INDICATORS FOR WASTE PREVENTION AND MANAGEMENT

Measuring circularity

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Waste Resources Innovation

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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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Contents

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).

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).

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).

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*.

WASTE INDICATORS	CIRCULAR ECONOMY INDICATORS
1. Available landfill lifespan (years)	36. Covered land area (km^2)
2. Bring points coverage (no. bring points/100000 p)	37. Crossing flows (t)
3. Collected waste (t)	38. Dependency on other systems (%)
4. Composition of collected waste (%)	39. Depletion contribution (%)
5. Controlled treatment or disposal (%)	40. Direct material input (t)
6. Cost of waste collection (EUR/t)	41. Domestic extraction (t)
7. Cost of waste disposal (EUR/t)	**42. Domestic material consumption (t)**
8. Cost of waste treatment (EUR/t)	43. Domestic processed output (t)
9. Food waste (kg/capita)	44. Energy productivity (EUR/kgoe)
10. Generation of waste (kg/capita)	45. Expenditure on products repair (EUR/cap)
11. Generation of waste (t)	46. Exports (t)
12. Hazardous substance presence (%)	**47. Greenhouse gas emissions (kg CO_2 eq)**
13. Hazardous waste generation (t)	48. Imports (t)
14. Landfill rate of waste (%)	49. Index of common bird species (n/a)
15. Material capture rate (%)	50. Industrial production (t)
16. Material collection (kg/cap)	51. Material needs characteristics (%)
17. Material recovery (t)	**52. Material productivity (EUR/t)**
18. Municipal solid waste generation (t)	53. Net additions to stock (t)
19. Residual waste share (%)	54. Non-renewable energy in final energy consumption (%)
20. Social participation in waste separation (%)	55. Physical trade balance (t)
21. Social perception on waste management (%)	56. Renewable energy in final energy consumption (%)
22. Uncollected waste (t)	57. Self-sufficiency (t)
23. Value of waste recycled (EUR)	**58. UM efficiency (%)**
24. Waste collection coverage (%)	59. Water exploitation index (%)
25. Waste collection efficiency (%)	60. Water productivity (EUR/m^3)
26. Waste concentration (t/ha)	
27. Waste disposal (t)	
28. Waste intensive consumption (kg/EUR)	
29. Waste intensive economy (kg/EUR)	
30. Waste management hierarchy (%)	
31. Waste management operations cost (EUR/t)	
32. Waste minimization (%)	
33. Waste recovery rate (%)	
34. Waste recycling rate (%)	
35. Wastewater collection coverage (%)	

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.

- 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)

Typology according to DPSIR framework: DRIVER indicator

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/km^2). 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.

Indicators description and application

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

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

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.

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): UNStats (https://unstats.un.org/sdgs/metadata/files/Metadata-11-06-01.pdf)

Typology according to DPSIR framework: DRIVER indicator

23. Value of waste recycled

Mass amount of waste recycled x 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

No. of households with reliable waste collection service/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)

Reference(s): Eurostat (http://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics); http://www.asci.org.in/sslb/solid2.htm; EC (2015); Wilson et al. (2015)

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/PccYwvucsiF7ygfRBQ955Q)

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] 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.

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

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)

Typology according to DPSIR framework: RESPONSE indicator

4.2. Circular economy indicators

36. Covered land area

Land area artificially covered

Unit: Area (km^2)

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)

Typology according to DPSIR framework: PRESSURE indicator

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)

Typology according to DPSIR framework: DRIVER/STATE indicator

38. Dependency on other systems (Dep)

Imports/ domestic material input

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)

Typology according to DPSIR framework: DRIVER/PRESSURE indicator

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

Typology according to DPSIR framework: DRIVER indicator

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).

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.

Reference(s): EC (2016)/Eurostat (https://ec.europa.eu/eurostat/web/products-datasets/-/T2020_RD310)

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 CO_2 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

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

52. Material productivity (MP)

GDP / 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)

Domestic material consumption – 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.

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).

Reference(s): EMF (2015); EASAC (2016); EC (2016); Eurostat (https://www.eea.europa.eu/data-and-maps/indicators/renewable-gross-final-energy-consumption-4)

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

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/m^3)

Water productivity measures the amount of economic output produced (EUR or PPS) per unit of water abstracted (m^3), 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.

Reference(s): EC (2016); Eurostat (https://ec.europa.eu/eurostat/web/products-datasets/-/t2020_rd210)

Typology according to DPSIR framework: STATE indicator

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.

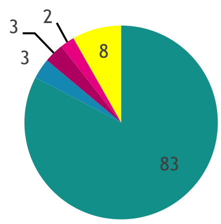
5.1. Dashboard indicators results

Generation of waste (kg/capita)

LEIRIA	SABADELL	MANRESA
397.2 kg/cap	402.3 kg/cap	394.2 kg/cap
Source: Statistics Portugal (INE)	*Source: opendata.sabadell.net*	*Source: Web de la estadistica official de Catalunya (www.idescat.cat)*

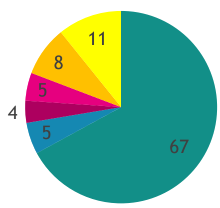
Composition of collected waste (%)

LEIRIA



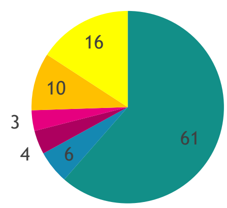
Source: Statistics Portugal (INE)

SABADELL

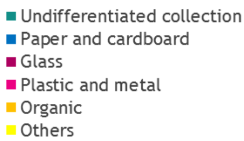


Source: opendata.sabadell.net

MANRESA



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



Food waste (kg/capita)

LEIRIA	SABADELL	MANRESA
280 kg/cap	157 kg/cap[1]	157 kg/cap[1]
Food waste disaggregated by stage (PT): 33% agricultural production 8% postharvest handling/storage 12% processing and packaging 6% distribution 41% consumption	Food wastage disaggregated by stage (Catalonia): 17% Markets and supermarkets 9% Other food shops 12% Restaurants 4% Institutions 58% Households	Food wastage disaggregated by stage (Catalonia): 17% Markets and supermarkets 9% Other food shops 12% Restaurants 4% Institutions 58% Households
Source: Estimate based on the national figures for food waste and on the organic waste collected in Leiria. Statistics Portugal (INE); Valorlis.	*Source: Estimate based on the regional figures for food waste in Catalonia (2010). Generalitat de Catalunya & Agència de Residus Catalunya.*	*Source: Estimate based on the regional figures for food waste in Catalonia (2010). Generalitat de Catalunya & Agència de Residus Catalunya.*

[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)

LEIRIA	SABADELL	MANRESA
337 bring points per 100000 p	1745 bring points per 100000 p	1963 bring points per 100000 p
Source: ERSAR (www.ersar.pt) (ref. year 2016)	*Source: Servei de Recollida i tractament de residus i neteja viària (ref. year 2018)*	*Source: Ayuntamento de Manresa (ref. year 2018)*

Waste intensive economy (kg/EUR)

LEIRIA	SABADELL	MANRESA
24.6 g/€	20.3 g/€	17.9 g/€
GDP Leiria Region (NUTS III): 16115 €/capita Generated waste: 397 kg/capita	GDP Sabadell: 19800 €/capita Generated waste: 402.33 kg/capita	GDP Manresa: 22000 €/capita Generated waste: 394.20 kg/capita
Source: Statistics Portugal (INE)	*Source: Statistics Institute of Catalonia (www.idescat.cat)*	*Source: Statistics Institute of Catalonia (www.idescat.cat)*

Waste management hierarchy (%)

LEIRIA	SABADELL	MANRESA
-60.2%	-49.0%	-41.8%
50.4% (incl. industrial waste)	-25.9% (incl. industrial waste)	24.1% (incl. industrial waste)
9959 t of urban waste recycled or recovered; 40079 t to landfill. 248150 industrial waste recycled or recovered; 42681 to landfill. *Source: Statistics Portugal (INE); UMAn model.*	24466 t of urban waste recycled or recovered; 71415 t to landfill. 21610 industrial waste recycled or recovered; 6945 to landfill. *Source: Waste Agency of Catalonia[1]; Catalan Water Agency[2]; UMAn model. Statistics Institute of Catalonia (www.idescat.cat)*	9395 t of urban waste recycled or recovered; 30891 t to landfill. 30891 industrial waste recycled or recovered; 1777 to landfill. *Source: Waste Agency of Catalonia[1]; Catalan Water Agency[2]; UMAn model. Statistics Institute of Catalonia (www.idescat.cat)*

[1] http://estadistiques.arc.cat/ARC/?municipals#; [2] https://aca-web.gencat.cat/aca/documents/ca/actuacions/sistemes_sanejament/com_funcionen_edars/evol_fangs_web.pdf

Domestic material consumption (t)

LEIRIA	SABADELL	MANRESA
2 286 908 t	994 356 t	531 344 t
Source: UMAn model	*Source: UMAn model*	*Source: UMAn model*

Greenhouse gas emissions (kg CO_2 eq)

LEIRIA	SABADELL	MANRESA
795 142 t CO_2 eq	903 898 t CO_2 eq	358 706 t CO_2 eq
Source: Statistics Portugal (INE); UMAn model.	*Source: Own calculations based on Pla d'Acció per a l'Energia Sostenible[1] and Catalonia: II. Catalonia_ Ari emissions (1990-2015)*	*Source: Own calculations based on Pla d'Acció per a l'Energia Sostenible[1] and Catalonia: II. Catalonia_ Ari emissions (1990-2015)*

[1] Available in http://ca.sabadell.cat/CanviClimatic/d/PAESSBD_1620_final.pdf

Material productivity (EUR/t)

LEIRIA	SABADELL	MANRESA
0.89 €/kg	4.14 €/kg	3.16 €/kg
Source: GDP (2013) from Statistics Portugal (INE); DMC from UMan model.	*Source: GDP (2013) from web de la estadistica official de Catalunya (https://www.idescat.cat); DMC from UMan model.*	*Source: GDP (2013) from web de la estadistica official de Catalunya (https://www.idescat.cat); DMC from UMan model.*

UM efficiency (%)

LEIRIA	SABADELL	MANRESA
11.3%	4.6%	7.6%
Source: UMan model.	*Source: UMan model.*	*Source: UMan model.*

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.

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.

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 Plan75.

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 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 of 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, 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).

Glossary

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.

Glossary

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).

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Annex I

Summary table

Annex I

Waste indicators (No. 1 – 35)

NO.	INDICATOR	DPSIR TYPOLOGY	CALCULATION	UNITS		DESCRIPTION
1	**Available landfill lifespan**	Pressure/ State	Available airspace/incoming waste volume per year	Time	years	This indicator informs on the need for new landfills and/or for diverting waste from landfills.
2	**Bring points coverage**	State	No. of bring points x 100 000/no. of inhabitants	Ratio	No. bring points/ 100 000 inhabitants	The amount of bring points by 100 000 inhabitants provides the density of bring sites. In general, better coverage yields better collection rates.
3	**Collected waste**	Driver/ Response	Mass amount of generated municipal solid waste collected	Mass	t	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).
4	**Composition of collected waste**	Driver/ Response	Waste fraction mass x 100 /total generated waste	Share	%	Share of each waste stream or waste material category (e.g., glass, metal, plastic, paper, e-waste, etc.) in the overall collected waste.
5	**Controlled treatment or disposal**	Driver/ Response	Solid waste that is dealt with in a 'controlled' facility/total solid waste destined for treatment or disposal	Share	%	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.
6	**Cost of waste collection**	State	Cost of collection per mass unit of collected waste	Monetary /Mass	EUR/t	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.
7	**Cost of waste disposal**	State	Cost of disposal per mass unit of disposed waste	Monetary /Mass	EUR/t	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.
8	**Cost of waste treatment**	State	Cost of treatment per mass unit of treated waste	Monetary /Mass	EUR/t	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.
9	**Food waste**	Driver	Mass amount of food waste/no. of inhabitants	Mass/ Absolute	kg/cap	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.
10	**Generation of waste (per capita)**	Driver	mass of waste generated/no. of inhabitants	Mass/ Absolute	kg/cap	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.
11	**Generation of waste (total)**	Driver	tonnes municipal solid waste generated	Mass	t	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.

12	**Hazardous substance presence**	Driver	No. of samples with hazardous substances/total no. of samples	Share	%	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.
13	**Hazardous waste generation**	Driver	total hazardous waste generated	Mass	t	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.
14	**Landfill rate of waste**	Driver	quantity of waste landfilled/total waste treated	Share	%	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.
15	**Material capture rate**	Response	Mass amount of a waste fraction collected separately/total generated waste of that fraction	Share	%	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.
16	**Material collection**	Driver/ Response	Mass of waste fraction separately collected/no. of inhabitants	Mass/ Absolute	kg/cap	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.
17	**Material recovery (MR)**	Driver/ Response	Mass amount of products that are reused, recycled or valorized energetically	Mass	t	End-of-life products that are reused, recycled or valorized energetically in the economy/geographical area.
18	**MSW generation**	Driver/ Response	mass amount of waste generated that is separately collected	Mass/ Absolute	kg	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.
19	**Residual waste share**	Driver	Residual collected solid waste/total solid waste collected	Share	%	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.
20	**Social participation in waste separation**	State/ Response	No. of households that separate waste/total no. of households	Share	%	Households that separate waste (of the total number of households). Population who participate in the separation of waste.
21	**Social perception on waste management**	State	No. of unsatisfied households/total no. of households	Share	%	This indicator expresses the share (%) of households that are not satisfied with the waste management.
22	**Uncollected waste**	Driver	Mass amount of uncollected waste	Mass	t	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.
23	**Value of waste recycled**	State	Mass amount of waste x Value by mass unit	Monet ary	EUR	Measures the value of recycled waste in the country for a defined period of time (e.g., 1 year)

24	**Waste collection coverage**	Response	No. of households with reliable waste collection service/total no. of households	Share	%	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.
25	**Waste collection efficiency**	Response	Waste collected/total waste generated	Share	%	This indicator expresses the percentage 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.
26	**Waste concentration**	State	Mass amount of waste in disposal site/disposal site area	Mass/ Area	t/ha	Waste concentration refers to the mass amount (tonnes) of waste that were already disposed of in a hectare (ha) of the disposal site. For its calculation waste in place and size of the site are used.
27	**Waste disposal**	Driver	Solid waste disposed of	Mass	t	This indicator provides the amount of waste that is disposed of (e.g., deposit in landfill, burned in incinerator, recycle, compost, etc.). It can also be presented as "waste disposal shares" (for each of those ways).
28	**Waste intensive consumption**	Driver/ State	Mass amount of generated waste/household consumption expenditure	Mass/ Monetary	kg/EUR	This indicator calculates the amount of solid waste generated per € of household consumption expenditure. It includes waste produced by households, but also from commerce, offices and public institutions.
29	**Waste intensive economy**	Driver/ State	Mass amount of generated waste/GDP	Mass/ Monetary	kg/EUR	Mass amount of generated waste per GDP output (excluding major mineral waste).
30	**Waste management hierarchy**	Response	(Recycled or recovered waste - incinerated or disposed waste) / total amount of waste	Share	%	This indicator considers a weighting factor of 1 to recycling and -1 to other treatments and disposal. 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 with very low efficiency) are negative.
31	**Waste management operations cost**	State	overall cost of waste management/mass amount of generated waste	Monetary /Mass	EUR/t	Average costs on waste management per tonne of waste. It considers the total annual budget spent on waste management including waste collection, treatment and disposal. It can be disaggregated into the different waste management operations.
32	**Waste minimization**	Driver/ Response	Mass amount of a waste fraction/mass amount of produced or consumed goods	Share	%	Total amount of waste associated with a sector/type of products compared to the total amount of produced or consumed products.
33	**Waste recovery rate**	Response	Waste recovered/total waste generated	Share	%	Waste recovery includes recycling and other recovery options (e.g., waste-to-energy).
34	**Waste recycling rate**	Response	Waste recycled/ Total waste generation	Share	%	The recycling rate is the percentage of total municipal solid waste generated that is recycled, for a defined period (e.g., 1 year). Recycling includes dry recyclables and organic valorization.
35	**Wastewater collection coverage**	Response	No. of households with reliable wastewaters collection/total no. of households	Share	%	Percentage of households connected to collective sewers or with on-site storage of all domestic wastewaters.

Annex I

Circular economy indicators (No. 36 – 60)

NO.	INDICATOR	DPSIR TYPOLOGY	CALCULATION	UNITS		DESCRIPTION
36	**Covered land area**	Pressure	Covered (artificial) land area	Area	km^2	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.
37	**Crossing flows**	Driver/ State	min(Imp,Exp)	Mass	t	Goods entering and leaving the economy/territorial unit without being used.
38	**Dependency on other systems (Dep)**	State/ Pressure	Dep = Imp/DMI	Share	%	This indicates the share of DMI that is from imports. It provides insight on the vulnerability of an urban are,a the extent to which it is dependent on other outer areas.
39	**Depletion contribution (Depl)**	State/ Pressure	Depl = non Renewable DMI / DMI	Share	%	It measures the pressure that nonrenewable resource use puts on the environment.
40	**Direct material input (DMI)**	Driver/ Pressure	DMI = DE + Imp; Mass amount of goods used in the geographic area	Mass	t	Measures the direct input of materials for use into the economy. It can be used to describe the total material needs of an urban area.
41	**Domestic extraction (DE)**	Driver	Mass amount of raw material extracted from the natural environment	Mass	t	Input from the natural environment to be used in the economy/territorial unit. DE is the annual amount of raw material (except for water and air) extracted from the natural environment.
42	**Domestic material consumption (DMC)**	Driver	DMC = DMI - Exp; Mass amount of a material directly used in the geographic area	Mass	t	Measures the total amount of material directly used in an economy (excluding indirect flows). It provides the effective quantities of goods consumed in a given area.
43	**Domestic processed output (DPO)**	Driver/ Pressure	DPO = emissions + waste + dissipative flows	Mass	t	Total mass of materials which are released back to the environment after having been used in the domestic economy. These flows occur at processing, manufacturing, use, and final disposal stages of the production-consumption chain.
44	**Energy productivity**	State indicator	GDP/energy use	Monetary /Mass	EUR/ kgoe	This is defined as the ratio between GDP (calculated in PPS) and gross inland consumption of energy (coal, electricity, oil, natural gas and renewable energy sources) and is expressed as kg of oil equivalent.
45	**Expenditure on products repair**	State/ Response	Household expenditure on products repair and maintenance/Nr of inhabitants	Monetary /Absolute	EUR/cap	Monitors the amount that is spent on product repair and maintenance. Favoring repair over renewal means extending product lifespans, thereby limiting the need for replacement, and a further drain on resources.
46	**Exports (Exp)**	Driver/ State	Mass amount of goods leaving the geographic area	Mass	t	Goods leaving an economy/territorial unit. 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 system.
47	**Greenhouse gas emissions**	Impact	IPCC 2013	Mass eq	t CO_2 eq	Measures the potential impact of greenhouse gas emissions produced.
48	**Imports (Imp)**	Driver	Mass amount of goods entering the geographic area	Mass	t	Goods entering the economy/territorial unit.

49	**Index of common bird species**	State	Number of common bird species	n/a	n/a	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).
50	**Industrial production (IP)**	Driver	Mass amount of goods produced	Mass	t	Amount of goods produced in the economy/territorial unit. Normally it excludes Agriculture, fisheries and forestry goods. Included in Domestic Extraction.
51	**Material needs characteristics (MNC)**	State	MNC = DMC/DMI	Share	%	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.
52	**Material productivity (MP)**	State	MP = GDP / DMC	Monetary /Mass	EUR/kg	Material productivity expresses the economic value generated per mass amount of domestic material consumption. This is an indicator of economy dematerialization.
53	**Net additions to stock (NAS)**	Driver/ State	NAS = DMC - DPO	Mass	t	Provides information about the quantity (weight) of products that stay in the economy/territorial unit for more than a year (stored). It provides insight on the materials potentially available for reuse or recycling.
54	**Non-renewable energy in final energy consumption**	State/ Response	Non-renewable energy generation/Gross inland energy consumption plus bunkers	Share	%	Indicates the share/proportion of energy consumption that is met from non-renewable energy sources (coal, natural gas, etc.).
55	**Physical trade balance (PTB)**	State	PTB = Imp - Exp	Mass	t	Defined as the difference between physical imports and physical exports. A physical trade surplus indicates a net import of materials, whereas a physical trade deficit indicates a net export.
56	**Renewable energy in final energy consumption**	State/ Response	Renewable energy generation/Gross inland energy consumption plus bunkers	Share	%	Indicates the share/proportion of energy consumption that is met from renewable energy sources (wind, solar, hydroelectric, tidal, geothermal and biomass).
57	**Self-sufficiency**	State	Suf = DMC - DE - NAS	Mass	t	Self-sufficiency of an urban area/municipality is quantified by comparing local resources with the amount of consumption, thus providing an understanding about the "true" amount of resources available.
58	**UM efficiency**	State/ Response	Eff = Recovery/DMC	Share	%	This indicator accounts for the share of different types of recovery solutions (recycling, energy, biological treatment) in DMC. It is intrinsically connected with MNC: as UM efficiency increases, MNC decreases.
59	**Water exploitation index (WEI)**	State/ Pressure	mean annual amount of freshwater abstraction/long-term average amount of available freshwater resources	Share	%	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.
60	**Water productivity**	State	GDP/water use	Monetary /Volume	EUR/m^3	Water productivity measures the amount of economic output produced (EUR or PPS) per unit of water abstracted (m^3) and provides some indication of how efficiently water resources are used.

Annex II

Application matrix

Annex II

INDICATOR	WASTE MANAGEMENT PHASE			
	PREVENTION	GENERATION	COLLECTION	END-OF-LIFE
1. Available landfill lifespan				X
2. Bring points coverage			X	
3. Collected waste		X	X	
4. Composition of collected waste		X	X	
5. Controlled treatment or disposal				X
6. Cost of waste collection			X	
7. Cost of waste disposal				X
8. Cost of waste treatment				X
9. Food waste	X	X		
10. Generation of waste (per capita)	X	X		
11. Generation of waste (total)	X	X		
12. Hazardous substance presence	X		X	
13. Hazardous waste generation	X	X		
14. Landfill rate of waste				X
15. Material capture rate			X	
16. Material collection		X	X	
17. Material recovery (MR)	X			X
18. MSW generation	X	X		
19. Residual waste share			X	
20. Social participation in w. separation			X	
21. Social perception on w. management				
22. Uncollected waste		X	X	
23. Value of waste recycled		X	X	X
24. Waste collection coverage			X	X
25. Waste collection efficiency			X	
26. Waste concentration				X
27. Waste disposal				X
28. Waste intensive consumption	X	X		
29. Waste intensive economy	X	X		
30. Waste management hierarchy			X	X
31. Waste management operations cost		X	X	X
32. Waste minimization	X	X		
33. Waste recovery rate			X	X
34. Waste recycling rate			X	X
35. Wastewater collection coverage			X	
36. Covered land area				
37. Crossing flows				
38. Dependency on other systems (Dep)				
39. Depletion contribution (Depl)	X			
40. Direct material input (DMI)	X			
41. Domestic extraction (DE)	X			
42. Domestic material consumption (DMC)	X			
43. Domestic processed output (DPO)		X		X
44. Energy productivity	X			
45. Expenditure on products repair	X	X		
46. Exports (Exp)				
47. Greenhouse gas emissions				
48. Imports (Imp)	X			
49. Index of common bird species				
50. Industrial production (IP)	X			X
51. Material needs characteristics (MNC)	X			
52. Material productivity (MP)	X			
53. Net additions to stock (NAS)	X	X		
54. Non-renewable energy in final energy consumption	X			
55. Physical trade balance (PTB)	X			
56. Renewable energy in final energy consumption	X			
57. Self-sufficiency	X			
58. UM efficiency	X	X		X
59. Water exploitation index (WEI)	X			
60. Water productivity	X			

Annex II

INDICATOR	DISAGGREGATION OPTIONS		
	ECONOMIC SECTORS	WASTE STREAMS	UNITS
1. Available landfill lifespan			
2. Bring points coverage		X	X
3. Collected waste	X	X	X
4. Composition of collected waste	X	X	
5. Controlled treatment or disposal	X	X	
6. Cost of waste collection	X	X	X
7. Cost of waste disposal	X	X	X
8. Cost of waste treatment	X	X	X
9. Food waste	X		X
10. Generation of waste (per capita)	X	X	X
11. Generation of waste (total)	X	X	X
12. Hazardous substance presence	X	X	
13. Hazardous waste generation	X		X
14. Landfill rate of waste			
15. Material capture rate	X	X	
16. Material collection	X	X	X
17. Material recovery (MR)	X	X	X
18. MSW generation	X	X	X
19. Residual waste share	X		
20. Social participation in w. separation		X	
21. Social perception on w. management		X	
22. Uncollected waste		X	X
23. Value of waste recycled	X	X	X
24. Waste collection coverage		X	
25. Waste collection efficiency	X	X	
26. Waste concentration			
27. Waste disposal	X	X	X
28. Waste intensive consumption	X	X	
29. Waste intensive economy	X	X	
30. Waste management hierarchy	X	X	
31. Waste management operations cost	X	X	X
32. Waste minimization	X	X	
33. Waste recovery rate	X	X	
34. Waste recycling rate	X	X	
35. Wastewater collection coverage			
36. Covered land area			X
37. Crossing flows	X		X
38. Dependency on other systems (Dep)	X		
39. Depletion contribution (Depl)	X		
40. Direct material input (DMI)	X		X
41. Domestic extraction (DE)	X		X
42. Domestic material consumption (DMC)	X		X
43. Domestic processed output (DPO)			X
44. Energy productivity	X		
45. Expenditure on products repair			X
46. Exports (Exp)	X		X
47. Greenhouse gas emissions	X		X
48. Imports (Imp)	X		X
49. Index of common bird species			
50. Industrial production (IP)	X		X
51. Material needs characteristics (MNC)	X		
52. Material productivity (MP)	X		
53. Net additions to stock (NAS)	X		X
54. Non-renewable energy in final energy consumption	X		
55. Physical trade balance (PTB)	X		X
56. Renewable energy in final energy consumption	X		
57. Self-sufficiency	X		X
58. UM efficiency	X		
59. Water exploitation index (WEI)	X		
60. Water productivity			

URBAN WINS

Waste Resources Innovation