INDICATORS FOR WASTE PREVENTION AND MANAGEMENT

Measuring circularity

4/3/2019
Abstract

This report presents a set of indicators on circular economy, waste prevention and management, and guidance on their application.

The indicators provide means to assess the performance of an urban area (e.g., municipality) and monitor progress over time; to measure the effectiveness of strategic planning (e.g., providing insight on the efficiency of implemented strategies and policies); to support decision-making (e.g., on priorities and targets for developing strategies and policies); and to compare to other urban areas (e.g., benchmark).

The work was developed within Task T2.3 of the UrbanWINS project “Definition of a set of key indicators for urban metabolism based on MFA and LCA”, and will be reported in Deliverable D2.3 “Urban Metabolism case studies. Reports for each of the 8 cities that will be subject to detailed study with quantification and analysis of their Urban Metabolism”.

Keywords

Circular economy; Waste prevention and management; Indicators
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1. Introduction

A diversity of monitoring tools and indicators are available to assess the performance of waste prevention and management systems, with different levels of detail and complexity, and at different scales, from a macro-level (e.g., global, national), to meso- (e.g., urban area, economic sector) and micro-levels (e.g., company, product) (Chavez et al. 2011; EC 2012). This report presents a set of indicators to assess waste prevention and management systems and strategies, as well as the associated environmental impacts, within a circular economy perspective. Furthermore, the document provides guidance on the application of these indicators, including an example for three UrbanWINS pilot cities: Leiria, Sabadell and Manresa.

The selection is focused on indicators that are suitable for urban areas (e.g., municipalities) that provide means to:

- assess performance and monitor progress across time;
- measure the effectiveness of strategic planning (e.g., providing insight on the efficiency of implemented strategies and policies);
- support decision-making (e.g., helping on the identification of priorities and targets for developing strategies and policies); and
- compare to other urban areas (e.g., benchmark).

The selection and application of indicators is framed within a circular economy perspective, i.e., instead of focusing or being limited to the assessment of waste management, it considers a wider scope including sustainable consumption and production aspects (e.g., from material extraction to the environmental impacts associated with consumption). The wider scope provides insight on resource use and efficiency, contributing to a more comprehensive assessment of the potential impacts and benefits of strategies and policies for waste prevention and management.

This report was developed within the UrbanWINS project, Task 2.3 “Definition of a set of key indicators for urban metabolism based on MFA and LCA”, which is reported in Deliverable 2.3 “Urban Metabolism case studies. Reports for each of the 8 cities that will be subject to detailed study with quantification and analysis of their Urban Metabolism”.
2. Review and selection of indicators

A review of indicators found in the literature in the context of waste prevention and management, resource use, circular economy and urban metabolism was carried out. This review was complemented with indicators collected from other tasks and WPs, namely WP1 (D1.2) and Tasks 2.1 and 2.2 of WP2. After compiling a list of 163 indicators, an indicator set was developed following three steps:

1. Reorganization and structuring of the indicators list

A number of the collected indicators from different sources and literature references had the same purpose and provided similar insight. In other cases, the collected indicators were disaggregated by waste material categories or streams, or by economic sectors. In this context, a first step was to reorganize and aggregate these indicators to avoid repetition. The aim was to have one single indicator to inform on each issue covered, which could be used at different levels of disaggregation.

   EXAMPLE
   
   The indicators for glass capture rate, paper capture rate, plastic capture rate, were aggregated into one single indicator “Material capture rate”, which can be disaggregated when applied, according to the existing waste streams.

2. Selection of indicators based on relevance and data availability

A set of indicators was then selected from the previous list based on relevance (according to the aims and scope of the project), data quality and availability. This document focuses on indicators for which there are generally available data and methodologies to provide insight on the performance and environmental impacts associated with waste management and circularity; however, it acknowledges that there are other relevant issues and indicators that should be pursued by decision-makers, when the quality and availability of data exists to adequately address them (section 6).
The indicator set

3. Check for diversity and comprehensiveness

Lastly, a revision and some adjustments were done to the selection, to ensure a wide and comprehensive range and diversity of economic, environmental and social issues, waste prevention and management phases, relevant waste material categories and economic sectors.

EXAMPLE

The indicators selected cover all waste management phases (i.e., prevention, generation, collection and end-of-life treatment/disposal. While there is a focus on waste management, a broader circular economy perspective is considered, with indicators on resource use and productivity, for example. The selection also includes a wide range of economic, environmental and, to some extent, social indicators.

3. The indicator set

A total of 60 indicators were selected focusing on waste prevention and management from a circular economy perspective, presented in Table 1. The indicators were organized into two thematic groups: a more objective and narrow scope of waste indicators, and a group of more general indicators within a circular economy perspective (focused on resource use and environmental impacts). Within the set of indicators, presented below, 10 (highlighted in blue) are presented as dashboard indicators, and the remaining 50 are complementary indicators. Dashboard indicators are a set of key indicators that should be calculated to have an overview/overall perspective of the urban area performance, to monitor progress across time and to compare with other urban areas (benchmark). Complementary indicators should be selected according to the specific needs and purposes of decision-makers, in their analyses. All indicators were characterized according to the DPSIR model (Driving Forces - Pressure - State - Impact - Responses approach), presented in the UrbanWINS Deliverable D1.2 (2017).

EXAMPLE

The selection of indicators does not address imported and exported waste, due to limitations in data availability; however, these flows can be highly significant and environmentally relevant. A transparent approach should be applied to address imported and exported waste, while avoiding double counting (JRC, 2012).
The indicator set

A summary table with a short description, calculation, DPSIR framing and references for all the 60 indicators is presented at the end of this document, in *Annex I - Indicators summary table*; and an application matrix, describing the waste management phases and disaggregation options for the indicators is presented in *Annex II - Application matrix*.

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*Table 1 - The indicator set: a selection of 60 indicators, separated into waste and circular economy indicators. Ten indicators, highlighted in blue, are dashboard indicators; the remaining 50 are complementary indicators.*
3.1. Indicators application matrix

The 10 dashboard indicators provide a summarized perspective of the urban area’s performance and waste prevention and management systems, which is crucial to assess and monitor the overall performance. Nonetheless, decision-making often has specific scopes and targets, and the 50 complementary indicators can be selected and applied accordingly. To ease the selection of indicators according to the specific scope and purposes of analysis and decision-making, we provide an application matrix, in Annex 2, classifying/mapping indicators according to:

- the waste prevention and management phases they can be associated with;
- the possibility of subdividing into (or looking at) specific economic sectors; and
- the possibility of disaggregating by (or looking at) specific waste material categories or streams.

Disaggregation into waste prevention and management phases includes prevention, generation, collection and end-of-life treatment/disposal. Disaggregation into economic sectors can focus the analysis in households (which can also be disaggregated into high, average and low income), food services, industry, construction, etc., depending on the targets and availability of disaggregated data. In cases, complementary indicators are specifically focused on household waste or specific waste streams (e.g., hazardous waste, food waste) because such disaggregation or subdivision is considered particularly relevant, regardless of the fact that they can be a subdivision or disaggregation of another complementary indicator.

Lastly, units for some indicators can also be adapted according to the scope and aims of the application. As mentioned, assessment of waste prevention and management can be focused on monitoring and evaluating progress of the system and the success of implemented policies (longitudinal analysis) or it can aim at comparing different cities to understand and frame the situation within an international context, for example (e.g., benchmarking, cross-country comparisons). For example, several indicators presented here can be calculated as total or per capita. Overall figures can be useful to monitor evolution across a defined period, while per capita figures can ease interpretation and comparability between different geographic areas or waste management systems.
4. Indicators description and application

4.1. Waste indicators

1. **Available landfill lifespan**
   
   *Available landfill airspace/incoming waste volume per year*
   
   Unit: Time (years)

   Monitoring landfill lifespan aims at evaluating whether available landfills can meet medium to long-term demands. This indicator is reported as landfill lifespan in years, calculated as available airspace divided by the incoming waste volume per year. It informs on the short/medium/long-term necessity of diverting waste from landfills, planning and permitting of new landfills.

   Reference(s): Arendse and Godfrey (2010)

   **Typology according to DPSIR framework: PRESSURE/STATE indicator**

2. **Bring points coverage**
   
   *No. of bring points x 100 000/no. of inhabitants*
   
   Unit: Unitless (ratio)

   This indicator expresses the amount of bring points by 100 000 inhabitants, providing insight on the coverage and density of bring sites across cities. In general, better coverage yields better collection rates and bring points are the main mean of collection for separated waste in many cities. Generally, the focus should be on the number of bring points for selective collection (as undifferentiated collection is done door-to-door in many cities). However, when relevant, the undifferentiated waste collection bring points can be considered as well.

   This indicator can be disaggregated by waste streams or material categories (e.g., paper, plastics and glass).

   Reference(s): EC (2015)

   **Typology according to DPSIR framework: STATE indicator**
3. Collected waste

*Mass amount of collected waste*

Unit: Mass (t)

This indicator refers to the overall waste collected, in terms of mass, by or on behalf of municipalities (including municipal waste collected by the private sector). It includes mixed waste, and fractions collected separately for recovery operations (through door-to-door collection and/or bring points).

It can be calculated as total or per capita. Overall figures can be particularly useful to see the evolution across a defined period, while per capita figures ease comparison between different systems and geographic areas.

This indicator can be disaggregated by:

- collection systems (e.g., door-to-door, bring points)
- waste streams or material categories (e.g., paper, plastics, glass)
- economic/waste generation sectors (e.g., households, commercial)

Reference(s): UN stats (https://unstats.un.org/unsd/environment/municipalwaste.htm)

**Typology according to DPSIR framework: DRIVER/RESPONSE indicator**

4. Composition of collected waste

*Mass amount of each waste stream / total mass of collected waste*

Unit: Unitless (share)

This indicator expresses the share of each waste stream or material category (e.g., glass, metal, plastic, paper, e-waste, etc.) in the overall collected waste, in terms of mass.

It can be disaggregated by:

- waste generation sector (e.g., households, commerce)
- socio-demographic groups (e.g., income level)

Reference(s): Chavez et al. (2011); Hoornweg and Bhada-Tata (2012); D-Waste (2013)

**Typology according to DPSIR framework: DRIVER/RESPONSE indicator**
5. **Controlled treatment or disposal**

Total waste that is dealt with in a 'controlled' facility/total solid waste destined for treatment or disposal

Unit: Unitless (share)

This indicator expresses the share of municipal solid waste destined for treatment or disposal (i.e., total waste collected excluding waste recycled or reused), which either goes to a state-of-the-art, an engineered or a 'controlled' treatment/disposal site, including incineration.

Reference(s): Wilson et al. (2015)

**Typology according to DPSIR framework: DRIVER/RESPONSE indicator**

6. **Cost of waste collection**

Cost of collection per mass unit of waste

Unit: Monetary/mass (EUR/t)

Costs of waste collection include costs associated with the manufacture and use of containers, vehicles, labour, equipment and sorting of waste, as well as costs on information provision or education on collection schemes. These costs depend on the number of collection points and resources spent to cover the network (affected by population density and traffic, among others), frequency of connection, labour costs, etc.

It is generally assumed that ‘collection’ ends when the specialized refuse collection vehicles discharge waste at a transfer station, a treatment plant, a material recycling facility or at landfill. It includes collection of solid waste from point of production (e.g., residential, industrial, commercial, institutional) to the point of treatment or disposal.

This indicator should be used with caution, as lower costs per tonne of collected waste do not necessarily indicate better performance (e.g., the separation of waste into different streams tends to increase the costs of collection). To ease interpretation, costs should be detailed and broken-down. It can be calculated per capita, instead of mass unit of waste.

This indicator can be disaggregated by:

- waste streams or material categories (e.g., residual waste, glass, paper)
- economic/waste generation sectors (e.g., households, commerce)

Reference(s): Hogg et al. (2002); Chavez et al. (2011)

**Typology according to DPSIR framework: STATE indicator**
7. **Cost of waste disposal**

*Cost of waste disposal per mass unit of waste*

Unit: Monetary/mass (EUR/t)

This indicator expresses the costs of waste disposal, including: acquisition costs, capital expenditure and development costs, operating costs, restoration, and aftercare costs. It can be calculated as a weighted average cost or disaggregated by different disposal systems/types (e.g., sanitary landfill, open dumping).

This indicator can also be disaggregated by:

- waste streams or material categories (e.g., residual waste, glass, plastic, paper)
- waste generation sectors (e.g., households, commerce)

Reference(s): Hogg et al. (2002)

Typology according to DPSIR framework: STATE indicator

8. **Cost of waste treatment**

*Cost of waste treatment per mass unit of waste*

Unit: Monetary/mass (EUR/t)

Costs of waste treatment (e.g., composting, anaerobic digestion, waste-to-energy incineration) include land acquisition, construction/manufacture and use of facilities and equipment, labour and disposal of rejects, as well as fees or taxes; sale revenues should also be included in the indicator (subtracted from costs). In this indicator, the costs are calculated per mass unit of waste (waste input in the case of landfills and waste throughput for other treatments).

For example:

- Cost of composting: excludes sale of finished compost (the costs of compost plant); includes costs of land acquisition; the requirements for land per unit of capacity; scale; plant utilization rate; the choice of technology, in particular the degree of process control. This may be linked to the input materials/the location; the purity of source separation (which will determine the need for screening); the nature and length of contracts and the materials received; revenues for sale of product, related to the quality of input material and the maturity of the end product.
Indicators description and application

- Cost of anaerobic digestion: includes sale of energy from methane and excludes cost of residue sale and disposal.

- Cost of waste-to-energy incineration: includes sale of any net energy; excludes disposal costs of bottom and fly ash (non-hazardous and hazardous)

It can be calculated as a weighted average cost or disaggregated by treatment type/option (e.g., composting, landfilling, etc.); and it can be disaggregated by waste streams or material categories (e.g., paper, glass, plastics).

Reference(s): Hogg et al. (2002)

Typology according to DPSIR framework: STATE indicator

9. Food waste

   **Mass amount of food waste/no. of inhabitants**

   Unit: Mass (t)

This indicator refers to overall food waste, in terms of mass. Food waste is any food item destined for human consumption (including inedible parts of food) that is discarded, to be recovered or disposed of. The indicator includes waste from production, processing/transformation, distribution, and households and restaurants/canteens consumption (Møller et al. 2014). It is calculated for a defined period of time (e.g., 1 year).

It can be calculated as total or per capita. Overall figures can be particularly useful to see the evolution across a defined period, while per capita figures ease comparison between different systems and geographic areas.

There is generally very limited availability of quality data on food waste; however, it is a highly relevant indicator and food waste reduction is a priority across Europe. While a simplified framework for quantification of food waste can be used, data gaps should be filled over time and a harmonized methodology should be adopted to adequately quantify and monitor food waste in European cities (Møller et al. 2014). More details on how to quantify and assess food waste are available in the scope of FUSIONS FP7 project (Møller et al., 2014 and Stenmarck et al., 2016)

Reference(s): SOeS (2017); Stenmarck et al. (2016); Møller et al. (2014)
Indicators description and application

**10. Generation of waste (per capita)**

*Mass of waste generated/no. of inhabitants*

Unit: Mass/capita (kg/cap)

This indicator expresses the amount of waste generated per capita in a defined period (e.g., a year). Generally, the indicator covers hazardous and non-hazardous waste from all economic sectors and from households, including waste from waste treatment, and excluding most mineral wastes. A per capita basis is particularly useful in comparative and benchmarking analyses.

This indicator can be disaggregated by:

- waste streams or material categories (e.g., metal, plastic, hazardous waste)
- waste generation sources/sectors (e.g., households, commerce)
- treatment/disposal types (e.g., waste recovered, recycled, landfill disposal)

Waste streams with hazardous substances and high environmental impacts are particularly relevant and should be monitored and assessed in detail.

This indicator can be complemented with the amount of waste generated on an area basis (e.g., t/km²). However, the generated waste per area unit should be used with caution, as it is subject to the geographic/administrative boundaries: a larger area (with lower population density) might contribute to lower results, overlooking the actual system’s performance.

Reference(s): Arendse and Godfrey (2010); EMF (2015); EC (2016)

**Typology according to DPSIR framework: DRIVER indicator**

**11. Generation of waste (total)**

*Mass amount of waste generated*

Unit: Mass (t)

The indicator provides the overall amount of waste generated in a defined period (e.g., a year). Generally, the indicator covers hazardous and non-hazardous waste from all economic sectors and from households, including waste from waste treatment, and excluding most mineral wastes. In absolute terms (total), it can be particularly useful as a time series, to provide the perspective of the indicator evolution over time.
This indicator can be disaggregated by:

- waste streams or material categories (e.g., metal, plastic, hazardous waste)
- waste generation sources/sectors (e.g., households, commerce)
- treatment/disposal options (e.g., waste recovered, recycled, landfill disposal)

Waste streams with hazardous substances and high environmental impacts are particularly relevant and should be monitored and assessed in detail.

Reference(s): Arendse and Godfrey (2010); EC (2011); D-Waste (2013); SOeS (2017)

**Typology according to DPSIR framework: DRIVER indicator**

### 12. Hazardous substances presence

*Number of samples with hazardous substances/total no. of samples*

**Unit:** Unitless (share)

This is a survey-based indicator on the presence of restricted hazardous substances (based on the Restriction of Hazardous Substances - RoHS - directive) in selected waste streams. It indicates how many out of a defined number of random samples of a specific waste fraction contain hazardous substances above RoHS thresholds.

Due to the nature of the methodology only homogeneous samples of plastics, metals, waste electrical and electronic equipment (WEEE) components, batteries and other samples of possible carriers of hazardous substances are usually covered. Nonetheless, as hazardous substances are often present in these separated or mixed waste streams, the indicator can cover significant share of wastes containing hazardous substances.

Reference(s): EC (2011)

**Typology according to DPSIR framework: DRIVER indicator**
13. **Hazardous waste generation**

*Total hazardous waste generated*

Unit: Mass (t)

This indicator expresses the mass amount of hazardous waste that is generated in a defined period (e.g., 1 year). Hazardous waste is a waste stream of high concern due to the potential risks it poses to human health and the environment if not managed properly. The EU Waste Framework Directive requires hazardous waste to be duly classified, labelled and kept separate from non-hazardous waste, and EU Member States have to ensure proper management and traceability from its production to final destination.

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

This indicator can be disaggregated by:

- waste generation sources/sectors (e.g., households, commerce, hospitals)
- treatment options (e.g., incineration with energy recovery, disposal)

Reference(s): EEA (2015)

**Typology according to DPSIR framework: DRIVER indicator**

14. **Landfill rate of waste**

*Mass amount of waste landfilled/total mass waste treated*

Unit: Unitless (share)

The indicator is defined as the share of waste that is landfilled (directly or indirectly) in the total waste treated, for a defined period (e.g., 1 year). It covers hazardous and non-hazardous waste from all economic sectors and from households, including waste from waste treatment (secondary waste), but usually excluding most mineral waste, contaminated soils and polluted dredging spoils. This exclusion enhances comparability, as mineral waste accounts for high quantities in some countries due to economic activities such as mining and construction. One exception, however, is that the indicator explicitly includes combustion wastes and solidified, stabilized and vitrified wastes, despite them being completely or partly mineral.
Indicators description and application

The indicator is based on data compiled according to Annex I of the Waste Statistics Regulation (Regulation 2150/2002/EC) and according to aggregates of the material-oriented statistical waste nomenclature EWC-Stat in Annex III of the Waste Statistics Regulation (WStatR).

This indicator can be disaggregated by:

- waste streams or material categories (e.g., metal, plastic, hazardous waste)
- waste generation sources/sectors (e.g., households, commerce)

Reference(s): Eurostat (http://ec.europa.eu/eurostat/cache/metadata/EN/tsdpc210_esmsip.htm); EEA (2015); EC (2016); SOeS (2017)

**Typology according to DPSIR framework: DRIVER indicator**

**15. Material capture rate**

*Mass amount of a waste fraction collected separately/mass amount of total generated waste of that fraction*

Unit: Unitless (share)

The material capture rate is the share of an estimated waste generation of a material fraction (e.g., paper, glass, metal, plastic, bio-waste, co-mingled, etc.) that is collected separately. The estimate of waste generation can be based on national or city residual waste composition data.

This indicator can be calculated for the overall separately collected waste or disaggregated by:

- waste fractions (e.g., paper, glass, metal, plastic, bio-waste, co-mingled)
- waste generation sources/sectors (e.g., households)
- waste collection systems (e.g., door-to-door, bring points)

Reference(s): EC (2015)

**Typology according to DPSIR framework: RESPONSE indicator**
Indicators description and application

16. **Material collection**

*Mass amount of a waste fraction collected separately*

Unit: Mass (t)

Material collection provides the mass amount of a waste fraction (e.g. paper, glass, metal, plastic, bio-waste, co-mingled, etc.) that is separately collected.

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

This indicator can be calculated for the overall sum of separately collected waste fractions or disaggregated by:

- waste streams or material categories (e.g., paper, glass, metal, co-mingled)
- waste generation sources/sectors (e.g., households, commerce)
- waste collecting systems (e.g., door-to-door, bring points)

Reference(s): EC (2015)

Typology according to DPSIR framework: DRIVER/RESPONSE indicator

17. **Material recovery (MR)**

*Mass amount of products that are reused, recycled or valorised energetically*

Unit: Mass (t)

This indicator refers to the mass amount of end-of-life products that are reused, recycled or valorised energetically in the economy/geographical area.

This indicator can be calculated for the overall amount or disaggregated by:

- waste streams or material categories (e.g., paper, glass, metal, plastic, bio-waste, co-mingled)
- waste generation sources/sectors (e.g., households, commerce)

References(s): UMan model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

Typology according to DPSIR framework: DRIVER/RESPONSE indicator
18. Municipal solid waste (MSW) generation  

*Mass amount of municipal solid waste generated*

Unit: Mass (t)

The indicator estimates the total municipal solid waste generated. It accounts for collected and uncollected waste, and it can be estimated by calculating collected waste per capita for the population who have access to collection systems, and upscale to the total population to estimate overall municipal solid waste generation.

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

This indicator can be calculated for the overall sum of separately collected waste fractions or disaggregated by:

- waste streams or material categories (e.g., paper, glass, metal, co-mingled)
- waste generation sources/sectors (e.g., households, commerce)

Reference(s): Hoornweg and Bhada-Tata (2012)

**Typology according to DPSIR framework: DRIVER/RESPONSE indicator**

19. Residual waste share  

*Residual collected solid waste/total solid waste collected*

Unit: Unitless (share)

This indicator quantifies the share of solid waste collected that is residual, i.e., mixed waste that is not subject to separate collection. It indicates how much waste is not covered by separate collection streams.

This indicator can be disaggregated by:

- waste generation sources/sectors (e.g., households, commerce)
- waste collecting systems (e.g., door-to-door, bring points)

Reference(s): EC (2015)

**Typology according to DPSIR framework: DRIVER indicator**
Indicators description and application

20. Social participation on waste separation
   No. of households that separate waste/total no. of households

   Unit: Unitless (share)

   This indicator refers to the share of households that separate waste (i.e., number of households that separate waste out of the total number of households). It can also be referred to as participation in waste separation or segregation. In neighbourhoods of single-family housing, it can be calculated (counted), while for multi-family housing areas it should be based on surveys.

   While this might be more insightful than the bring points coverage, the bring points coverage was selected as a dashboard indicator, as proxy for social participation, due to the limited availability of quality data on the number of households that separate waste. Nonetheless, social participation on waste separation should be surveyed when possible.

   Reference(s): Malik et al. (2015)

Typology according to DPSIR framework: STATE/RESPONSE indicator

21. Social perception towards waste management
   No. of unsatisfied households/total no. of households

   Unit: Unitless (share)

   This survey-based indicator expresses the share of households that are not satisfied with the waste management. The indicator is useful to monitor evolution in time and compare social perception across different geographic areas. Nonetheless, a more detailed survey should be carried out for identification of the limitations and improvement opportunities for the waste management systems.

   Reference(s): Chavez et al. (2011)

Typology according to DPSIR framework: STATE indicator

22. Uncollected waste
   Mass amount of uncollected waste

   Unit: Mass (t)

   This indicator refers to the solid waste generated in a city that is not collected due to lack or limitations of collection services. The amount of uncollected waste can be estimated by multiplying the waste generation per capita in the city by the population who does not have access to solid waste collection services.
Indicators description and application

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.


Typology according to DPSIR framework: DRIVER indicator

23. Value of waste recycled

\[ \text{Value of waste recycled} = \text{Mass amount of waste recycled} \times \text{Value of waste recycled by mass unit} \]

Unit: Monetary (EUR)

Value of waste recycled indicates the value of recycled waste for a defined period of time (e.g., 1 year).

This indicator can be disaggregated into:
- Waste streams or material categories (e.g., paper, metal, plastic, co-mingled)

Reference(s): Arendse and Godfrey (2010)

Typology according to DPSIR framework: STATE indicator

24. Waste collection coverage

\[ \text{Waste collection coverage} = \frac{\text{No. of households with reliable waste collection service}}{\text{total no. of households}} \]

Unit: Unitless (share)

Waste collection coverage represents the percentage of population (households) that have access to a reliable waste collection service, including both formal municipal and informal sector services. A ‘collection service’ may be ‘door-to-door’ or by deposit into a community container or bring point. ‘Collection’ includes collection for recycling, as well as for treatment and disposal (e.g., collection of recyclables by itinerant waste buyers). ‘Reliable’ means regular (frequency depends on local conditions and on waste separation).

Reference(s): Wilson et al. (2015)

Typology according to DPSIR framework: RESPONSE indicator
25. Waste collection efficiency

*Collected waste / total waste generated*

Unit: Unitless (share)

This indicator expresses the share of waste generated that is actually collected (handled completely) by the waste management and recycling system; thus the waste that is not lost through illegal burning, burying or dumping in unofficial areas.

Waste captured by the system represents all the waste materials that are collected and delivered to an official treatment/disposal facility or to a recycling factory. This includes street sweepings, wastes collected, and waste materials collected for and delivered to recycling; and both formal municipal and informal sector services.

This indicator can be calculated for the sum of separately collected waste fractions or disaggregated by:

- waste streams or material categories (e.g. paper, glass, metal, plastic, bio-waste, co-mingled)
- waste generation sources/sectors (e.g., households, commerce)
- waste collecting systems (e.g., door-to-door, bring points)


**Typology according to DPSIR framework:** RESPONSE indicator

26. Waste concentration

*Mass amount of waste in disposal site / disposal site area*

Unit: Mass/Area (t/ha)

Waste concentration refers to the mass amount (tonnes) of waste that were already disposed per hectare (ha) of the disposal site.

Reference(s): D-Waste (2013)

**Typology according to DPSIR framework:** STATE indicator
27. Waste treatment and disposal

*Mass amount of waste that is treated or disposed of*

Unit: Mass (t)

This indicator provides the amount of waste that is disposed of through alternative disposal options (e.g., deposit in landfill, burned in incinerator, recycle, compost, etc.). For more insight, the indicator should be complemented with the shares of waste disposed in each of those ways.

This indicator can be disaggregated by:

- waste streams or material categories (e.g., paper, glass, metal, plastic, bio-waste, co-mingled)
- waste generation sources/sectors (e.g., households, commerce)

Reference(s): Hoornweg and Bhada-Tata (2012)

Typology according to DPSIR framework: DRIVER indicator

28. Waste intensive consumption

*Mass amount of generated waste/household consumption expenditure*

Unit: Mass/Monetary (kg/EUR)

This indicator calculates the amount of solid waste generated per monetary unit (e.g., EUR) of household consumption expenditure. It considers waste produced by households, but can include also similar waste generated from sources such as commerce, offices and public institutions.

This indicator can be disaggregated by:

- waste streams or material categories (e.g. paper, glass, metal, plastic, bio-waste, co-mingled)

Reference(s): D-Waste (2013)

Typology according to DPSIR framework: DRIVER/STATE indicator
29. Waste intensive economy

**Mass amount of generated waste/GDP**

Unit: Mass/Monetary (kg/EUR)

Mass amount of generated waste per gross domestic product (GDP)\(^1\) output (excluding major mineral waste). Generally, it excludes major mineral wastes.

It can be disaggregated by:

- waste streams or material categories (e.g., paper, glass, metal, plastic, bio-waste, co-mingled)

Reference(s): EMF (2015); EU open data (https://data.europa.eu/euodp/data/dataset/PccYwvucsiF7ygRBQ955Q)

**Typology according to DPSIR framework: DRIVER/STATE indicator**

30. Waste management hierarchy

\((Recycled\ or\ recovered\ waste - incinerated\ or\ disposed\ waste) / total\ amount\ of\ waste\)

Unit: Unitless (score)

This indicator provides insight on the level of application of hierarchy principles in the waste management of municipal waste. The circular economy aims at increasing the share of waste that is re-used or recycled - a higher share of recycled waste is the result of a higher level of application of the waste management hierarchy.

The waste management hierarchy comprises: (1) prevention and reduction of waste, (2) preparing for re-use, (3) recycling, (4) other recovery (e.g., energy recovery) and (5) disposal. Since there is generally no statistical data available for the amount of waste prevented and prepared for re-use (1 and 2), this indicator considers a weighting factor of 1.

---

\(^1\) Note: Two main types of GDP can be used to measure productivity (EC 2016):

GDP in purchasing power standards: to compare countries at the same moment in time, GDP is converted into an artificial currency unit via purchasing power parities. The GDP in PPS represents pure output volumes, after subtracting price-level differences between countries.

GDP in market exchange rates using a reference year market exchange rates (EUR) with chain-linked changes in volumes: GDP in chain-linked volumes measures the variation in the quantity of output (rather than the variation in prices) and allows productivity trends in a single geographic area to be tracked over time. GDP in chain-linked volumes is a way to adjust nominal GDP for inflation.
Indicators description and application

1 to recycling and -1 to other treatments (e.g., incineration) and disposal. As such, the solutions that convert waste into a resource to be reintroduced in the economy are considered positive (recovery) and the solutions that do not redirect waste back into the economy (or does so, but with very low efficiency) are negative, as they do not promote a circular economy.

The indicator results in a range between -100% (where there is no recycling and recovery of waste, i.e., no application of the waste hierarchy) to 100% (where all waste is recycled or organically recovered, i.e., full application of the waste hierarchy).

Reference(s): Pires & Martinho (2015)

Typology according to DPSIR framework: RESPONSE indicator

31. Waste management operations cost

*Expenditure on waste management/mass amount of generated waste*

Unit: Monetary/Mass (EUR/t)

This indicator expresses the average costs of waste management per tonne of waste. It considers the total annual budget spent on waste management including waste collection, treatment and disposal.

This indicator can be disaggregated by:

- operation types (e.g., collection, recycling, disposal)
- waste generation sectors/sources (e.g., households, commerce)
- waste streams or material categories (e.g., paper, plastic, metal)

It is generally calculated at local authority level, i.e., expressing the municipal response to waste management.

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

Reference(s): Arense and Godfrey (2010); Chavez et al. (2011); Hoornweg and Bhada-Tata (2012)

Typology according to DPSIR framework: STATE indicator

32. Waste minimization

*Mass amount of a waste fraction/mass amount of produced goods of that fraction*

This indicator expresses the mass amount of waste generated per mass of produced goods of that waste fraction.
Indicators description and application

**Unit: Unitless (share)**

This indicator compares the amount of waste associated with a sector/type of products to the total amount of produced or consumed products. It measures an unwanted output per input: the higher the output, the less efficient the material use.

This indicator can be used for different waste fractions and products, for example:

- Amount of packaging waste in an economy compared to the total amount of packed products (produced or consumed)
- Food waste/food supply or consumption
- Biological waste generated/biological resources used

Reference(s): EC (2011)

**Typology according to DPSIR framework: DRIVER/RESPONSE indicator**

33. Waste recovery rate

*Recovered waste/ total waste generation*

**Unit: Unitless (share)**

This indicator expresses the share of generated waste that is recovered in a defined period (e.g., 1 year). Waste recovery includes recycling and other recovery options (e.g., waste-to-energy).

This indicator can be disaggregated by:

- recovery options (e.g., recycling, waste-to-energy)
- waste generation sectors/sources (e.g., households, commerce)
- waste streams or material categories (e.g., paper, plastic, metal)

**Typology according to DPSIR framework: RESPONSE indicator**

34. Waste recycling rate

*Recycled waste/ total waste generation*

**Unit: Unitless (share)**
The recycling rate is the share of total municipal solid waste generated that is recycled, i.e., mass amount recycled from municipal waste divided by the total waste mass generated, for a defined period (e.g., 1 year). Recycling includes dry recyclables and organic valorisation (from composting, anaerobic digestion and animal feed).

This indicator can be disaggregated by:
- waste fractions (e.g. paper, glass, metal, plastic, bio-waste, packaging waste)
- waste generation sources/sectors (e.g., households, commerce)

### WASTE OF ELECTRICAL AND ELECTRONIC EQUIPMENT (WEEE)

It is particularly important to calculate the waste recycling rate of electrical and electronic equipment (EEE) due to its use of a range of valuable resources in their manufacture (e.g., rare earth metals), which are of strategic importance to the European industry. They are also associated with high environmental impacts and can contain hazardous substances.

For the calculation of recycling rates of WEEE, it is crucial to know the volume of end-of-life electrical and electronic equipment. As this is difficult to deduct for many devices and countries, the average volume of EEE put on the market during the previous 3 years (considered as easier to deduct) can be considered as proxy for the volume of WEEE in the reference year.

Reference(s): Eurostat (http://ec.europa.eu/eurostat/cache/metadata/EN/t2020_rt120_esmsip.htm); EMF (2015); Wilson et al. (2015); EASAC (2016); EC (2016)

**Typology according to DPSIR framework: RESPONSE indicator**

### 35. Wastewater collection coverage

*No. of households with reliable wastewaters collection/total no. of households*

Unit: Unitless (share)

Share of households connected to collective sewers or with on-site storage of all domestic wastewaters.

Reference(s): Dong and Hauschild (2017)
4.2. Circular economy indicators

36. Covered land area

*Land area artificially covered*

Unit: Area (km²)

Land is a finite resource and changes in its use (especially from natural to artificial land, i.e., ‘land take’) have economic and environmental impacts (e.g., higher risk of flooding, higher temperatures and increasing erosion in surrounding areas).

This indicator quantifies the land that is artificially covered. It can be expressed as a total, per capita or as a share of the total land area. It can be disaggregated by built-up areas (e.g., roofed constructions) and non-built-up areas (e.g., parking areas, yards and roads).

Reference(s): EC (2016); Eurostat (2011)

37. Crossing flows

*Mass amount of goods that enter and leave the area without being used.*

Unit: Mass (t)

Goods entering and leaving the economy/territorial unit without being used.

Reference(s): UMan model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

38. Dependency on other systems (Dep)

*Imports / domestic material input*
Indicators description and application

Unit: Unitless (share)

This indicator provides the share of direct material input (DMI) that is from imports (Imp). It relates to the vulnerability of an urban area and reveals the extent to which it is dependent on other outer areas, either regional or global. It uses the DMI and data on both international and intra-national imports.

This indicator can be disaggregated by dependency on other systems in the same country and in the rest of the world (using national and international imports).

Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

Typology according to DPSIR framework: STATE/PRESSURE indicator

39. Depletion contribution (Depl)

Non-renewable material input/total material input

Unit: Unitless (share)

The depletion contribution indicates the pressure that direct material input (DMI), i.e., material use (domestic extraction + imports) puts on the environment, regarding the contribution to resource depletion. It quantifies this effect for non-renewable materials.

Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

Typology according to DPSIR framework: STATE/PRESSURE indicator

40. Direct material input (DMI)

Mass amount of domestic extraction + imports

Unit: Mass (t)

This indicator measures the direct input of materials for use in the economy, i.e., all materials that feature economic value and are used in production and consumption activities. It is the sum of domestic extraction (DE) and Imports (Imp). It can be used to describe the total material needs of an urban area to inform the design of differentiated resource management policies. It also provides insight on the pressure on the environment regarding the contribution to the depletion of resources.

Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)
41. Domestic extraction (DE)

*Mass amount of raw materials extracted from the natural environment*

Unit: Mass (t)

Domestic extraction (DE) quantifies the input from the natural environment to be used in the economy/territorial unit. DE is the annual mass amount of raw material (except for water and air) extracted from the natural environment.

Reference(s): UMan model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat

42. Domestic material consumption (DMC)

*Domestic extraction + Imports - Exports*

Unit: Mass (t)

The demand for goods and services from economic players requires the extraction of raw materials from the environment, as well as the export and import of both raw materials and manufactured goods.

Domestic Material Consumption (DMC) expresses the mass amount of material(s) directly used in an economy or geographic area (excluding indirect flows, i.e., materials used abroad in order to manufacture imported goods, e.g., fossil fuels burned to produce imported steel).

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

This indicator can be disaggregated by material categories (e.g., fossil energy materials, biomass, metal ores and non-metallic materials).

Domestic material consumption does not adequately express the environmental pressure caused by consumer behaviour (SOeS 2017). In order to supplement this approach, it should be combined with the materials and products footprint (i.e., life-cycle impacts associated with the materials and manufactured goods accounted for in DMC).

Reference(s): UMan model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2001); Mudgal et al. (2012); SOeS (2017).
Indicators description and application

Typology according to DPSIR framework: DRIVER indicator

43. **Domestic processed output (DPO)**

*Mass amount of emissions + waste + dissipative flows*

Unit: Mass (t)

Measures the total mass of materials and emissions that are released back to the environment, after the use of resources in the domestic economy. These flows occur at processing, manufacturing, use, and final disposal stages of the production-consumption chain (i.e., emissions to air, landfilled wastes deposited in controlled and uncontrolled landfills, material loads in waste water and dissipative flows). Recycled material flows in the economy are not included. It provides insight on the pressure on the environment (outputs to nature).

Reference(s): UMan model; UrbanWINS Deliverable D2.1; Rosado et al. (2016); Eurostat (2001)

Typology according to DPSIR framework: DRIVER/PRESSURE indicator

44. **Energy productivity**

*GDP/energy use*

Unit: Monetary/Energy (EUR/kgoe)

This indicator is defined as the ratio between GDP and gross inland consumption of energy (coal, electricity, oil, natural gas and renewable energy sources), expressed as kg of oil equivalent (kgoe). It can be disaggregated by energy sources.


Typology according to DPSIR framework: STATE indicator

45. **Expenditure on products repair**

*Household expenditure on products repair and maintenance*

Unit: Monetary (EUR)
Indicators description and application

The extension of products’ service life is a key factor in mitigating the environmental impacts of consumption. Favouring repair over renewal means extending product lifespans, thereby reducing the need for replacement, which often represents a larger drain on resources. Monitoring the amount each inhabitant spends on product repair and maintenance enables us to analyse the development of household practices in this regard.

While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

It can be disaggregated by consumption purpose or group (e.g., personal vehicles, clothing and footwear, household appliances, etc.).

Reference(s): SOeS (2017)

**Typology according to DPSIR framework: STATE/RESPONSE indicator**

### 46. Exports (Exp)

*Mass amount of goods leaving the geographic area*

Unit: Mass (t)

Goods leaving an economy or geographic area. It can be used to describe the support provided by an urban area to other areas; displays the role of the city in meeting the needs of other systems.

Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2001)

**Typology according to DPSIR framework: DRIVER/STATE indicator**
47. **Greenhouse gas emissions (GHG)**

   Greenhouse gas emissions

   Unit: Mass equivalent (t CO₂ eq)

   This indicator provides insight on the potential impact of greenhouse gas (GHG) emissions produced for a defined period. It is calculated based on the global warming potential metric according to the IPCC 5th Assessment Report (IPCC 2013).

   While the overall/absolute results are useful to trace and monitor the evolution in time, this indicator can also be expressed on a per capita basis to ease interpretation and comparability.

   Reference(s): EC (2016); EASAC (2016)

**Typology according to DPSIR framework: IMPACT indicator**

48. **Imports (Imp)**

   Mass amount of goods entering the geographic area

   Unit: Mass (t)

   This indicator expresses the mass amount of goods entering an economy or geographic area, for a defined period (e.g., 1 year).

   Reference(s): UMAN model; UrbanWINS Deliverable D2.1; Rosado et al. (2016); Eurostat (2001)

**Typology according to DPSIR framework: DRIVER indicator**

49. **Index of common bird species**

   Number of common bird species

   Unit: Unitless

   The populations of common birds are often considered to be a general proxy for measuring the biodiversity of the natural environment (EEA 2018). Although they are highly sensitive to anthropogenic changes and their numbers also fluctuate due to other environmental factors, such as climate and interactions with other species, the long-term trends are considered reliable and indicative of the natural ‘health’ of the environment (or particular ecosystems). The EU Resource Scoreboard (EC 2016) tracks bird populations using the
Indicators description and application

Common Birds Index, which monitors common farmland species (39 species), common forest species (34 species) and all common bird species (167 species).

Reference(s): EC (2016)

Typology according to DPSIR framework: STATE indicator

50. Industrial production (IP)

*Mass amount of goods produced*

Unit: Mass (t)

This indicator expresses the mass amount of goods produced in an economy or geographic area, for a defined period of time (e.g., 1 year). Industrial production comprises the output of industrial establishments, including: mining and quarrying; manufacturing; and electricity, gas and water supply; and it usually excludes agriculture, fisheries and forestry goods.

Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2001)

Typology according to DPSIR framework: DRIVER indicator

51. Material needs characteristics (MNC)

*Domestic material consumption/Direct material input*

Unit: Unitless (share)

This indicator uses Domestic material consumption (DMC) and Direct material input (DMI) to calculate the proportion of the total material needs that goes to final consumption. It helps understanding the role of material flows in an economy or geographic area.

Reference(s): UMAN model; UrbanWINS Deliverable D2.1; Rosado et al. (2016)

Typology according to DPSIR framework: STATE indicator
Indicators description and application

52. Material productivity (MP)

\[ \text{Material Productivity} = \frac{\text{GDP}}{\text{Domestic material consumption}} \]

Unit: Monetary/Mass (EUR/t)

Material Productivity (also referred to as “resource productivity”) is the ratio between economic output per unit of material used, in this case, GDP and domestic material consumption (DMC). It expresses the economic value generated per mass amount of domestic material consumption.

This is an indicator of economy dematerialization, underlining the fact that a lower amount of materials is required to serve the same economic function in a society. MP is the reverse of material intensity, and is calculated as GDP output per unit of material consumption. MP can correspond also to the generation of some types of waste.

Limitations: it is highly influenced by the industrial structure in a given country and weight does not relate directly to environmental impact.

All material entering the economy will leave it as a waste, or as an emission to air, water, soil, sometimes after a varying period of stock building. The indicator is thus a larger-than-waste indicator. Due to data availability the indicator on resource productivity is restricted to the total amount of material.

Reference(s): UMan model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2017)

Typology according to DPSIR framework: STATE indicator

53. Net additions to stock (NAS)

\[ \text{Net additions to stock} = \text{Domestic material consumption} - \text{Domestic processed output} \]

Unit: Mass (t)

This indicator provides insight on the quantity (mass weight) of products that stay in the economy or geographic area, for more than one year. For example, new construction materials used in buildings and other infrastructure, and materials incorporated into new durable goods such as cars, industrial machinery, and household appliances. It is used to compute the amount of materials stored in a geographic area (e.g., urban area), i.e., the accumulation of materials, thus providing insight on the amount of materials potentially available for reuse or recycling at the end of the product service life.
Indicators description and application
Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2001)

**Typology according to DPSIR framework: DRIVER/STATE indicator**

54. **Non-renewable energy in final energy consumption**

   *Non-renewable energy generation/Gross inland energy consumption plus bunkers*

   Unit: Unitless (share)

   This indicator provides the share/proportion of energy consumption that is met from non-renewable energy sources (e.g., crude oil, coal, natural gas, etc.).

   This indicator can be disaggregated by energy source and by sector (of consumption).

   Reference(s): EASAC (2016); EC (2016)

**Typology according to DPSIR framework: STATE/RESPONSE indicator**

55. **Physical trade balance**

   *Mass amount of imports - Mass amount of exports*

   Unit: Mass (t)

   This indicator is defined as the difference between physical imports and physical exports. Thus, a physical trade surplus indicates a net import of materials, whereas a physical trade deficit indicates a net export.

   Reference(s): UMAN model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016); Eurostat (2001)

**Typology according to DPSIR framework: STATE indicator**

56. **Renewable energy in final energy consumption**

   *Renewable energy generation/Gross inland energy consumption plus bunkers*

   Unit: Unitless (share)
Indicators description and application

This indicator expresses the share/proportion of energy consumption that is met with renewable energy sources (wind, solar, hydroelectric, tidal, geothermal and biomass).

It can be disaggregated by energy source and by sector (of consumption).


Typology according to DPSIR framework: STATE/RESPONSE indicator

57. Self-sufficiency

*Domestic material consumption - Domestic extraction - Net addition to stock*

Unit: Mass (t)

Self-sufficiency of an urban area/municipality is quantified by comparing local resources with the amount of consumption, using domestic material consumption (DMC), domestic extraction (DE) and net addition to stock (NAS) indicators, thus providing an understanding about the “true” amount of resources available (different from “available resources”).

Reference(s): UMAn model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

Typology according to DPSIR framework: STATE indicator

58. UM efficiency

*Recovered materials/Domestic material consumption*

Unit: Unitless (share)

This indicator accounts for the share of different types of recovery solutions (recycling, energy, biological treatment) in domestic material consumption (DMC). It is intrinsically connected with Material needs characteristics (MNC): as UM efficiency increases, MNC decreases.

Reference(s): UMAn model; UrbanWINS Deliverable D2.1 (2017); Rosado et al. (2016)

Typology according to DPSIR framework: STATE/RESPONSE indicator
Indicators description and application

59. **Water exploitation index (WEI)**

Annual amount of freshwater abstraction/long-term average amount of available freshwater resources

Unit: Unitless (share)

The water exploitation index (WEI) monitors water scarcity by measuring the ratio between the mean annual total amount of freshwater abstraction (including public drinking water, industrial and agricultural uses) and the long-term average amount of available freshwater resources. A high WEI indicates water stress (i.e. overexploitation of available water resources).

Reference(s): EC (2016); EEA (2009)

Typology according to DPSIR framework: STATE/PRESSURE indicator

60. **Water productivity**

GDP/volume of water use

Unit: Monetary/Volume (EUR/m³)

Water productivity measures the amount of economic output produced (EUR or PPS) per unit of water abstracted (m³), providing insight on how efficiently water resources are used.

A limitation of the indicator is that it is influenced by cities’ or countries’ GDP and economic make-up. Cities and countries with high GDP and large low water-using sectors (e.g. financial services) will perform better while countries with large agricultural and food manufacturing sectors (which use large amounts of water) will not perform as well.


Typology according to DPSIR framework: STATE indicator
A cross-city comparative analysis

5. A cross-city comparative analysis

To illustrate the application of indicators, this section presents the results for the 10 dashboard indicators for three pilot cities: Leiria (Portugal), Sabadell and Manresa (Spain). When a specific time period is not mentioned, data and results are for 2013.

5.1. Dashboard indicators results

**Generation of waste (kg/capita)**

<table>
<thead>
<tr>
<th>City</th>
<th>Waste Generation (kg/cap)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>397.2 kg/cap</td>
<td>[Statistics Portugal (INE)]</td>
</tr>
<tr>
<td>SABADELL</td>
<td>402.3 kg/cap</td>
<td>[opendata.sabadell.net]</td>
</tr>
<tr>
<td>MANRESA</td>
<td>394.2 kg/cap</td>
<td>[Web de la estadística oficial de Catalunya (<a href="http://www.idescat.cat">www.idescat.cat</a>)]</td>
</tr>
</tbody>
</table>

**Composition of collected waste (%)**

<table>
<thead>
<tr>
<th>City</th>
<th>Composition of Collected Waste (%)</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>87% paper; 3% plastic; 3% others</td>
<td>[Statistics Portugal (INE)]</td>
</tr>
<tr>
<td>SABADELL</td>
<td>67% paper; 8% plastic; 11% others</td>
<td>[opendata.sabadell.net]</td>
</tr>
<tr>
<td>MANRESA</td>
<td>61% paper; 16% plastic; 10% others</td>
<td>[Statistics Institute of Catalonia (<a href="http://www.idescat.cat">www.idescat.cat</a>)]</td>
</tr>
</tbody>
</table>
A cross-city comparative analysis

### Food waste (kg/capita)

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food waste</td>
<td>280 kg/cap</td>
<td>157 kg/cap¹</td>
<td>157 kg/cap¹</td>
</tr>
</tbody>
</table>

Food waste disaggregated by stage (PT):
- 33% agricultural production
- 8% postharvest handling/storage
- 12% processing and packaging
- 6% distribution
- 41% consumption

Source: Estimate based on the national figures for food waste and on the organic waste collected in Leiria. Statistics Portugal (INE); Valorlis.

¹ These figures are likely underestimated, as estimates for waste for the food production and packaging stages was not included in the estimate.

### Bring points coverage (selective collection)

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>337 bring points per 100000 p</td>
<td>1745 bring points per 100000 p</td>
<td>1963 bring points per 100000 p</td>
</tr>
</tbody>
</table>

Source: ERSAR (www.ersar.pt) (ref. year 2016)  
Source: Servei de Recollida i tractament de residus i neteja viària (ref. year 2018)  
Source: Ayuntamiento de Manresa (ref. year 2018)

### Waste intensive economy (kg/EUR)

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24.6 g/€</td>
<td>20.3 g/€</td>
<td>17.9 g/€</td>
</tr>
</tbody>
</table>

GDP Leiria Region (NUTS III):
- 16115 €/capita
- Generated waste: 397 kg/capita

Source: Statistics Portugal (INE)

GDP Sabadell:
- 19800 €/capita
- Generated waste: 402.33 kg/capita

Source: Statistics Institute of Catalonia (www.idescat.cat)

GDP Manresa:
- 22000 €/capita
- Generated waste: 394.20 kg/capita

Source: Statistics Institute of Catalonia (www.idescat.cat)
A cross-city comparative analysis

**Waste management hierarchy (%)**

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>-60.2%</td>
<td>-25.9% (incl. industrial waste)</td>
<td>24.1% (incl. industrial waste)</td>
</tr>
<tr>
<td>SABADELL</td>
<td>50.4% (incl. industrial waste)</td>
<td>9959 t of urban waste recycled or recovered; 40079 t to landfill.</td>
<td>9395 t of urban waste recycled or recovered; 30891 t to landfill.</td>
</tr>
<tr>
<td>MANRESA</td>
<td></td>
<td>21610 industrial waste recycled or recovered; 6945 to landfill.</td>
<td>20479 industrial waste recycled or recovered; 1777 to landfill.</td>
</tr>
</tbody>
</table>

Source: Statistics Portugal (INE); UMan model.

**Domestic material consumption (t)**

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>2,286,908 t</td>
<td>994,356 t</td>
<td>531,344 t</td>
</tr>
<tr>
<td>SABADELL</td>
<td></td>
<td>Source: UMan model</td>
<td>Source: UMan model</td>
</tr>
<tr>
<td>MANRESA</td>
<td></td>
<td>Source: UMan model</td>
<td>Source: UMan model</td>
</tr>
</tbody>
</table>

**Greenhouse gas emissions (kg CO₂ eq)**

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>795,142 t CO₂ eq</td>
<td>903,898 t CO₂ eq</td>
<td>358,706 t CO₂ eq</td>
</tr>
<tr>
<td>SABADELL</td>
<td>Source: Own calculations based on Pla d’Acció per a l’Energia Sostenible and Catalonia: II. Catalonia_ Ari emissions (1990-2015)</td>
<td>Source: UMan model</td>
<td></td>
</tr>
<tr>
<td>MANRESA</td>
<td>Source: Own calculations based on Pla d’Acció per a l’Energia Sostenible and Catalonia: II. Catalonia_ Ari emissions (1990-2015)</td>
<td>Source: UMan model</td>
<td></td>
</tr>
</tbody>
</table>

**Material productivity (EUR/t)**

<table>
<thead>
<tr>
<th></th>
<th>LEIRIA</th>
<th>SABADELL</th>
<th>MANRESA</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEIRIA</td>
<td>0.89 €/kg</td>
<td>4.14 €/kg</td>
<td>3.16 €/kg</td>
</tr>
<tr>
<td>MANRESA</td>
<td>Source: GDP (2013) from Statistics Portugal (INE); DMC from UMan model.</td>
<td>Source: UMan model</td>
<td>Source: UMan model</td>
</tr>
</tbody>
</table>

5.2. Interpretation and remarks

The overall generation of municipal solid waste was similar across the Portuguese and Spanish municipalities – between 394 and 402 kg (~2% difference), but significantly larger in the four Italian cases (31 to 59%). However, the composition of collected waste was significantly different across the cities. Cremona had the largest share of selective collection (about 49%), followed by Torino (43%), Manresa (39%) and Sabadell (33%), and Albano Laziale had the lowest share (6%). Regarding the selectively collected waste, the individual share of each stream or material category did not vary significantly for the most common material categories (paper and cardboard, plastics and metals, and glass). The most significant differences were associated with organic waste and other material categories. Data on these indicators was relatively easy to obtain. These results seem strongly correlated with the bring points coverage for selective collection: for the Portuguese and Spanish cities, a higher bring points coverage is linked to a higher share of selective collection. In Cremona, which is the city with the highest share of selective collection, this is achieved with door-to-door collection. Data for the other pilot cities was unavailable.

On waste management hierarchy, Cremona had around 40% while all other cities had a negative score, as most urban waste goes to landfill. It was followed by Torino (-10%), Leiria had the lowest result with -60%, and all other cities had -20 to -40%. The results show that most cities have room for improving the end-of-life treatment of waste and increasing the results for waste management hierarchy. When industrial waste is included, all cities have significantly better results, and only Pomezia, Albano Laziale and Sabadell still have less than half of the overall waste recycled or recovered (-7.3%, -13.6% and -14.9%, respectively).

Food waste figures were relatively similar in most cities (146-188 kg/cap), except for Albano Laziale and Pomezia, where an estimate for Rome was considered of 60 kg per capita. It is important to stress that the availability and quality of data on food waste was very limited and the results should be considered with caution. The estimates were based on figures for larger geographic areas (national, in the case of Leiria, and regional, in the case of Sabadell and Manresa), and data lacked transparency (particularly, it lacked detail on what it included, e.g., food wastage, packaging, etc.) and uniformity (different cities included different components in their food waste estimates). The analysis highlights the need for better quality data on food waste, as it is a critical issue in municipal waste management.
Other relevant issues and indicators

To ease interpretation and comparability of domestic material consumption (DMC), per capita figures were estimated: Leiria had a significantly higher result of 18 t per capita, while all other cities had between 4.4 and 6.4 t per capita. These figures are likely linked to material productivity (MP), which related the DMC with GDP: Leiria had 888 €/t, while all other cities were above 2000 €/t. The fact that Leiria’s DMC is substantially higher than that for other cities can be explained by the fact that Leiria is a city that includes a significant amount of extraction and production activities, while others probably depend much more on imports for their consumption. Albano Laziale had a material productivity of 12017 €/t, which suggests that it depends more on the tertiary sector and hence produce products with higher added value, in opposition to Leiria where raw materials and low-added value products are being produced.

Regarding the waste intensity per EUR, Cremona and Manresa had a better performance (16.8 and 17.9 g/€, respectively), while all other cities had 22 to 25 g/€. GHG emissions per capita were about 5.8 to 6.4 t CO2 eq in Cremona, Leiria, Albano Laziale and Pomezia, and 4.4 to 4.7 t CO2 eq in the Spanish municipalities and Torino.

6. Other relevant issues and indicators

The list of 60 indicators described here is not exhaustive. A survey on existing indicators was carried out and these were selected according to the scope and aims of the project, environmental relevance and data availability, but others exist that can be considered according to the scope of the analysis and site-specific data availability and quality. There is a large body of literature and a much wider range of issues to consider in the development and implementation of waste prevention and management strategies. We present below several examples of other relevant issues and indicators that can be considered.

Provider inclusivity (Wilson et al. 2015)

The degree of provider inclusivity represents the level to which service providers from both municipal and non-municipal (including the formal private, community or ‘informal’) sectors are included in the planning and implementation of waste management and recycling services and activities. This is a composite indicator made up by marking 5 criteria: one assesses the presence of legal instruments which enable both the public and private sectors to get involved in providing stable waste management services; two criteria focus in turn on representation of the private sector and acknowledgement of the role of the informal/community sectors respectively; another criterion looks at the ‘balance’ between public and private sector interests, so that neither party is unduly advantaged over the other; and the last criterion assesses the actual bid process. Each criterion is assigned a score and all individual scores are then summed to provide an overall %.
User inclusivity (Wilson et al. 2015)

The degree of user inclusivity represents the level to which users, or potential users, of the waste management services (i.e., households, business and other waste generators) have access to services, and are involved in and influence how those services are planned and implemented. This is a composite indicator made up by marking 6 criteria: one expresses the extent to which all citizens, irrespective of their income level, receive a good service; three criteria focus on assessing the degree to which users, or potential users, of the waste management services are involved in the planning, policy development, implementation and evaluation of those services; and the last two criteria address complementary aspects of public awareness and education. Each criterion is assigned a score and all individual scores are then summed to provide an overall %.

Financial sustainability (Wilson et al. 2015)

The degree of financial sustainability represents the degree to which a city’s solid waste management service is financially sustainable. This is a composite indicator made up by marking 6 criteria: the first assesses transparent cost accounting procedures; the second criterion addresses the adequacy of the total budget, irrespective of the source of revenues; the third criterion considers local cost recovery from households; the fourth focuses on the affordability of user charges; the fifth criterion considers the coverage of disposal costs, focusing on how far disposal is ‘priced’; and the last expresses the ability to raise capital for investment. Each criterion is assigned a score as indicated in their own guidance note. All the individual scores are then summed to provide an overall %, which is reported here alongside a qualitative assessment.

Waste imports and exports (JRC 2012)

The selection of 60 indicators does not address imported and exported waste; however, in cases, these flows are highly significant and environmentally relevant. A transparent approach should be applied to address imported and exported waste to avoid double counting, with particular attention to hazardous waste.

It is suggested that the potential environmental impacts associated with the treatment of imported waste should ideally be excluded from the waste management indicators. At the same time, those impacts that are associated with the treatment of exported waste and occur within the treatment country should be added. The influence of imports in the treatment data and the exclusion of exports on the indicator results of a specific waste stream cannot be quantified.
Other relevant issues and indicators

Life-cycle impacts of waste management (JRC 2012)

The life-cycle environmental impacts of waste management can be calculated for different waste streams, considering requirements and impacts associated with collection, transportation, pre-treatment and end-of-life phases, as well as possible credits from recovery and recycling.

Data sources, guidelines and recommendations are provided for the European context (JRC, 2012), and an application is presented for 12 selected environmentally relevant waste streams and a wide range of impact categories, including climate change, ozone depletion, human toxicity, acidification, eutrophication, land use and resource depletion.

Eco-innovation (EC 2016; www.eco-innovation.eu)

Moving towards a circular economy requires a change in our production and consumption patterns. Innovation and research on resource efficiency and the circular economy are key of the EU Circular Economy Package, the Horizon 2020 work programmes (2014-15 and 2016-17) and the Eco-innovation Action Plan 75.

An important indicator measuring innovation and R&D is the Eco-innovation index, which assesses and illustrates eco-innovation performance by capturing the different aspects of eco-innovation using 16 indicators. These indicators are grouped into five thematic areas: eco-innovation inputs, eco-innovation activities, eco-innovation outputs, resource efficiency and socio-economic outcomes (see the box below for more detail). The index shows compares the performance across different dimensions of eco-innovation with the EU average (set at 100).

Employment in the circular economy (SOeS 2017)

This indicator aims to quantify the number of full-time or equivalent (FTE) jobs held in economic activities that form part of the circular economy. This indicator allows us to measure the transition towards an economic system that is more frugal in its use of resources. Employment in the circular economy is estimated across two levels: the 1st level examines the core activities of the circular economy via the 7 pillars defined by Ademe; the 2nd level is an “8th pillar”, and includes what are known as “adjacent” activities - those whose primary objective is not the circularity of production processes or the reduction of resources used, but which will nonetheless contribute to these goals in a more or less permanent fashion.

Ecolabel holders (SOeS 2017)

Another indicator that can be used to measure circularity is the number of products carrying ecolabels recognised throughout the EU. These ecolabels are awarded based on voluntary measures and approaches. Products carrying an ecolabel can potentially have less environmental impact at each stage of their life cycle (manufacturing, use, transport
Other relevant issues and indicators

and disposal) than non-certified products. A manufacturer may be awarded ecolabels for one or several products across different product categories.

Use of recycled raw materials in production processes (SOeS 2017)

Recycled raw materials, also known as secondary raw materials, are waste products that, having been sorted and processed, remain of sufficient quality to be reintroduced into the production process. They can be substituted for raw materials, thereby economising on resources. The “cyclical material use rate” shows the proportion of waste that has been recovered weighed against the material demands of the economy as a whole.

The incorporation rate can be disaggregated by material/product type (e.g., paper/cardboard, glass, aluminium, plastic, etc.).

Decoupling of waste generation from private consumption expenditure (EC 2011)

Decoupling is much claimed, but the concept is in need of a standard approach: an indicator to show the degree to which waste generation follows the trends of material consumption.

In general, decoupling refers to “the relative growth rates of a pressure on the environment and of an economically relevant variable to which it is causally linked.” Applied on household waste generation per capita (the pressure on the environment) the growth rate may be compared with the growth rate of consumption (increasing consumption as the driving force). Applied on other waste generation the driving force may be the growing gross domestic product.

A decoupling indicator can describe the relationship between the change in environmental pressure as compared to the change in the driving force over the same period. Decoupling occurs when the waste generation (or its impact) grows less than the economy over a given period. In most cases, however, absolute changes in environmental pressures are of fundamental concern. Hence the importance of distinguishing between absolute and relative decoupling.

“Absolute decoupling” occurs when the pressure through waste does not grow or even declines, even when its economic driver is increasing.

“Relative decoupling” occurs when pressure through waste increases, but not as fast as its economic driver.

“Coupling” means that pressure through waste and its economic driver evolve exactly in the same way.

“Negative decoupling” can be used when the environmental pressure increases at a higher rate than its economic driving force.
Output assessment (EC 2011)

A standardized checklist with yes/no questions on the policy mix of public waste prevention measures leading to a single overall score, expressed as a percentage. The indicator is a self-assessment tool with a scoring system. The indicator does not aim at measuring compliance with the legal provisions but at measuring prevention efforts above the legal minimum. It score measures suggested but not imposed by the European Legal framework (or national equivalents). It scores enforcing or supporting measures above legal implementation.

The result is an indication on the degree to which prevention measures are being taken, but not on the result of these measures on the waste management practice. It covers waste prevention in general, although some questions are on specific waste streams for which directives have been developed: packaging waste, ELV, batteries and accumulators, and WEEE.

7. Concluding remarks

This document focuses on environmental aspects of waste prevention and management and, to some extent, on economic and social/societal aspects. The main aim is to support and encourage consistent development, monitoring and assessment of waste prevention and management strategies by decision-makers and other users, in cities.

Due to differences in data collection methods and over time, waste and resource use statistics need to be used with caution (EC 2016). For cross-country comparisons, some obstacles arise in the use of these indicators, such as differences in waste management systems. For example, differences in the sources of waste (types/sectors) that are included in municipal solid waste can lead to significant differences in the results that are of difficult interpretation. While in some countries management of all wastes is the responsibility of municipalities, in others, municipal waste includes household waste only, or household waste and some other fractions, such as sewage sludge.

To ease comparability across different regions and systems, indicators and the associated methodological choices should be uniform. However, data quality and availability differ, and such uniformity is difficult to ensure. As such, the indicators here are given with some flexibility and variations (options regarding their disaggregation or reference units, e.g., per capita, per unit area, etc.), providing their users a degree of freedom to adapt to the specific needs and data availability. It is important that all assessments, calculations and methodological choices while using and adapting these indicators are transparent, to ease interpretation and comparability of the results, and to effectively support decision-making. Precise and transparent definitions are also crucial to the interpretation and comparability of results (e.g., what is included in municipal solid waste).

Reliable data is crucial for an insightful application of these indicators. In particular, to measure and assess the effectiveness of strategic planning policies, it is important to have detailed and disaggregated statistical data on economic and waste management activities,
Concluding remarks

including consistent life-cycle inventory data for waste management operations (Chavez et al. 2011, Hoornweg and Bhada-Tata 2012; JRC 2012). Transparency and clear use of data is crucial for an insightful application of the indicators presented here.

This document aims primarily at providing indicators for assessing the performance along time or comparing cities in the European Union. While many might apply to most cities in the world, country or city-specific problems might differ. In particular, priorities and performance indicators for high- and low-income or developed and developing countries are significantly different.
Glossary

Anaerobic digestion
A process where biodegradable waste material is decomposed by micro-organisms into CH\(_4\) and CO\(_2\) (biogas), in an enclosed vessel in the absence of oxygen. The solid product can be used for fertilizer and the gas byproducts used to power electricity turbines or to generate heat.

Collection
The gathering of (solid) waste from point of production (residential, industrial commercial, institutional) to the point of treatment or disposal, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility (EC 2008; 2015)

Municipal solid waste is collected in several ways:

- **House-to-House:** Waste collectors visit each individual house to collect garbage. The user generally pays a fee for this service.

- **Bring points:** Users bring their garbage to community bins that are placed at fixed points in a neighbourhood or locality. MSW is picked up by the municipality, or its designate, according to a set schedule. These are also referred to as “Community bins”.

- **Curbside Pick-Up:** Users leave their garbage directly outside their homes according to a garbage pick-up schedule set with the local authorities (secondary house-to-house collectors not typical).

- **Self-delivered:** Generators deliver the waste directly to disposal sites or transfer stations, or hire third-party operators (or the municipality).

- **Contracted or Delegated Service:** Businesses hire firms (or municipality with municipal facilities) who arrange collection schedules and charges with customers. Municipalities often license private operators and may designate collection areas to encourage collection efficiencies.

Co-mingled
Mixed recyclables that are collected together after having been separated from mixed MSW (e.g., plastic and metals).
Composting
Biological decomposition of solid organic materials by bacteria, fungi, and other organisms into a soil-like product.

Disposal
The final handling of solid waste, following collection, processing, or incineration. It comprises any operation that is not recovery even when the operation has as a secondary consequence the reclamation of substances or energy (EC 2008). Disposal most often means deposit of wastes in a landfill or controlled dump.

E-waste
Waste of electrical and electronic equipment (WEEE).

Food waste
Fractions of “food and inedible parts of food removed from the food supply chain” to be recovered or disposed of (including composting, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer or landfill, and discarding to sea).

Incineration
Incineration comprises the use of waste as fuel, mainly in power plants and cement kilns, and the thermal treatment of waste for disposal with the aim of reducing the volume and/or the hazardousness of the waste (e.g. incineration of health care waste).

Incineration of waste (with energy recovery) can reduce the volume of disposed waste by up to 90%. These high volume reductions are seen only in waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Recovering the energy value embedded in waste prior to final disposal is considered preferable to direct landfilling — assuming pollution control requirements and costs are adequately addressed. Typically, incineration without energy recovery (or non-autogenic combustion, the need to regularly add fuel) is not a preferred option due to costs and pollution.

Landfill
The waste or residue from other processes should be sent to a disposal site. Landfills are a common final disposal site for waste and should be engineered and operated to protect the environment and public health. Landfill gas (LFG), produced from the anaerobic decomposition of organic matter, can be recovered and the methane (about 50% of LFG) burned with or without energy recovery to reduce GHG emissions. Proper landfilling is often lacking, especially in developing countries. Landfilling usually progresses from open-dumping, controlled dumping, controlled landfilling, to sanitary landfilling.
Municipal solid waste (MSW)

Municipal waste is collected and treated by, or for municipalities. It covers waste from households, including bulky waste, similar waste from commerce and trade, office buildings, institutions and small businesses, yard and garden, street sweepings, contents of litter containers, and market cleansing (e.g., commercial businesses, institutions, light industry and agricultural enterprises and nontoxic wastes from hospitals and laboratories).

Waste from municipal sewage networks and treatment, as well as municipal and “bulk” construction and demolition, commercial and industrial wastes from larger industries are excluded.

Generally, municipal solid waste is composed of paper/packaging, yard waste, food waste, magazines/newspapers, plastics, glass, wood/fabric, disposable diapers, and other contributions such as tires, appliances, and nontoxic home maintenance supplies.

Processing

Preparing waste materials for subsequent use or management, using processes such as baling, magnetic separation, crushing, and shredding. The term is also sometimes used to mean separation of recyclables from mixed municipal solid waste.

Recovery

Any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy (EC 2008). Recovery includes, for example, composting and anaerobic digestion.

Recycling

Any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations (EC 2008).

Treatment

Recovery or disposal operations, including preparation prior to recovery or disposal (EC 2008).

Waste management

Collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker (EC 2008).


References


Available at: https://www.catasto-rifiuti.isprambiente.it/index.php?pg=mcomune&aa=2013&regid=12058&nomereg=

ISPRA - Istituto Superiore per la Protezione e la Ricerca Ambientale, Roma. ISBN 978-88-448-0899-0


References


Annex I

Summary table
### Annex I

#### Waste indicators (No. 1 - 35)

<table>
<thead>
<tr>
<th>NO.</th>
<th>INDICATOR</th>
<th>DPSIR TYPOLOGY</th>
<th>CALCULATION</th>
<th>UNITS</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Available landfill lifespan</td>
<td>Pressure/State</td>
<td>Available airspace/incoming waste volume per year</td>
<td>Time</td>
<td>This indicator informs on the need for new landfills and/or for diverting waste from landfills.</td>
</tr>
<tr>
<td>2</td>
<td>Bring points coverage</td>
<td>State</td>
<td>No. of bring points x 100 000/no. of inhabitants</td>
<td>Ratio</td>
<td>The amount of bring points by 100 000 inhabitants provides the density of bring sites. In general, better coverage yields better collection rates.</td>
</tr>
<tr>
<td>3</td>
<td>Collected waste</td>
<td>Driver/Response</td>
<td>Mass amount of generated municipal solid waste collected</td>
<td>Mass</td>
<td>Waste collected by or on behalf of municipalities, as well as municipal waste collected by the private sector (including undifferentiated waste and separately collected fractions).</td>
</tr>
<tr>
<td>4</td>
<td>Composition of collected waste</td>
<td>Driver/Response</td>
<td>Waste fraction mass x 100 /total generated waste</td>
<td>Share</td>
<td>Share of each waste stream or waste material category (e.g., glass, metal, plastic, paper, e-waste, etc.) in the overall collected waste.</td>
</tr>
<tr>
<td>5</td>
<td>Controlled treatment or disposal</td>
<td>Driver/Response</td>
<td>Solid waste that is dealt with in a ‘controlled’ facility/total solid waste destined for treatment or disposal</td>
<td>Share</td>
<td>Percentage of municipal solid waste destined for treatment or disposal (i.e., total waste collected minus waste recycled or reused) that goes to either a state-of-the-art, engineered or ‘controlled’ treatment/ disposal site, including incineration.</td>
</tr>
<tr>
<td>6</td>
<td>Cost of waste collection</td>
<td>State</td>
<td>Cost of collection per mass unit of collected waste</td>
<td>Monetary/Mass EUR/t</td>
<td>Includes costs associated with the manufacture and use of containers, vehicles, labor, equipment and sorting of waste, as well as costs on information provision or education on collection schemes.</td>
</tr>
<tr>
<td>7</td>
<td>Cost of waste disposal</td>
<td>State</td>
<td>Cost of disposal per mass unit of disposed waste</td>
<td>Monetary/Mass EUR/t</td>
<td>Includes acquisition costs, capital expenditure and development costs, operating costs, restoration and aftercare costs. It can be calculated as a weighted average cost or disaggregated into disposal types.</td>
</tr>
<tr>
<td>8</td>
<td>Cost of waste treatment</td>
<td>State</td>
<td>Cost of treatment per mass unit of treated waste</td>
<td>Monetary/Mass EUR/t</td>
<td>Includes costs associated with composting, anaerobic digestion, waste-to-energy incineration, for land acquisition, construction/manufacture and use of facilities and equipment, labor and disposal of rejects.</td>
</tr>
<tr>
<td>9</td>
<td>Food waste</td>
<td>Driver</td>
<td>Mass amount of food waste/no. of inhabitants</td>
<td>Mass/Absolute kg/cap</td>
<td>Food waste is any food item destined for human consumption that is discarded, to be recovered or disposed. It includes waste from production, processing, distribution, and consumption.</td>
</tr>
<tr>
<td>10</td>
<td>Generation of waste (per capita)</td>
<td>Driver</td>
<td>mass of waste generated/no. of inhabitants</td>
<td>Mass/Absolute kg/cap</td>
<td>Amount of waste generated per capita in a defined period (e.g., 1 year). Generally, the indicator covers hazardous and non-hazardous waste from all economic sectors and from households.</td>
</tr>
<tr>
<td>11</td>
<td>Generation of waste (total)</td>
<td>Driver</td>
<td>tonnes municipal solid waste generated</td>
<td>Mass</td>
<td>Overall amount of waste generated in a defined period (e.g., 1 year). It can be particularly useful as a time series, to provide the perspective of the indicator evolution over time.</td>
</tr>
<tr>
<td>No.</td>
<td>Indicator</td>
<td>Response Type</td>
<td>Driver</td>
<td>Description</td>
<td></td>
</tr>
<tr>
<td>-----</td>
<td>-----------</td>
<td>---------------</td>
<td>--------</td>
<td>-------------</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Hazardous substance presence</td>
<td>Driver</td>
<td>No. of samples with hazardous substances/total no. of samples</td>
<td>This is an analysis driven indicator on the presence of restricted hazardous substances (based on the Restriction of Hazardous Substances (RoHS) directive) in selective waste streams. How many out of a defined number of random samples of a specific waste fraction contain quantities of hazardous substances above RoHS thresholds.</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Hazardous waste generation</td>
<td>Driver</td>
<td>total hazardous waste generated</td>
<td>Mass amount of hazardous waste that is generated in a defined period (e.g., 1 year). Hazardous waste is a waste stream of high concern due to the potential risks it poses to human health and the environment if not managed properly.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Landfill rate of waste</td>
<td>Driver</td>
<td>quantity of waste landfilled/total waste treated</td>
<td>Rate or share of waste landfilled (directly or indirectly) in the total waste treated for a defined period (e.g., 1 year). It covers hazardous (hz) and non-hazardous (nh) waste from all economic sectors and from households.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Material capture rate</td>
<td>Response</td>
<td>Mass amount of a waste fraction collected separately/total generated waste of that fraction</td>
<td>The material capture rate is the percentage of the estimated generation of a waste fraction (e.g., paper, glass, metal, plastic, bio-waste, etc., or co-mingled) that is collected separately.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Material collection</td>
<td>Driver/Response</td>
<td>Mass of waste fraction separately collected/no. of inhabitants</td>
<td>Material collection rate provides the mass amount of a waste fraction (e.g., paper, glass, metal, plastic, bio-waste, etc., or co-mingled) that is separately collected per inhabitant.</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Material recovery (MR)</td>
<td>Driver/Response</td>
<td>Mass amount of products that are reused, recycled or valorized energetically</td>
<td>End-of-life products that are reused, recycled or valorized energetically in the economy/geographical area.</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>MSW generation</td>
<td>Driver/Response</td>
<td>mass amount of waste generated that is separately collected</td>
<td>The indicator sets the basis of separate collection in terms of waste generated. The quantity of MSW generated depends on a number of factors such as food habits, standard of living, degree of commercial activities and seasons.</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Residual waste share</td>
<td>Driver</td>
<td>Residual collected solid waste/total solid waste collected</td>
<td>This indicator quantifies the percentage of solid waste collected that is residual, i.e., mixed waste that is not subject to separate collection. Indicates how much waste is not covered by separate collection streams.</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Social participation in waste separation</td>
<td>State/Response</td>
<td>No. of households that separate waste/total no. of households</td>
<td>Households that separate waste (of the total number of households). Population who participate in the separation of waste.</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Social perception on waste management</td>
<td>State</td>
<td>No. of unsatisfied households/total no. of households</td>
<td>This indicator expresses the share (%) of households that are not satisfied with the waste management.</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Uncollected waste</td>
<td>Driver</td>
<td>Mass amount of uncollected waste</td>
<td>Solid waste generated in a city but uncollected due to the lack or to limitations of collection services. It can be estimated by multiplying the waste generation per capita in the city by the population who does not have access to the solid waste collection service.</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Value of waste recycled</td>
<td>State</td>
<td>Mass amount of waste x Value by mass unit</td>
<td>Measures the value of recycled waste in the country for a defined period of time (e.g., 1 year).</td>
<td></td>
</tr>
<tr>
<td>No.</td>
<td>Indicators</td>
<td>Response</td>
<td>Description</td>
<td></td>
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<tr>
<td>24</td>
<td>Waste collection coverage</td>
<td>Response</td>
<td>No. of households with reliable waste collection service/total no. of households</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Waste collection efficiency</td>
<td>Response</td>
<td>Waste collected/total waste generated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Waste concentration</td>
<td>State</td>
<td>Mass amount of waste in disposal site/disposal site area</td>
<td></td>
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<tr>
<td>27</td>
<td>Waste disposal</td>
<td>Driver</td>
<td>Solid waste disposed of</td>
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<tr>
<td>28</td>
<td>Waste intensive consumption</td>
<td>Driver/</td>
<td>Mass amount of generated waste/household consumption expenditure</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>State</td>
<td>State</td>
<td>Mass/ Monetary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Waste intensive economy</td>
<td>Driver/</td>
<td>Mass amount of generated waste/GDP</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>State</td>
<td>State</td>
<td>Mass/ Monetary</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Waste management hierarchy</td>
<td>Response</td>
<td>(Recycled or recovered waste - incinerated or disposed waste) / total amount of waste</td>
<td></td>
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<tr>
<td>31</td>
<td>Waste management operations cost</td>
<td>State</td>
<td>Overall cost of waste management/mass amount of generated waste</td>
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<tr>
<td></td>
<td></td>
<td>Monetary</td>
<td>EUR/t</td>
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<td>32</td>
<td>Waste minimization</td>
<td>Driver/</td>
<td>Mass amount of a waste fraction/mass amount of produced or consumed goods</td>
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<tr>
<td></td>
<td>Response</td>
<td>Response</td>
<td>Share %</td>
<td></td>
<td></td>
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<tr>
<td>33</td>
<td>Waste recovery rate</td>
<td>Response</td>
<td>Waste recovered/total waste generated</td>
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<td></td>
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<tr>
<td>34</td>
<td>Waste recycling rate</td>
<td>Response</td>
<td>Waste recycled/ Total waste generation</td>
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<td></td>
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<tr>
<td>35</td>
<td>Wastewater collection coverage</td>
<td>Response</td>
<td>No. of households with reliable wastewaters collection/total no. of households</td>
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*UrbanWINS-T2.3-Indicators-for-waste-prevention-and-management.docx*
### Circular economy indicators (No. 36 - 60)

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<th>NO.</th>
<th>INDICATOR</th>
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<th>UNITS</th>
<th>DESCRIPTION</th>
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<tr>
<td>36</td>
<td>Covered land area</td>
<td>Pressure</td>
<td>Covered (artificial) land area</td>
<td>Area</td>
<td>km²</td>
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<td>37</td>
<td>Crossing flows</td>
<td>Driver/State</td>
<td>min(Imp,Exp)</td>
<td>Mass</td>
<td>t</td>
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<td>38</td>
<td>Dependency on other systems (Dep)</td>
<td>State/Pressure</td>
<td>Dep = Imp/DMI</td>
<td>Share</td>
<td>%</td>
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<td>39</td>
<td>Depletion contribution (Depl)</td>
<td>State/Pressure</td>
<td>Depl = non Renewable DMI / DMI</td>
<td>Share</td>
<td>%</td>
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<tr>
<td>40</td>
<td>Direct material input (DMI)</td>
<td>Driver/Pressure</td>
<td>DMI = DE + Imp; Mass amount of goods used in the geographic area</td>
<td>Mass</td>
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<tr>
<td>41</td>
<td>Domestic extraction (DE)</td>
<td>Driver</td>
<td>Mass amount of raw material extracted from the natural environment</td>
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<tr>
<td>42</td>
<td>Domestic material consumption (DMC)</td>
<td>Driver</td>
<td>DMC = DMI - Exp; Mass amount of a material directly used in the geographic area</td>
<td>Mass</td>
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<tr>
<td>43</td>
<td>Domestic processed output (DPO)</td>
<td>Driver/Pressure</td>
<td>DPO = emissions + waste + dissipative flows</td>
<td>Mass</td>
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<tr>
<td>44</td>
<td>Energy productivity</td>
<td>State indicator</td>
<td>GDP/energy use</td>
<td>Monetary</td>
<td>EUR/ kgoe</td>
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<td>45</td>
<td>Expenditure on products repair</td>
<td>State/Response</td>
<td>Household expenditure on products repair and maintenance/Nr of inhabitants</td>
<td>Monetary</td>
<td>EUR/cap</td>
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<tr>
<td>46</td>
<td>Exports (Exp)</td>
<td>Driver/State</td>
<td>Mass amount of goods leaving the geographic area</td>
<td>Mass</td>
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<td>47</td>
<td>Greenhouse gas emissions</td>
<td>Impact</td>
<td>IPCC 2013</td>
<td>Mass</td>
<td>eq t CO₂ eq</td>
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<td>48</td>
<td>Imports (Imp)</td>
<td>Driver</td>
<td>Mass amount of goods entering the geographic area</td>
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<td>No.</td>
<td>Indicator Description</td>
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<tr>
<td>49</td>
<td>Index of common bird species</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>50</td>
<td>Industrial production (IP)</td>
<td></td>
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</tr>
<tr>
<td>51</td>
<td>Material needs characteristics (MNC)</td>
<td></td>
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<tr>
<td>52</td>
<td>Material productivity (MP)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>53</td>
<td>Net additions to stock (NAS)</td>
<td></td>
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</tr>
<tr>
<td>54</td>
<td>Non-renewable energy in final energy consumption</td>
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<td>Physical trade balance (PTB)</td>
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<td>56</td>
<td>Renewable energy in final energy consumption</td>
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<tr>
<td>57</td>
<td>Self-sufficiency</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>58</td>
<td>UM efficiency</td>
<td></td>
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</tr>
<tr>
<td>59</td>
<td>Water exploitation index (WEI)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Water productivity</td>
<td></td>
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</tr>
</tbody>
</table>

The populations of common birds are often considered to be a general proxy for measuring the biodiversity of the natural environment. The long-term trends are considered reliable and indicative of the natural 'health' of the environment (or particular ecosystems).

- **Industrial production (IP)**: Mass amount of goods produced (Mass t). Amount of goods produced in the economy/territorial unit.
- **Material needs characteristics (MNC)**: \( MNC = \frac{DMC}{DMI} \). This indicator utilizes DMI and DMC to calculate the proportion of the total material needs that goes to final consumption. It helps understanding the role of material flows in an urban economy.
- **Material productivity (MP)**: \( MP = \frac{GDP}{DMC} \). Material productivity expresses the economic value generated per mass amount of domestic material consumption.
- **Net additions to stock (NAS)**: \( NAS = DMC - DPO \). Provides information about the quantity (weight) of products that stay in the economy/territorial unit for more than a year (stored).
- **Non-renewable energy in final energy consumption**:
- **Physical trade balance (PTB)**: \( PTB = Imp - Exp \). Defined as the difference between physical imports and physical exports.
- **Renewable energy in final energy consumption**:
- **Self-sufficiency**:
- **UM efficiency**:
- **Water exploitation index (WEI)**: \( \text{mean annual amount of freshwater abstraction/long-term average amount of available freshwater resources} \). The water exploitation index (WEI) monitors water scarcity by measuring the ratio between the mean annual total amount of freshwater abstraction and the long-term average amount of available freshwater resources.
- **Water productivity**: \( \text{GDP/water use} \). Water productivity measures the amount of economic output produced (EUR or PPS) per unit of water abstracted (m³) and provides some indication of how efficiently water resources are used.
Annex II

Application matrix
## Annex II

### UrbanWINS - T2.3 - Indicators for waste prevention and management.docx

<table>
<thead>
<tr>
<th>INDICATOR</th>
<th>WASTE MANAGEMENT PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PREVENTION</td>
</tr>
<tr>
<td>1. Available landfill lifespan</td>
<td>X</td>
</tr>
<tr>
<td>2. Bring points coverage</td>
<td>X</td>
</tr>
<tr>
<td>3. Collected waste</td>
<td>X</td>
</tr>
<tr>
<td>4. Composition of collected waste</td>
<td>X</td>
</tr>
<tr>
<td>5. Controlled treatment or disposal</td>
<td>X</td>
</tr>
<tr>
<td>6. Cost of waste collection</td>
<td>X</td>
</tr>
<tr>
<td>7. Cost of waste disposal</td>
<td>X</td>
</tr>
<tr>
<td>8. Cost of waste treatment</td>
<td>X</td>
</tr>
<tr>
<td>9. Food waste</td>
<td>X</td>
</tr>
<tr>
<td>10. Generation of waste (per capita)</td>
<td>X</td>
</tr>
<tr>
<td>11. Generation of waste (total)</td>
<td>X</td>
</tr>
<tr>
<td>12. Hazardous substance presence</td>
<td>X</td>
</tr>
<tr>
<td>13. Hazardous waste generation</td>
<td>X</td>
</tr>
<tr>
<td>14. Landfill rate of waste</td>
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</tr>
<tr>
<td>15. Material capture rate</td>
<td>X</td>
</tr>
<tr>
<td>16. Material collection</td>
<td>X</td>
</tr>
<tr>
<td>17. Material recovery (MR)</td>
<td>X</td>
</tr>
<tr>
<td>18. MSW generation</td>
<td>X</td>
</tr>
<tr>
<td>19. Residual waste share</td>
<td>X</td>
</tr>
<tr>
<td>20. Social participation in w. separation</td>
<td>X</td>
</tr>
<tr>
<td>21. Social perception on w. management</td>
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</tr>
<tr>
<td>22. Uncollected waste</td>
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<tr>
<td>23. Value of waste recycled</td>
<td>X</td>
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<tr>
<td>24. Waste collection coverage</td>
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</tr>
<tr>
<td>25. Waste collection efficiency</td>
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<td>26. Waste concentration</td>
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</tr>
<tr>
<td>27. Waste disposal</td>
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<td>28. Waste intensive consumption</td>
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<td>29. Waste intensive economy</td>
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<td>30. Waste management hierarchy</td>
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</tr>
<tr>
<td>31. Waste management operations cost</td>
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<td>32. Waste minimization</td>
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<td>33. Waste recovery rate</td>
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<td>34. Waste recycling rate</td>
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<td>35. Wastewater collection coverage</td>
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<td>36. Covered land area</td>
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<td>37. Crossing flows</td>
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<td>38. Dependency on other systems (Dep)</td>
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<td>41. Domestic extraction (DE)</td>
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<td>43. Domestic processed output (DPO)</td>
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<td>45. Expenditure on products repair</td>
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<td>46. Exports (Exp)</td>
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<td>47. Greenhouse gas emissions</td>
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<td>60. Water productivity</td>
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## Annex II

### UrbanWINS-T2.3-Indicators-for-waste-prevention-and-management.docx

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<td>2. Bring points coverage</td>
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