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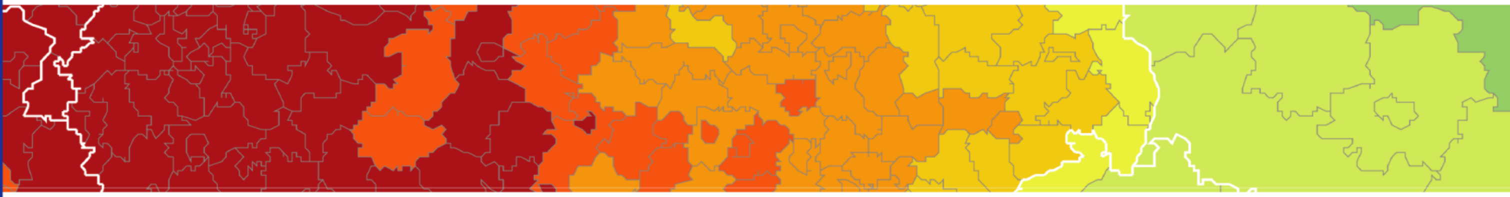
Inspire policy making by territorial evidence



CIRCTER – Circular Economy and Territorial Consequences

Applied Research

Final Report

Annex 10

Measuring urban circularity based on a territorial perspective

Version 10/10/2019

Final Report

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Information on ESPON and its projects can be found on www.espon.eu.

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Abbreviations

B2B	business-to-business
B2C	Business to Consumer
C2C	Consumer to Consumer
CBM	Circular Business Model
CDC	Caisse des dépôts et consignations
CE	Circular Economy
CEAP	Circular Economy Action Plan
CER	European Remanufacturing Council
CLD	Causal Loop Diagram
DE	Domestic Extraction
DMC	Domestic Material Consumption
DMI	Direct Material Input
EC	European Commission
EEA	European Environmental Agency
EMAS	European Monitoring and Audit Scheme
EMF	Ellen MacArthur Foundation
EPR	Extended Producer Responsibility
ERDF	European Regional Development Fund
ESPON	European Territorial Observatory Network
EU	European Union
GDP	Gross Domestic Product
GPP	Green Public Procurement
GWR	Geographically Weighted Regression
JRC	Joint Research Centre
IS	Industrial Symbiosis
LMM	Last Minute Market
MBT	Mechanical-Biological Treatment
MFA	Material Flow Analysis
MS	Member States
MSW	Municipal Solid Waste
NACE	Nomenclature of Economic Activities
NUTS	Nomenclature of Territorial Units for Statistics
OLS	Ordinary Least Squares/Linear Regression
OVAM	Public Waste Agency of Flanders
P2B	Peer-to-business
P2P	Peer-to-peer
PPP	Purchasing Power Parity
RMC	Raw Material Consumption
RMI	Raw Material Input
ResCoM	Resource Conservative Manufacturing
SME	Small and Medium Enterprises
RIS3	Regional Innovation Strategies for Smart Specialisation
ToR	Terms of Reference
WEEE	Waste from Electrical and Electronic Equipment

1. Introduction

The CIRCTER project on behalf of ESPON analysed the territorial dimension of transformations towards a circular economy: The European regions (here analysed on a NUTS2 level) clearly have very different potentials as well as starting points for increasing the circularity of material flows due to e.g. the share of industrial activities or the economic well-being measured in GDP per capita. Within the project specific indicators have been developed that combine resource consumption and waste management and illustrate the differences on a regional level. These maps provide valuable insights for the development of tailor-made CE policies.

In cooperation with the Urban Agenda for the EU and the Partnership on Circular Economy[1] it has been discussed to analyse the specific contributions of this work for circular economy indicators at city-level: Cities will clearly have to play a crucial role in supporting the circular economy – at the same time e.g. the European Commission´s Circular Economy Monitoring Framework focuses on indicators that pose severe challenges for monitoring trends and developments at city-level.

Against this background, this report aims to

1) establish an analytical framework of city-level Circular Economy indicators that highlights a basis for a hierarchy of indicators based on an analysis of the links between objectives and indicators;
2) provide suggestions on possible governance indicators that go beyond status quo and waste based figures and focus on meaningful good governance;
3) highlight the territorial specificities that need to be considered when designing indicator systems on Circular Economy, e.g. with regard to large and small cities, remote and close cities, richer and poorer cities;
4) discuss considerations on data availability for specific CE indicators at city level;

[1] https://ec.europa.eu/futurium/en/system/files/ged/urban_agenda_partnership_on_circular_economy.pdf

2. Conceptual models of the CE

2.1. Necessity of an explicit conceptional understanding of CE

Despite the growing academic literature on the circular economy, the theoretical foundations for a shared ground of knowledge or a set conceptional model have not been established yet (see e.g. Kalmykova et al., 2018; Prendeville et al., 2018). It is generally accepted that this area of research is still in a consolidation phase in terms of definition, boundaries, principles and associated practices (Korhonen et al., 2018b, Merli et al., 2018). This also holds for the understanding of how complex socio-economic systems and sub-systems may affect and be affected by the so-called 'circular-economy transitions' (Korhonen et al., 2018a). A recent publication highlighted that in the scientific literature alone more than 100 definitions of a circular economy can be differentiated.

It is important to take into account that this broad variety of definitions – from very academic, complex models to often simple and pragmatic visualisations – is linked to an often very diverging understanding of the objectives of becoming circular. Against that background, measuring progress towards circularity requires as a crucial first step an explicit understanding of the objectives and the rationality of a circular economy – otherwise the development of indicators as well as monitoring these indicators might completely overlook the actual relevant trends and developments. The overview on existing indicator frameworks by Kirchherr, 2017 very clearly highlighted that the robustness or accuracy of specific indicators can only be assessed with a clear conceptional understanding of a circular economy and its objectives that also allows to develop a specific hierarchy of targets and indicators, e.g. in the case of trade-offs. The aspired transformation of our patterns of consumption and productions will require a complex systemic change that will have to take into account all sorts of intended or uninteded side effects, variables and causal links as illustrated in the causal loop diagram[2] in figure 1.

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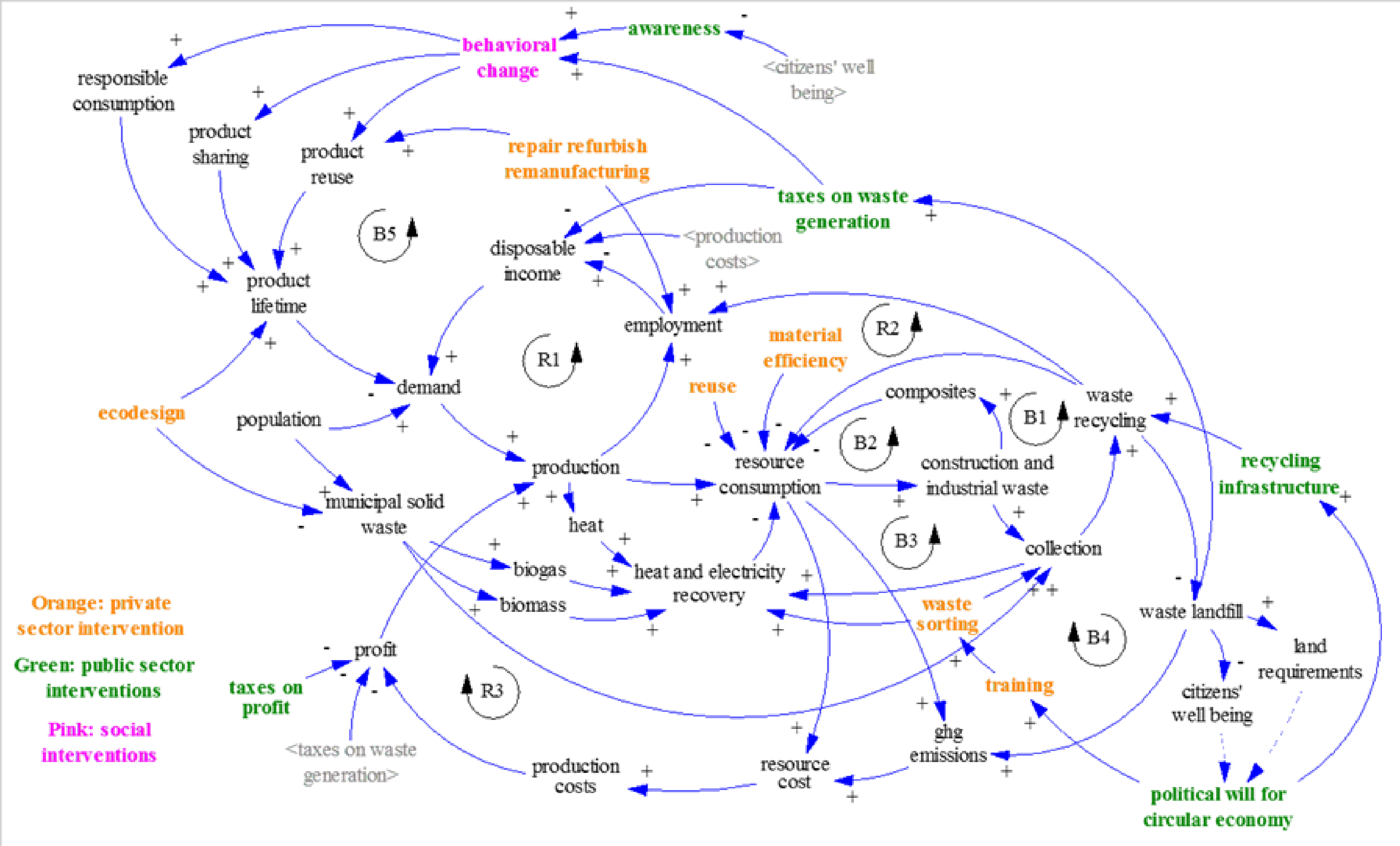
[2] The CLD for Maribor shows for the problem of increasing amounts of landfill waste (red) which counteracting activities (orange) are associated with which interlinkages. The objective is to reduce the amount of waste landfilled, e.g. by creating a recycling infrastructure, to eliminate the prospect of waste incineration as well as avoid the expansion of waste landfill. This is implemented in conjunction with training for public servants to ensure the implementation of waste sorting. These activities introduce four balancing loops in the system (B1, B2, B3 and B4), which limits the growth of landfilled waste. At the same time, these interventions would create new opportunities which could lead to increasing economic growth and resource consumption (R1 and R2), and hence increasing generation of waste (R3). Emphasis is also put on material efficiency in industrial processes and on awareness raising for behavioral change at the household level. This complementary intervention adds a fifth balancing loop (B5), which would reduce waste generation. Overall, the strategy of Maribor practically combines efforts on the supply side (e.g. sorting and recycling) with interventions that reduce the generation of waste for long-term sustainability (Source: ESPON 2019)

Figure 1: Causal loop diagram for the circular economy and its interlinkages, case study for reducing waste landfill in Maribor



Source: ESPON, 2019

2.2. Objectives of a circular economy

Following the different definitions and conceptionalisations of a circular economy, different analytical categories have to be differentiated in order to gain an explicit understanding of the objectives to be achieved in a more circular – or if that´s even possible – completely circular economy.

Strategic objectives highlighted in analysed practices and concepts of circular economy do not always include the three environmental, economic and social objectives. The starting point for most definitions is an environmental rationale to protect natural resources, to avoid environmental burdens to ecosystems, species and thus indirectly also to avoid negative impacts on human health. Most concepts focus on the output-side of the socio-economic metabolism – the waste streams and their disposal and recovery - as well as on the input-side, measured e.g. by material-flow based indicators like domestic material consumption. Increasingly also the potential contributions to climate change mitigation by circularity are seen as a strategic objective (Material Economics, n.d.).

Despite this focus on the environmental benefits of the circular economy, it should be noted that e.g. the Circular Economy Action Plan by the European Commission has been initiated primarily by DG Grow and has a clear focus on the cost savings, job creation and competitiveness potentials (European Commission, 2015):

“The circular economy will boost the EU's competitiveness by protecting businesses against scarcity of resources and volatile prices, helping to create new business opportunities and innovative, more efficient ways of producing and consuming. It will create local jobs at all skills levels and opportunities for social integration and cohesion. At the same time, it will save energy and help avoid the irreversible damages caused by using up resources at a rate that exceeds the Earth's capacity to renew them in terms of climate and biodiversity, air, soil and water pollution. (...) Action on the circular economy therefore ties in closely with key EU priorities, including jobs and growth, the investment agenda, climate and energy, the social agenda and industrial innovation, and with global efforts on sustainable development.“

Obviously environmental objectives on the one hand and economic objectives on the other can be very well aligned – this is the unique opportunity of the circular economy as e.g. illustrated by the assessments published by the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2017). Nevertheless it has to be stated that these co-synergies are not an automatic and necessary must – but have to be ensured by an appropriate regulatory framework! Trade-offs can be imaginable on many different levels, e.g. lowering the technical thresholds for pollutants in recycled plastics could definitely lead to new business opportunities but at the same time pose severe risks to the health of consumers. From a more conceptional point of view the circular economy often has a clear emphasis on the consistency of our socio-economic metabolism – neglecting the need for an absolute reduction of the natural resource requirements of our industry (UNEP, 2017). Looking at the mostly positively connoted image of the “circle”, its overall long-term sustainability will depend not only on its closure but also on the total amount of resources that will be necessary to keep it floating. CE indicator frameworks from the global down to the urban level will have to ensure that these aspects are comprehensively covered, e.g. by not only focussing on recycling rates and neglecting waste generation.

Other important analytical dimensions e.g. include the temporal perspective with a majority of indicators focussing on current data, looking at improvements of the status quo compared to the past. A very different set of indicators in contrast has a focus on future developments, measuring e.g. eco-innovation potentials in terms of R&D expenditures or based on patent analysis (O’Brien et al., 2018).

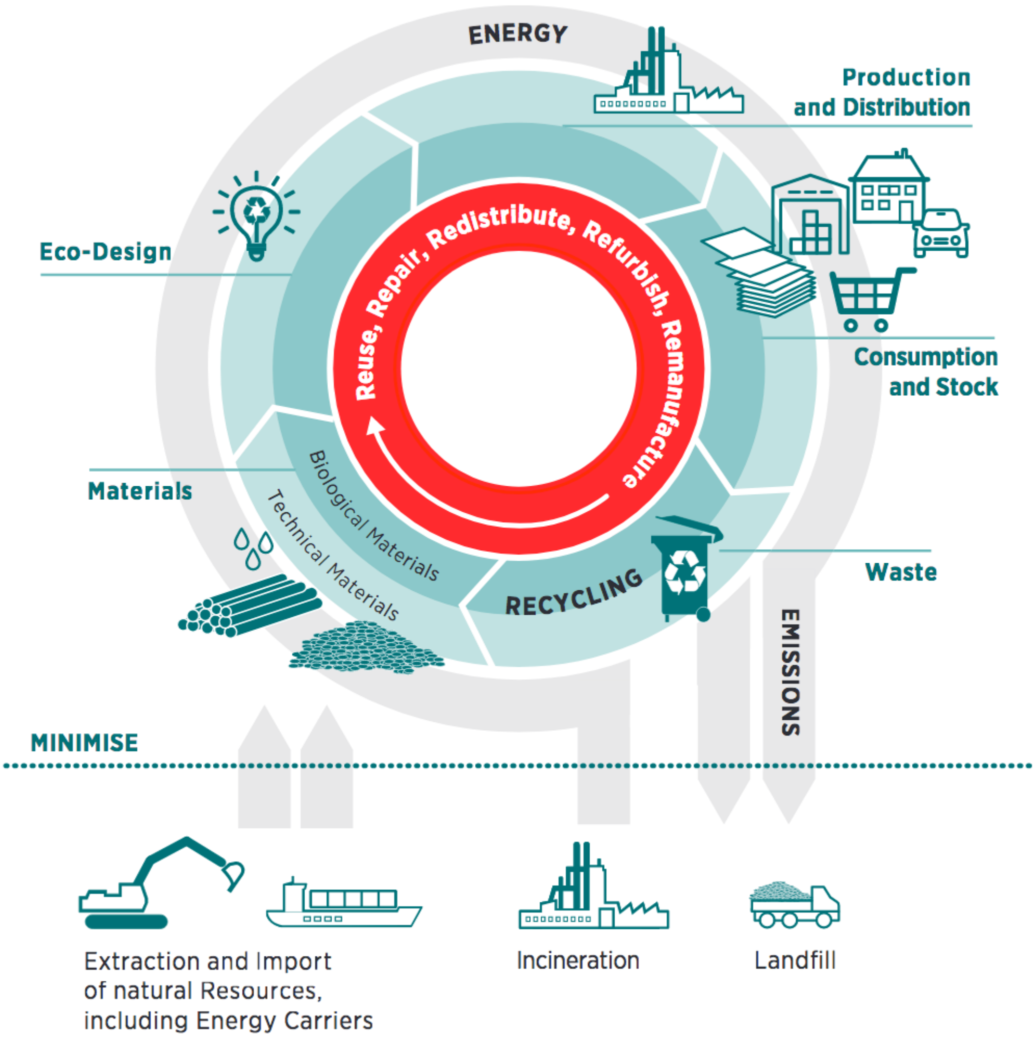
2.3. Spatial perspective

Starting point of the CIRCTER project has been the specific challenges of a spatial perspective on the circular economy: the regulation of local circuits and the relational logic of geographical norms and scales as factors for circular economy development remain very little discussed for the moment (Barles, 2009). In our view, three key analytical challenges need to be sorted out to characterise the circular economy under a territorial perspective, namely: (1) the scales of operation of circular economic systems and sub-systems; (2) the territorial factors that may affect the development of closed material and energy loops, and; (3) the territorial outcomes that might derive from the penetration of Circular Business Models (CBM) at various levels.

Regarding the first challenge, we argue that the circular economy can be characterised and studied at different scales depending on the specific sub-systems that are considered, which are also tightly linked with the notion of ‘organizational width’ introduced above. The circular economy clearly has a multi-scalar expression that should be analysed beyond the borders of single companies, cities, regions or countries. At a national and global levels (macro scale), this can be done by e.g. focusing on the geographies of international supply chains and globalised waste flows (Clapp, 2001, Velis, 2015). Some argue that intermediate regional areas (meso-scale) may be the most suitable level for closing material loops and creating sustainable industrial ecosystems (Sterr & Ott, 2004). But the circular economy also has an expression at the urban and local levels (micro-scale). Here is where the circular economy can be materialised in very tangible initiatives, for instance in the form of local food systems or closed circuits of secondary materials of the lowest value (e.g. demolition materials or organic wastes). In any case, the debate on the territorial definition of a circular economy goes well beyond the delimitation of scales of operation based on administrative-unit boundaries. In fact, the identification of the scales of operation ultimately links to the definition of appropriate system boundaries for the characterization of circular economies at various territorial levels.

These somehow theoretical considerations become very concrete when it comes to the assessment of imports and exports of materials as well as waste streams: The circular economy is often conceptionalised as a self-sufficiency approach where the reliance on raw material imports is reduced, as e.g. illustrated in the following schematic CE figure by the European Environment Agency that explicitly states that for a circular system material imports and waste exports should be minimized.

Figure 2: The Concept of Circular Economy



Source: Wilts & Berg, 2017

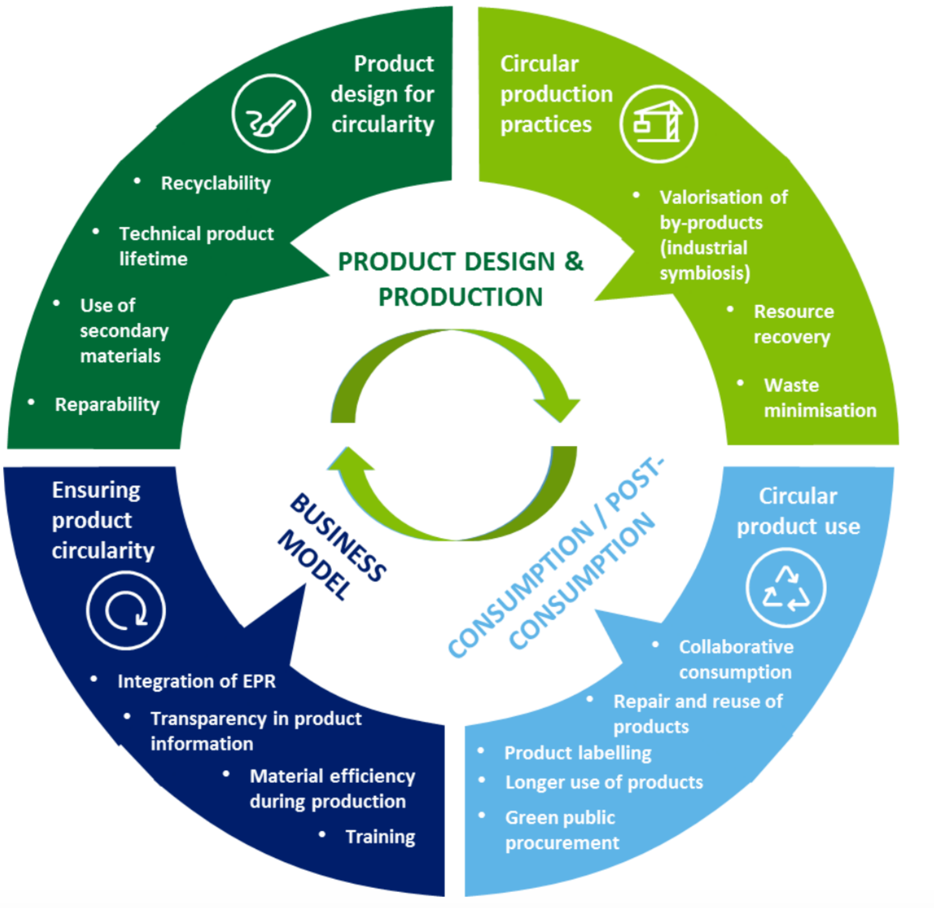
From an environmental point of view such an approach aims of course to reduce a simple shifting of burdens to other regions of the world e.g. by disposing residual waste in countries with lower environmental standards as highlighted by the Chinese ban of low quality waste imports.

At the same time the strict self-sufficiency approach also bears the risk of neglecting relevant territorial factors as outlined above: If one region has established high quality waste treatment infrastructures – why shouldn´t it import waste from regions without appropriate technology where waste would e.g. just landfilled.

The second important aspect is of course the spatial scale chosen for the closing of material cycles: The assessment of recovery rates for example for municipal solid waste would be completely different if calculated on a city level, on an average national level or in contrast on a city quarter level – and despite the completely different results for the same indicator just on different spatial levels, the environmental performance of the system could be exactly the same.

Taking these different aspects and issues into account, the following figure shows an analytical CE framework that goes beyond the rather static perspective of flows but focuses on circular activities, business models and innovations instead.

Figure 3: Framework for monitoring and evaluation of product eco-innovation for the circular economy



Source: O'Brien et al., 2018,p. 20

The framework encompasses three main areas (business model, product design/production and use/post-consumption) and associated indicators that effect the circularity of the system:

- Business model: factors applied in business models to ensure the full circularity potential of a product e.g. establishment of take back schemes, application of extended producer responsibility (EPR), integration of circular product design and production into business models, etc.
- Product design and production: product design and manufacturing elements that influence the circularity potential of the product from a technical perspective e.g. dura-

bility, reparability, recyclability, type of materials used, efficient production processes in terms of less resources used and waste produced, etc.

- Use and post-consumption: consumer behaviour elements that contribute towards close-looped product cycles e.g. innovative consumption models, longer use of products, recycling, etc.

From a specific urban perspective, the following table shows possible indicators for such a framework as well as a first assessment how i) territorial considerations, ii) data availability and iii) monitoring on city level can be considered. These aspects will be analysed in more details in Chapter 3 but obviously especially the focus on the circularity of products is a specific challenge for indicators at city-level.

Table 1: Indicators related to the circular economy from a materials perspective

Phase	Product circularity aspects	Possible indicators	Appropriateness for an analysis on city-level
Business model	Shift of business strategies towards circular concepts	• Number of product-service systems e.g. remanufacture and service-based offers such as offering consumers take-back schemes for products • Number of EMAS certified companies • Uptake of EPR schemes • Training programmes for employees and suppliers • Transparency in product information • Other trends on the adaptation of business models to integrate product eco-innovation and circular economy principles	+
Product design and production	Products designed to last longer; products designed for disassembly	• Product environmental footprint (PEF) • EU Eco-design related data • Evidence that businesses are implementing practices to improve product durability	-
	Recycled materials included in product design; products designed to be recycled	• Percentage of recycled content in products • Product environmental footprint (PEF) • EU Eco-design related data	-
	Lower volume and number of environmentally hazardous substances used in production	• Amount of hazardous waste generated and treated	-
	Less waste in production being generated	• Waste generation • Recycling statistics, decoupling and waste minimization statistics	0

	Fewer materials used in production; valorisation and use of secondary materials	• Materials / resource efficiency indicators • Industrial symbiosis indicators	+
Use and post-consumption	Alternatives to the purchase of new products	• Replacement rates of products • Average lifetime of products (based on real use) • Re-use, leasing and repair data	- (products)/ + (reuse)
	Evidence that product labels and other information tools influence consumer purchasing decisions	• Trends on EU Ecolabelled products and services	0
	Evidence that consumers are recycling more and increasingly repairing products	• Product take-back and repair statistics • EU, MS level product recycling trends • Recycling market statistics • Statistics on household waste separation and collection	0
	Other societal or consumption trends promote circular economy principles	• Number of sharing schemes • Collaborative consumption statistics	+

Source: O'Brien et al., 2018, p. 21

2.4. Strengths/ weaknesses of different indicator frameworks for implementation on city level

Taking into account the different strategic objectives as well as spatial perspectives on circular economy does of course not lead to a clearly defined set of indicators at city level. The selection of indicators has obviously a political component, e.g. if monitoring reports on indicators can be used to steer the public discourse as well as the policy agenda.

Nevertheless the analysis might help to identify specific strengths and weaknesses that should be considered during the selection process. The following highlights some of these characteristics taking the exemplary analytical frameworks outlined in the issue paper by Ecorys:

1. Indicators on recycling

   All indicators on recycling are highly dominated by the spatial distribution of recycling plants; interpretation of such indicators should always ask about the fate of waste streams from a specific city: how much of that waste has actually been recycled?

2. Indicators on material consumption

   Material consumption is closely linked to economic well-being; all input-oriented indicators (as well as e.g. indicators for C&D waste generation) are highly influenced by economic growth rates rather than illustrating the effectiveness of CE policies. Nevertheless they are important for an assessment of circularity potentials.

3. Indicators on cyclical use rates/ recycled content

   Compared to recycling rates, these indicators would have to take into account the share of imported products that in most cases clearly dominate consumption patterns in cities. They do give an impression of awareness amongst citizens and could very well be used e.g. for green public procurement.

4. Indicators on environmental professionals/ economic relevance of green sectors etc.

   These figures are often difficult to compare between cities due to different sectoral definitions of green/ circular activities. They are correlated with waste generation and thus with economic wellbeing. Nevertheless they provide excellent justifications for investments in circular economy and increase whenever a city manages to climb up the waste hierarchy (with waste recycling being much more labour intensive than e.g. waste incineration).

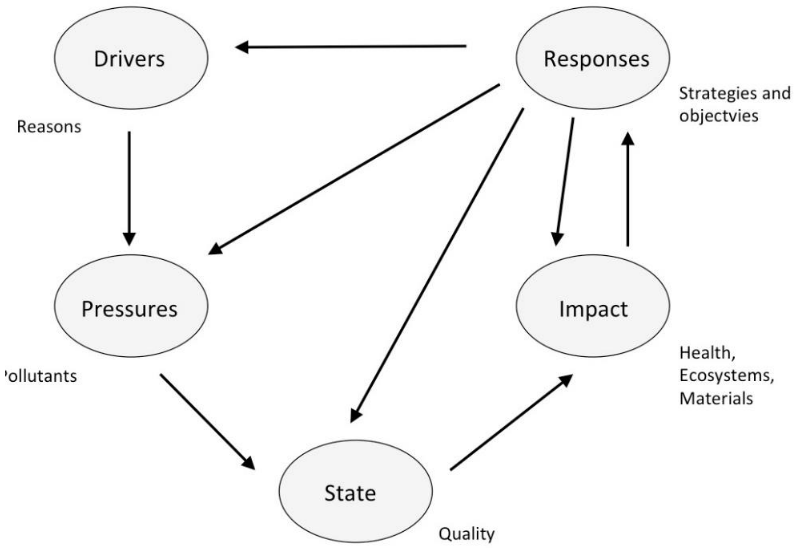
3. Governance indicators – the transformation process towards CE

3.1. Indicators on pressures vs responses

Looking at the broad variety of existing CE indicators and monitoring frameworks, a useful approach for a structuring classification has been further developed by the European Environment Agency and the OECD, the so called DPSIR framework.

The DPSIR concept is used as an approach for an integrated environmental assessment; the focus is on the interactions between the environment and socio-economic activities through the system analytical perspective. In a chain of causal links, a distinction is made between driving forces (economic sectors; human actions), pressures (environmental pollution), states (state of soil, water, air; changes in physical, biological or chemical processes), impacts (influence on ecosystems or human health) and responses (socio-political reactions). Indicators can thus be structured in terms of ecological quality and the resulting influence of policy decisions (see figure 4 below). This enables a clear differentiation of closed cycle indicators according to their different starting points, which distinguish between driving forces, environmental impacts caused by them and their specific impacts, the state of individual environmental media and concrete measures aimed at avoiding waste.

Figure 4: DPSIR concept for environmental assessment



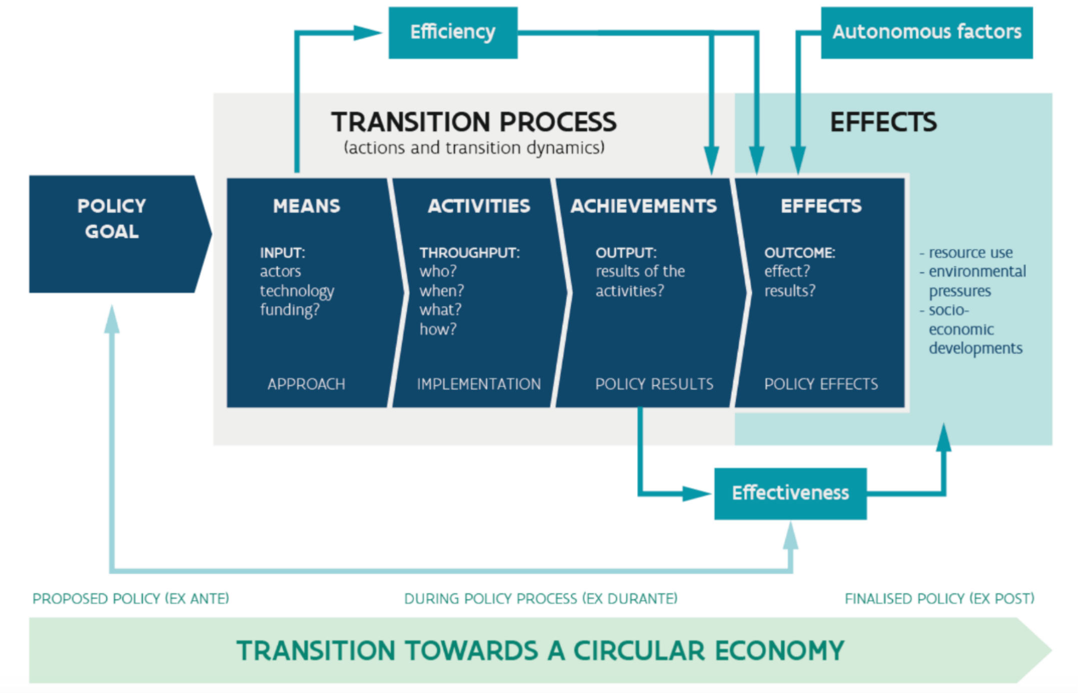
Source: Own compilation based on Kristensen (2004)

A recently finalised research project on behalf of the German EPA (von Gries et al, 2017) has highlighted that in the specific context of waste prevention in a circular economy, that there are virtually no impact or state-related waste prevention indicators. This gap is due to structural methodological problems, as the direct relationship between waste generation and direct environmental impacts depends on so many spatial and temporal factors that it is difficult to map consistently. In quite clear contrast, most of the specific CE indicator sets very much focus on the aspect of pressures like waste generation with recycling or recovery rates as a specific type of response indicators.

Taking into account the specific challenges on the urban level, a combination of indicators seems useful that integrate i) measuring the success of circular activities together with ii) the level of activity and the institutional set up of achieving circularity, the governance of CE transformations. The following will identify such indicators and discuss their appropriatness for application on the city level.

The circular economy transition is evidently rooted in technology: due to the complexity of our materials and products, technology is at the core of the transition, for instance when it comes to design and recycling. Then the measurement of stocks and flows of materials at the macro level and of product properties at the micro level can be considered. But the transition also clearly includes socio-institutional changes in which technology is not key but rather plays a secondary or supporting role (Potting et al., 2017). An example is the emergence of the sharing economy: for this to happen the availability of mobile networks has been crucial, but mobile networks have not been developed for the prime purpose of facilitating sharing, they rather have had a supporting role. Hence it is also important to have reflections of aspects beyond technology and material flows in the monitor, for instance the innovations in models of product and consumption, in product design, and socio-institutional evolutions. (Alaerts et al., 2018, p. 11)

Figure 5: Assessment framework for measuring the progress of the transition towards a circular Economy



Source: Alaerts et al., 2018, p. 11

3.2. Identification of relevant CE governance indicators

As perfectly shown by UA issue paper, there is no lack of suggested indicators, either by public institutions like the European Commission´s CE monitoring framework, the EU member states or actors like the OECD, proposed approaches by research institute like IVL or VITO or industry driven initiatives like the Ellen MacArthur Foundation. Against this background the following doesn´t aim to give a full picture on possible CE governance indicators but to rather discuss strengths and weaknesses of selected indicators in order to allow an informed discussion about the development of indicators, not a simple selection.

Sources analysed for this selection inter alia include the above mentioned sources but with the specific focus on governance especially existing CE, waste management and waste prevention monitoring frameworks provided by the EU member states have been analysed (EEA, 2015 and EEA, 2017). The following table lists indicators that have been identified in these sources that on very different levels refer to the governance of CE transformations.

Table 2: Identified CE government indicators

Green Public Procurement
Food waste prevention monitoring
Investments, eg in industrial symbiosis
Innovation/ patents
Integration of waste infrastructure planning in cities
Awareness raising – motivating stakeholders to take up CE measures
Number of pilot projects on the CE (e.g. on involving retailors)
Citizens involvement
Availability of a roadmap for resource management
Availability of innovative schemes for businesses at the city level, which are related to CE (not just for CO2 emissions trading)
Awards for circular businesses (e.g. stamps, stickers)
Cross-learning and exchanges between cities
Selective waste collection
Number of organisations with environmental certification
Number of schools that participate in environmental education projects
Number of organisations with registered environmental management systems according to EMAS and/or ISO 14001 CE funding Landfill tax rates, the tax levied per tonne of municipal waste disposed in landfills Public energy technology RD&D expenditures directed at “renewable energy ” and “fossil fuel energy”, expressed as percentages of total public energy RD&D
Technology development: the number of inventions (simple patent families) developed by a country’s inventors, independent of the jurisdictions where a patent application has been registered (i.e. all known patent families worldwide are considered)
Employment and value added in selected environmental protection activities expressed as a percentage of total; sewerage, waste management and remediation
Share of environmentally related tax revenue, expressed as a percentage of total tax revenue and compared to GDP and to labour tax revenue
Number of legislative and normative barriers identified and resolved
Number of legislative and normative incentives created
Number of people trained in CE trades
Number of students trained in CE occupations

Number of pilot cases set up via calls for projects / living lab
Number of seminars organized on the CE under the PREC
Number of economic operators sensitized on CE
Budget amount allocated to calls for projects / living lab made / implemented and number companies having benefited.
Budget amount and number of pilot public markets in CE developed in Brussels-Capital Region
Number of companies informed / aware of the opportunities of the Brussels public markets
Number of new neighbourhoods incorporating the principles of the CE
Number of enterprises receiving financial support in connection with the CE
Amount of financial aid granted to companies in connection with the CE
Number of economic operators accompanied in CE
Number of job-seekers put to work following training developed in the context of PREC

Based on this review it becomes clear that also the governance of circular economy transformations refers to a variety of specific questions that indicators aim to answer:

- How do specific activities develop in terms of number/ relevance/ participation that aim to support CE transformations?
- Is there an identified responsibility for specific aspects of CE transformations?
- Are there established specific indicators or targets for these processes?
- Is there a defined monitoring to collect and analyse data?
- How is the process financed/ subsidised or financially supported?
- If and how are effectiveness and/ or efficiency of the process monitored?
- How is the process perceived in relevant stakeholder groups, e.g. with regard to awareness in the public?

With these questions in mind, the following chapter aims to conceptionalize concrete CE governance indicators that specifically refer to concrete activities (or responses in the DPSIR terminology) with relevance for circular economy transformations at city or at least regional level. For these indicators the general importance as well as issues of data availability and monitoring schemes are discussed. In order to give a first impression of necessary efforts for establishing a monitoring scheme for the indicator, necessary working days have been roughly estimated – the specific efforts will clearly depend on already available information or the size of the specific city.

The following indicators have been formulated in a way that focuses on progress towards circularity within a specific city; they could of course also be used to monitor progress towards circular economy for a group of cities as the Urban Partnership; using e.g. the share of cities that formulated a dedicated urban circular economy strategy or the number of cities with a concrete contact person for circular economy. Obviously establishing a set of indicators always has to take into account the strategic objectives: guiding developments within a city, demonstrating progress in a cooperation or also highlighting specific challenges that would require external interventions e.g. in form of regulatory frameworks.

3.3. Discussion of specific indicators

3.3.1. Awareness raising for CE transformations

Proposed indicators

1. Number of communication measures (campaign, provision of information, events for the public) on circular transformations and waste prevention in general (period-related) and their reception
2. Number of other CE governance related activities by municipal public authorities (working group, events, implementation/award of expert reports) on circular transformations or waste prevention (period-related)
3. Level of public awareness for circular economy and waste prevention and development over time

Explanations

Initiatives to raise awareness for CE transformations might span across very different areas such as research and development, public information and awareness-raising and general organisation/activities. The collection of information on proposed indicators should distinguish and describe different types of actions. For example, only those activities that actually consist of such a campaign should be included as a campaign (in some cases, individual flyers or individual events were also specified as a campaign in the country survey). If possible, also data on the number of recipients or optimally evaluations of actual impacts on consumption patterns should be included.

In addition to information campaigns, other general activities on circular economy and waste prevention should also be included. Here, too, supplementary qualitative information is required in addition to the purely numerical value, and here too it would be useful to also list the activities of the federal government.

During the annual European Week for Waste Reduction (EWWR)[3], numerous local campaigns are held on the subject of waste avoidance and waste reduction. These are registered by various actors (authorities, associations, companies, educational institutions, private individuals, etc.) and are often supported by several actors. In all member states there are specific institutions that coordinate the EWWR and collect data on the actors involved. Due to the diversity of the actors involved, it makes sense to evaluate only a limited part within the framework of an indicator, e.g. public waste management companies as well as participating public authorities and educational institutions could be evaluated.

With regard to the public level of awareness for circular economy, the questions should be very carefully formulated in order to avoid confusions with aspects of cleanliness/ littering

[3] European Week for Waste Reduction (n.d.), More information at http://www.ewwr.eu

alone. It should also be taken into account that a high level of awareness in general could be a sign for a positive perception of the city´s activities or rather a feeling that actually more action would be necessary.

Data collection

Indicator 1: Number of communication measures (campaign, provision of information, events for the public) on circular transformations and waste prevention in general (period-related) and their reception	
Criteria	**Evaluation**
Are the data "ready" available?	No; clear need for additional data collection schemes e.g. via surveys. EWWR related activities as a first starting point are publicly accessible on the EWWR website.
Amount of material costs or personnel expenses (working days) for data:	Once the methodology of the survey has been established, a personnel expenditure of approx. 10 working days must be planned for the implementation and evaluation of the survey for all indicators collected through the survey.
Are the data confidential?	Individual answers yes, but the aggregated/ anonymised information for the indicator is not.
Frequency of updating:	as needed
Stability of the data quality:	Stable with the same methodology; the data quality depends on whether only the "correct" activities are actually mentioned; the completeness of the data must be ensured by mandatory participation in the survey.

Indicator 2: Number of other CE governance related activities (working group, events, implementation/award of expert reports) on circular transformations or waste prevention (period-related)	
Criteria	**Evaluation**
Are the data "ready" available?	No
Who collects the data / who is the data source?	Data source are the responsible authorities, the query would have to be made specifically via a questionnaire
Amount of material costs or personnel expenses (working days) for data:	Once the methodology of the survey has been established, a personnel expenditure of approx. 10 working days must be planned for the implementation and evaluation of the survey for all indicators collected through the survey.
Are the data confidential?	Individual answers yes, but the aggregated/ anonymised information for the indicator is not.
Frequency of updating:	as needed

Stability of the data quality:	Stable with the same methodology; the data quality depends on whether only the "correct" activities are actually mentioned; the completeness of the data must be ensured by mandatory participation in the survey.

Indicator 3: Level of public awareness for circular economy and waste prevention and development over time	
Criteria	**Evaluation**
Are the data "ready" available?	No, only in limited cases
Who collects the data / who is the data source?	Regular surveys on attention for environmental issues or general perception of living quality in cities with the general public as target audience
Amount of material costs or personnel expenses (working days) for data:	Limited expenditures if relevant questions can be added to existing surveys
Are the data confidential?	Yes
Frequency of updating:	Annually
Stability of the data quality:	Interpretation depends on specific formulation of questions

3.3.2. Circular economy on company level

Proposed indicators

4. Number of activities that support waste prevention in enterprises (e.g. information campaign, information or advisory services, exchange of experience) (period-related)
5. Number or share of companies that have implemented an environmental management system in specific cities (e.g. EMAS, Ökoprofit, QuB, ISO 14001 certification)

Explanations

A number of indicators can be formulated in the area of consultancy for enterprises and environmental management systems (EMS) (e.g. number of consultations carried out, volume of posts employed for consultations, number of specially trained consultants), but there are likely to be problems in determining which programmes/consultations actually substantially address the waste prevention aspect. However, a general census of the introduced relevant EMSs is possible via the relevant organisations and can be used as a proxy indicator (the data for the different systems should be listed separately due to their differences). In most countries only few larger systems for EMS (like Ökoprofit, EMAS etc.) exist for which information is available on the number of certified establishments can be used here. In addition to the purely numerical values, it is useful to describe the depth to which waste prevention plays a role in the various systems. In addition, there are numerous other industry-specific environmental management labels whose coverage by the indicator would, however, significantly increase the effort involved in collecting the data. Optimally, not only the total number but also the share of companies within a city that are involved in such activities should be monitored; this is nevertheless often challenging due to lacking differentiations between companies and production sites in a city.

Data collection

Indicator 4: Number of activities that support activities in the field of waste prevention in enterprises (e.g. information campaign, information or advisory services, exchange of experience) (period-related)	
Criteria	**Evaluation**
Are the data "ready" available?	No
Who collects the data / who is the data source?	Data source are the responsible state and federal authorities, the query would have to be made specifically via a questionnaire.
Amount of material costs or personnel expenses (working days) for data:	Once the methodology of the survey has been established, a personnel expenditure of approx. 10 working days must be planned for the implementation and evaluation of the survey for all indicators collected through the survey.
Are the data confidential?	Individual answers yes, but the aggregated/ anonymised information for the indicator is not.
Frequency of updating:	as needed
(Stability of the data quality):	Stable with the same methodology; data quality depends on whether only the "correct" activities are actually mentioned; completeness of the data must be ensured by mandatory participation in the survey

Indicator 5: Number or share of companies that have implemented an environmental manage-ment system (EMAS, Ökoprofit, QuB, ISO 14001 certification)	
Criteria	**Evaluation**
Are the data "ready" available?	The data must be requested from the respective supporting organisations (partly available online, partly necessary by telephone).
Who collects the data / who is the data source?	Supporting organisations of the EMA
Amount of material costs or personnel expenses (working days) for data:	Low personnel expenses
Are the data confidential?	No, it doesn´t
Frequency of updating:	Annually
(Stability of the data quality):	Good / constant; however, in some cases (EMAS, ISO 14001) not only companies but also public authorities and associations are included (these could be deducted with a certain additional effort) and some companies can be included in several systems at the same time.

3.3.3. Extending the useful life of products

Proposed indicators

6. Number of visitors in reuse centres/ repair or second hand shops (period-specific)
7. Turnover of reuse centres/ repair or second hand shops (period-specific)
8. Mass and proportion of the mass of waste electrical and electronic equipment to be prepared for reuse

Explanations

In the area of support for reuse, there are currently significant differences with regard to activities at city-level. Both the absolute mass and the share of equipment in the WEEE waste stream can already be mapped without much additional effort on the national level – based on data that often have to be collected at city-level. The data are available separately for 11 different categories of equipment, according to which differentiation could be made, but small quantities in individual sub-indicators could indicate fluctuations that are purely random and whose significance would be overestimated by a separate presentation. Better than presenting the quantity of equipment entering the preparation for re-use would be the quantity of equipment actually available for re-use at the end of the process, but these data are not available. It should also be considered whether a separation into private and commercial devices would be possible.

Gathering data on the number of visitors in reuse/ repair centres etc requires setting up a clear network of such facilities/ companies that identify themselves with this sector. Such processes can be supported by setting up quality labels or even financial support by the sector – for which in return mandatory reporting obligations are established (see e.g. in Brussels and Flanders). Data on financial turnover are in many cases easier to obtain that data on tonnages; in many countries this also hinders proper estimations of materials that are actually reused and standardized average weights for specific products could be helpful.

The problem here, however, is that most repairing enterprises also sell new products and the repair services are not shown separately in turnover. This problem of demarcation also exists in particular in cases where, for example, electronic equipment is given to the original manufacturer for repair. In some areas (shoemakers, tailors) there are firms that repair almost exclusively, but these represent only a very small part of the repair trade as a whole and the data therefore do not seem to be sufficient to support an indicator. A 2-level indicator could be an option to overcome this specific challenge: The share of companies that mostly do repair/reuse activities as well as the share of companies that have repair/reuse only as part of their activitiy but that also sell new products could be used as more specific calculation method.

Indicators on visitors e.g. of reuse centres could of course also be linked to indicators measuring the awareness of citizens for waste prevention in general or specific waste prevention opportunities like reuse. Indicator 3 (see Chapter 3.3.1) that would be based on survey could be amended by specific questions on the knowledge amongst the population about the location of second hand shops or repair services. Several cities like for example Berlin provide guidebooks to repair shops in the different parts of the city, aiming specifically to increase the awareness of such service offers.

Data collection

Indicator 6: Number of visitors in reuse centres/ repair or second-hand shops (period-specific)	
Criteria	**Evaluation**
Are the data "ready" available?	No
Who collects the data / who is the data source?	Data source are the responsible state and federal authorities, the query would have to be made specifically via a questionnaire.
Amount of material costs or personnel expenses (working days) for data:	After the initial establishment of a network of actors within the city, a personnel expenditure of approx. 5 working days must be planned for data collection from the centres.
Are the data confidential?	No.
Frequency of updating:	as needed
(Stability of the data quality):	Yes

Indicator 7: Turnover of reuse centres/ repair or second hand shops (period-specific)	
Criteria	**Evaluation**
Are the data "ready" available?	Yes
Who collects the data / who is the data source?	Data must be reported for financial/ taxation reasons; often not directly available for other municipal actors.
Amount of material costs or personnel expenses (working days) for data:	After the initial establishment of a network of actors within the city, a personnel expenditure of approx. 5 working days must be planned for data collection from the centres.
Are the data confidential?	Yes
Frequency of updating:	Annualy
(Stability of the data quality):	Stable with the same methodology; the data quality depends on whether only the "correct" activities are actually mentioned.

Indicator 8: Mass and proportion of mass of waste electrical and electronic equipment sent for preparation for re-use	
Criteria	**Evaluation**
Are the data "ready" available?	Yes, on national/ regional level; in limited cases also at city-level
Who collects the data / who is the data source?	Different collection schemes in place, obligatory reporting to Eurostat on the national level
Amount of material costs or personnel expenses (working days) for data:	No additional expenditure if the data are recorded again as until 2014.
Are the data confidential?	No, it doesn´t
Frequency of updating:	Annually
(Stability of the data quality):	The data quality is limited, the data is not completely complete (cf. the explanations above in the text)

3.3.4. Prevention of food waste

Proposed indicator

9. Number of activities that have been carried out to prevent food waste (e.g. information campaign, events, publication of recommendations, establishment of a working group, research project) (period-related)

Explanations

In the area of food waste prevention, most, but not all, cities are quite active. The proposed indicator represents the total number of publically recorded activities in this area. It would be useful to include and present some qualitative information on the type of activities, as well as the activities of the federal government.

Measuring the total amount of food waste and thus monitoring food waste prevention would definitely be preferable, such an approach would require a clear definition of food waste as well as a regular composition analysis of all different waste streams. The European COmmission is currently working on a harmonized measurement methodology and the cities should carefully analyse if this could be implemented also at city level.

Data collection

Indicator 9: Number of activities that have been carried out to prevent food waste (e.g. information campaign, events, publication of recommendations, establishment of a working group, research project) (period-related)	
Criteria	**Evaluation**
Are the data "ready" available?	No

Who collects the data / who is the data source?	The query would have to be made specifically via a questionnaire.[4]
Amount of material costs or personnel expenses (working days) for data:	Once the methodology of the survey has been established, a personnel expenditure of approx. 10 working days must be planned for the implementation and evaluation of the survey for all indicators collected through the survey.
Are the data confidential?	Individual answers yes, but the aggregated/anonymised information for the indicator is not.
Frequency of updating:	as needed
(Stability of the data quality):	Stable with the same methodology; the data quality depends on whether only the "correct" activities are actually mentioned; the completeness of the data must be ensured by mandatory participation in the survey.

3.3.5. Public Procurement

Proposed indicator

10. Existence of concrete guidelines on public procurement in which waste prevention and other circular economy related aspects (reuse/repair, take-back options, recycled content) are explicitly addressed

11. Share of public procurement that chose different products/ services due to waste prevention and other circular economy related aspects

Explanations

Although the European procurement regulations as well as regulations at state level provide for an inspection obligation or target regulation for aspects such as longevity, ease of repair and reuse in public tenders, this inspection obligation is hardly applied in practice. Some federal states have guidelines that address these aspects. Although following such guidelines is voluntary and their mere existence therefore does not provide any information on their practical application, they do indicate a certain degree of involvement with the issue in public procurement and may attract attention. For the indicator, it is necessary to define which approaches to public procurement are considered waste avoidance (e.g. procurement of used goods, durable, repair-friendly products). In order to get an indication of the scope and depth of the consideration of the issue, some qualitative information on the nature and scope of the requirements/proposals should also be collected.

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[4] It was also proposed to use the BMEL's website https://www.lebensmittelwertschaetzen.de/aktivitaeten/ for data collection, which lists food waste prevention activities. However, most of these activities are carried out by private initiatives.

Indicators that would monitor the actual relevance of such prevention oriented procurement guidelines would be desirable, but extremely challenging to implement: They would require a detailed evaluation of specific procurement processes and might in the beginning be based on selected cases for a limited group of products with high potential for circular/ waste preventing solutions.

Data collection

Indicator 10: Existence of concrete guidelines on public procurement in which the waste prevention aspect is explicitly addressed	
Criteria	**Evaluation**
Are the data "ready" available?	No
Who collects the data / who is the data source?	The data would have to be collected separately. The guidelines have been compiled, in Germany for example, by the Competence Centre for Sustainable Procurement (Beschaffungsamt des Bundesministeriums des Innern, 2012); it would also be useful to conduct further research to find out whether other current guidelines are available.
Amount of material costs or personnel expenses (working days) for data:	For the first compilation and evaluation of these guidelines, approx. 2 working days of personnel expenditure are to be taken into account, for later updates less.
Are the data confidential?	No, it doesn´t
Frequency of updating:	as needed
(Stability of the data quality):	Depends on whether there is a consistent understanding in the evaluation of when the waste prevention aspect is explicitly addressed; this should be ensured by collecting qualitative information

Indicator 11: Share of public procurement that chose different products/ services due to waste pre-vention aspects	
Criteria	**Evaluation**
Are the data "ready" available?	No
Who collects the data / who is the data source?	The data would have to be collected based on an assessment of individual procurement processes. In the future such an assessment could be included as mandatory information for procurements.
Amount of material costs or personnel expenses (working days) for data:	Efforts would depend on the scope and depth of analysis, probably at least 20 days
Are the data confidential?	No, it doesn´t
Frequency of updating:	as needed

(Stability of the data quality):	Will depend on the chosen approach; a common methodology would be preferable but to be developed.

4. Data availability of comprehensive CE indicators

However, the governance indicators only address certain aspects of a circular economy. To get a complete picture of the circularity of cities, local decision-makers need a comprehensive picture of the input and output flows (waste and emissions) that enter and leave their urban systems or is accumulated within the system. In 1965 Wolman coined the term **Urban Metabolism** (UM) to describe this analogy: a city is like a living organism that absorbs material, energy and nutrients from nature and the surrounding regions, transforms them via technical and socio-economic processes within its city, grows and releases them again as Exports, Emissions and Waste.

Over the last 20 years, the literature on urban metabolism has grown considerably and a review of the various studies (Beloin-Saint-Pierre et al. 2017) shows that the concept of urban metabolism can be used to calculate very different indicators. These, in turn, were developed using different methods, data sources and differentiations.

Several UM studies only investigate individual material flows and changes in the in-use stock, such as copper or nitrogen (Van Beers et al. 2003, Forkes 2007), others concentrate on energy flows (Haberl 2001, Fikar 2009, Krausmann 2013). Other UM studies again focus on greenhouse gas emissions in order to make a statement on the environmental impacts of an urban region (Hillman/Ramaswami 2010).

Some studies methodically follow the indicators of the Economy-wide MFA (EW-MFA), which basically records all material inputs and all outputs from the spatially defined anthroposphere, and all the different data can be combined into uniformly defined indicators. At the national and international level, most of these EW-MFA indicators are now gathered and published by the relevant statistical offices as official environmental data; be it direct material inputs or emissions and waste flows as output. At the same time, these are often part of the headline indicators that measure and evaluate progress towards sustainability or circular economy.

At the regional or local level, however, these data are not available for the formation of these indicators. The main obstacle to collecting these indicators at sub-national levels is the difficulty in capturing trade linkages on both the input and output sides. Corresponding legal regulations for gathering such transport data exist only at national and European level in the form of corresponding regulations and reporting obligations for imports and exports. However, especially in cities with hardly any significant domestic extraction, the import and export of materials, energy and goods are extremely relevant. Waste statistics are usually collected at the recycling facility level. However, here too the incoming waste streams are only differentiated according to nationally generated or imported quantities. There is no further subdivision of these domestic flows into regional and municipal origins.

These methodological difficulties lead to the fact that interested cities cannot collect the data for comprehensive indicators without enormous effort, and which at the same time are connectable to the indicator discussion on national or European levels (see e.g. the 10 Circular Economy Indicators from Eurostat[5]). Nevertheless, there are plenty of studies which, for example, have collected corresponding MFA input indicators for cities (in Europe, among others: Paris: Barles 2009, Pina et al. 2015; Hamburg and Vienna: Hammer/Giljum 2006; Lisbon: Niza et al. 2009, Rosado et al. 2013, Pina et al. 2015; Amsterdam: Voskamp et al. 2016; Madrid: Sastre et al. 2015; Stockholm: Rosado et al. 2016, Kalmykova et al. 2015; Lille, Lyon, Frankfurt, Liverpool, Manchester, Porto, Berlin: Duarte 2016). How were the indicators compiled in these studies? Either via very labour-intensive bottom-up calculations, or using a very similar approach to regionalisation as in CIRCTER: National or international data were disaggregated to the urban level using proxy indicators. In some cases, hybrid models were also used, in which top-down data are combined with bottom-up data. In other cases, input-output models were used, which allow detailed disaggregation by economic sectors and the type of final use.

The enormous complexity in collecting these comprehensive indicators also prevents the regular compilation of these data, so that to a large extent these studies only includes data for one specific year. A regular monitoring of the progress of an urban circular economy does not seem possible on this basis of data avialability, but even with high effort only an annual examination is possible. In addition, these comprehensive indicators are also a prerequisite for the compilation of further indicators such as local recycling rates.

The different methods, data availability, time periods and spatial system boundaries lead to very different data on the material consumption of cities (see Table 3). Therefore, no temporal development (e.g. Lisbon) can be derived from these different studies and no benchmark of the cities among themselves can be made. Rather, the results once again underline the methodological difficulties in determining comprehensive indicators for urban spaces that claim to reflect urban metabolism.

[5] https://ec.europa.eu/eurostat/web/circular-economy/indicators/monitoring-framework

Table 3: Overview of different DMC per capita results for European cities

DMC in t per capita		Duarte (2016)	Rosado et al. (2016)	Rosado et al. (2014)	Barles (2009)	Voskamp et al (2016)	Niza et al. (2009)	Hammer/ Giljum (2006)	Sastre (2015)	Kalmykova et al. (2015)	Pina et al. (2015)	CIRCTER
		for 2011	for 2011	for2005	for 2003	for 2012	for 2004	for 2001	for 2010	for 2011	for 2000	for 2014
France	Lille	12,7										
	Lyon	15,5										
	Paris	11,8			7,1						15,5	
Germany	Berlin	17,9										4,9
	Hamburg	20,9				8,2		11,0				9,1
	Frankfurt	17,9										
	Bremen											8,5
Portugal	Lisbon	19,0		10,4			20,1				17,1	8,5
	Porto	16,5										
Spain	Madrid								12,9			9,5
UK	Liverpool	8,3										
	Manchester	9,1										4,9
Sweden	Stockholm	22,0	10,3							10,1		
	Gothenburg		11,9									
	Malmo		10,9									
Netherlands	Amsterdam					16,0						
Austria	Vienna					5,0						5,4
Belgium	Region de Bruxelles-Capitale											4,5
Czech Republic	Praha											8,5

Source: own compilation

5. Territorial specificities

The development of indicator systems at local level depends i) on the specific question that a municipality would like to address in particular, ii) but also strongly on the availability of local data and the willingness and capability of local authorities to provide the necessary time and financial resources for the collection of suitable bottom-up data. The local availability of data will not only differ both between countries but also within countries. Due to the complexity of compiling comprehensive CE indicators (whether using bottom-up approaches and collecting the corresponding basic data or by disaggregating national data through estimation models), it is probably not possible for most municipalities to create this database themselves. Rather, cooperation with external experts in the form of a joint project appears to be the more promising approach. Unfortunately, this restricts the possibility of smaller and/or poorer municipalities. From a financial point of view, these cities will probably be much less able to carry out such projects.

Compared to the national average data, the CIRCTER project has already provided some results which show a fundamentally different dynamic of cities compared to other regions of their country, regardless of differences between individual cities. From these differences, first indications can be derived which specific material and waste flows in cities should be addressed as a priority by local CE activities.

The CIRCTER project estimated various Circular Economy indicators at NUTS 2 levels. At the same time, some NUTS2 regions are territorially equivalent to the city area (or a slightly larger metropolitan region). This mostly concerns capitals. Brussels, Prague, Berlin, Bremen, Hamburg, Madrid, Vienna, Lisbon and Manchester have been identified as NUTS2 regions and representing cities at the same time. London is spread over at least 2 NUTS2 regions (Inner London) or even 5 if Outer London is included.

In the following, the CIRCTER indicators (see Table 4) for these cities are presented in relation to their national averages resulting from the NUTS2 results in CIRCTER. The national DMC averages from CIRCTER correspond quite closely to the national indicators published by Eurostat.

It is striking that the Domestic Material Consumption (DMC) per capita and its subcategories in cities are significantly lower than the national average. This corresponds with the CIRCTER results, where urban regions (regions with dominant cities, but also their hinterland) generate less input per capita than rural regions. These can be partly explained by the very low domestic extraction used (DEU) in urban areas. There will still be some extraction in urban areas via gardening or farms within the cities and also possibly some clay, sand and gravel pits. But this is likely to be negligible in most cities. Accordingly, in CIRCTER no domestic extraction was estimated for most of regions that are also cities.

Table 4: CIRCTER Input indicators for Cities and the national average (data for 2014)

	DMC in t per cap	DMC biomass in t per cap	DMC metal ores in t per cap	DMC construction in t per cap	DEU in t per cap
Region de Bruxelles-Capitale	4,53	1,92	0,01	3,11	0,00
Belgium	**14,41**	**4,89**	**0,47**	**5,88**	**9,35**
Praha	8,50	1,26	0,02	4,80	0,00
Czech Republic	**15,15**	**2,20**	**0,44**	**6,83**	**14,92**
Berlin	4,88	1,83	0,04	3,01	0,00
Bremen	8,49	3,19	0,41	4,27	0,00
Hamburg	9,11	1,98	0,20	4,03	0,00
Germany	**18,12**	**4,15**	**0,60**	**7,45**	**14,93**
Comunidad de Madrid	5,22	1,60	0,06	2,31	2,37
Spain	**9,54**	**3,20**	**0,58**	**4,29**	**8,63**
Wien	5,40	2,25	0,01	4,30	0,00
Austria	**22,65**	**5,56**	**0,88**	**12,99**	**18,88**
Área Metropolitana de Lisboa	8,50	1,69	0,04	6,15	3,83
Portugal	**17,48**	**3,68**	**1,65**	**10,16**	**16,51**
Greater Manchester	4,86	2,52	0,02	2,16	2,56
United Kingdom	**10,51**	**2,93**	**0,34**	**4,05**	**9,38**

In addition to the lack of domestic extraction used, lower DMC values per capita in cities can be explained by a more efficient use of buildings and infrastructure, which is a major driver of material consumption. The share of multi-storey buildings is significantly higher in cities and thus provides lower material quantities per newly built square meter of living space. Infrastructures such as water and wastewater pipelines are used by significantly more people per km than in rural areas. The same applies to road infrastructure.

Cities located on coasts or large rivers have often grown because of their function as a hub for goods. Therefore, in cities like Rotterdam, Hamburg or Amsterdam there is a big difference between measuring the material input of a city using the indicator DMC or the Direct Material Input (DMI). In the literature, this is referred to as the Rotterdam effect, when the DMI are increased by imports that actually only cross the urban area. At the national level, this effect can only be measured in a few smaller countries with important ports such as the Netherlands.

If one compares the different waste indicators determined in CIRCTER (see Table 5), it is noticeable that, depending on the indicator, different behaviour patterns can be identified compared to the national average. The differences thus illustrate for which individual waste fractions cities apparently produce larger quantities than the rest of the country and for which waste streams exactly the opposite is the case.

At the same time, some waste indicators do not differ at all from the national average. For example, the amount of total waste excluding major mineral waste per capita. Nor are there any significant differences in the amount of household waste per capita. However, cities record significantly higher quantities of food waste per capita than the national average. This may be due to a better collection schemes of food waste in urban areas, but also to the lack of the possibility of composting it in one's own garden or feed it in one's own animal husbandry for one's own needs, as is still frequently the case in rural areas. The higher quantities of plastic waste in cities can probably be partly explained by the corresponding consumption behaviour in cities. However, there might also be a more separated collection of different waste stream in urban areas, which enables a larger amount of collected plastic waste and thus increases the per capita value compared to the national average.

Sectoral waste streams also differ between cities and their national average. This is not surprising for agricultural waste and waste from the mining and quarrying sectors. What is surprising, however, is the sometimes high amount of mineral waste from construction activities. There is a contradiction between the lower quantities on the material input for construction in cities and the high level of mineral waste generated by construction activities. It can be ruled out that the construction activities in cities are more waste-intensive as in other parts of the country. However, above-average construction activity in metropol regions such as Berlin, which could explain higher quantities of construction waste, would also have to be reflected on the input side.

Table 5: Waste Indicators used in CIRCTER (in kg per capita)

	Total Waste[1)]	**House-hold Waste**	**Food Waste**	**WEEE**	**Agri-culture NACE Waste**	**Mining and Quarring Waste**	**Manu-facturing Waste**	**Mineral and solidified Waste[2]**	**Plastic Waste**
Region de Bruxelles-Capitale	2.623	445	803	10,43	0,05	1,02	176	822	157
Belgium	**2.974**	**483**	**565**	**10,10**	**26,64**	**6,50**	**975**	**1.093**	**103**
Praha	1.415	308	276	7,21	0,50	9,12	103	1.545	58
Czech Republic	**1.113**	**311**	**128**	**5,58**	**12,15**	**24,76**	**408**	**862**	**32,68**
Berlin	1.661	430	335	9,01	0,00	0,15	147	1.939	37,09
Bremen	2.200	424	314	19,10	0,04	0,00	140	378	8,48
Hamburg	1.768	451	312	11,83	0,35	7,56	245	976	30,89
Germany	**1.892**	**452**	**225**	**8,59**	**5,45**	**93,08**	**599**	**2.048**	**25,68**
Comunidad de Madrid	1.369	382	379	4,63	1,01	29,99	235	640	43,61
Spain	**1.336**	**425**	**162**	**3,61**	**82,40**	**424,03**	**182**	**235**	**11,88**
Wien	1.817	514	486	9,08	0,07	0,07	179	4.498	65,98
Austria	**1.864**	**472**	**282**	**9,10**	**11,45**	**4,22**	**515**	**3.756**	**32,97**
Área Metro-politana de Lisboa	1.285	471	200	5,44	0,24	1,39	83	108	40,85
Portugal	**1.113**	**464**	**85**	**5,15**	**4,81**	**24,05**	**124**	**72**	**16,55**
Greater Manchester	1.754	483	330	7,63	0,03	16,43	139	2.072	37,38
United Kingdom	**1.521**	**506**	**243**	**7,94**	**12,27**	**1.034,60**	**117**	**1.616**	**28,24**

(1) excluding major mineral waste
(2) generated by construction activities

6. Conclusions

The analysis of potential CE indicators at city level in this report has highlighted that the establishment of such an indicator set is rather a technical challenge but requires various strategic decisions on circular economy transitions. Measuring progress towards circularity requires as a crucial first step an explicit understanding of the objectives and the rationality of a circular economy – otherwise the development of indicators as well as monitoring these indicators might completely overlook the actual relevant trends and developments.

A necessary part of such a discussion is a specific spatial perspective on urban circularity: Circular economy as a guiding principle could lead to completely different structures if implemented on a city district, a municipal or a regional level. Also the completely different framework conditions e.g. with regard to waste generation, waste treatment infrastructure or composition of materials should be taken into account at least for the interpretation of urban CE indicators.

The discussion of data availability for comprehensive CE indicators at city level clearly highlights that existing monitoring systems and indicators as e.g. established by the European Commission have a clear focus on a national perspective and have important limitations to properly capture circular economy processes at city level. If cities are actually seen as one of the key actors in this area and especially circular innovations are expected to be developed and implemented in front runner cities, more emphasis should be put on enabling cities to monitor and steer such development. Currently there is a clear trade-off between the comprehensiveness of urban CE indicator sets and often prohibitive costs and necessary efforts to gather data and to make them comparable on a European level. It can be seen as one of the key outcomes of the CIRCTER project that national CE indicators only poorly reflect the broad variety and complexity of circular transformations on the regional as well as municipal level.

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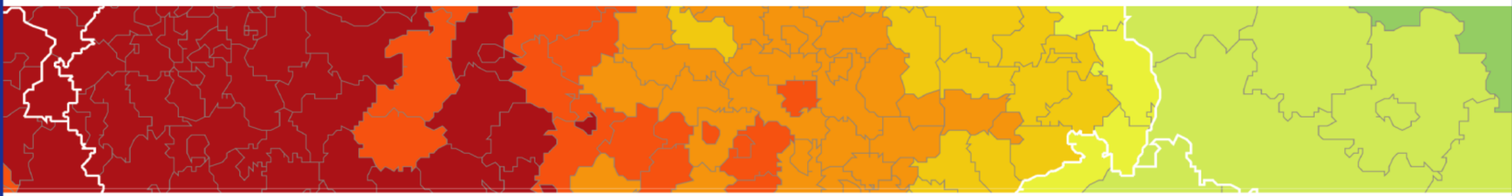

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