.3	22.7	26.0	26.5

[16] the measures considered include not only labelling but other actions aimed at clarifying sorting instructions
[17] see above

Croatia	50.7	51.7	65.0	66.3	0.0	0.0	26.0	26.5	19.0	19.4
Cyprus	37.5	37.5	74.3	74.3	35.3	35.3	14.2	14.2	9.0	9.0
Czechia	59.8	61.0	57.6	58.7	80.8	82.4	44.1	45.0	51.0	52.0
Denmark	55.2	55.2	77.4	77.4	32.2	32.2	50.3	50.3	60.0	60.0
Estonia	47.8	48.8	38.3	39.0	43.9	44.8	38.0	38.8	24.0	24.5
Finland	55.5	55.5	60.2	60.2	94.5	94.5	23.9	23.9	47.0	47.0
France	30.9	30.9	54.5	54.5	24.2	24.2	33.6	33.6	50.0	50.0
Germany	92.8	94.7	66.1	67.4	84.2	85.9	97.1	99.0	62.0	63.2
Greece	42.2	43.1	26.8	27.3	26.0	26.5	14.0	14.3	8.0	8.2
Hungary	21.3	21.8	79.0	80.5	33.6	34.2	15.3	15.7	43.0	43.9
Ireland	47.7	47.7	60.0	60.0	24.6	24.6	52.1	52.1	34.0	34.0
Italy	56.6	56.6	77.8	77.8	57.5	57.5	50.9	50.9	68.0	68.0
Latvia	55.1	56.2	36.1	36.9	6.0	6.1	17.6	18.0	20.0	20.4
Lithuania	71.0	71.0	59.6	59.6	86.2	86.2	21.0	21.0	41.0	41.0
Luxembourg	64.8	66.1	56.1	57.3	47.0	47.9	52.8	53.9	60.0	61.2
Malta	77.5	79.1	66.6	67.9	71.3	72.7	28.7	29.3	34.0	34.7
Netherlands	77.6	77.6	58.1	58.1	26.3	26.3	42.6	42.6	63.0	63.0
Poland	52.7	53.7	59.1	60.3	27.7	28.2	2.1	2.2	43.0	43.9
Portugal	43.1	43.1	59.1	59.1	6.7	6.7	28.1	28.1	10.0	10.0
Romania	13.0	13.2	14.0	14.3	8.7	8.9	13.7	13.9	8.0	8.2
Slovakia	50.5	51.5	52.0	53.1	90.9	92.8	33.1	33.8	36.0	36.7
Slovenia	86.5	88.2	63.2	64.5	88.7	90.5	59.3	60.5	73.0	74.5
Spain	55.9	55.9	25.3	25.3	22.6	22.6	19.2	19.2	10.0	10.0
Sweden	59.3	59.3	62.6	62.6	87.4	87.4	35.1	35.1	51.0	51.0

Table 7: Purity levels assumed in the baseline (B) and in the scenario where implementing labelling (L) (corresponding in an increase of 12% in the purity). Notice that values are reported as percentages and that "S" stands for single stream collection, while "C" for commingled stream collection. Caps were set for each waste stream as follows: paper and cardboard 98.5%, glass 98%, metal 98%, plastic 96%, and bio-waste 98%.

	Paper and cardboard		Glass		Metal		Plastic		Bio-waste	
	B	L	B	L	B	L	B	L	B	L
Austria	95	98.5	96	98	84	94.1	87	96	92	98
Belgium	95	95	96	96	84	84	87	87	92	92
Bulgaria	S:95 C:87	S:98.5 C:97.4	96	98	88	98	87	96	92	98
Croatia	95	98.5	96	98	S:92 C:84	S:98 C:94.1	S:87 C:87	S:96 C:96	92	98
Cyprus	95	95	96	96	84	84	87	87	92	92
Czechia	S:95 C:87	S:98.5 C:97.4	96	98	S:92 C:88	S:98 C:98	S:87 C:87	S:96 C:96	92	98
Denmark	95	95	96	96	83	83	77	77	92	92
Estonia	S:95 C:87	S:98.5 C:97.4	96	98	88	98	87	96	92	98
Finland	95	95	96	96	92	92	87	87	92	92
France	87	87	96	96	88	88	87	87	92	92
Germany	95	98	96	98	84	94	87	96	92	98
Greece	50	56	50	56	50	56	50	56	92	98
Hungary	S:95 C:87	S:98.5 C:97.4	96	98	88	98	87	96	92	98
Ireland	87	87	96	96	88	88	87	87	92	92
Italy	86	86	96	96	83	83	77	77	92	92
Latvia	95	98.5	96	98	92	98	87	96	92	98
Lithuania	S:95 C:87	S:95 C:87	96	96	S:92 C:88	S:92 C:88	S:87 C:87	C:87 S:87	92	92
Luxembourg	95	98.5	96	98	92	98	87	96	92	98
Malta	87	97.4	96	98	88	98	87	96	92	98
Netherlands	95	95	96	96	84	84	87	87	92	92
Poland	95	98.5	96	98	84	94.1	87	96	92	98
Portugal	95	95	96	96	84	84	87	87	92	92
Romania	50	56	50	56	50	56	50	56	92	98
Slovakia	95	98.5	96	98	S:92 C:84	S:98 C:94.1	S:87 C:87	S:96 C:96	92	98
Slovenia	95	98.5	96	98	84	94.1	87	96	92	98
Spain	95	95	96	96	84	84	87	87	92	92
Sweden	95	95	96	96	92	92	87	87	92	92

4. Assessment of impacts: methodology

This section describes the methodology used to quantify the environmental and economic effects associated with MSW management in the EU27. The main elements that are considered include environmental impacts (e.g., climate change, acidification, and resource use), economic costs and benefits of different actors and society at large, and employment.

The analysis is guided by the 2021 Better Regulation Toolbox. Three quantitative approaches were used to estimate economic adjustment and administrative costs, as well as benefits. The first is an Excel spreadsheet cost model that estimates the regulatory adjustment costs with a straightforward calculation of the cost of affixing printed or purchased labels to all affected waste collection receptacles. Secondly, the administrative costs are estimated using the EU standard cost model, which includes costs related to legal, training, management, reporting, enforcement, etc. Thirdly, by means of the software EASETECH, life cycle assessment and, in particular, societal life cycle cost (LCC) modelling were carried out, which includes a quantification of the economic impacts of the initiative on employment and the secondary material market due to the increase in recyclable packaging collected and recycled (while reducing landfilling and incineration). Finally, the results of the different quantitative approaches are integrated to form the basis for an overall cost-benefit assessment of the proposed measure.[18]

4.1 Environmental impacts

This section details the life cycle assessment (LCA) methodology used in the study to quantify the environmental impacts of MSW management in the EU27. The LCA has been carried out in accordance with the guidelines of the ISO 14040/14044 standards (ISO, 2006a, 2006b).

4.1.1 Goal, scope and functional unit definition

The scope of the LCA is the MSW management in the EU27 Member States, with the overarching goal of quantifying environmental impacts associated with MSW management. The functional unit of the LCA, which defines qualitatively and quantitatively the service under assessment, is "the management of 1 tonne (wet) of MSW in the EU27", with material fraction composition and properties as detailed in Table 1. Note that waste management encompasses different processes, and a number of products or co-products arise from the valorisation of the waste, notably recyclates, heat, electricity, organic fertilisers or soil amending material. How to account for such processes and outputs is described in the following sections. Notice that the material flow handled in the system corresponds to 80% of the total MSW generated in EU27 due to lack of information on treatment on the following fractions: batteries, discarded equipment, chemicals and pharmaceuticals, rubber waste, textile, and wood.

4.1.2 System boundary definition

The system boundary includes all the operations involved in the life cycle of the waste once this is generated, i.e. collection (intended as the collection and hauling to the first treatment facility: sorting plant for dry recyclables; composting/digestion for biowaste; incineration/landfill/MBT for residual waste), transport (i.e. transport of sorted bales to recycling plants; recyclates to the market; digestate or compost to use-on-land; bottom ash to final disposal; etc.), recycling, incineration, landfilling and other operations that may be required prior to final recovery or disposal (e.g. bottom ash treatment).

Since prevention is not assessed as a policy measure, the generated waste is assumed to carry no prior environmental burden (prior to becoming a waste) following the so-called "burden-free" assumption that is often applied in LCA of waste management (Laurent, Bakas, et al., 2014; Laurent, Clavreul, et al., 2014). Additionally, managing waste generates useful outputs such as recyclates and energy. This is called "multi-functionality" because the management system delivers multiple functions additionally to the main service strictly consisting in managing the waste. To address this multi-functionality, the so-called system expansion approach was applied following common practice in waste management LCA (ISO, 2006a, 2006b) (Laurent, Bakas, et al., 2014; Laurent, Clavreul, et al., 2014). Accordingly, the products generated along with managing the waste (e.g. recyclates, electricity and heat, compost, digestate, bottom ash) were credited to the waste

[18] See Section 4.1 of Martinez Sanchez et al. (2021) for a more detailed explanation of the methodological relationship between LCA, LCC and Cost-Benefit Analysis.

management system by assuming the displacement of the corresponding market products obtained from virgin material (i.e. recyclates are assumed to substitute corresponding virgin material production) or from conventional energy sources (i.e. electricity and heat from waste incineration are assumed to substitute electricity and heat produced from conventional energy sources in the EU27) as illustrated in Figure 6. In other words, the substitution of materials and energy incurs environmental savings (or credits) that are attributed to the waste management system in a similar fashion as for the economic revenues.

Notice that such system expansion is a common approach used in waste management LCAs and is also in line with the end-of-life approach of the EF-Method (Environmental Footprint-Method). To represent the substituted materials (notably plastic, glass, metals, paper and cardboard, wood, mineral fertilisers), the current market average for those products was used (see Annex 5) relying on background datasets taken from the Ecoinvent 3.8 database (Wernet et al., 2016). To model the substitution of electricity and heat in the years 2020-to-2030 we forecasted the evolution of the EU electricity and heat mix using the official GECO projections of the European Commission JRC (GECO reports; (Keramidas et al., 2018) and subsequent updates).

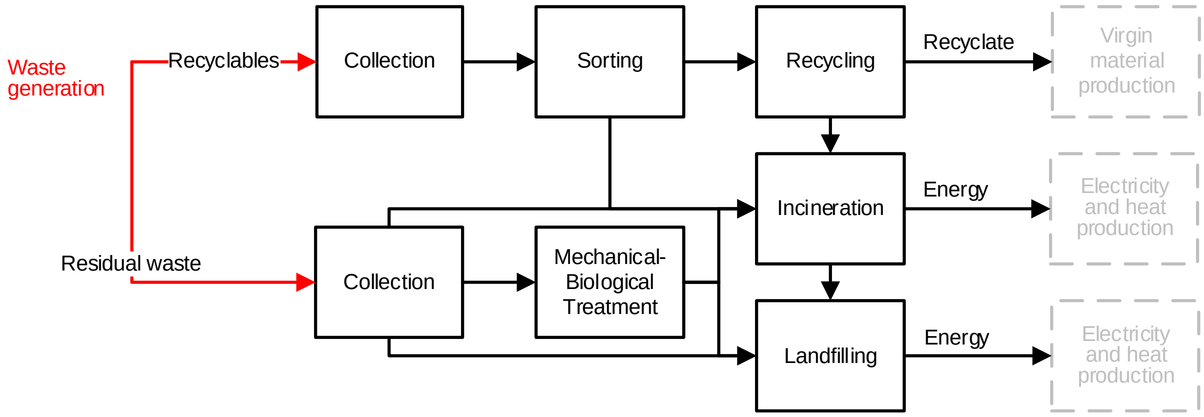

Figure 6: Generic system boundary for MSW management in the EU27. Black-continuous boxes indicate induced processes, while grey-dashed boxes indicate avoided processes (substitution of energy and virgin material, i.e., credits for waste valorisation) following the so-called system expansion approach (ISO, 2006a, 2006b).

4.1.3 Environmental impact categories

The environmental impacts were quantified following the Environmental Footprint Life Cycle Impact Assessment method (EF, v3.0) (EC-JRC, 2012). The following 16 impact categories included in the EF v3.0 method were considered: climate change; ozone depletion; Human toxicity, cancer; Human toxicity, non-cancer; particulate matter; ionising radiation; photochemical ozone formation; acidification; eutrophication, terrestrial; eutrophication, freshwater; eutrophication, marine; ecotoxicity, freshwater; land use; water use; resource use, minerals and metals; resource use, energy carrier. The LCA software EASETECH v3.4.0, specifically developed to assess waste and technology systems (Astrup et al., 2012; Clavreul et al., 2014), has been used to model the waste management in the EU27 baseline and policy scenarios.

4.1.4 Modelling features: Inventory data and key assumptions

Two levels must be differentiated: the foreground system, where waste treatment technologies and processes are modelled, and the background system, which determines the choice of inventory data.

The foreground system refers to all those processes of the waste management, like collection, sorting, recycling, incineration, landfilling, on which the policy maker can have a direct influence via this specific study or its implications thereof. Each stage of the waste management system was modelled in the dedicated waste-LCA model EASETECH 3.4.0 using input-data from the scientific and technical literature.

For the collection of plastic, fuel consumption was based on (Andreasi Bassi et al., 2022) (average value 0.00335 L/kg), for paper it was based on (Larsen et al., 2009) (average value 0.00406 L/kg), for glass on Larsen et al. (2009) (Table 4), for metals and commingled dry recyclables on (Jaunich et al., 2016) (average value 0.02023 L/kg), for bio-waste on (Gredmaier, L., Heaven, S., Vaz, 2013) (average value 0.00808 L/kg), and for residual waste on Larsen et al. (2009) and Jaunich et al. (2016) (average value 0.0048 L/kg).

For the sorting of dry recyclables, the material-specific recovery rates at sorting and recycling facilities were taken from the work of (Caro et al., 2022) and are reported in Annex 3. Consumption of electricity was 50 kWh/tonne, while fuel consumption was 2.35 L/tonne based on Andreasi Bassi et al. (2022).

Recycling of glass was based on (Rigamonti, 2007) and (Rigamonti et al., 2009). Recycling of paper and cardboard was taken from (Skjern Papirfabrik A/S, 2005). Recycling of PET plastic was based on (Kägi, 2017b) and for the other polymers on (Kägi, 2017a). Recycling of ferrous metals and aluminium was modelled based on (Rigamonti, 2007) and (Rigamonti et al., 2009). Composting was modelled as a windrow composting plant as described in (Boldrin et al., 2009), while anaerobic digestion was modelled as a wet thermophilic digester as described in (Tonini et al., 2018), while use on-land emissions were based on (Yoshida et al., 2016). The MBT was modelled as described in (Montejo et al., 2013), while incineration was modelled as described in (Albizzati et al., 2021) and landfilling as an engineered landfill as detailed in (Olesen & Damgaard, 2014). Finally, transport distances were based on (Reid, 2020), (Andreasi Bassi et al., 2022), (Bisinella et al., 2018) and (Tonini et al., 2020).

Finally, the background system refers to all those processes that are used in the waste management operations, such as electricity/heat or chemicals/material supply, but on which the policy maker has not direct influence via this specific study or its implications thereof. For all the background processes, datasets from the Ecoinvent 3.8 database (allocation at the point of substitution; (Wernet et al., 2016) were used.

4.2 Life-cycle-costing (LCC) impacts

4.2.1 General LCC considerations

Monetising and extending the environmental assessment, the overall life cycle economic impacts of managing MSW were calculated using a life cycle costing (LCC) approach, following state-of-the-art approaches for waste management economics as detailed in (Hunkeler et al., 2008; Martinez-Sanchez et al., 2015). The LCC shares the same object, scope, functional unit, and system boundaries as the life cycle assessment (LCA). The cost assessment included two types of costs: internal costs and externalities (external costs). Internal costs include budget costs and transfers; strictly, budget costs are costs incurred by the different actors involved in the management chain of municipal solid waste (collectors, operators, transporters, etc.), while transfers refer to money redistributed among stakeholders (taxes, subsidies, value added tax - VAT, and fees). In our analysis, for the purpose of simplicity, we will refer only to the aggregated internal costs.

Externalities are non-monetary transactions representing the costs caused by each emission to society, reflected by the so-called shadow prices of emissions as proposed in (Bijleveld et al., 2018). Notice that these include prices for air/soil/water emissions but not for disamenities such as nuisance, noise, odour, congestions, time spent or other similar social effects. Notice that any externality priced in (e.g. in form of a tax) by an authority and paid by a stakeholder within the management system becomes a transfer, i.e. an internal cost.

As for terminology, we distinguish two types of LCC: the conventional LCC (CLCC) describes the financial cost, as sum of budgets costs and transfers, of managing the waste reflecting a classic financial assessment. The societal LCC (SLCC) sums the internal costs to the external costs, both expressed as shadow prices[19], to quantify the total cost carried by the society, thus reflecting a socio-economic assessment.

No discounting or inflation was applied to costs or externalities occurring in the future. All costs that were found in the literature or collected as primary data were adjusted for inflation to EUR2020. Capital investments (CAPEX) were first amortised, assuming a 5% market interest rate, and then annualised using a 20-year lifetime for buildings and 7-year for equipment, as suggested in (Martinez-Sanchez et al., 2015). Maintenance and insurance were accounted for and assigned to the OPEX.

[19] In the CLCC, budget costs are accounted for in “factor prices” (market prices excluding transfers). Internal costs costs are then the sum of budget costs expressed as factor prices (market prices) plus transfers. Instead, budget costs in the SLCC should be accounted for in “shadow prices” (also called accounting prices or opportunity costs, and representing the willingness to pay for a good or service). Thus, when reporting the internal costs costs in the SLCC one should in principle remove the transfers and recalculate the remaining budget costs as shadow costs (e.g. the literature suggests the following calculation: market price x 1.325; (Martinez-Sanchez et al., 2015). In this analysis, we assume that the shadow price (of the SLCC) is equal to the internal costs price (of the CLCC), which implies assuming perfect market conditions. This approach was also taken in recent life cycle costing studies e.g. Albizzati et al. (2021).

The CLCC also allows deriving the total employment induced by the waste management system, expressed as full-time equivalent jobs per tonne of waste managed (FTE/tonne). For the specific shadow price of CO_2 we used the updated figure suggested by CE Delft and DG MOVE for 2030, i.e. 100 $€_{2016}$/tonne CO_2 that is recommended as default value, with a min-max range 60-189 $€_{2016}$/tonne CO_2 (van Essen et al., 2019). The remaining internal costs (based on literature) and external prices (using the report from CE Delft; Bijleveld et al., 2018) were kept constant between 2020 and 2030, in the absence of specific information. The LCC was implemented using the software EASETECH v3.4.0 (Astrup et al., 2012; Clavreul et al., 2014).

4.2.2 Cost inventory and key assumptions for the waste management systems (other than labelling)

The unit-cost (EUR2020/tonne) for waste management processes and treatments were collected from scientific and technical literature. In particular, for paper and cardboard collection, costs were based on (Bilitewski et al., 2018; COLLECTORS, 2020c; ISPRA, 2021; Utilitalia & Bain & Company, 2018). The average collection cost was estimated at 157.3 €/tonne. For glass collection, costs were based on (ACR+, 2021; ADEME, 2021; COLLECTORS, 2020c; FEVE, 2012; ISPRA, 2021; Utilitalia & Bain & Company, 2018). The average collection cost was estimated at 92.7 €/tonne. For metal, collection costs were based on (ISPRA, 2021), where the average collection cost was estimated at 152.5 €/tonne. For plastic, collection costs were based on (ISPRA, 2021; Utilitalia & Bain & Company, 2018). The average collection cost of plastic was estimated at 267.5 €/tonne. For bio-waste, collection costs were based on (ISPRA, 2021; NVRD, 2017; Utilitalia & Bain & Company, 2018). The average collection cost for biowaste was estimated at 128 €/tonne. For commingled collection of dry recyclables, costs were based on (ADEME, 2021; Blok & Kort, 2017; COLLECTORS, 2020c; ISPRA, 2021; NVRD, 2017; Utilitalia & Bain & Company, 2018). The average collection cost for commingled dry recyclables was estimated at 246 €/tonne. Finally, the collection costs of residual waste were based on (ADEME, 2021; COLLECTORS, 2020c; NVRD, 2017; Utilitalia & Bain & Company, 2018). The average collection cost of residual waste collection was estimated at 127 €/tonne.

Similarly, unit-cost data for waste sorting, recycling, incineration, landfilling, transport and other waste treatments and processes were collected from various sources, notably the EU reference model for waste (Eionet, 2018) and recent publications on plastic (Andreasi Bassi et al., 2020, 2022) and organic waste management (Tonini et al., 2020). More details on the unit-costs used to model the waste management may be found in Annex 5. To quantify employment in the MSW management sector we mainly relied on the detailed statistics provided in (Hall & Nguyen, 2012) for the specific case of France. Based on this, it is estimated that the labour required equals (in FTE per 1000 tonnes): 1.82 (residual waste collection), 1.93 (separate waste collection, including labour for civic amenity sites and transfer stations), 6.63 (recycling, generic), 0.66 (sorting), 0.34 (incineration), 0.2 (landfill). For the remaining technologies and processes, we applied data available from literature and (Eionet, 2018): anaerobic digestion (0.2).

4.3 Direct cost impacts related to the implementation of the measure (compliance costs)

This section describes the methodology guiding the economic analysis of the costs of the harmonised Nordic-style pictogram labels for the EU. There are precedents for similar labelling initiatives in existing EU policies referred to as "information labelling for third parties" in the Better Regulation Toolbox. This type of EU label informs actors along the value chain of characteristics of a variety of products. For example, energy labels such as Regulation C(2019)2124 that revised the labels of household washing machines and washer-driers (European Commission, 2018). A relevant example and precedent for the envisioned scale of the mandatory harmonised EU labels for recycling containers analysed herein, is the regulation on the classification and labelling of hazardous chemicals with pictograms (EU CLP-Regulation (EC) No 1272/2008) (European Commission, 2022a). The methods of past Impact Assessments for similar information labelling are applied in the current case. Key cost items include:

- Estimate the costs for *developing* a new set of Nordic-style pictogram labels harmonised for the EU.
- Estimate the costs for *placing* the new harmonised Nordic-style pictograms on receptacles for MSW.
- Estimate the general administrative costs of implementing the measure.

4.3.1 Administrative burden

The assessment of the administrative burden of the new labels is conducted using the Commission's Standard Cost Model for new information obligations. The regulatory adjustment and administrative costs are quantified to the extent practicable. Adjustment costs include equipment (the PVC labels), materials and labour (the cost of affixing new labels), and external service costs (contracting for the design, testing, and rollout of the EU set of labels. For the purpose of this analysis, these adjustment costs are treated as one-off administrative costs and are incorporated as such in the Standard Cost Model. Recurring administrative costs include training, reporting, familiarising with the obligation to use the EU label and designing information material.

Given that labelling waste containers for proper separate collection of recyclables is a core function of waste collection services, there are only two recurring administrative costs that are additional to the baseline. First, waste collectors will conduct annual inspections to ensure that the new EU labels are in use. Second, the EU Institutions will run a small program to oversee the new labels through communication with MS, updating and disseminating the open-source label templates and corollary materials as necessary. No recurring administrative costs are allocated to citizens/consumers or MS.

4.3.2 Operational and material costs of implementing the labelling

A detailed methodology was followed to quantify specifically the cost of labelling, which was then integrated with the remaining costs of managing MSW described later (Section 5.2.2). It is common practice that receptacles for recyclable packaging have some form of information to help citizens put their waste in the correct receptacle. This may include labels and or colour of labels, bins, bags or tops. There are many different visual cues used across the EU on many types of receptacles

For the majority of MS that already use some form of durable PVC label on bins, the task-based training and information on how to affix the labels is assumed to be minimal. Equipment (other than the new pictogram labels) is a business-as-usual cost. However, direct administrative costs such as information for familiarisation, citizen training on the new pictogram system, and record keeping in order to manage an accelerated implementation of the new pictogram labels is an additional – albeit transitory - cost for the waste collection system. For MS without any labelling on bins, the costs could be considered as new and additional costs, solely due to this initiative. However, given the clear trend to adopt such systems, it can be assumed that most if not all of these MS would eventually adopt a labelling system, even without the EU initiative considered here.

Accordingly, JRC made the following simplifying assumptions in order to develop cost estimates for the process of affixing new harmonised pictogram:

- 100 percent of waste collection receptacles are owned by the municipalities or private waste management companies that provide the containers or bins to households, businesses, multi-family and mixed-use buildings, public areas, and civic amenity sites. The municipalities and contractors (waste collectors) own and are responsible for the provision, care, and maintenance of adequate containers to allow for efficient separate waste collection. Therefore, waste collectors will implement the new harmonised EU labels at the local level.
- 100 percent of waste receptacles currently used for recyclable packaging have some form of labelling, in all MS. However, a lesser percentage of MS have pictograms on bins or products. 100 percent of containers in all 27 MS will use the new pictogram labels. Any costs apply to all MS.

In order to estimate the time effort needed to apply new stickers on bins, the Waste Management Department of the City of Vienna was contacted (Kloud & Binder, 2022). In 2019, 18.000 bins for separate collection of light packaging were relabelled at the collection banks. The labels on the bins are mostly 55 x 55 cm in size. One worker was capable of changing stickers on 40 bins in an 8-hour shift (480 minutes). The change of a sticker includes the processes of removing the old sticker, cleaning and drying the surface, and affixing the new sticker. This process takes approximately 12 minutes and includes the rides from one collection point to another to cover all bins in the city area. To estimate the time needed to apply new EU wide harmonised stickers on bins at the place of the collection points, the following aspects were considered:

- Each label represents one waste stream and multiple labels can be used in case of commingling. For example, a bin for paper and cardboard would have two labels, one for paper and one for cardboard, while the residual waste bin would have one label.
- The Vienna labels are 55cm x 55cm, considerably larger than the envisioned Nordic-style pictogram, which are approximately 15cm x 18cm.
- Assuming that the majority of the work time is spent on removing old labels and cleaning, then affixing 1-5 smaller adhesive labels to each bin can be expected to require the same amount of time as changing one big label, approximately 12 minutes per bin.

For the current case, the cost of the design of the label for the European Institutions, the cost of labels for bins to waste collectors, and the cost of affixing the labels on bins to waste collectors are treated as one-off administrative costs, incorporated in the Standard Cost Model. The cost to waste collectors of the labels and affixing them to bins is discounted at 3% per year. The default costs for these key inputs are developed as follows.

- Cost of a label – Two market analyses were carried out to estimate the cost of a Nordic-style durable PVC label (15cm X 18cm) for the default costs for the EU. The default label cost is based on estimates from municipalities that recently implemented a form of labelling. Seven estimates were gathered from publicly available sources and direct communication with two municipalities. Based on the sample data, with mixed unit cost and per capita, the unit cost of one label is €1.49. These labels were bespoke, as they were ordered at relatively small quantities by the municipalities. One municipality specifically indicated that the unit costs for large orders would decrease. A second market analysis gathered data from commercial sources (online sales of bespoke and ready-made labels). There are three ways in which similar labels are produced currently, e.g., hazardous waste pictogram labels on steel and plastic drums stored outdoors. First, the labels can be printed in-house using special printers and heavy-duty PVC film with permanent or semi-permanent adhesive backing. Second, bespoke pre-printed labels are ordered from a number of websites (prices vary). Third, if the pictogram is common, pre-printed heavy-duty PVC labels for outdoor use are available from a number of websites for about € 0.94. Given the range of alternatives in the market, and the municipalities' reported costs, €1.49 per label is assumed as the default for the analysis.
- Number of waste containers/bins- The total number of waste containers for the default option is based on the previously discussed estimate on EU-wide waste receptacles in section 3.2. The 2025 baseline estimate for the number of bins in the EU is 98.2 million.
- Cost of designing a label- The one-off cost of designing and testing the label with stakeholder consultation is estimated at €450k, occurring in the first year. This estimate is based on an internal costs review of similar Commission tenders.

4.4 Indirect economic impacts

Indirect economic impacts are costs and benefits arising from changes, e.g. in markets, that are induced by the proposed regulation. They often affect actors that are not directly addressed by the regulation itself. Here we describe how impacts on business and in particular on SMEs are analysed.

4.4.1 Economic impacts on business

There are two categories of enterprises affected by harmonised EU pictogram labels in the packaging materials recycling value chain. These are waste collectors and waste recyclers/processors (treatment and disposal, materials recovery). Several waste collectors are also waste recyclers/processors. Each category experiences different market dynamics as explained below.

Waste collectors can be a department of the municipality run by public service employees or private companies contracted by the municipality. Both models exist in every MS at varying percentages over time as municipalities seek operational improvements (Weghmann, 2017). Although waste collectors can be private or public entities, they are expected to operate efficiently at cost or profitably.

Regardless of the ownership structure, waste collection is a public service rather than a tradeable good. Citizens do not choose their own MSW collectors in a free market. Waste collection is a fee-for-service business model whose revenue is based on economic incentives (fees or taxes). Enterprises (public and/or private) can charge the full cost of service. Waste collectors that are directly impacted and have to bear the direct compliance costs related to affixing the new labels will pass on these costs to citizens or the public budget.

Waste processors are indirectly impacted by the harmonised pictogram initiative. The indirect impacts stem from the increase in quantity and quality of recyclables collected and processed into secondary materials. This segment is reliant on market prices for its inputs and manufactured products. Remarkably, “in general, private participation was more prevalent in the collection and transport phase than in the treatment phase” (Weghmann, 2017).

EU sectoral data about waste collection and processing enterprises is collected by Eurostat in the Structural Business Statistics for NACE Section E. As shown in Figure 7, Eurostat reports that there are 46,000 enterprises employing over 1 million persons in the EU in 2019 (European Commission, 2019a).

Sectoral analysis of key indicators, Water supply; sewerage, waste management and remediation activities (NACE Section E), EU, 2019

	Number of enterprises (thousands)	Number of persons employed (thousands)	Turnover (EUR million)	Value added (EUR million)	Personnel costs (EUR million)
Water supply; sewerage, waste management and remediation activities	77.0	1 560.0	257 000.0	100 000.0	55 500.0
Water collection, treatment and supply	:	346.1	:	:	11 667.9
Sewerage	:	140.0	24 000.0	13 900.0	:
Waste collection, treatment and disposal activities; materials recovery	46.0	1 035.4	172 000.0	58 000.0	37 000.0
Remediation activities and other waste management services	4.3	36.0	5 994.5	1 800.0	:

(:) not available

Source: Eurostat (online data code: sbs_na_ind_r2)

eurostat

Figure 7: Indicators of economic activity in the water and waste management sector

Small and Medium Enterprises

Against the backdrop of the Commission’s commitments to reduce regulatory burdens on Small and Medium Enterprises (SMEs), the sector is analysed using the SME Test, Better Regulation Tool 23. The basis of the analysis is the Eurostat Structural Business Statistics 2019 that provides a “size class analysis” (European Commission, 2022c). As noted in Figure 8, large companies employ more than 50 percent of people in the sector and large companies make up for more than 50 percent of the total value added. Nevertheless, given the size of the remaining shares, SMEs are within the scope of the legislative initiative.

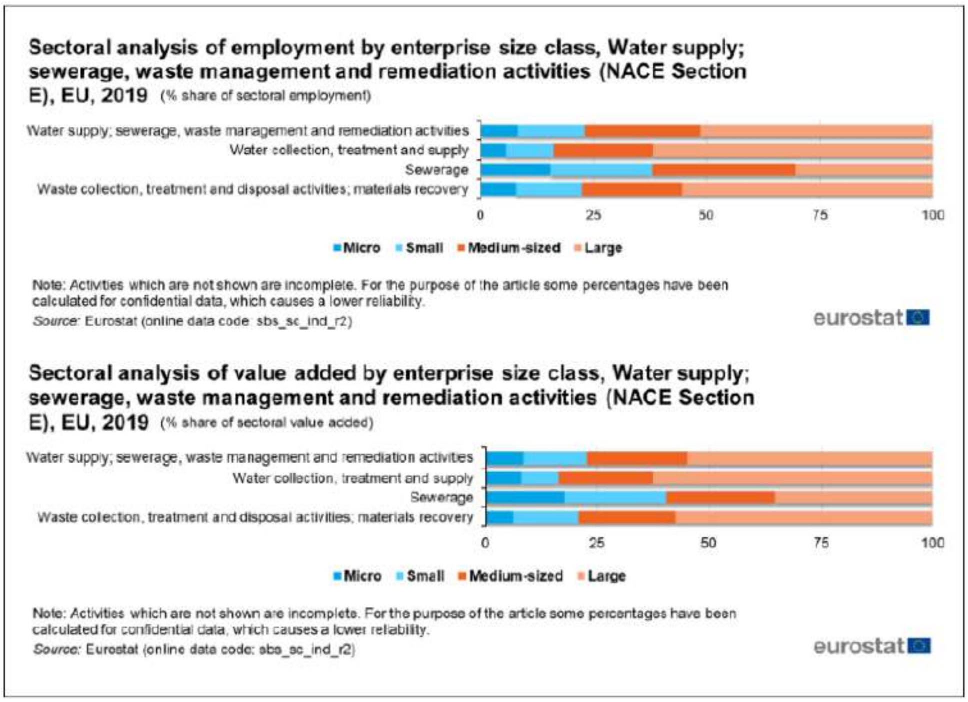

Figure 8: Eurostat Size Class Analysis for Waste Collection Treatment and Disposal

4.4.2 Other Indirect economic impacts

Other indirect impacts that will be assessed mostly qualitatively include

- impact on markets;
- impacts on competitiveness, trade and investment;
- impacts on citizens/consumers;
- impacts on public authorities.

5. Impact assessment results

5.1 Environmental impacts

The results of the LCA for the cumulative period 2024-2030 show an increase of environmental savings for both sub-measure 1 and 2, relative to the baseline, across all 16 impact categories assessed. Focusing on climate change effects, additional savings equalling 5 Mt CO_2-eq. and 4.8 Mt CO_2-eq. were estimated for sub-measure 1 and 2, respectively. A similar trend with increased benefits can be observed for the remaining environmental impact categories in Table 8. The conversion of emission savings into monetised impacts (i.e. external costs, expressed as shadow prices) is shown in the bottom of the same Table 8 (687 and 619 M€).

Table 8: Annual and cumulative environmental effects of the policy sub-measure 1 and sub-measure 2 relative to the baseline. Year 2024 does not incur effects as it is assumed that during year 2024 the labels are conceptualised and developed (i.e. not yet incurring environmental effects, only economic costs), while actual implementation of labelling on receptacles is assumed to start in year 2025 and to generate benefits starting from that year onwards. Positive values represent burdens to the environment, negative values represent savings. Note that values are rounded.

Impact category		2024	2025	2026	2027	2028	2029	2030	Cumulative (2025-2030)
Climate change (Mt CO2-eq.)	Sub-measure 1	0	-0.36	-0.71	-1.07	-1.07	-1.06	-1.06	-5
	Sub-measure 2	0	-0.27	-0.54	-0.80	-1.07	-1.07	-1.06	-4.8
Ozone Depletion (tonne CFC-11 eq-)	Sub-measure 1	0	-0.31	-0.63	-0.94	-0.94	-0.94	-0.93	-5
	Sub-measure 2	0	-0.24	-0.50	-0.71	-0.94	-0.94	-0.94	-4
Human Toxicity, cancer effects (CTU h)	Sub-measure 1	0	0	-1	-1	-1	-1	-1	-5
	Sub-measure 2	0	0	0	-1	-1	-1	-1	-4
Human Toxicity, non-cancer effects (CTU h)	Sub-measure 1	0	-18	-36	-55	-55	-55	-55	-273
	Sub-measure 2	0	-14	-27	-41	-55	-55	-55	-246
Particulate matter (Disease incidence)	Sub-measure 1	0	-11	-23	-34	-34	-34	-33	-168
	Sub-measure 2	0	-8	-17	-25	-34	-34	-34	-152
Ionising radiation (MBq U-235 eq.)	Sub-measure 1	0	9	17	26	26	26	26	130
	Sub-measure 2	0	6	13	19	26	26	26	117
Photochemical ozone formation (Mmol H+ eq)	Sub-measure 1	0	-1	-2	-3	-3	-3	-3	-16
	Sub-measure 2	0	-1	-2	-2	-3	-3	-3	-14
Acidification (Mmol N eq)	Sub-measure 1	0	-1	-2	-3	-3	-3	-3	-15
	Sub-measure 2	0	-1	-2	-2	-3	-3	-3	-14

Eutrophication terrestrial (Ktonne N eq)	Sub-measure 1	0	-3	-5	-8	-8	-8	-8	-40
	Sub-measure 2	0	-2	-4	-6	-8	-8	-8	-36
Eutrophication freshwater (Ktonne P eq)	Sub-measure 1	0	-5	-9	-14	-14	-13	-13	-68
	Sub-measure 2	0	-3	-7	-10	-14	-14	-13	-62
Eutrophication marine (Ktonne N eq)	Sub-measure 1	0	-0.17	-0.34	-0.51	-0.51	-0.51	-0.51	-3
	Sub-measure 2	0	-0.13	-0.26	-0.39	-0.51	-0.51	-0.51	-2
Ecotoxicity (MCTU e)	Sub-measure 1	0	-4 776	-9 552	-14 328	-14 281	-14 230	-14 175	-71 342
	Sub-measure 2	0	-3 582	-7 164	-10 746	-14 328	-14 275	-14 218	-64 311
Land Use (Billion Pt)	Sub-measure 1	0	-27	-55	-82	-82	-81	-81	-408
	Sub-measure 2	0	-20	-41	-61	-82	-82	-81	-368
Water Use (M m3)	Sub-measure 1	0	-170	-339	-509	-507	-505	-503	-2 535
	Sub-measure 2	0	-127	-255	-382	-509	-507	-505	-2 285
Resource use, minerals (tonne Sb eq)	Sub-measure 1	0	-1	-3	-4	-4	-4	-4	-21
	Sub-measure 2	0	-1	-2	-3	-4	-4	-4	-19
Resource use, energy (billion MJ)	Sub-measure 1	0	-2	-5	-7	-7	-7	-7	-34
	Sub-measure 2	0	-2	-3	-5	-7	-7	-7	-31
External costs (M€)	Sub-measure 1	0	-46	-92	-138	-138	-137	-137	-687
	Sub-measure 2	0	-34	-69	-103	-138	-137	-137	-619

5.2 Economic impacts

The results of three quantification exercises are included in the below cost estimates for affected stakeholders: businesses (waste collectors and recyclers), citizens and consumers who prepare and separate recyclables at source, national authorities of each MS, and the European Commission. The costs and benefits are expressed in Million Euros (M€) per year in the tables. Additionally, Euros per tonne of MSW waste and Euros per inhabitant (2.3 inhabitants per household on average) are presented for overall costs.

In the following sections, we report the breakdown of economic impacts as:

- Labelling: the sum of all additional costs associated with the activities required to set-up and implement the new labelling system in the EU. Expressed as EUR2020.
- Other internal costs: the sum of all changes in costs due to the change of waste flows throughout the EU waste management system (e.g. more separate collection, less mixed collection, less incineration and landfill, more recycling). Expressed as EUR2020.
- Revenues: the sum of all changes in revenues due to the change of waste flows throughout the EU waste management system (e.g. less energy recovery via incineration, more material recycling). Expressed as EUR2020.

5.2.1 Labelling

Municipal waste collectors will pay the initial cost for labelling the waste collection containers in the EU. However, maintaining the facades of waste collection containers to include sorting instructions with labels or colours is a routine function of the sector. Likewise, training employees on the signs and symbols designated for the local collection system is routine. Also, gathering and reporting data for the MS authorities on the management of the collection system is routine. Therefore, the majority of costs associated with the labelling are considered business-as-usual and are part of the baseline. A 2019 study on waste management cost coverage in the EU concluded that "the operational and maintenance costs seem to a large degree to be covered in the majority of countries" (European Commission, 2019b). The JRC has conservatively estimated that the waste collectors will initiate annual inspections of all the approximately 98.2 million bins in the EU in order to track and report progress. The inspections, estimated to cost €15.4 million per year, are a recurring administrative cost above the baseline.

In the EU, nearly all citizens use municipal solid waste collection services, for which they pay fees and taxes to the waste collectors. In general, these enterprises recover costs through fees. Therefore, additional direct and indirect costs of labelling containers for recyclable packaging are passed on to the citizens. The estimated total cost to business, citizens, and the public administrations of implementing the new EU harmonised pictogram scheme between 2024 and 2030 is €327 million when implemented over 3 years and €331 million when implemented over 4 years. As shown in Table 8, the cumulative cost of the measure to 2030 is less than €1.00 per individual and less than €2.00 per household.

As 100% of municipalities are assumed to already use some form of labelling on the approximately 98.2 million waste containers (bins, rolling containers, etc.), it is assumed that the action of adding the EU harmonised pictograms on waste collection containers is primarily a business-as-usual cost. Other costs to waste collectors and MS, such as training members and employees about the information obligations and submitting information to the designated recipient are considered business as usual costs. Although the local costs of implementing the new labels will be passed on to citizens and consumers, the analysis assumes that citizens do not incur any additional costs for familiarizing themselves with the new labels. There are only two new recurring administrative costs of the initiative estimated. Waste collectors spend approximately €15 million each year to inspect that the new EU labels are in use. Also, EU Institutions spend approximately €500 thousand each year to manage the program.

5.2.2 Other internal costs and revenues

Changes in citizens' sorting behaviour due to the implementation of labelling and associated sorting instructions is assumed to incur changes in material capture rate, leading to increased separate collection, material recycling and reduced mixed waste collection as well as landfilling or incineration because less residual waste is generated and sent to such disposal facilities, including mechanical-biological pre-treatments (MBTs). Such changes in material flows throughout waste treatment facilities and processes are associated with changes in costs and revenues, as reported in Table 9. The decrease in internal costs for the EU27 waste management system was quantified as 372 M€ for sub-measure 1 and to 335 M€ for sub-measure 2 for the cumulative period 2024-2030 (Table 9). In the same cumulative period, revenues decreased by 242 M€ for sub-measure 1 and by 217 M€ for sub-measure 2 (Table 9). This is a consequence of lower revenues from energy recovery (electricity and heat) at incinerators because of the decreased amount of residual waste sent to these facilities. This is only partially compensated by the increased revenues from material recycling. This result highlights that: i) waste incineration with energy recovery generates important revenues and is a financially competitive treatment and/or ii) revenues from secondary materials as estimated here might be conservative, i.e. at the lower end of the range.[20] The life cycle cost analysis of incineration of municipal solid wastes incorporates the future implementation of the EU Emissions Trading Scheme (ETS) in 2026 for waste-to-energy-plants. The modelled costs of incineration goes up after 2026 to fund ETS credits for each tonne of carbon emitted by fossil fraction of the input waste (e.g. plastics). Notice that for illustrative purposes we present the breakdown of the waste management costs (e.g. collection, transport, incineration, recycling, landfilling, MBT) for the year 2025 in Annex 7.

Notwithstanding the decrease in (other than labelling) internal costs of the waste management, the sum of the effects due to: i) labelling, ii) other (than labelling) internal costs and iii) revenues, indicates an overall net economic burden for the EU27 equal to 198 M€ for sub-measure 1 and to 213 M€ for sub-measure 2 in the cumulative period 2024-2030. Landfilling/incineration, transport, and other processes involved) is not sufficient to compensate for labelling costs and decreased revenues from energy recovery. Notice that this burden corresponds to ca. 0.44 and 0.47 €/person for the cumulative period 2024-2030 (Table 10) for sub-measure 1 and 2, respectively, or about 0.15 and 0.16 €/tonne MSW managed.

Table 9: Effects on internal costs - Annual estimated internal costs and revenues of new EU label scheme with €1.49 labels for all containers/bins. Positive values represent a net increase in costs, negative values net decrease in costs, relative to the baseline. Similarly, for consistency "Foregone revenues" are a cost when a positive number is reported, and a gain (i.e. additional revenues as compared to baseline) with a minus (-). The mathematical sum of the elements in the "Cost breakdown" makes "Total". Values are in million EUR2020 (M€) and rounded.

Measure	Cost breakdown	2024	2025	2026	2027	2028	2029	2030	Cumulative (2024-2030)
Sub-measure 1 (labelling over 3 years)	Labelling	0.45	93.2	93.2	93.2	15.9	15.9	15.9	328
	Other internal costs[2]	0	-25	-50	-75	-74	-74	-74	-372
	Foregone revenues	0	16	32	48	48	49	49	242
	Total	0.45	84	75	66	-10	-9.1	-9.1	198
Sub-measure 2 (labelling over 4 years)	Labelling	0.45	74.8	74.8	74.8	74.8	15.9	15.9	331
	Other internal costs[2]	0	-19	-37	-56	-75	-74	-74	-335
	Foregone revenues	0	12	24	36	48	48	49	217
	Total	0.45	68	62	55	48	-10	-9.1	213

[20] A recent study of Italian municipalities showed that "the marginal cost tends to decrease and become almost constant over the production of recycling waste, implying that increasing the amount of recycled waste will not necessarily increase additional cost to the municipality" (Cialani & Mortazavi, 2018).

[2]Other (than labelling) internal cost effects, i.e. net difference between the internal cost of the sub-measure and baseline scenarios due to the implementation of the labelling. These effects account for all the remaining (life cycle) cost variations due to the change induced in the MSW management, e.g., increased capture rate and recycling of materials, reduced landfilling and incineration.

Table 10: Effects on internal costs and revenues - per person or tonne. Positive values represent a net increase in costs, negative values net decrease in costs, relative to the baseline. Similarly, for consistency "Foregone revenues" are a cost when a positive number is reported, and a gain (i.e. additional revenues as compared to baseline) with a minus (-). The mathematical sum of the elements in the "Cost breakdown" makes "Total". Values are rounded.

Measure	Cost breakdown	Cumulative 2024-2030 [M€]	Cost per person Cumulative 2024-2030 [€]	Average cost per tonne MSW[3] 2024-2030 [€]
Sub-measure 1	Labelling	327	0.73	0.24
	Other internal costs[2]	-372	-0.83	-0.27
	Foregone revenues	242	0.54	0.18
	Total	197	0.44	0.15
Sub-measure 2	Labelling	331	0.74	0.24
	Other internal costs[2]	-335	-0.75	-0.24
	Foregone revenues	217	0.48	0.16
	Total	213	0.47	0.16

[2]Other (than labelling) internal cost effects, i.e. net difference between the internal cost of the sub-measure and baseline scenarios due to the implementation of the labelling. These effects account for all the remaining (life cycle) cost variations due to the change induced in the MSW management, e.g. increased capture rate and recycling of materials, reduced landfilling and incineration.

[3]Additional cost effect (cost or saving) per tonne of MSW managed each year, calculated as average of the effects in 2024-2030 period.

5.2.3 Market impacts

Harmonizing EU pictograms for waste collection is expected to increase the amount of recyclable packaging materials collected for recycling into secondary materials sold on the market in Europe and potentially globally. Therefore, the initiative has several indirect, difficult to quantify, effects on sectoral competitiveness, trade, and investment.

Sectoral competitiveness, trade and investment

The increase in secondary materials on the market is the main limited and indirect impact on sectoral competitiveness. Long-term, market effects due to the increases in supply and quality of secondary raw materials will likely result in a change in the market price of recyclables such as PET bottles and metal cans. In some segments of the market, recyclers currently experience a "shortage" of high-quality recyclables. For example, several industry articles report that recyclers of PET experience high prices for post-consumer bottles and that the supply of post-consumer bottle is low and, in some cases, the high prices of recycled PET means that manufacturers chose primary PET instead (EUWID, 2022; Recyclingtoday, 2022). The recent joint statement of UNESDA Soft Drinks Europe and others requests that beverage producers be given the right of first refusal for recycled PET streams. This indicates that beverage manufacturers perceive a "shortage" of their preferred material input, recycled PET (UNESDA, 2022). An increase in secondary materials supply could contribute to alleviating recyclers supply challenges.

The EU harmonised pictogram label initiative would decrease misthrows, thereby improving the operational efficiency of the value chain for secondary materials and products made from post-consumer materials. Under the default assumptions, the pictograms lead to an increase of the total recyclables collected, and thereby to a higher turnover for recyclers. Theoretically, these indirect impacts could have a positive effect on the sector's cost to price competitiveness, as recyclers are able to collect or purchase inputs (post-consumer packaging) at lower prices due to increased supply. In addition, higher quality separately collected inputs would lead to more cost-efficient processing, leading to more competitive prices—therefore a positive impact on value added of the sector. Beccarello & Di Foggia (2018) found "that higher recycling goals are associated with positive effects on job creation, production and value added (Beccarello & Di Foggia, 2018). For the present case, increased recycling due to the harmonised pictogram labels is expected to have a limited and positive effect on job creation, production, and value added in the sector.

In general, the above-mentioned factors improve the investment climate in the sector, which historically responds to market forces. Plastic Recyclers Europe's 2022 mapping of the industry highlights the current growth trend in installed capacity. In the MS27+3 countries, "installed plastics recycling input capacity" grew by around 60 percent between 2017 and 2020 (Plastics Recyclers Europe, 2020). The same cannot be said for all recyclable waste fractions. "Some wastes have very low or negative prices." (Martinez Sanchez et al., 2021). Improved overall quantity and quality of recyclable waste streams is an indirect positive impact for the sector's investment climate.

5.2.4 Cost impact on citizens and consumers

Generically, citizens are all people who rely upon municipal solid waste management, including businesses such as retail, restaurants, and services. Citizens include those who directly consume packaging of products, and those who do not consume packaging of products. All citizens pay the direct cost of municipal waste management services through higher taxes, and fees. Consumers of product packaging pay higher product prices due to economic instruments that implement the polluter pays principle, thereby internalizing externalities. Externalities occur "when the full cost of waste management is not borne by waste producers" (Martinez Sanchez et al., 2021). For example, in some cases product packaging producers pay the cost of packaging waste management with Extended Producer Responsibility and Deposit Refund Schemes.

The cost to individual citizens of the harmonised label on waste containers, cumulatively to 2030, is about € 0.74. The analysis assumes that citizens do not incur any additional costs for familiarizing themselves with the new labels.

The literature on waste sorting behavioural change shows that improved written instructions improves recycling behaviours with clear instructions such as labelling at the point of collection (Austin, 1993). Given that most citizens might sort waste and packaging several times per week as they empty consumer products, it is plausible that the matched pictograms on packaging and bins would save citizens' time; thereby, increasing convenience (unquantified) which reduces a common barrier to recycling behaviour (Bernstad, 2014; Di Giacomo, 2018).

5.2.5 Cost impact on public authorities: European Institutions, Member States and municipalities

European Institutions, municipalities, waste collectors, and MS are all already engaged in improving separate waste collection. One widely followed method is labelling waste collection bins with better signage. Thus, the periodic revamping of signage, sorting instructions, and public awareness materials is not an additional cost for municipalities. In some cases, labels on bins that match labels on products are already implemented, e.g., Nordic pictogram system. In other cases, labels on bins are not matched with products. It is not possible to quantify the EU-wide costs of these already ongoing efforts, which occur at the local level.

Costs to Municipalities and Member States - As noted in the discussion of costs assumed for the measure, the majority of activities associated with the measure at the municipal and member states level are business-as-usual and do not imply costs above the baseline. The only exception are the annual inspections at the municipal waste collector level. In addition, the proposed measure relieves municipalities, MS, and regions from the future costs of designing and testing on their own pictogram labels for bins that match pictogram labels on products.[21] The potential future costs of MS and municipalities designing and testing labels

[21] Data to estimate the avoided costs for MS is unavailable; however, an indication of the magnitude of savings could be derived as follows. The default cost to the European Institutions for designing the pictograms in 2024 is estimated at €450 thousand. Notably, the top five packaging waste generating countries of the EU in 2019, are Ireland, Germany, Luxembourg, Italy, and France (source: Eurostat env_waspac). If each of these countries developed its own pictogram system at the national level, in the absence of the EU harmonised pictograms for waste containers, the initial avoided costs would be €2.25 million. As this estimate of potential benefit is highly uncertain, it is not included in the summary of costs and benefits.

individually are avoided because this service will be provided at the European level under the proposed measure.

Costs to European Institutions - The cost for designing the new set of waste container pictograms for the EU is estimated to be initially about €450 thousand, and managing the program is about €518 thousand per year. These costs are assumed to be borne by a European Institution, either the Commission or an agency such as the European Environment Agency.

5.3 Regulatory impact on SMEs

SME waste collectors will be directly impacted as they will implement the new labelling scheme. SME waste recyclers/processors are indirectly impacted as they will manage increased volumes of recyclables due to labelling. However, SMEs are not disproportionately affected compared to large companies by the new labels. Further, SMEs in this sector can be assumed to routinely apply labels to bins and communicate sorting instructions to citizens now. The costs of these activities are passed on to consumers who are obliged to pay increased costs through waste taxes and fees. Therefore, adding new labels or replacing old labels to waste bins is not considered to constitute a new regulatory burden for SMEs.

In conclusion, given the assessment of businesses likely to be affected by the intervention and the qualitative assessment of those impacts, the introduction of new Nordic-style pictogram labels for the EU is relevant to SMEs but not highly relevant. The estimated costs and benefits apply equally to all impacted enterprises. There is no additional regulatory burden. No specific measures or exemptions for SMEs are necessary.

5.4 Employment and other social impacts

Employment effects are the main relevant socioeconomic impact of the new harmonised pictogram labels. They prompt better waste sorting by citizens, resulting in less residual waste and more waste directed into separately collected waste streams. This can induce a positive employment effect on recyclers, but a negative effect for incinerators and landfills. However, the aim of separate waste collection, according to the Waste Framework Directive, is to incentivise more environmentally friendly and circular waste management, so a reduction of landfilling and incineration is in principle desirable.

Overall, a slight increase in employment is estimated for the MSW management sector, related to the increase in separate material collection and subsequent recycling, while reducing employment in the collection of residual (mixed) MSW and associated landfilling and incineration. The sum of the employment effects for the cumulative period 2024-2030 was estimated to a total of 218 and 196 annual FTE for sub-measure 1 and 2, respectively (Table 11). This corresponds to around 44 new jobs. In a nutshell, the results show that negligible effects are expected under the assumptions taken. Note that these estimates should be used carefully as they are based on a limited sets of literature sources and are not representative of variations across MS.

Table 11: Employment effects relative to the baseline reported as annual full-time equivalents (FTE) increase.

	2024	2025	2026	2027	2028	2029	2030	Cumulative (2024-2030)
Sub-measure 1	-	14	29	43	44	44	44	218
Sub-measure 2	-	11	22	33	43	44	44	196

Health and safety impacts are associated with recyclable waste collection, handling, and sorting. As the number of people working in the sector increases, the number of people exposed to the occupational health risk increases. A literature review by Poole et al. (2017) found that the "main occupational hazards in the waste and recycling sector are heavy manual handling and exposure to bioaerosols, heavy metals and organic pollutants" (Poole & Basu, 2017). The current proposed measure would not increase relative occupational health risks in the sector.

6. Combined societal impacts (environmental and economic)

The societal cost is reported in Table 9 and Table 10, representing a cost-benefit analysis where internal costs (expressed as shadow prices, i.e. not including taxes) are summed to external costs (monetisation of environmental impacts, see Table 8 above). In the following, the breakdown of the societal cost and benefits encompasses the following categories (all expressed in shadow prices):

- Labelling: the sum of all costs associated with the activities required to produce and implement the new labelling system in the EU.
- Other internal costs: the sum of all changes in costs due to the change of waste flows throughout the EU waste management system (e.g., less incineration and landfill, more recycling).
- Revenues: the sum of all changes in revenues due to the change of waste flows throughout the EU waste management system (e.g. less energy recovery via incineration, more material recycling).
- External costs: monetised environmental impacts (see Table 8 above).

For the EU27, the societal cost of the cumulative period 2024-2030 indicate net societal savings of around 316 M€ for sub-measure 1 and 250 M€ for sub-measure 2 (Table 12), corresponding to a saving during the same cumulative period of 0.67 and 0.58 €/person for sub-measure 1 and 2 respectively (Table 13), or about 0.22 and 0.18 €/tonne MSW managed.

These figures suggest two main messages:

I) The sum of internal cost savings from the improved management of MSW and the monetised environmental benefits are larger than the financial burdens incurred by labelling costs and revenues loss, during the cumulative period 2024-2030. In other words, this suggests that a 2% increase in capture rate (here assumed for those MS not having mandatory or voluntary labelling schemes) is sufficient to compensate for the financial losses, at a societal level.

II) There is no substantial difference at the level of societal benefits between sub-measure 1 and sub-measure 2.

Table 12: Effects on the societal costs: labelling, other internal costs, revenues, and external costs, all expressed in shadow prices. Positive values represent a net increase in costs, negative values net decrease in costs, relative to the baseline. Similarly, for consistency "Foregone revenues" are a cost when a positive number is reported, and a gain (i.e. additional revenues as compared to baseline) with a minus (-). The mathematical sum of the elements in the "Cost breakdown" makes "Total". Values are in million EUR2020 (M€) and rounded.

Measure[1]	Cost breakdown	2024	2025	2026	2027	2028	2029	2030	Cumulative (2024-2030)
Sub-measure 1	Labelling	0.45	93	93	93	16	16	16	327
	Other internal costs[2]	0	-13	-27	-40	-40	-40	-39	-198
	Foregone revenues	0	16	32	48	48	49	49	242
	External costs	0	-46	-92	-138	-138	-137	-137	-687
	Total	0.45	50	6	-37	-114	-112	-111	-316
Sub-measure 2	Labelling	0.45	75	75	75	75	75	75	331
	Other internal costs[2]	0	-10	-20	-30	-40	-40	-40	-179
	Foregone revenues	0	12	24	36	48	48	49	217
	External costs	0	-34	-69	-103	-138	-137	-137	-619
	Total	0.45	43	10	-22	-55	-54	-53	-250

[1]Sub-measure 1: New labels over 3 years. Sub-measure 2: New labels over 4 years.

[2]Other (than labelling) internal cost effects, i.e., net difference between the internal cost of the sub-measure and baseline scenarios due to the implementation of the labelling. These effects account for all the remaining (life cycle) cost variations due to the change induced in the MSW management, e.g. increased capture rate and recycling of materials, reduced landfilling and incineration. Notice that the internal costs have been calculated as shadow prices, removing selected taxes (e.g., landfill and incineration tax), thus are slightly different than the internal costs reported in Table 9 above.

Table 13: Effects on the societal cost per person or tonne: labelling, other internal costs, revenues, and external costs, all expressed in shadow price. Positive values represent a net increase in costs, negative values net decrease in costs, relative to the baseline. Similarly, for consistency "Foregone revenues" are a cost when a positive number is reported, and a gain (i.e. additional revenues as compared to baseline) with a minus (-). The mathematical sum of the elements in the "Cost breakdown" makes "Total". Values are rounded.

Measure[1]	Cost breakdown	Cumulative 2024-2030 [M€]	Cost per Person Cumulative 2024-2030 [€]	Cost per average tonne MSW 2024-2030 [€]
Sub-measure 1	Labelling	327	0.73	0.24
	Other internal costs[2]	-198	-0.44	-0.14
	Foregone revenues	242	0.54	0.18
	External costs	-687	-1.5	-0.50
	Total	-316	-0.67	-0.22
Sub-measure 2	Labelling	331	0.74	0.24
	Other internal costs[2]	-179	-0.40	-0.13
	Foregone revenues	217	0.48	0.16
	External costs	-619	-1.4	-0.45
	Total	-250	-0.58	-0.18

[1]Sub-measure 1: New labels over 3 years. Sub-measure 2: New labels over 4 years.

[2]Other (than labelling) internal cost effects, i.e. net difference between the internal cost of the sub-measure and baseline scenarios due to the implementation of the labelling. These effects account for all the remaining (life cycle) cost variations due to the change induced in the MSW management, e.g. increased capture rate and recycling of materials, reduced landfilling and incineration. Notice that the internal costs have been calculated as shadow prices, removing selected taxes (e.g. landfill and incineration tax), thus are slightly different than the internal costs reported in Table 10 above.

Which EU Member States benefit most?

There are 15 MS for which the EU harmonised labels would be the first time that pictograms on bins and products are comprehensively employed, according to our check of current practices. Table 14 provides an overview of these MS. These countries would reap the largest share of the waste management efficiency gains. However, most of the reductions of environmental externalities, like lower greenhouse gas emissions, come to the benefit of all MS.

Table 14: Summary of MS that receive most waste management benefits from 2025 as example

MS to implement matched pictograms for first time.	Total Population in 2025 (number)	Total MSW Generated in 2025 [of which packaging] (Mtonne)
AT, BG, HR, CZ, EE, DE, EL, HU, LV, LU, MT, PL, RO, SK, SI	202,150,503	95 [22]

7. Sensitivity analysis

The quantitative assessment, for lack of precise data, is based on a series of assumptions. In this section we test how our main findings change if some of these assumptions are modified.

7.1 Labelling cost

The default cost assumptions are conservative and to some extent "worst case", possibly resulting in a higher cost than will occur in practice. First, our estimates do not consider the savings from discontinuing other label schemes or the equal costs of starting to implement Nordic-style pictograms that are already included in the budget of several MS. Second, the durable PVC label cost of €1.49 per unit is estimated from actual municipal costs as of 2022 when Nordic-style pictograms for recycling are not ubiquitous. This results in an estimate of €164 million for labels alone. However, similar durable PVC labels available in the market for other information labelling mandates cost significantly less, one figure being €0.94. In which case, labels would cost € 104 million, €60 million less than the default estimates of the measures. This sensitivity analysis of the label price suggests that in the future, when the new label is ubiquitous, the market will very likely provide lower cost options, which would decrease costs significantly.

7.2 Waste management cost

In the default calculations we assumed a 2% increase in the capture and 12% in the purity rate for the dry recyclables and biowaste in the MS where neither a mandatory nor a voluntary product labelling scheme is in place. While this should be seen as a conservative estimate (literature reports increases in capture rates in the range 2-45%), any further increase in the capture rate would simply translate into more environmental (and thus external cost) savings. We therefore test the model by assuming instead a decreased capture rate equal to 1%, to verify whether the CBA would still overall incur societal savings. The sensitivity analysis is only performed on a different capture rate keeping the additional purity level constant (i.e. 12%) as the results are mainly driven by the quantity collected of material, rather than how much of targeted material is found in the collected waste stream. Under this assumption, the internal cost savings relative to the baseline would equal M€ 160 and 144 (sub-measure 1 and 2, respectively) and the external costs savings would equal 595 and 537, respectively, in the cumulative period 2024-2030. The overall societal savings would equal M€ 197 and 143, respectively, in the cumulative period 2024.

Table 15: Effects on the societal costs if higher improvements for capture rates are assumed. Labelling, other internal costs, revenues, and external costs, all expressed in shadow prices. Positive values represent a net increase in costs, negative values net decrease in costs, relative to the baseline. Similarly, for consistency "Foregone revenues" are a cost when a positive number is reported, and a gain (i.e. additional revenues as compared to baseline) with a minus (-). The mathematical sum of the elements in the "Cost breakdown" makes "Total". Values are in million EUR2020 (M€) and rounded.

Measures[1]	Cost breakdown	2024	2025	2026	2027	2028	2029	2030	Cumulative 2024-2030
Sub-measure 1	Labelling	0.45	93	93	93	16	16	16	327
	Other internal costs (without taxes)[2]	0	-11	-21	-32	-32	-32	-32	-160
	Foregone revenues	0	15	31	46	46	46	47	231
	External costs	0	-40	-80	-120	-119	-119	-118	-595
	Total	0.45	57	23	-13	-89	-89	-87	-197
Sub-measure 2	Labelling	0.45	75	75	75	75	75	75	331
	Other internal costs (without taxes)[2]	0	-8	-16	-24	-32	-32	-32	-144
	Foregone revenues	0	11	23	34	46	46	46	207
	External costs	0	-30	-60	-90	-120	-119	-119	-537
	Total	0.45	48	22	-5	-31	-30	-30	-143

8. Conclusions and recommendations

Cost Benefit Analysis (CBA) performed with Societal Life Cycle Costing methodology suggests that the financial costs associated with the implementation of a harmonised EU labelling scheme for waste receptacles, matched to product packaging labels, are more than compensated by the lower costs of waste management and reduced environmental externalities. This result is contingent on the assumption that the labelling scheme induces a 2% increase in the capture rates and 12% increase in the purity rates of the separately collected waste streams, which appears to be a conservative assumption in light of related analyses found in the (albeit limited) literature. As a sensitivity analysis shows, the positive sign of the net social benefits is preserved even if a lesser improvement in the capture rate (only 1%) is assumed.

Without the benefits associated with the reduction of externality costs, the financial costs implied by the measure would be higher than the savings obtained from the improved MSW management. The latter notably consists of reduced costs for the management of residual waste, e.g., collection, landfilling, incineration.

The two sub-measures assessed here only differ in their implementation time: 3 years for sub-measure 1 and 4 years for sub-measure 2. While the cost of labelling *per se* was quantified to about 327 and 331 M€ or 0.73 and 0.74 €/person (sub-measure 1 and 2, respectively) cumulatively over the period 2024-2030, the cumulative cost reduction in overall MSW management over the same period amounts to approximately 316 and 250 M€ or 0.67 and 0.58 €/person, for sub-measure 1 and 2, respectively. In other words, the cost savings are similar and slightly less than the costs for implementing the labelling measure. Still, when including the savings associated with the external costs, net societal (internal plus external costs) benefits are realised. The absolute numbers are comparable for the two sub-measures, which means that the decision between implementing one or the other sub-measure can be guided by financial costs or other technical/practical reasons, such as giving enough time to municipalities and operators to adapt to the new labelling system.

It should be kept in mind that the environmental benefits (i.e. the reduction of external societal costs) have been estimated assuming a conservative 2% increase in material capture rate for both biowaste and dry recyclables (notably packaging waste materials). While few literature studies exist that have investigated the effects of improved labelling and sorting instructions on citizens' waste sorting, the range reported by these studies imply increases between 2% and 45% of the capture rate. This on one hand suggests that the potential environmental benefits of the two sub-measures assessed in this study might be much larger than what we conservatively estimated. On the other hand, the number of available studies is very limited, and the reported results are not referring to the isolated effect of labelling only.

Finally, as a recommendation, the harmonisation of labels on waste containers/bins should be started before product packaging labels are harmonised, in order to prepare waste management systems and citizens for the change. This is the case because the effort needed for waste management entities to change labels on containers/bins is lower than that needed for the packaging industry, but the adaptation time for citizens to any such change is long, supporting an earlier rollout on bins. The change at the waste management collection stage can serve to smoothly introduce citizens to the new system.
In addition, the transition should be accompanied by appropriate sorting instructions and awareness campaigns to maximise the benefits of the measure, as regularly emphasised in stakeholder consultations and in the literature. With good complementary measures put in place, the improvement could exceed the 2% increase in the capture rate and thereby generate even higher net social benefits that estimated here (as also suggested in Table 5 presenting the range of improvements from literature).

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List of abbreviations and definitions

CAS	Civic Amenity Site
Capture rate	Quotient of mass between the quantity of waste separated at source (including impurities) and the quantity of the same waste generated (%) (e.g. glass waste separately collected over total glass waste generated)
CBA	Cost Benefit Analysis
CLCC	Conventional Life Cycle Costing
DRS	Deposit Refund Scheme
EC	European Commission
EEA	European Environment Agency
EF	Environmental Footprint (of the EC)
EWR	Early Warning Report
Impurity rate	In this study it is defined as 100% minus purity rate; it represents the % of non-target material in a given waste stream (e.g. percent of non-glass in a glass waste stream)
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LWP	Light Weight Packaging
MBT	Mechanical-Biological Treatment
MS	Member State
MSW	Municipal Solid Waste
OPRL	On-Pack Recycling Label
PPW	Packaging and Packaging Waste
PPWD	Packaging and Packaging Waste Directive
Purity rate	Quotient of mass between the amount of target material in a separately collected waste stream and the amount of that waste stream (%) (e.g. % of glass in a glass waste stream)
Recycling rate	Quotient of mass between the amount of material recycled in a recycling facility (including market-accepted impurities) and the amount of the same material entering the facility (%)
SLCC	Societal Life Cycle Costing
Sorting rate	Quotient of mass between the amount of material recovered in a sorting facility (including market-accepted impurities) and the amount of the same material entering the facility (%)
SWC	Separate Waste Collection
Waste receptacle	Waste container (bin) or bag destined to contain waste
WFD	Waste Framework Directive

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Annexes

Annex 1. Collection schemes across Member States

	Paper and cardboard	Metal	Glass	Plastic	Bio-waste	Beverage carton
Austria	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Belgium	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Bulgaria	50% single stream, 50% commingled with metal, plastic, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Croatia	100% single stream	25% single stream, 75% commingled with plastic, beverage carton	100% single stream	25% single stream, 75% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Cyprus	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Czechia	50% single stream, 50% commingled with plastic, metal, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Denmark	100% single stream	100% commingled with plastic	100% single stream	100% commingled with metal	100% single stream	-
Estonia	75% single stream, 25% commingled with plastic, metal, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Finland	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream
France	100% commingled with plastic, metal, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Germany	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal

Greece	100% commingled with glass, metal, plastic, beverage carton	100% commingled with paper and cardboard, glass, plastic, beverage carton	100% commingled with paper and cardboard, metal, plastic, beverage carton	100% commingled with paper and cardboard, metal, glass, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, glass, plastic
Hungary	50% single stream, 50% commingled with metal, plastic, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Ireland	100% commingled with metal, plastic, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Italy	100% commingled with beverage carton	100% commingled with plastic	100% single stream	100% commingled with metal	100% single stream	100% commingled with paper and cardboard
Latvia	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream
Lithuania	75% single stream, 25% commingled with metal, plastic, beverage carton	75% single stream, 25% commingled with paper and cardboard, plastic, beverage carton	100% single stream	75% single stream, 25% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, plastic
Luxembourg	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream
Malta	100% commingled with metal, plastic, beverage carton	100% commingled with paper and cardboard, plastic, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, beverage carton	100% single stream	100% commingled with paper and cardboard, plastic, metal
Netherlands	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Poland	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Portugal	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Romania	100% commingled with glass, metal, plastic, beverage carton	100% commingled with paper and cardboard, glass, plastic, beverage carton	100% commingled with paper and cardboard, metal, plastic, beverage carton	100% commingled with paper and cardboard, metal, glass, beverage carton	100% single stream	100% commingled with paper and cardboard, metal, glass, plastic
Slovakia	100% single stream	50% single stream, 50% commingled with plastic,	100% single stream	50% single stream, 50% commingled with metal,	100% single stream	100% commingled with

		beverage carton		beverage carton		metal, plastic
Slovenia	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Spain	100% single stream	100% commingled with plastic, beverage carton	100% single stream	100% commingled with metal, beverage carton	100% single stream	100% commingled with plastic, metal
Sweden	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream	100% single stream

Annex 2. Capture rate per waste stream and Member State for 2018

Member State	Paper and cardboard waste	Metal waste	Glass waste	Plastic waste	Bio-waste	Discarded equipment	Batteries and accumulators waste	Textile waste	Wood waste	Rubber Waste	Construction and demolition
Austria	87	75	77	52	80	50	46	40	96	100	100
Belgium	74	72	87	23	67	44	62	47	93	100	100
Bulgaria	37	40	43	23	26	64	54	30 [γ]	23	100	100
Croatia	44	0	57	20	19	68	96	9	62	100	100
Cyprus	51[α]	41	54	14	9	28	36	9	3	100	100
Czechia	68	83	64	52	51	19[δ]	47	39	85	100	100
Denmark	68	34	89	33	60	40	49	11	65 [γ]	100	100
Estonia	56	60	57	31	24	52	34	10	61	100	100
Finland	60	90	66	21	47	50	45	30 [γ]	81	100	100
France	35 [α]	28 [α]	69	19 [α]	50	42	47	19	96	100	100
Germany	91	64	79	73	62	36	48	73	93 [δ]	100	100

Greece	46	32	15	11	8	6 [δ]	34	30 [γ]	8	100	100
Hungary	21	34	42	11	43	30	47	7	49 [δ]	100	100
Ireland	54	28	78	30	34	62	51	4	77	100	100
Italy	59	56	88	44	68	28	42	22	86	100	100
Latvia	62	6	37	13	20	41	45	30 [γ]	65 [γ]	100	100
Lithuania	72	92	59	27	41	40	47	5	52	100	100
Luxembourg	71	56	76	32	60	48	69	44	65 [γ]	100	100
Malta	56	26	60	11	34	31	35	15	85	100	100
Netherlands	84	35	65	42	63	37	47	29	86	100	100
Poland	51 [α]	32 [α]	60 [α]	1 [α]	43 [γ]	39	81	30 [γ]	65 [γ]	100	100
Portugal	40	5	52	21	10	41	31	1	50	100	100
Romania	15 [β]	9 [β]	15 [β]	16 [β]	8 *	24	53	30 [γ]	65 [γ]	100	100
Slovakia	55	91	58	35	36	43	58	8	65 [γ]	100	100
Slovenia	91	92	85	50	73	37	39	9	95	100	100
Spain	51 [α]	26	33	17	10	44	38	6	11	100	100
Sweden	57 [δ]	92 [δ]	85 [δ]	36 [δ]	51	50	45	4	65 [γ]	100	100
EU27	55	47	59	28	43	39	49	30	65	100	100

[α] Criterion 2 of the hierarchy.
[β] Criterion 3 of the hierarchy.
[γ] Criterion 4 of the hierarchy.
[δ] Criterion 5 of the hierarchy.
* Assumed as Greece.

Annex 3. Distribution of waste receptacles volumes for Germany (%) (information provided by stakeholders).

Type of receptacle	Residual waste	Biowaste	Paper & Cardboard	Light Weight Packaging (LWP)**	Glass***	Other
Bag	0	0	0.1	26.6	0	0
35-50 litre	0.3	0.2	0	0	0.3	0
60-80 litre	12.8	9.8	0.1	0	12.8	0
110-120 litre	22.5	31	9.7	6.8	22.5	0
240-360 litre	21.5	34.7	60.7	44.4	21.5	0
550-770 litre	5.8	0.5	1.7	1.1	5.8	0
1100 litre	32.9	1	26.8	20.6	32.9	0
Container / others*	4.3	22.7	0.9	0.5	4.3	100
Total	100	100	100	100	100	100
Single-Family (35L-to-360L)	*57*	*76*	*71*	*78*	*57*	*0*
Multi-Family (550L-to-2500L)	*43*	*24*	*29*	*22*	*43*	*100*

* Assumption: 2500 litre
** For all types of light weight packaging collection (plastic, metal, paper & cardboard, and beverage carton), single material or co-mingled collection, the same distribution was applied.
*** For glass collection, no distribution was available. Therefore, the same distribution as for residual waste was assumed.

Annex 4. Coverage of the DRS in Member States for specific waste fractions (%) (information provided by stakeholders).

DRS coverage	HR	DK	EE	FI	DE	LT	SK
Cover of glass on glass generated	60	16	20	61	2	14	29
Cover of PET on the PET generated	90	90	90	90	90	90	90
Cover of HDPE on HDPE generated	0	0	0	0	0	0	0
Cover of Al cans on Al cans generated	90	90	90	90	90	90	90
Cover of steel cans on steel cans generated	90	0	90	0	0	90	90

Annex 5. Unit-costs used to model the cost of MSW management in the EU27.

Cost of waste collection, EUR2020 per tonne				
Total cost of MSW collection				
Waste stream	Default	*Lower Bound*	*Upper Bound*	*Sources*
Paper and cardboard	157	*60*	*419*	*Bain & Utilitalia (2018), Umwelt Bundesamt (2018), COLLECTORS (2020), ISPRA (2021)*
Glass	93	*42*	*186*	*Bain & Utilitalia (2018), ADEME (2021), ACR+ (2021), COLLECTORS (2020), FEVE (2012), ISPRA (2021)*
Metal	153	*88*	*217*	*ISPRA (2021)*
Plastic	268	*121*	*448*	*Bain & Utilitalia (2018), ISPRA (2021)*
Biowaste	128	*35*	*365*	*Bain & Utilitalia (2018), NVRD (2021), ISPRA (2021)*
Commingled fractions	246	*72*	*475*	*Bain & Utilitalia (2018), ADEME (2021), Blok and Kort (2017), COLLECTORS (2020), NVRD (2021), ISPRA (2021)*
Residual waste	128	*52*	*316*	*Bain & Utilitalia (2018), ADEME (2021), COLLECTORS (2020), NVRD (2021)*

Costs of waste treatment, EUR2020 per tonne										
CAPEX are amortised and annualised. CAPEX and OPEX are also re-calculated using HICP starting from the 2015 costs reported in Eionet (2018)										
Treatment Type	CAPEX	*Lower Bound*	*Upper Bound*	OPEX	*Lower Bound*	*Upper Bound*	Total	*Lower Bound*	*Upper Bound*	*Source*
Anaerobic Digestion	17.0	*16.0*	*20.2*	30	*21*	*41*	47	*37*	*61.2*	*Tonini et al. (2021)*
Open air composting	10.6	*4.2*	*17.0*	31.0	*31.0*	*31.0*	41.6	*35.2*	*48.0*	*Eionet (2018)*
In Vessel Composting	17.0	*4.0*	*53*	23	*16.4*	*36.4*	40	*20.4*	*89.4*	*Tonini et al. (2021)*
Incineration	50.0	*12.4*	*185.6*	75.0	*18.6*	*278.4*	125.0	*31.0*	*464.0*	*Andreasi Bassi et al. (2022)*
Landfill	27.8	*2.0*	*80.0*	41.7	*3.0*	*120.0*	69.5	*5.0*	*200.0*	*Andreasi Bassi et al. (2022)*
MBT	54	*4.2*	*54*	32	*32*	*32*	86	*36.2*	*86*	*Tonini et al. (2021)*
Sorting	18.3	*13.8*	*22.3*	50.0	*20.0*	*100.0*	68.3	*33.8*	*122.3*	*Eunomia & COWI (2022)*
Recycling glass*							12.8	*10.4*	*15.2*	*ISPRA (2021)*
Recycling metal*							20.8	*14.2*	*27.4*	*ISPRA (2021)*
Recycling paper & cardboard*							23.02	*20.9*	*25.1*	*ISPRA (2021)*
Recycling plastic PET	56.7	*56.7*	*56.7*	144.4	*144.4*	*144.4*	201.2	*201.2*	*201.2*	*Andreasi Bassi et al. (2020)*
Recycling plastic film	62.8	*41.7*	*93.1*	171.0	*155.0*	*171.0*	233.8	*196.7*	*264.1*	*Andreasi Bassi et al. (2020)*
Recycling plastic rigid	62.8	*41.7*	*93.1*	171.0	*155.0*	*171.0*	233.8	*196.7*	*264.1*	*Andreasi Bassi et al. (2020)*

Price of material recycled, EUR2020 per tonne				
Recalculated to yr 2020 from yr 2015				
Type of Facility	Default	*Lower Bound*	*Upper Bound*	*Source*
Aluminium	920	*529*	*1,269*	*Eionet (2018)*
Price of urea	462	*386*	*532*	*Andreasi Bassi et al. (2021)*
Price of K2O	369	*304*	*434*	*Andreasi Bassi et al. (2021)*
Price of P2O5	565	*561*	*760*	*Andreasi Bassi et al. (2021)*
Glass	19	*5*	*106*	*Eionet (2018)*
Paper & Cardboard	118	*11*	*190*	*Eionet (2018)*
Plastics	121	*21*	*212*	*Eionet (2018)*
Steel	129	*79*	*264*	*Eionet (2018)*
Textiles	314	*106*	*1,058*	*Eionet (2018)*

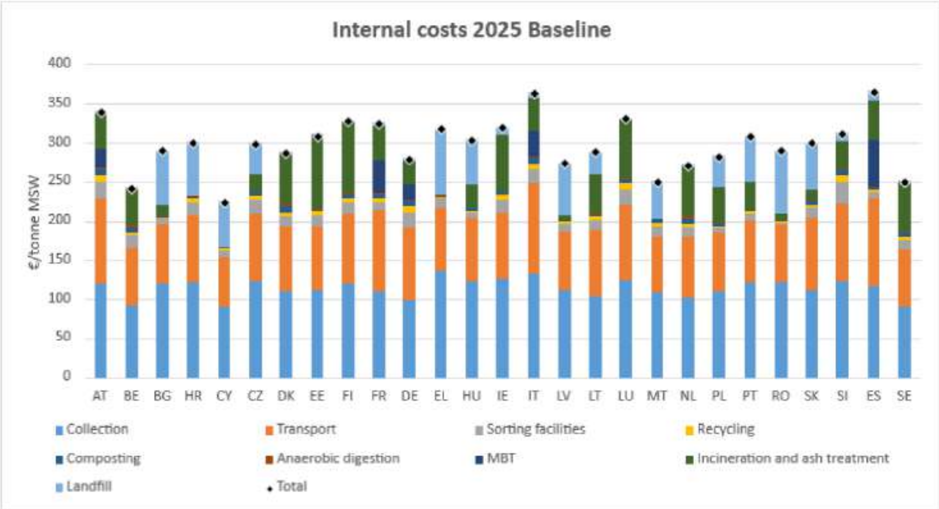
Labour resources required for waste management (Full Time Equivalent person (FTE) per tonne)				
Labour required, FTE/tonne				
Treatment Type	Default	*Lower Bound*	*Upper Bound*	*Source*
Anaerobic Digestion	0.0007	*0.00038*	*0.00102*	*Tonini et al. (2021)*
In Vessel Composting	0.0006	*0.00038*	*0.00101*	*Tonini et al. (2021)*
Incineration	0.0001	*0.00001*	*0.00027*	*Andreasi Bassi et al., (2022)*
Landfill	0.0001	*0.00005*	*0.00010*	*Andreasi Bassi et al., (2022)*
MBT	0.0004	*0.0004*	*0.0004*	*Eionet (2018)*
Sorting	0.0007	*0.0001*	*0.0043*	*Andreasi Bassi et al., (2022)*
Recycling glass	0.0008	*0.0008*	*0.0008*	*Eionet (2018)*
Recycling aluminium	0.0110	*0.0110*	*0.0110*	*Eionet (2018)*
Recycling ferrous	0.0054	*0.0054*	*0.0054*	*Eionet (2018)*
Recycling non-ferrous	0.0065	*0.0065*	*0.0065*	*Eionet (2018)*
Recycling paper & cardboard*	0.0018	*0.0018*	*0.0018*	*Eionet (2018)*
Recycling PET	0.0007	*0.0001*	*0.0013*	*Andreasi Bassi et al., (2022)*
Recycling plastic film	0.0007	*0.0001*	*0.0013*	*Andreasi Bassi et al., (2020)*
Recycling plastic rigid	0.0007	*0.0001*	*0.0013*	*Andreasi Bassi et al., (2020)*
Recycling bulky	0.0136	*0.0136*	*0.0136*	*Eionet (2018)*
Recycling wood	0.0008	*0.0008*	*0.0008*	*Eionet (2018)*
Recycling textile	0.0050	*0.0050*	*0.0050*	*Eionet (2018)*

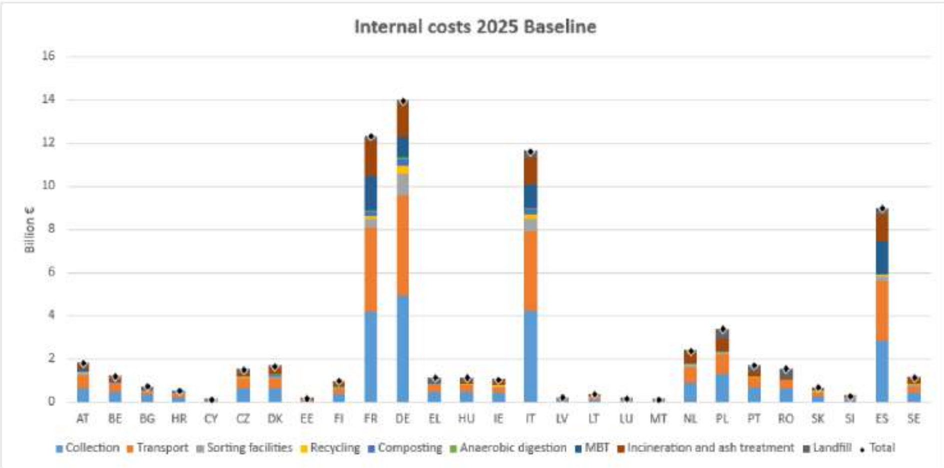
Annex 6. Sorting and recycling (material recovery) rates used in the modelling of MSW in the EU27

Recovery Rates, sorting and recycling %												
Either as individual rate at sorting and recycling, or total recovery. Notice that recovery rate = 100% - reject rate.												
Material group	Material fraction	Product	Sorting	*Lower Bound*	*Upper Bound*	Recycling	*Lower Bound*	*Upper Bound*	Total	*Lower Bound*	*Upper Bound*	*Sources*
Beverage cartons	Beverage cartons	Drinks							75%	*75.0%*	*75.0%*	*Eionet (2018)*
Biowaste	Food waste								88%	*76.0%*	*99.0%*	*Eionet (2018)*
	Garden waste								88%	*76.0%*	*99.0%*	*Eionet (2018)*
Glass	Blue								91%	*87.4%*	*94.0%*	*Eionet (2018)*
	Brown								91%	*87.4%*	*94.0%*	*Eionet (2018)*
	Clear								91%	*87.4%*	*94.0%*	*Eionet (2018)*
Metal	Aluminium	cans							94%	*89.0%*	*99.0%*	*Eionet (2018)*
	Ferrous	cans							95%	*92.0%*	*98.0%*	*Eionet (2018)*
		Tin plate							94%	*92.0%*	*95.0%*	*Eionet (2018)*
		Other							62%	*38.0%*	*85.0%*	*Eionet (2018)*
	Nonferrous								51%	*27.0%*	*74.0%*	*Eionet (2018)*
Paper & cardboard	Brown board								93%	*89.0%*	*97.0%*	*Eionet (2018)*
	Grey & white board								91%	*86.0%*	*96.0%*	*Eionet (2018)*
	Newspaper & pamphlets								96%	*93.0%*	*99.0%*	*Eionet (2018)*
	Paper & card								84%	*70.0%*	*97.1%*	*Eionet (2018)*
Plastic	EPS	Food & EEE Packaging	48%	*31.0%*	*79.0%*	66%	*57.0%*	*90.0%*	32%	*17.7%*	*71.1%*	*Caro et al.(2022)*
	HDPE	Bottles & containers	76%	*53.0%*	*91.0%*	84%	*70.0%*	*95.0%*	64%	*37.1%*	*86.5%*	*Caro et al.(2022)*

		PTTs	76%	*53.0%*	*91.0%*	84%	*70.0%*	*95.0%*	64%	*37.1%*	*86.5%*	*Caro et al.(2022)*
	LDPE	Monolayer	79%	*21.0%*	*89.0%*	71%	*50.0%*	*94.0%*	56%	*10.5%*	*83.7%*	*Caro et al.(2022)*
		Multilayer	56%	*21.0%*	*89.0%*	59%	*50.0%*	*71.0%*	33%	*10.5%*	*63.2%*	*Caro et al.(2022)*
	PET	Bottles	89%	*45.0%*	*97.0%*	80%	*63.0%*	*95.0%*	71%	*28.4%*	*92.2%*	*Caro et al.(2022)*
		Trays	58%	*45.0%*	*91.0%*	80%	*63.0%*	*95.0%*	46%	*28.4%*	*86.5%*	*Caro et al.(2022)*
	PP	Bottles & containers	50%	*21.0%*	*89.0%*	59%	*50.0%*	*71.0%*	30%	*10.5%*	*63.2%*	*Caro et al.(2022)*
		Monolayer	50%	*21.0%*	*89.0%*	59%	*50.0%*	*71.0%*	30%	*10.5%*	*63.2%*	*Caro et al.(2022)*
		Multilayer	50%	*31.0%*	*91.0%*	71%	*53.0%*	*95.0%*	36%	*16.4%*	*86.5%*	*Caro et al.(2022)*
		PTTs	50%	*31.0%*	*91.0%*	71%	*53.0%*	*95.0%*	36%	*16.4%*	*86.5%*	*Caro et al.(2022)*
	PS	PTTs & Diary Pack	48%	*31.0%*	*79.0%*	66%	*57.0%*	*90.0%*	32%	*17.7%*	*71.1%*	*Caro et al.(2022)*
Textile			0%									

Annex 7. Breakdown of MSW internal costs for 2025





Annex 8. Cost Results for 2031-2040 for EU27

		2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Cumulative 2031-2040
Sub-measure 1	Other internal cost	-73	-73	-73	-72	-72	-71	-70	-70	-69	-69	-712
	Other internal costs (without taxes)	-39	-39	-39	-38	-38	-38	-37	-37	-37	-36	-378
	Foregone revenues	49	49	50	50	50	50	51	51	51	52	503
	External costs	-136	-135	-135	-134	-133	-132	-132	-131	-130	-129	-1 327
Sub-measure 2	Other internal cost	-74	-73	-73	-72	-72	-71	-71	-70	-69	-69	-713
	Other internal costs (without taxes)	-39	-39	-39	-38	-38	-38	-37	-37	-37	-36	-378
	Foregone revenues	49	49	49	50	50	50	51	51	51	51	501
	External costs	-136	-136	-135	-134	-134	-133	-132	-131	-130	-129	-1 330

Annex 9. Cost Results per Member State

		Austria		Belgium		Bulgaria		Croatia	
		Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040
Sub-measure 1	Other internal cost	-38	-82	0	0	-3	-5.2	2	3.7
	Other internal costs (without taxes)	-26	-56.8	0	0	-0.2	-0.2	5	11.5
	Foregone revenues	36	77.5	0	0	-6	-8.6	-10	-21.2
	External costs	-54	-117.3	0	0	-17	-26.1	-14	-29.7
Sub-measure 2	Other internal cost	-34	-81	0	0	-3	-5.4	2	3.7
	Other internal costs (without taxes)	-23	-56.3	0	0	-0.2	-0.3	5	11.4
	Foregone revenues	32	76.8	0	0	-5	-8.9	-9	-21.1
	External costs	-49	-116.3	0	0	-16	-27.1	-12	-29.5

		Cyprus		Czechia		Denmark		Estonia	
		Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040
Sub-measure 1	Other internal cost	0	0	-31	-60.5	0	0	-1	-1.8
	Other internal costs (without taxes)	0	0	-11	-21.8	0	0	-0.01	-0.02
	Foregone revenues	0	0	-23	-43.9	0	0	3	6.8
	External costs	0	0	-81	-158	0	0	-4	-8.7
Sub-measure 2	Other internal cost	0	0	-28	-60.5	0	0	-1	-1.8
	Other internal costs (without taxes)	0	0	-10	-21.8	0	0	-0.01	-0.02
	Foregone revenues	0	0	-20	-43.9	0	0	3	6.8
	External costs	0	0	-73	-157.9	0	0	-4	-8.7

		Finland		France		Germany		Greece	
		Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040	Cumulative 2024-2030	Cumulative 2031-2040
Sub-measure 1	Other internal cost	0	0	0	0	-161	-320.6	-3	-3.4
	Other internal costs (without taxes)	0	0	0	0	-78	-155.2	3	4.1
	Foregone revenues	0	0	0	0	278	554.0	-14	-18.4
	External costs	0	0	0	0	-308	-613.3	-23	-29.5

Sub-measure 2	Other internal cost	0	0	0	0	-145	-320.7	-2	-3.5
	Other internal costs (without taxes)	0	0	0	0	-70	-155.2	3	4.1
	Foregone revenues	0	0	0	0	251	554.3	-13	-19.3
	External costs	0	0	0	0	-277	-613.6	-21	-30.8

		Hungary		Ireland		Italy		Latvia	
		Cumulative 2024-2030	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**
Sub-measure 1	Other internal cost	-13	-25.9	0	0	0	0	-1	-2.6
	Other internal costs (without taxes)	-6	-11.8	0	0	0	0	0.1	0.1
	Foregone revenues	-7	-13.4	0	0	0	0	-2	-5.1
	External costs	-33	-67.6	0	0	0	0	-4	-8.7
Sub-measure 2	Other internal cost	-11	-25.7	0	0	0	0	-1	-2.5
	Other internal costs (without taxes)	-5	-11.8	0	0	0	0	0.1	0.1
	Foregone revenues	-6	-13.3	0	0	0	0	-2	-5.1
	External costs	-30	-67.2	0	0	0	0	-4	-8.7

		Lithuania		Luxembourg		Malta		Netherlands	
		Cumulative 2024-2030	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**
Sub-measure 1	Other internal cost	0	0	-8	-16.8	-3	-7.1	0	0
	Other internal costs (without taxes)	0	0	-6	-12.6	-1	-3.1	0	0
	Foregone revenues	0	0	5	11.1	-4	-8.6	0	0
	External	0	0	-4	-8.5	-7	-15.9	0	0

	costs								
Sub-measure 2	Other internal cost	0	0	-7	-16.6	-3	-7.0	0	0
	Other internal costs (without taxes)	0	0	-5	-12.4	-1	-3.0	0	0
	Foregone revenues	0	0	5	11.0	-3	-8.4	0	0
	External costs	0	0	-4	-8.4	-6	-15.6	0	0

		Poland		Portugal		Romania		Slovakia	
		Cumulative 2024-2030	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**
Sub-measure 1	Other internal cost	-75	-126.5	0	0	-2	-4	-34	-58.5
	Other internal costs (without taxes)	-55	-50	0	0	1	2.7	-28	-49
	Foregone revenues	0	0.7	0	0	-9	-16.1	-8	-13.5
	External costs	-48	-80.5	0	0	-25	-46.9	-41	-69.8
Sub-measure 2	Other internal cost	-68	-128.5	0	0	-2	-4	-31	-58.9
	Other internal costs (without taxes)	-93.6	-95.1	0	0	1	2.7	-26	-49.3

	Foregone revenues	0	0.7	0	0	-8	-16.2	-7	-13.6
	External costs	-43	-81.8	0	0	-23	-47.2	-37	-70.3

		Slovenia		Spain		Sweden	
		Cumulative 2024-2030	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**	**Cumulative 2024-2030**	**Cumulative 2031-2040**
Sub-measure 1	Other internal cost	-0.21	-0.4	0	0	0	0
	Other internal costs (without taxes)	4	8.2	0	0	0	0
	Foregone revenues	1	1.2	0	0	0	0
	External costs	-24	-46.8	0	0	0	0
Sub-measure 2	Other internal cost	-0.19	-0.4	0	0	0	0
	Other internal costs (without taxes)	4	8.2	0	0	0	0
	Foregone revenues	1	1.2	0	0	0	0
	External costs	-21	-46.9	0	0	0	0

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