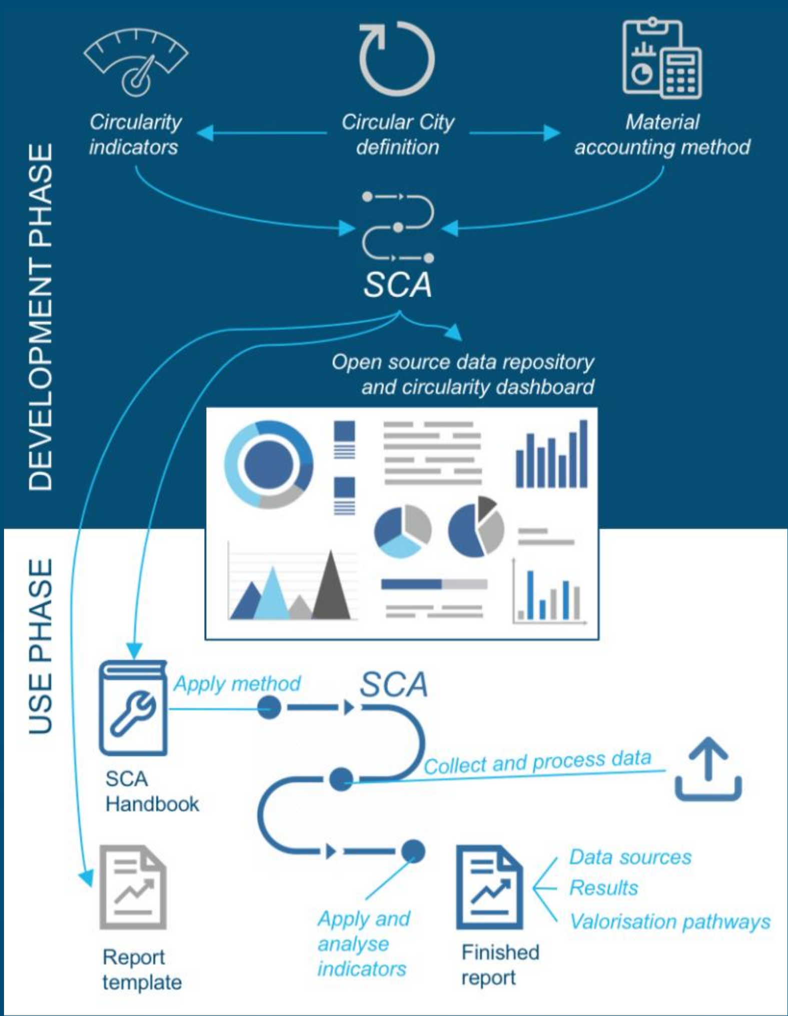
SECTOR-WIDE CIRCULARITY ASSESSMENT METHOD

Deliverable 4.3

Metabolism of Cities



Version	2.0* (2021-08-10) *Second version of this document to update the biomass sector material scope and Layer 3, after applying the method with users, as well as to correct minor formatting mistakes.
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Abstract	The document presents an accounting method for cities to evaluate the circularity of their construction and biomass sector(s). Firstly, it goes through some general definitions and concepts of circularity in cities and sectors. The next section showcases the proposed sector-wide circularity assessment method and discusses related data needs, processing, and analysis. This method combines material flow accounting and key "circularity" indicators to assess circularity in economic sectors. The developed method seeks to find a balance between scientific rigor and comprehensiveness on the one hand, and operability by urban policy makers and practitioners on the other. Finally, this document provides a handbook for urban policy makers and practitioners on how to apply this method for the biomass and construction sector of their city.
Keywords	Material flow analysis; sector circularity assessment; circular sector; Urban metabolism;
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Acronyms and Abbreviations

AS-MFA	Activity-based Spatial MFA
CDW	Construction and Demolition Waste
CE	Circular Economy
CHA	Circularity Hotspot Analysis
CPA	Classification of Products by Activity
CN	Combined Nomenclature
DA	Demonstration Action
DMC	Domestic Material Consumption
ECSO	European construction sector observatory
EMP	Energy, materials and products (catalogue)
EU	European Union
EW-MFA	Economy-Wide Material Flow Analysis
EWC	European Waste Catalogue
FUA	Functional Urban Area
GDP	Gross Domestic Product
GVA	Gross Value Added
ISIC	International Standard Industrial Classification of All Economic Activities
LAU	Local Administrative Units
LCA	Life Cycle Assessment
LoW	List of Waste
MFA	Material Flow Analysis
MFSA	Material Flow and Stock Analysis
MoC	Metabolism of Cities
MuSIASEM	Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical Classification of Economic Activities in the European Community)
NAS	Net Addition to Stock
NST	Standard goods classification for transport statistics
NUTS	Nomenclature of Territorial Units for Statistics
PRODCOM	PRODuction COMmunautaire" (Community Production)
SCA	Sector Circularity Assessment
SDG	Sustainable Development Goal
SO	Strategic Objective
UCA	Urban Circularity Assessment
UMan	Urban Metabolism Analyst Model
VE	Vision Element

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Introduction

CityLoops is an EU Horizon 2020 funded project that brings together seven ambitious European cities to demonstrate a series of innovative tools and urban planning approaches, aimed at closing the loops of urban material flows and increasing their regenerative capacity. This report is part of Work Package (WP) 4: Urban Circularity Assessment (UCA). This WP has two objectives:

- To **develop and implement a sector-wide material flow and stock accounting method**, designed to **help optimise demonstration activities** through a detailed analysis of material flows (exploring stakeholder involvement and valorisation pathways).
- To develop and demonstrate a comprehensive city-wide urban circularity assessment procedure, designed to enable cities to effectively integrate circularity into planning and decision making.

This report addresses the first objective of WP4 and is a deliverable of Task 4.3: Sector-Wide Circularity Assessment (SCA). The aim of the task at hand was to develop a method that would account for sector-wide material flows and stocks, which paired with indicators would assess the circularity of a sector. The method is meant for cities (of the CityLoops project) to undertake a SCA to **establish an evaluation baseline for the demonstration actions** (DA) and help optimise and upscale the measures to be demonstrated in the project within their wider economic sector(s). The goal of applying the methods is to:

- Provide a better understanding to partner cities of the overall functioning of their sector(s) and what appear to be “pressure points” to make these sectors more circular
- Help cities to put their actions in a broader context (their sector) and better appreciate the “impact” of their demonstrators in terms of circularity

Although WP4 is titled *“urban* circularity assessment”, it was decided in the project design phase that a UCA was too wide to integrate the DAs and therefore, the sector-wide level was created to develop a bridge between the two. The proposed indicators will cover both the sector and urban levels.

The report and SCA method development partly builds on the two previous deliverables in WP4, “Deliverable 4.1: Urban Material Flows and Stocks Accounting: A Review of Methods and Their Application” and “Deliverable 4.2: Development of an Urban Material Flow and Stock Database Structure”. Deliverable 4.1 demonstrated the findings and insights from a literature review on the different urban material flow and stock accounting methods, as well as an overview of other projects that deal with such methods. Deliverable 4.2 documented the development of a database structure that caters to the data used and generated by the accounting methods. Figure 1 depicts the relationship of Task 4.3 to the just mentioned and the remaining tasks in WP4.

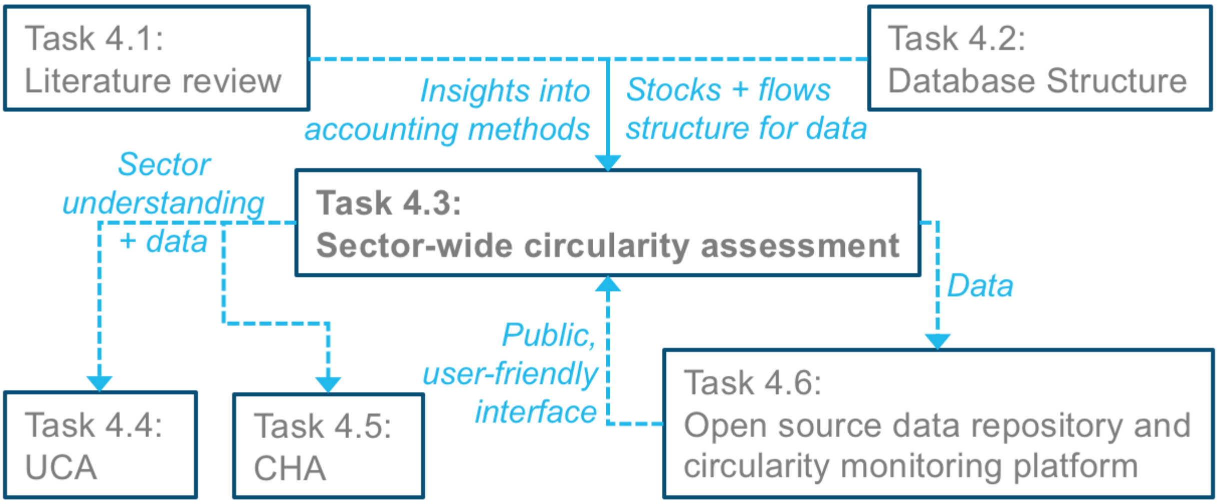


Figure 1: Relationship of tasks in WP4 and the information and/or function that they provide

This document is split up into two main parts. Part 1 is about the background and considerations of the SCA method development, whereas Part 2 is a Handbook that describes the SCA method in a step-by-step manner. **Part 1** first puts the SCA into the context of what is to follow, namely the urban circularity assessment (UCA) and the circularity hotspot analysis (CHA), before addressing some key components such as the definitions of circularity and circular economy. Thereafter, it describes how the actual material accounting method was determined and defined, including the understanding of sectors, and how the accounting method is linked to data and indicators. **Part 2** reiterates why a SCA is necessary and then lays out the SCA method in its single steps, involving system diagrams, data collection layers, data processing needs, data analysis and the expected end result. This handbook is seen as a preliminary document that will be finalised and complemented with online videos that will be produced as part of two online courses on data collection and data processing, concluding in June 2021.

Part 1: Sector-Wide Circularity Assessment – Method Development

Part 1 first describes the aim of the SCA method and puts it into the context of what is to follow, namely the urban circularity assessment (UCA) and the circularity hotspot analysis (CHA), before addressing the definitions of circularity and circular economy. Thereafter, it describes how the actual material accounting method was determined and defined, including the understanding of sectors, and how the accounting method is linked to data and indicators.

1. Aim of the SCA method

The **starting point for the SCA method development** was to take stock of existing accounting methods and take into account preoccupations from the demonstration cities in their path towards circularity. In reality, this resulted in translating the scientific rigor of current accounting methods into an user-friendly technique to kickstart the journey of cities into circular economy, both by monitoring their progress as well as building capacity for urban administrations and other relevant stakeholders.

Ultimately, the aim was to develop a method for **measuring circularity at a sector level by spatialising and disaggregating as much as possible the metabolic (or resource use and waste) flows and stocks, infrastructures and actors** to better understand how the demonstration actions are part of a broader system, what impact they have on it and how to upscale those within the same sector. In other words, the SCA was designed to mainly support the demonstration measures and show how they fit within their larger ecosystem of stakeholders and supply chains, instead of seeing them isolated, thus ignoring their impact. As a result, this can also help cities optimise their planning and demonstration activities through a detailed analysis of material flows, stakeholder involvement and valorisation options.

In developing the method and its embedded components and an attempt to explore the various pathways towards the aim, a number of fundamental questions emerged, which heavily conditioned the circularity assessment method:

- **What does circularity mean and what does that entail for material flows and stocks? How can it be measured?**
- **What is a sector?**
- **Which materials should be accounted for?**
  - Which material accounting method is suitable?
  - What are desirable features of accounting methods that best fit urban administrations' journey towards circularity?
- **What is the right balance between accurate and comprehensive datasets?**

- **What is the extent of the scope of analysis that is sensible and meaningful for CityLoops and its cities?**

Figure 2 visualises how the single components of the SCA are related, while the following chapters seek to answer these questions in the various chapters and uncover step by step how the method development came about and what was consolidated in the end.

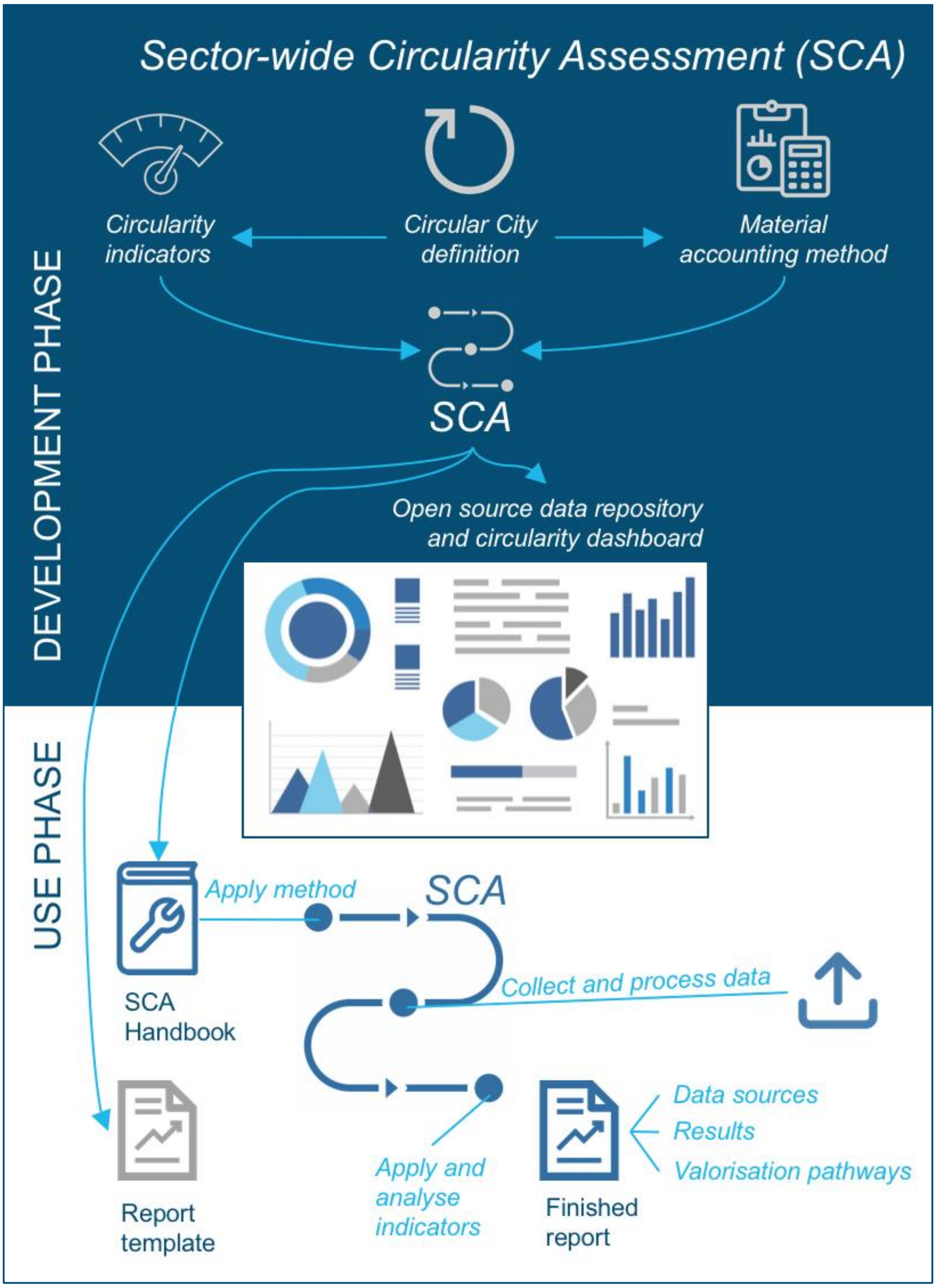


Figure 2: Components of the Sector-wide Circularity Assessment and their relationships

2. SCA in context of UCA and CHA

The SCA is not an analysis that stands on its own in the CityLoops project nor within WP4 which focuses on Circularity Assessment of Cities as a whole. In addition to the SCA, there will be the development of an Urban Circularity Assessment (UCA) and a Circularity Hotspot Analysis (CHA) method, later in the CityLoops project. The SCA, UCA and CHA are in fact connected and complementary analyses which help to further advance cities towards their circular economy journey until they can develop their own circularity roadmap. These steps have to be carried out in that very order, since the information output of one method will become input for the next analysis. That implies that these three types of analyses do and have to build on each other in a logical and complementary way, and are integrated with each other to make the overall approach coherent and easiest for the cities to work with.

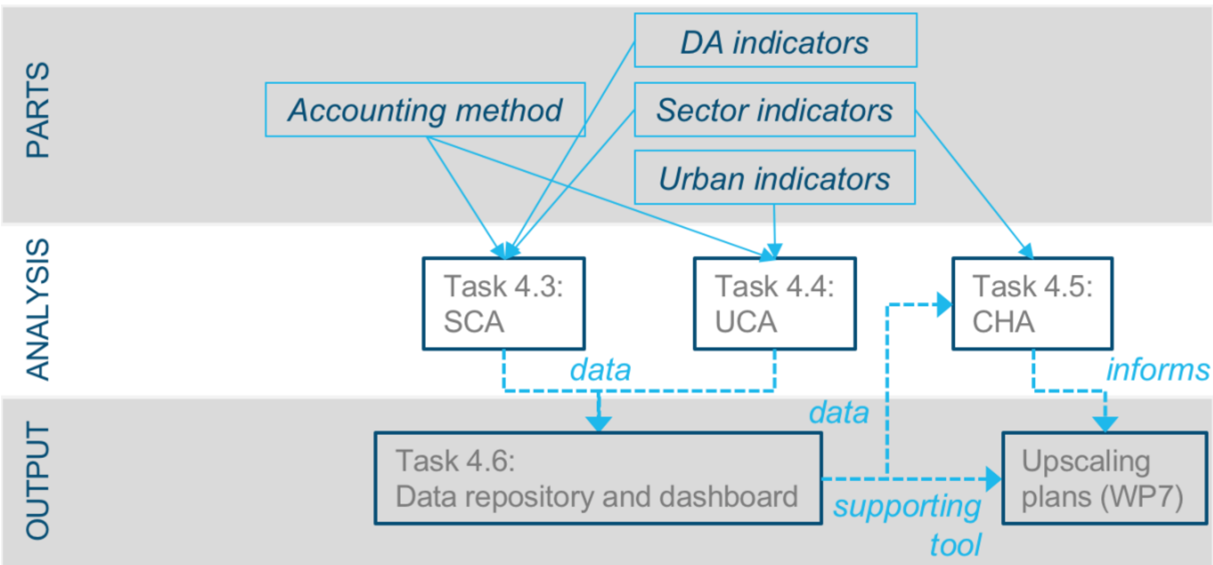


Figure 3: Relationship of Sector Circularity Assessment (SCA), Urban Circularity Assessment (UCA), Circular Hotspot Analysis (CHA) and other project components

In order to ensure a meaningful development of the SCA and a full integration of SCA, UCA and CHA, it is necessary to already look at the requirements and expected input and output of the UCA and CHA and to make sure that the SCA and UCA share the same understanding of the connecting components and deliver the respective data. In order to find out, the task descriptions of all three analyses from the proposal were unpacked, their parts explored and the components of Tasks 4.3 (SCA), 4.4 (UCA) and 4.5 (CHA) were linked with each other as well as to 4.6 (data repository and dashboard), see Figure 3:

- SCA
  - Quantifies metabolic flows and stocks of a sector, spatialises it and links it to economic activities and actors.

   - One purpose of this data is to link it to and inform indicators, which measure if a sector is circular and what the situation in the various dimensions is
- UCA
   - Quantifies metabolic flows and stocks of a city, spatialises it and links it to economic activities and actors.
   - One purpose of this data is to link it to and inform indicators, which measure if a city is circular and what the situation in the various dimensions is
- CHA
   - Utilises the SCA and/or UCA results to identify which sectors and what actions have the highest circularity potential.
   - Combines metabolic flows and stocks data with economic data and ranks sectors by order of priority.
   - The hotspot is not a physical location in a city or region, but an (economic activity of a) sector/industry/value chain or a specific material whose flow is significant, either in terms of size or economic importance, and very linear.

Studying all three assessments, it reveals that **sectors play a central role**, hence the importance of determining their definition (Chapter 3.2.2). In SCA, sectors are analysed on their own. For the UCA, it could be imagined that a city is made up of (all economic) sectors, and therefore, the SCA is scaled up to UCA by (adding up all) sectors. In fact, the reason that the SCA level exists at all, is because when the proposal was originally written, it became clear that the UCA was too wide to integrate the demonstration actions (DA) of the project, which are on an even smaller level than sectors, namely an action as part of an economic activity of the value chain. Therefore, the sector-wide level was created to place the DAs in a context, to better look at the impact of DAs in a sector and ideally identify pathways to upscale their circularity impact (Figure 4). The indicators developed in WP6 (and partially used in WP4) reflect that too, as they also exist at a DA, sector and city level (see Chapter “Indicators”). Since the DAs are embedded in the sector, it has to be asked how the sector can be scaled up, namely from specific economic sectors (construction and food/biomass) to the entire city to achieve a more systemic understanding as well as to provide a comparable circularity baseline for the entire city.

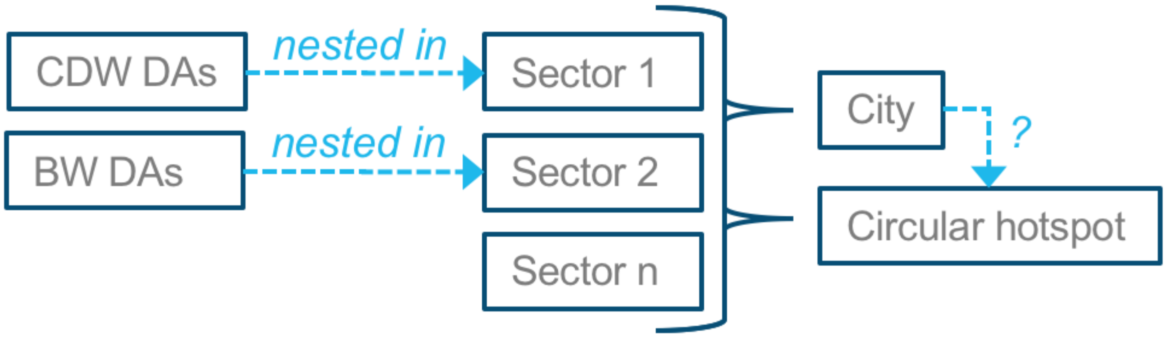


Figure 4: Relationship of Demonstration Actions (DA), sectors, city, and circular hotspots

Finally, CHA will be developed to identify how cities can use the insights from UCA in order to plan their future interventions by ranking the potential sectors to achieve a more circular economy and develop CE roadmaps for their cities. In turn, this could mean that in order to carry out a CHA, one has to analyse all sectors or at least a number of relevant ones to determine the hotspots. Alternatively, one could identify and rank the most critical materials of those sectors. The latter has been done by Westin et al. (2019) with an interesting method described for three Swedish cities, in which MFA and LCA are combined to create "hotspots", which are particular product groups that should be targeted due to having the highest environmental impact, measured by using multiple environmental impact categories. This method could provide some additional insights as it not only quantifies the material flows but also their associated environmental impacts (including global warming, acidification, etc.). While it is not a full LCA perspective (cradle to gate), it manages to link material flows quantities to environmental challenges as they are not proportional *per se*. There are also a number of places where uncertainty is introduced, and it seems best as a way to broadly understand the right place to start working on, rather than to get exact numbers of certain impacts.

At this stage, it is difficult to make any further observations or predictions about how these three pieces of analysis will be integrated, since two of them (UCA and CHA) are yet to be developed and the SCA has not yet been tested by cities. Therefore, it remains open if all sectors will have to be analysed and at which level of detail.

3. Measuring circularity

A fundamental pillar for developing this method was to properly define and contextualise what circular economy is, and especially at the urban level. In addition, as Task 4.3 focuses on the economic sectors within which the demonstration actions are carried out in WP2 and 3, a definition also needed to be downscaled and applied at a sector level.

This chapter will present several definitions, starting with those for circular economy and circular city, before attempting to define a (circular) sector. Thereafter, it will describe how those can be measured and evaluated with strategic objectives and indicators for circularity.

3.1. Circular Economy and Circular City definition in CityLoops

As is commonly known among circular economy experts, there is a plethora of existing definitions of "circular economy" and with them, associated values, pathways, and schools of thought. While a lot of effort was put within this WP and WP6 to develop a common circular economy definition this report will not go into detail of this situation and simply presents definitions for circular economy and a circular city, which have been agreed upon for CityLoops. The work was first presented by Vangelsten et al. (2020, 11) in "D6.1 Circular City Indicator Set", where more information can be found on arriving at those.

CIRCULAR ECONOMY DEFINITION
The Circular Economy is a regenerative system in which resource input, waste and emissions are minimised by slowing, closing, and narrowing material loops. This can be achieved by cooperative approaches, reuse, adaptation, resource stewardship, stock management, sharing, and other new business models that foster longevity, renewability, refurbishment, capacity sharing, dematerialisation and recycling and are induced by multi-stakeholder and multi-sectoral collaboration with the ultimate aim to increase resilience and maximize ecosystem functioning and human well-being.

CIRCULAR CITY DEFINITION

"A circular city is one in which

1. The local government, civil society, businesses, the research community and other local stakeholders collaborate to promote the transition from a linear to a circular economy. This means in practice:
2. fostering business models and economic behavioural patterns that maintain the value and utility of products, components, materials and nutrients for as long as sensible, in order to
3. close material loops and minimize as much as possible harmful resource use and waste generation locally, and thereby
4. improve human well-being, minimize net environmental impacts, protect and enhance biodiversity, and promote social inclusion, both within the city and globally, in line with the sustainable development goals."

Studying both definitions, it can be seen that the circular city definition is derived from the circular economy definition. To better highlight the circular city definition, Figure 5 visualises it and its four Vision Elements, illustrating how they are connected and all needed to enable a circular transition. For the SCA method, the focus lies on Vision Element 3 "Closing material loops and reducing harmful resource use" and supporting this objective through identifying and accounting the various materials, tracking their pathways, and revealing a status quo with the indicators.

The circular city definition in turn is the basis onto which the circularity indicators could be built and the material accounting method decided on. In addition, the definition of a circular sector can be derived from the here presented definitions as well.

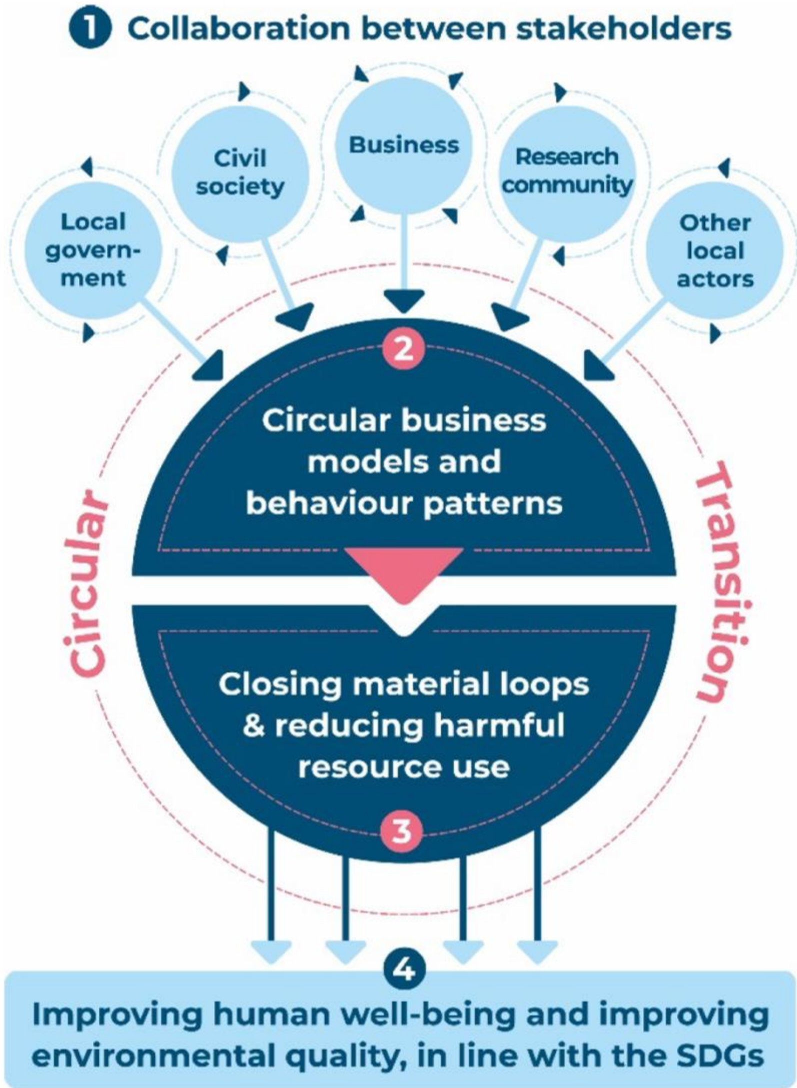


Figure 5: The four Vision Elements of the Circular City vision and causal links for CE transition (Vangelsten et al. 2020)

3.2. Definition of circular sector (?)

Following the definition of a circular economy and circular city above (Chapter 3.1), this section will focus on defining what a "circular sector" is. Originally, a *sector*-wide circularity assessment was meant to be developed. Therefore, it was deemed crucial to establish the definition of "sector" in order to define and understand the meaning and implications of "sector" and "sector-wide" in regards to circularity.

The following paragraphs will illustrate how sectors (and subsequently industry) are defined in the CityLoops project and how this definition came about. The chapter will first present the research on definitions of sectors and their classifications which was carried out, before settling on one and defining the construction and biomass sectors. It will then discuss, if those sectors could be made circular, what this even entails and how sector-specific circularity is. This chapter will then reveal the implications of strict wording of the sector definition.

3.2.1. Existing definitions and classifications of sector

In order to establish an understanding around the sector definition, three activities were carried out:

1. Research of various definitions of sector and related terms
2. Review of existing sector and economic activity groupings
3. Application of definitions on examples

(1) Research of various definitions of sector and related terms

Looking up definitions from different sources quickly brought to light that there is a lack of universal understanding of the term sector and also made apparent the need to determine definitions of economic activities, industry, supply chain, value chain, and life cycle, because they have to do with how sectors can relate to each other. These additional terms were then looked up and into as well and definitions, preferably from official (EU) sources, such as Eurostat's Concepts and Definitions Database, were collected.

The evaluation revealed the linkages and dependencies between the different activities of a sector and between different sectors and that the term sector and industry are often used interchangeably, even within the same article describing a sector.

(2) Review of existing sector classifications and groupings

The use of the classification of sectors is to divide up an entire economy and a number of such classifications already exist but each focus on different features/facets of the economy. The approaches for both sectors and industry groupings that were identified, were listed below and the coherence behind them were briefly evaluated and presented, anticipating that these would hopefully guide us to find a suitable definition of sectors for measuring circularity.

The following classifications of sectors were found:

- By **economic activity:** primary sector, secondary sector, tertiary sector
- By **product**: For example construction industry, food industry, car industry. It is a way of grouping industry activities based on similar production processes, similar products that they generate, or even similar behaviour in financial markets.
- By **ownership**: Private sector, public sector, business sector, voluntary sector
- By **social groupings**: For example "social economy sector", "tourism sector", "high-rise residential sector"
- By **similar behaviour:** "The main institutional sectors covered are Non-financial corporations, Financial corporations, General government, Households, Non-profit institutions serving households" (Eurostat 2020a) (see also European System of Accounts)

It was determined that a classification by economic activity was most suitable for the SCA, as those activities inherently relate to materials and stakeholders carrying them out, two essential components for the method.

The **sector classification by economic activity** results in the classical structure of the three-sector model of primary (raw materials), secondary (manufacturing), and tertiary sectors (services), which in themselves have a number of typical sectors. It shows that this kind of grouping can take place on a very aggregated level. This well-known high-level breakdown of economic activities sometimes has two new categories, the quaternary and quinary sectors added.

The classification goes beyond these high levels of primary, secondary, tertiary etc. sector and further into detail on economic activities groups. Three classifications systems exist that produce a standard for these groupings and they each describe the single economic activities in more detail, by giving them an exact name and description. These classification systems are the International Standard Industrial Classification of All Economic Activities (ISIC), Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical Classification of Economic Activities in the European Community) (NACE) and Eora26. All three identified industry or sector classifications are linked with each other, since Eora26 is based on ISIC Revision 3, which evolved into ISIC Rev. 4 (world) onto which NACE Rev. 2 (Eurostat 2008) (Europe) is built.

Table 1: Sector classification by economic activity and respective NACE section codes

Primary sector (raw materials)	Secondary sector (finished goods)	Tertiary sector (service industry)	Quaternary sector (intellectual activities)	Quinary sector (human services)
Agriculture, forestry, and fishing (A) Mining and quarrying (B)	Manufacturing (C) Electricity, gas, steam and air conditioning supply (D) Water supply; sewerage, waste management and remediation activities (E) Construction (F)	Wholesale and retail trade; repair of motor vehicles and motorcycles (G) Transportation and storage (H) Accommodation and food service activities (I) Information and communication (J) Financial and insurance activities (K) Real estate activities (L) *Administrative and support service activities (N)* *Arts, entertainment and recreation (R)* *Other service activities (S)* *Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use (T)*	*Professional, scientific and technical activities (M)* Public administration and defence; compulsory social security (O) Education (P) Activities of extraterritorial organisations and bodies (U)	Human health and social work activities (Q)

Since CityLoops deals with European cities and therefore also European data, it was decided to select the **NACE codes as representatives of economic activities and a classification of sectors and industries**. In this European context, organisations are classified in NACE codes and EU countries collect and report their data in those classifications as well, producing comparable statistics. Another potential benefit is that NACE codes are also more detailed than ISIC at lower levels.

Table 1 illustrates which activities around materials or services can generally be found in these large classifications and which top-level NACE sections (indicated with a capital letter) can be sorted under them. The first three sectors logically build on each other, much like a supply chain or life cycle of a product, whereas the remaining too can be seen as "supporting sectors" to complement activities that are needed to make up the value chain.

To illustrate the level of detail of an economic activity in this sector classification, Table 2 provides an example of a NACE code. With its various levels of section, division, group, and class, the example shows the plethora of data that can exist with up to 615 NACE codes on the classes level, represented by their four-digit numerical codes (01.11 to 99.00).

Table 2: Example for general structure of a code, using NACE code 23.61 "concrete manufacture" (Eurostat 2008, 152)

Level	Code	Description
Section	C	Manufacturing
Division	23	Manufacture of other non-metallic mineral products
Group	23.6	Manufacture of articles of concrete, cement and plaster
Class	23.61	Manufacture of concrete products for construction purposes
		This item includes: ▪ manufacture of precast concrete, cement or artificial stone articles for use in construction: – tiles, flagstones, bricks, boards, sheets, panels, pipes, posts etc. ▪ manufacture of prefabricated structural components for building or civil engineering of cement, concrete or artificial stone

(3) Application on examples

As a third step in trying to find a suitable definition of sector and an overall fitting of the other terms, some definitions were taken, applied to examples and drawn out as value chains. This attempt of operationalising definitions uncovered if the terms could be coherent with each other or if the understandings clashed.

It also helped to establish a technical link between economic activities, flow diagrams and sectors as they are meant to be embedded on the Data Hub and to determine if the logic holds there as well.

The application of examples led to the understanding that sectors have a vertical connection and industries, following a supply chain, a horizontal one (Figure 6).

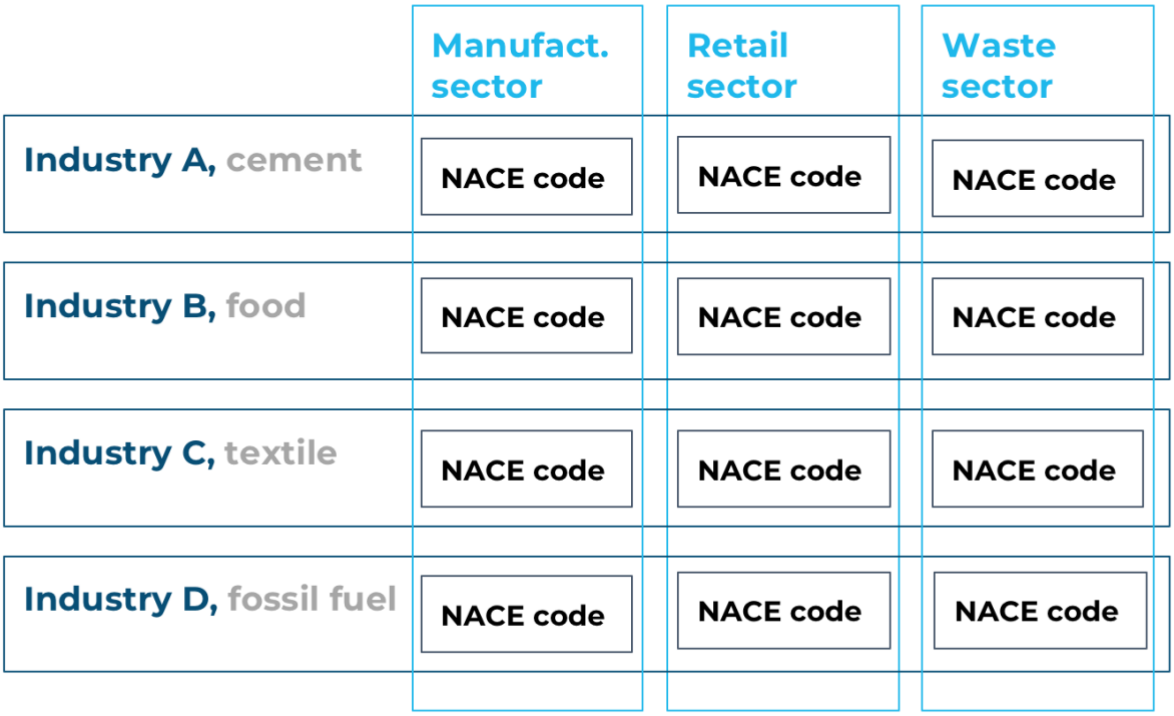


Figure 6: Scheme of example sectors, industries and the connecting economic activities (as NACE codes)

3.2.2. Definition of sector(-wide) in CityLoops

Based on the research of existing definitions, the most fitting one for the SCA was agreed on. A sector is defined as a **“general term used to describe a group of establishments engaged in similar kinds of economic activity”** (International Monetary Fund 2010). This definition makes clear that the economic activity is what the grouping revolves around or in other words, the sector grouping is economic-activity based. Therefore, it enables taking advantage of the European NACE codes that exist for and detail each economic activity (see chapter on “Existing definitions and classifications of sector”).

Building on this understanding, it needed to be determined what “sector-wide” consequently means. In principle, going by the proper wording, it means to stay within the same kind of activity, for example retail (NACE Section G). **However, from the CityLoops project description and goal, it was clear that by sector-wide, really industry-wide or supply-chain-wide should be pursued.** In turn, this could be translated into:

- **Entire supply chain (down- and upstream), or in other terms cradle-to-grave (or other such boundaries)**
- **<u>All</u> materials in the sector, including auxiliary ones (e.g. water, energy)**
- **<u>All</u> related economic activities (side-stream) for one product**
- **<u>All</u> actors from the supply chain**

Although all these features are desirable, to be very thorough and exhaustive, satisfying all these options would clearly lead to an insurmountable data collection exercise or to using a too complex approach for urban administrations (such as Multi-Regional Input-Output Analysis). When weighing the implications for the cities, it became necessary to **decide between comprehensive or accurate results**, which sit on the opposite sides of the spectrum. For example, to be accurate one could pick one specific material (e.g. concrete) and its waste and study it for a number of economic activities and not the entire supply chain (e.g. only manufacturing and use). To be comprehensive, one could look at several materials in a part of the supply chain (i.e. all food flows), by only looking at all associated different sectors (e.g. from harvesting to manufacturing, to retail, use and waste collection/treatment), but in less detail.

The results gained from an accurate analysis would neither be very meaningful to the cities, as they will not cover a broad enough challenge, nor inform their baseline evaluation and at the same time this work can become highly time consuming. In addition, by picking an accurate approach, cities might omit to look at some parts of the system which might have a significant impact in terms of flows/value added, etc. In short, cities could lose focus on the strategic priorities to follow for advancing their circularity journey, as they might not know what they do not know and therefore act "blindly" towards an unquantified goal. For this reason, it was **decided to promote and pursue a comprehensive approach which will look at the challenges and flows holistically**. As such, even if the quantification of flows and stocks might not be the most accurate possible, at least it will cover all of the parts of the system and will provide a first full overview with reliable order of magnitude for the flows and stocks which can eventually become incrementally more accurate, depending on the needs and priorities of each city.

In the case of CityLoops, to keep the comprehensive approach, it was decided to **select a few main material streams that are representative for the sectors**. The choice of the mentioned flows was strategically done, by using two criteria:

1. Aligned with demonstration actions materials
2. Cover majority of the sector's mass

Criteria 1 was straightforward to assess for, by looking at the materials of the demonstration actions of the CityLoops project and ensuring that these are included. Ultimately, this also helped to create a link between DAs and sector circularity assessment, while also taking advantage of the data that will be collected there on that "smaller than sector" level. Criteria 2 was used, as in reality the materials present in both sectors follow the Pareto principle (also known as 80/20 rule) or in other words, a small number of flows are responsible for the greatest share (in mass terms) of the total (sectoral) material flows. To measure this, the domestic material consumption (DMC) of EU-28 was looked at, for the highest level of material flows disaggregation for the years 2016 to 2018 (Eurostat 2020b). In the case of the biomass sector, the addition of the DMC for the twelve selected materials accounted for more than 65% of the total biomass DMC. Some additional materials can be added to get to 80% (e.g. roots, oil-bearing crops, sugar crops), however these additional materials will be further explored with cities to consider context-specificity. For the construction sector, sand and gravel already constitute more than 65% on their own. For the additional materials included in the construction sector in Figure 7, it is difficult to estimate the added percentage in the total mass of materials, as they are either transformed materials (and these are not represented in the EW-MFA dataset) or the materials are not unique to the construction sector (for instance, iron can be used to make steel for very different applications). Therefore, the additional materials were selected by looking at material stock analysis case studies (Stephan and Athanassiadis 2017).

Table 3: CityLoops cities and their selection of focus on the construction and/or biomass sector

City (Country)	Apeldoorn (Netherlands)	Mikkeli (Finland)	Seville (Spain)	Porto (Portugal)	Bodø (Norway)	Roskilde (Denmark)	Høje-Taastrup (Denmark)
Focus on construction	yes	yes	yes	no	yes	yes	yes
Focus on biomass	yes	yes	yes	yes	no	no	no

In terms of sector or sector-wide circularity, it was concluded that for investigating it, the circularity of the different material streams will be the ones considered and added up to represent the sector itself. With all cities including the same material scope, assessing the same materials will widen their scope of analysis and potentially enable comparability with their fellow demonstrator cities. To indicate cities that can possibly be compared, Table 3 shows the sectors that the cities are related to through their DAs and carry out the SCA for. It can be seen that all cities except for Porto will study the construction sector and that four out of the seven cities will assess the biomass sector.

Construction sector

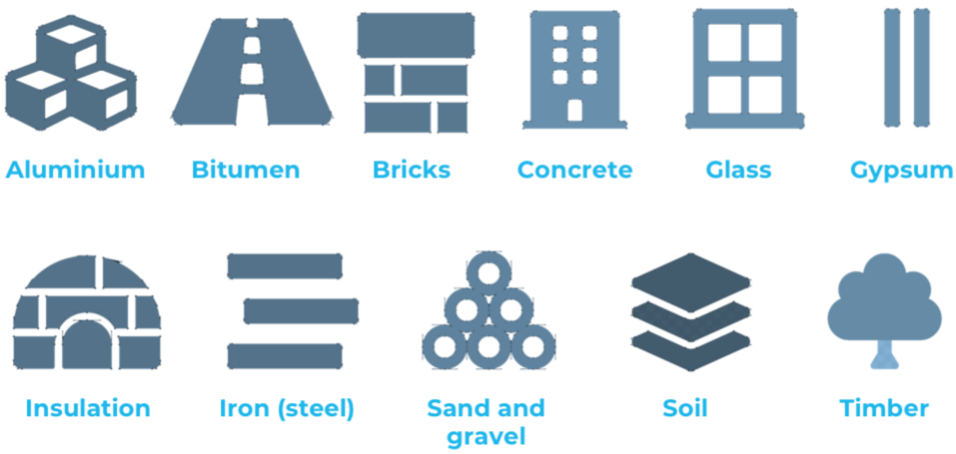


Figure 7: The eleven materials of the construction sector

In order to accommodate the supply chain thinking, it was decided to represent the construction sector by selecting and studying the most representative materials and/or products. In CityLoops, the construction sector is represented by eleven selected materials, as illustrated in Figure 7.

Table 4: Materials of the construction sector with those from the demonstration actions marked in bold

MF1. Biomass	MF2. Metal ores		MF3. Non-Metallic Minerals						MF4. Fossil energy materials/carriers	
wood/ timber	steel	aluminium	**concrete**	sand and gravel	**soil**	bricks	glass	plasterboard / gypsum	**bitumen/ asphalt**	insulation (plastics based)

Table 4 shows how those materials are classified into the four main material groups of the economy-wide MFA, MF1 biomass, MF2 metal ores, MF3 non-metallic minerals, and MF4 fossil fuel carriers. It can be seen that MF3 is most strongly represented with six out of the eleven materials.

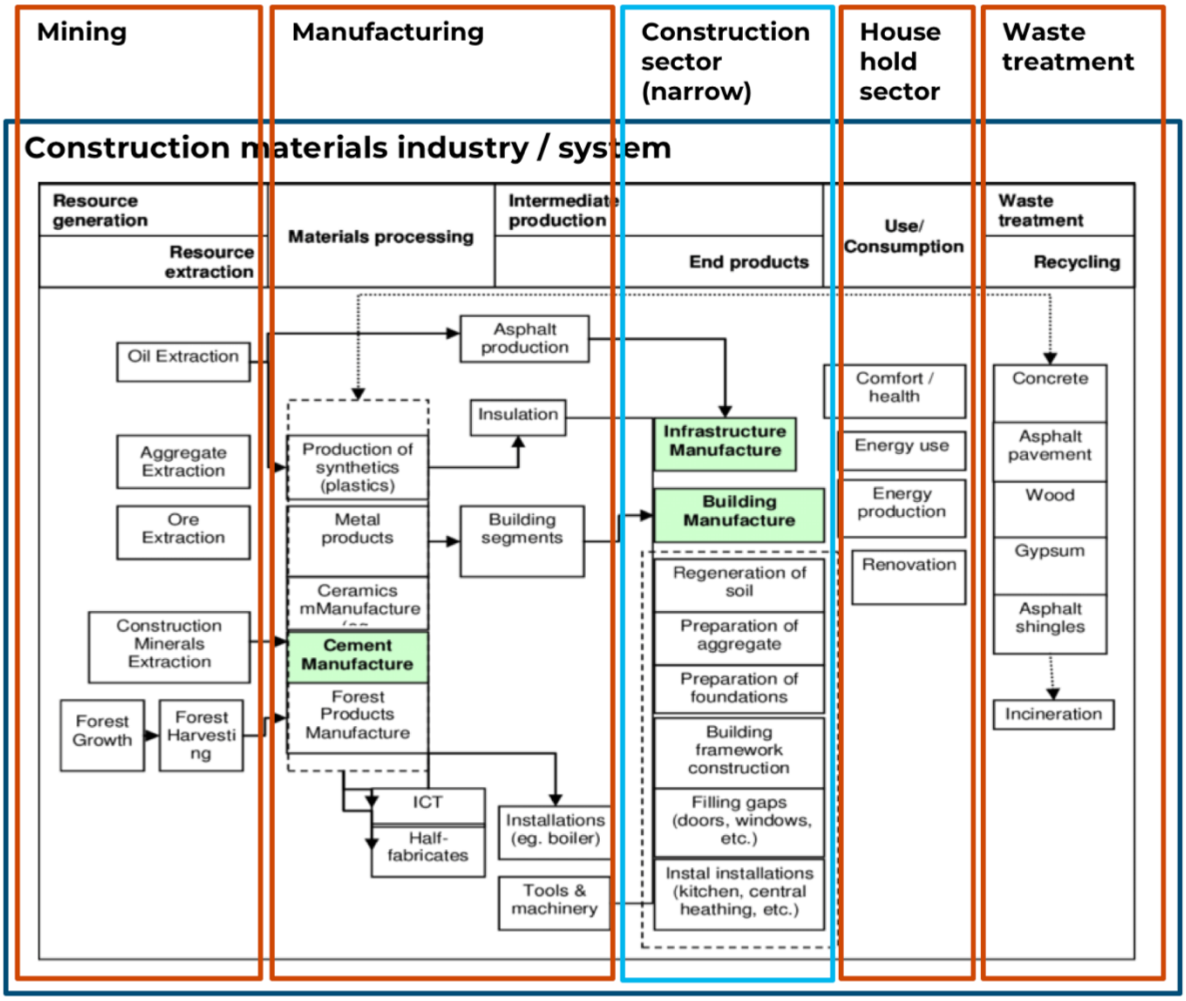


Figure 8: Construction sector and industry (adapted Figure 2-6 from Montalvo, Diaz Lopez, and Brandes 2011)

To give some insight what this sector understanding means for the construction industry, here the definition of construction: "Economic activity directed to the creation, renovation, repair or extension of fixed assets in the form of buildings, land improvements of an engineering nature and other such engineering constructions as roads, bridges, dams" (United Nations 1997). This definition picks up the respective economic activities and shows that it is important to also consider infrastructures in construction.

In Europe, the European construction sector observatory (ECSO) defines the construction sector in narrow and broad terms, using NACE codes. According to the ECSO, the NACE Rev. 2 codes that make up the narrow construction sector are F41, F42, F43.1, F43.2, F43.3, F43.9. It can be seen that these are all the codes from F- construction. For the definition of the broad sector, ECSO takes the narrow sector and adds manufacturing activities (NACE C16.2, C23.3, C23.5, C23.6, C23,7, C25.1), real estate activities (NACE L68.1, L68.2, L68.3) and architectural and engineering services (NACE M71.1).

Considering these definitions, two observations can be made. (1) This definition neither covers the beginning of the supply chain, as for example the quarrying of sand is missing, nor the end, as waste management is missing. When questioning ECSO about this, it was stated that a compromise always needs to be made and that their definition focuses on principal parts of the sector. Furthermore, they are aware that the NACE system is neither perfect, nor detailed enough, especially when it is required to summarise some data and data beyond the sector is included, but they aim to improve this in the future (Horvath 2020). (2) So far, services, like architectural services have not been touched upon. Since these do not involve materials directly, these economic activities are less interesting from a material accounting perspective. There is acute awareness that design hugely influences the types and amounts of materials consumed and therefore it cannot be disregarded when striving for solutions.

Combining this information with the sector and industry understanding presented above, Figure 8 shows what the construction industry parts look like in a flow diagram. There is ECSO's narrow construction sector definition and the other parts belonging to the rest of the industry.

Biomass sector

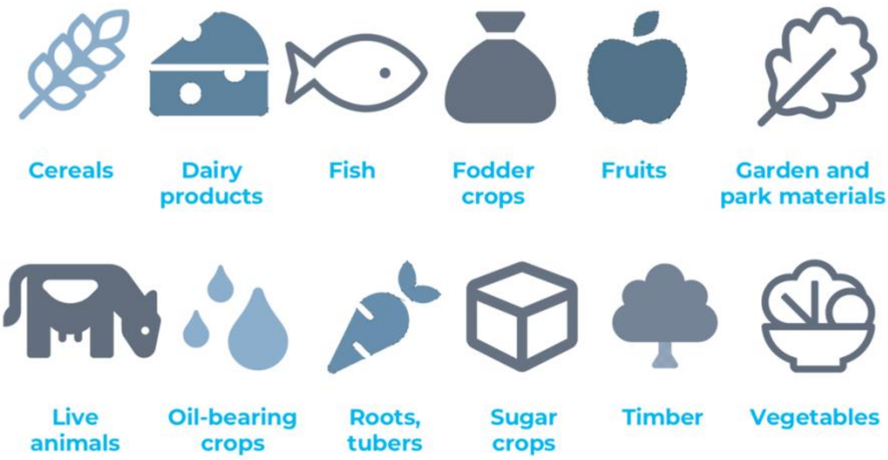


Figure 9: The twelve material categories of the biomass sector

The biomass sector is represented by twelve selected materials, as depicted in Figure 9. It shows that six of them are related to food for human or other animal consumption and the other two (horticulture and timber) to biomass in general.

3.2.3. Implications of sector definition: what is assessed for circularity

In order to conclude this chapter on the circular sector, having established that various definitions of sectors exist and defined how it should be understood in CityLoops, this topic needs to be brought full circle by considering the reason for starting it, namely to determine what exactly the object of study for circularity is: the sector. It is necessary, because the sector definition has some implications on the economic activities studied, materials accounted for, terminology in the project used, and possibly as a way to represent a city.

To briefly recap the previous subchapters, it has been shown that a sector revolves around the alikeness of economic activities, expressed in NACE codes, such as retail of ketchup, retail of cement, retail of textiles, which is all still retail. An industry, however, is product-based, e.g. the ketchup industry or more broadly, the food industry, textile industry and so on, capturing supply chain thinking. Figure 10 illustrates that understanding, by showing how a single sector spans various industries and different products, while an industry revolves around a single product, spanning the various sectors over the life cycle.

	Manufact. sector	Retail sector	Waste sector
Industry A, cement	NACE code	NACE code	NACE code
Industry B, food	NACE code	NACE code	NACE code
Industry C, textile	NACE code	NACE code	NACE code
Industry D, fossil fuel	NACE code	NACE code	NACE code

Figure 10: Scheme of exemplary sectors, industries and the connecting economic activities (as NACE codes)

Looking at a sector with this presented understanding, it can be seen that there is no such thing as an “bio-waste sector” or a “CDW sector”. This terminology should be redefined if one wants to be precise.

Another insight that it brings, is that making a sector circular does not make that much sense and might actually be impossible (Figure 11). It is not really feasible to close loops between the same activities of the same sector, e.g. that of retail and between different industries, as for example between food and textiles. Staying with the shown example of food and textile, it can certainly be argued that there are innovative ideas such as vegan leather from fruit waste, but that is not going to solve the closing of the main share of flows. More importantly, this innovation would not stay within the retail sector since there are whole production processes involved and it requires a number of other sectors, not just retail of fruit waste and leather, to employ this solution. Consequently, it was suggested to include other sectors along the value chain of an industry and explore whether making an industry circular is possible and whether it would better capture the challenges of circularity that are sought to be achieved in CityLoops.

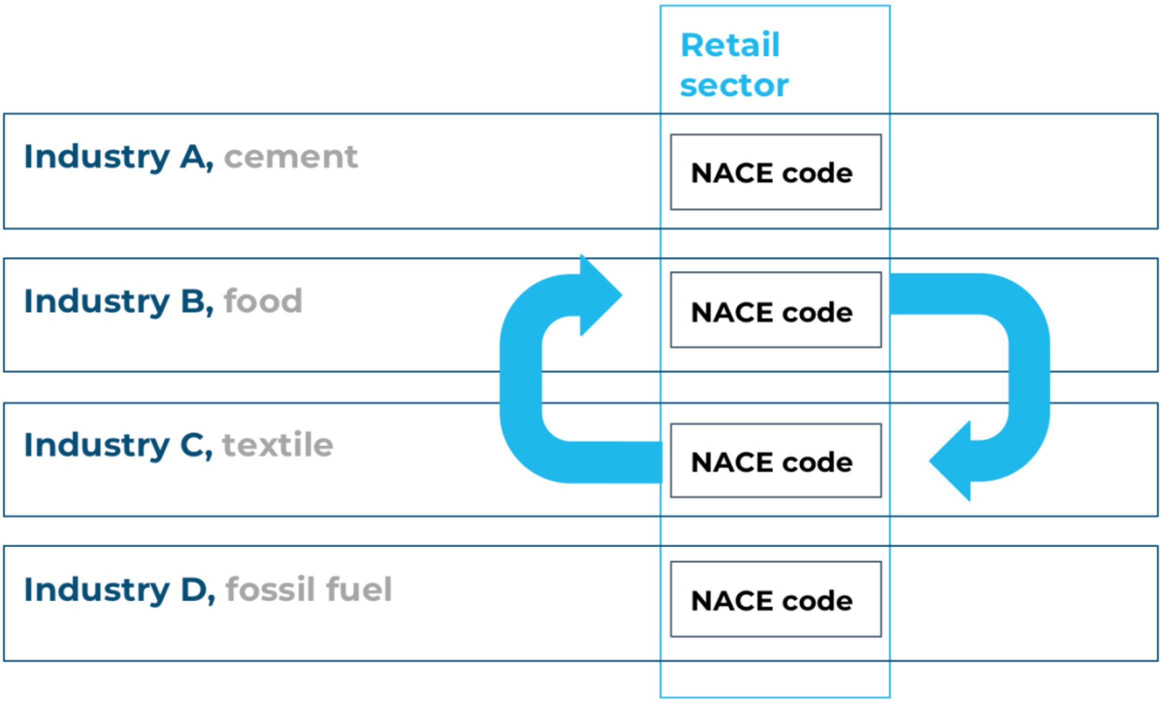


Figure 11: Making a single sector circular?

Figure 12 depicts what making an industry circular could look like. It shows that resource flows from certain economic activities of a sector could be closed with those of another sector. It seems as if a circular industry is possible. However, if it is reduced to the industry of a single product, it does not necessarily seem desirable, because it is too limited in the options and opportunities that it brings to close material loops. For example, food waste could certainly be used as feedstock and be fed to animals, however, some food waste can bring more value and can be upcycled in the biochemical industry. Closing the loop there would not be an option if the food industry was made circular in its strictest sense, where the materials circulate in its original industry, as opposed to also others. As a result of these considerations, it was realised that the **material itself is the connecting element of industry and sector** and the **key element for which circularity really matters**. Therefore, it is **ultimately a "Material (flow) Circularity Assessment"**.

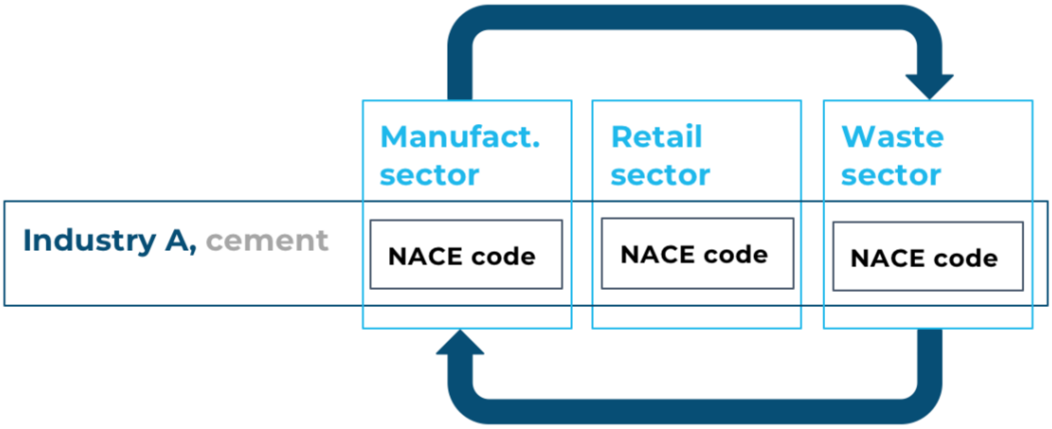


Figure 12: Making a single industry circular

Finally, this implies that instead of sector-wide or industry-wide circularity, the current method would focus on material circularity, since the closing of the loop of a material is desirable and should be aimed for regardless of a leaving or crossing of sectors and industries, as long as this circularity facilitates a systemical reduction of net environmental impacts of cities and territories in a socially just manner and context-specific way. (These here explained circularity considerations were presented to the CityLoops consortium, which received it with an agreement and shared understanding of this situation.) Figure 13 illustrates what this could look like if these flows moved "optimally" in the system.

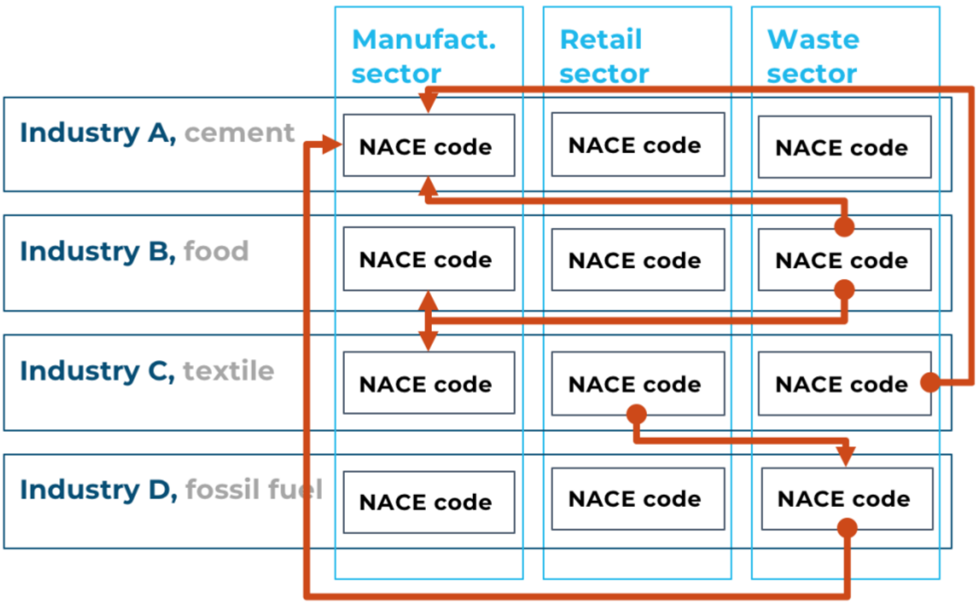


Figure 13: Making materials circular

To summarise, a **sector is**

- **neither circular** in its strictest sense, when the materials circulate in its original sector, as opposed to also others,
  - For example, when the material can only flow within the retail sector to be sold in other industries, but cannot flow to the manufacturing sector to be remanufactured.
- **nor** when all its (produced) flows are subjected to loops, regardless of which loops and which (other) sectors, and as long as the materials are not incinerated or landfilled.
  - For example, when all construction wastes are reused, remanufactured and recycled, but the overall consumption of virgin materials still increases, continuously causing harmful social and environmental impacts.

A sector is circular when it advances in all four Vision Elements (Figure 5). This way of circular sector understanding is necessary to adhere to and be in line with the logic of a circular city, which is made up of all four VEs. However, operationally, when aiming to extend and relate this thinking to the strategic objectives, this may not be as feasible, as some of the 44 SOs do not apply to a sector. Therefore, **measuring sector circularity relates to VE3**, while acknowledging that actions in VE1 and 2 are relevant for enabling the closing of the material flows, as it is dependent on the stakeholders and business activities pursuing the goals of the circular city. And since VE4 benefits from the collaboration of stakeholders, the circular business models & behaviour patterns and closed loops and reduced resource use, by improved human well-being and environmental quality, it shows that the VE1, 2, and 4 are indirectly included and contribute to a circular sector too.

Finally, the **SCA seeks to create an understanding of an urban sector, its economic significance, material flows and stocks, related infrastructure, and stakeholders to capture, assess and present its situation around closed material loops and harmful resource use**. By focusing on the material flows, it therefore only covers the strategic objectives of Vision Element 3 (while other WPs cover the evaluation of vision Elements 1, 2, and 4.).

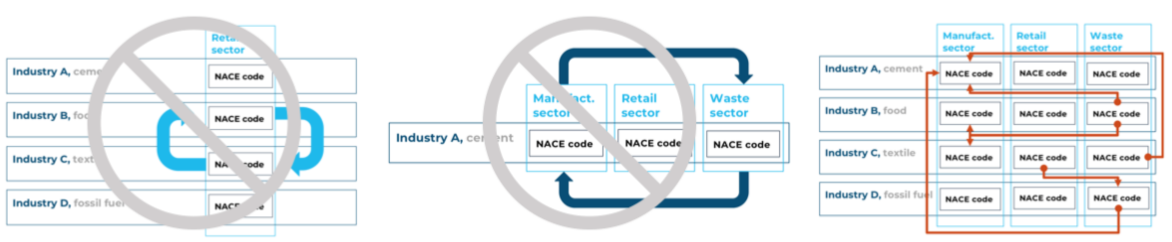


Figure 14: Neither sector, nor industry circular, but circularity of material flows between different economic activities

3.3. Strategic objectives and indicators

After having defined circular economy, circular city (Chapter 3.1), and circular sector (Chapter 3.2), the essential element towards evaluating and measuring circularity was to translate these definitions to strategic objectives (SO) and ultimately indicators. Therefore, both SOs and indicators were developed, which could be applied on top of the metabolic flow and stock accounting to inform about the demonstration actions', sectors', and cities' status and progress towards circularity. This chapter will first present the strategic objectives, before discussing the corresponding indicators and respective data needs in more detail.

3.3.1. Strategic Objectives

The work on the showcased strategic objectives briefly recaps some of the original work of WP6 and D6.1 "Circular City Indicator Set", in order to better ground the method presented in this deliverable. The strategic objectives are themselves nested in four vision elements, which are illustrated in Figure 5. For the SCA method, Vision Element 3 "Closing material loops and reducing harmful resource use" is most relevant, since it is the one directly related to material flows and stocks. Within that Vision Element, a total of seven strategic objectives were defined, as illustrated in Figure 15.

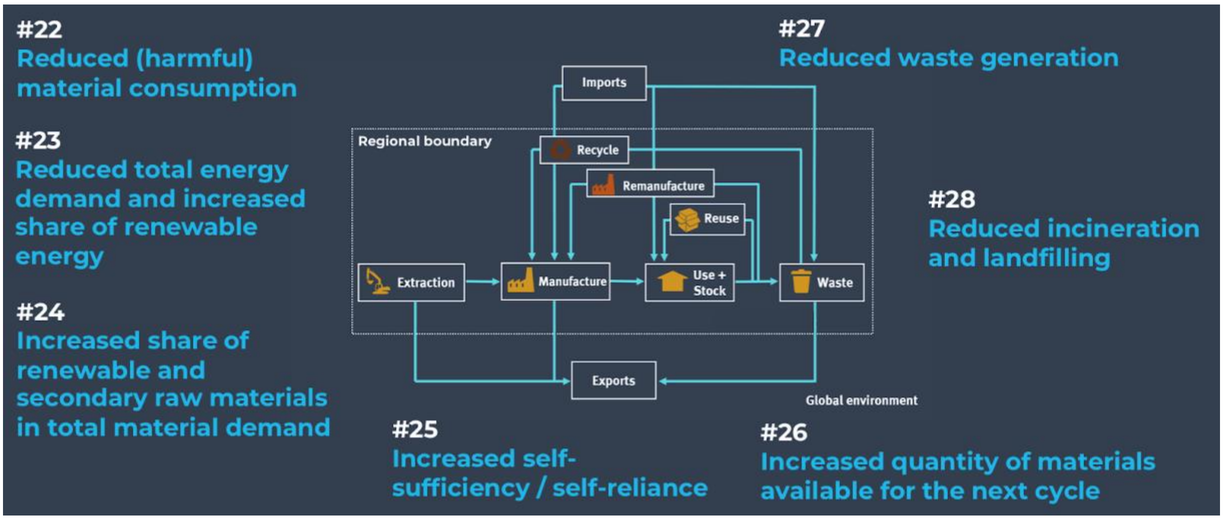


Figure 15: Seven strategic objectives of vision element 3 mapped along the value chain

These seven SOs were mapped along the value chain to graphically represent how the chain was covered and to understand whether the SOs were complementary to each other. Each of the SOs were then defined in Table 5 and connected to relevant Sustainable Development Goal(s) (SDG). The SOs were also grouped into three "strategic objective groups", (1) material / energy flow, (2) re-use and recycling, and (3) waste generation / management (Table 5). From the figure and the table, it becomes clear that the SOs revolve around materials at their core, and attempt to unpack their essential properties, namely their origin, level of hazardousness, state of raw or recycled material, pathways for application and treatment, quantities at the end of life, etc. This reveals the complexity of the system and makes evident that it is hardly possible to have one single value, score or indicator represent the overall status of a system, but that instead several are needed in conjunction in order to monitor progress towards circularity.

Table 5: Strategic objective (SO) group, SO name and definition and Sustainable Development Goals (SDG) reference of Vision Element 3 (Vangelsten et al. 2020, 20)

Strategic objective group	#	Strategic objective	Definition	SDG reference
Material / energy flow	22	Reduce harmful raw material consumption	A state in the local material economy of reduced material consumption (i.e. grouped into non-metallic minerals, metals, fossil energy carriers and biomass) by **refusing** product or material use (abandoning its function, making it redundant or deploying a radically different solution) through reducing overall consumption, consumption of raw materials, and consumption of overexploited or hazardous materials.	12
	23	Reduce overall energy demand and increased share of renewable energy	A state in the local physical economy, in which the consumption of (local) renewable energy is increased and overall (also embodied) consumption of fossil fuels is reduced in absolute terms.	7,13
Re-use and recycling	24	Increase share of renewable and secondary raw materials in overall material demand	A state in the local material economy of an increased share of secondary materials in overall raw materials demand and an increased share of renewable raw materials in overall materials demand.	12
	25	Increase self-sufficiency / self-reliance	Self-sufficiency will be increased by decreasing the imports of virgin raw materials, using locally available materials, such as reusing secondary raw materials that were locally treated (including urban mining) and decreasing the export of waste materials, instead treating it locally. This will also bring about a state in the local material economy where retention of nutrients (e.g. phosphorus in wastewater) is captured and retained, bringing about an economic benefit, and counteracting resource scarcity.	12
	26	Increase quantity of materials available for the next cycle	The increase of material amounts for the next cycle of use by following the 2018 EU waste hierarchy with the preference starting from the top, namely through **preserving** materials and products (extending lifetimes), **reusing** products or materials (i.e. use of the same product and function by another user), **repairing** products (as to maintain its original function), **repurposing** products (using products or their components in a new product with different function), through **refurbishing** or **remanufacturing**, and **recycling** of products or materials (obtaining higher or lower grade recycled materials for the same function or for inferior products (backfilling)).	12

Waste generation / management	27	Reduce waste generation	Reduced waste generation, assessed according to different waste fractions, including biodegradable materials (e.g. zero avoidable food waste).	12
	28	Reduce incineration and landfilling activities and amounts subjected	Reduced amounts of (waste) materials, assessed according to different waste fractions, including biodegradable materials, subjected to final destinations such as incineration and landfilling.	12

Table 6: Relevance of Strategic Objectives to Construction and Biomass sectors

SO#	Strategic Objective	Construction sector	Biomass sector
22	Reduce harmful raw material consumption	Relevant	
23	Reduce overall energy demand and increased share of renewable energy	Difficult to assess on the sector level in general. To illustrate with the example of energy demand, it is not purely the energy demand at one stage and one type of actor, such as the energy demand of households, but would pertain to all energy related to economic activities, processes and transport in each stage of the value chain. This is very specific data that is difficult to obtain at sector level and will multiply the data collection efforts.	
24	Increase share of renewable and secondary raw materials in overall material demand	Relevant	Partly relevant for secondary raw materials. Due to the nature of organic materials, it is not possible to increase the share of renewable materials, since they are by default renewable. There are secondary organic materials, those that have been recycled which an increase is relevant for, e.g. using food waste for feedstock instead of grain or soy.
25	Increase self-sufficiency / self-reliance	Relevant	
26	Increase quantity of materials available for the next cycle	Relevant	Not as applicable due to the nature of organic materials and their limited lifetime. More materials for the next cycle means that too much was produced, which for most biomass materials means that they will have gone bad and prevents their intended use, namely consumption.
27	Reduce waste generation	Relevant	
28	Reduce incineration and landfilling activities and amounts subjected	Relevant	

In order to assess whether the general strategic objectives defined at a city level are sensible for the construction and biomass sectors, the relevance for them was checked separately. Table 6 shows the results of this assessment, revealing that four of the seven objectives are relevant for both and six of the seven relevant for the construction sector. SO 23, which although relevant at a city level, will not be determined for the sector. As for the biomass sector, only a part of SO 24 is applicable, whereas SO 26 is not at all.

3.3.2. Indicators

Aside from attempting to represent the material system through their strategic objectives towards a circular city, it was necessary to go a step further and define indicators that could make a statement regarding the status of those objectives. In trying to select indicators, there were some fixed starting points that were used as starting points:

- There is a need for two sets of indicators, one for each sector.
- There are 7 SOs and their relevance was checked for both sectors (Table 6).
- There are 11 materials for the construction sector and 8 materials for the biomass sector that will need to be reflected.
- At a minimum, there is EU data and therefore there can also be certain indicators. That means that even if the cities do not have data, they will still be able to calculate the indicators because there is some EU data.

While there is a very large number of indicators that could be selected from this starting point, the number of indicators needed to be limited to a manageable amount so as not to overwhelm the cities with the workload of collecting respective data and evaluation of indicators. Still, the situation may occur in which a city’s priorities conflict with the completeness of the objectives and the indicators needed to address those. In order to resolve this, two paths should be pursued:

1. **Facilitate calculations and assessments for the cities:** Metabolism of Cities sought to link the indicators to the data collection on the CityLoops Data Hub, by showing how indicators can be satisfied with what kind of data, and aims to provide a semi-automatic option to calculate the indicators on the platform.
2. **Promote CE thinking and understanding of cities:** Although the cities are already aware of CE principles and are already implementing actions on the ground, a lot can be gained by reiterating the complexity of the topic and the importance of systems thinking to persuade them that a certain number of indicators is needed to maintain completeness of the topic.

Based on this understanding, it was found that for the SCA method there should be a mandatory minimum amount of indicators to be able to arrive at an informed assessment of circularity, at least with regards to Vision Element 3. Therefore, there is at least one unique indicator per SO that is mandatory to assess, except for the SO on energy (SO23). Depending on the ambition of cities, they can choose additional indicators that they want to evaluate depending on their context specific needs.

Table 7 lists the indicators that were selected to support the strategic objectives for the construction sector and the biomass sector respectively. It can be seen that a total number of 8 mandatory and 16 additional indicators for the construction sector and a total number of 9 mandatory and 15 additional indicators for the biomass sector were identified.

Table 7: Construction and biomass sector indicators; with numbers for each sector indicating importance/relevance; 1 = core/mandatory, 2 = relevant/important, 3 = optional

<table>
<tr><th>#</th><th>Strategic Objective</th><th>Indicators supporting this Strategic Objective</th><th>Construction sector</th><th>Biomass sector</th></tr>
<tr><td rowspan="2">22</td><td rowspan="2">Reduce harmful raw material consumption</td><td>35:Domestic material consumption (DMC)</td><td colspan="2">1</td></tr>
<tr><td>35a: Domestic material consumption (DMC) of virgin materials</td><td colspan="2">3</td></tr>
<tr><td rowspan="3">23</td><td rowspan="3">Reduce overall energy demand and increased share of renewable energy</td><td>41:Total energy demand</td><td colspan="2">3</td></tr>
<tr><td>45:Share of renewable energy in total energy demand</td><td colspan="2">3</td></tr>
<tr><td>47:Local biomass for energy generation</td><td>-</td><td>3</td></tr>
<tr><td rowspan="3">24</td><td rowspan="3">Increase share of renewable and secondary raw materials in overall material demand</td><td>48:Share of renewable raw materials in domestic material consumption</td><td colspan="2">3</td></tr>
<tr><td>49:Share of secondary materials in domestic material consumption</td><td>-</td><td>1</td></tr>
<tr><td>44:Circular Material Use Rate</td><td>1</td><td>-</td></tr>
<tr><td rowspan="7">25</td><td rowspan="7">Increase self-sufficiency / self-reliance</td><td>50:Share of local secondary materials in raw material demand</td><td colspan="2">3</td></tr>
<tr><td>51:Imports of materials</td><td colspan="2">2</td></tr>
<tr><td>52:Export of waste materials</td><td colspan="2">3</td></tr>
<tr><td>52a: Export of waste materials to incineration</td><td colspan="2">3</td></tr>
<tr><td>52b: Export of waste materials to landfill</td><td colspan="2">3</td></tr>
<tr><td>52c: Export of waste materials to composting</td><td>-</td><td>3</td></tr>
<tr><td>54:EU self-sufficiency for raw materials</td><td colspan="2">1</td></tr>
<tr><td rowspan="3">26</td><td rowspan="3">Increase quantity of materials available for the next cycle</td><td>56:Quantity of materials subjected to reuse</td><td colspan="2">2</td></tr>
<tr><td>57:Quantity of materials subjected to repair</td><td>2</td><td>-</td></tr>
<tr><td>58:Quantity of materials subjected to remanufacturing</td><td>2</td><td>-</td></tr>
</table>

		59:Quantity of materials subjected to recycling	2	-
		60:Quantity of material for anaerobic digestion	-	1
		66:Quantity of material for composting	-	1
		65:EOL-RR (End of Life Recycling Rate)	1	-
27	Reduce waste generation	62:Amount of sector specific waste that is produced	1	
		61:End of Life Collection Rate	3	
		64:End of Life Processing Rate	1	
28	Reduce incineration and landfilling activities and amounts subjected	67:Incineration rate	1	
		67a:Incineration rates per material fractions	2	
		68:Landfilling rate	1	
		68a:Landfilling rates per material fractions	2	

Indicator properties

The indicators that were selected for the construction and biomass sector (Table 7), all have some properties in common. To better understand the indicators, these properties are listed here:

- **Type:** They are all quantitative indicators.
- **Data source:** Indicators fit with the data collection and data layers from the SCA.
- **Trends:** Indicator names themselves do not indicate their desired trend, meaning that it is not included if something should be reduced or increased. This can be derived from the strategic objective that an indicator is nested in or better yet, the indicator protocol.
- **Indication:** The indicator on its own as a single number does not reveal the status of the SO or if it has been achieved. Most have to be seen in the context of a time series, which requires data from several years (see more in "Evaluation").
- **Material group:** The indicator should always represent the sector (material group). Data on a single material is needed first, to then aggregate for the entire material group.
- **Two types of indicators:** Direct and indirect indicators.
  - **Direct indicators** mean that the indicator values come directly from the processed material flow data, simply because those values themselves speak to a state of a situation, e.g. (XX) amounts of CDW waste collected. These could either come from a specific dataset or the Sankey diagram produced by the developed method.
  - **Indirect indicators** are, as the name suggests, indirectly assessed by calculating them with a formula from (several) direct or other indirect indicators, e.g. (XX) circular material use rate. There is a sub-group of the indirect

indicators, which are the additional indicators. These are indicators not requiring any additional data to be collected and that can be calculated from existing indicators. However, there is more evaluation work needed as well then.

- **Three spatial scales:** There are the three spatial scales of Demonstration Actions, sector, and city. Some indicators only make sense on one spatial scale, whereas others are applicable to two or all three. The single indicator description, as well as the overview of all indicators show the spatial scale that the indicators are applied on. For the SCA, only the sector level indicators are relevant.
- **Link to SOs:** In some cases, an indicator does not only apply to one SO, but addresses several.
- **Link to Sankey diagram:** Not only the SOs are connected to the Sankey diagram, which is a graphical representation of the main method output, but naturally, by extension the indicators are as well. Some because they are derived from the Sankey data, others because they are mapped along the Sankey on the dashboard.
- **No "per capita":** Generally, "per capita" indicators are not included for now. They can be seen as an extension and could be included later for measurement and evaluation.

Calculations

To address the just mentioned calculations that are required, both to cover the whole material group and the indirect indicators, it is briefly outlined what these entail.

Firstly, to address the material group, again, since a sector is made up of several materials, the single material values are needed to make up the group. For example, to determine the "domestic extraction used" (DEU), a component of indicator "34:Domestic material consumption (DMC)", the extraction values of all single 11 construction materials are required to arrive at the DEU for the construction sector.

An alternative, if building it up from all 11 materials for the three DMC components (DEU, IMP, EXP) does not work, could be to rely on national data. For the DMC, there is data on the national economy that can be downscaled by using proxies (such as employment or GDP). Choosing the alternative would mean that the sector is represented with a total amount of materials and not divided by materials. As for the three components, there is for example the following data to calculate it:

a) DEU: Info on national level exists → It can be downscaled.
b) IMP and EXP: Data at NUTS2 level from NST. There is data for agriculture and partly also for construction, but not too detailed. It would be difficult to downscale, but could be attempted with the number of people employed in the sector.

Secondly, the indirect indicators will each have a method that details their calculations. Once their method has been finalised in WP6, the information can be found on the Indicator section of the Data Hub: https://cityloops.metabolismofcities.org/indicators/

Evaluation

To evaluate if an indicator measures the progress towards a desired state, it is required to have at least one of two things, namely either (1) evolution in time, otherwise it is just a snapshot of a point in time or (2) a certain share or rate that can be compared to official goals, such as EU targets.

1. **Evolution in time:** To evaluate evolution in time, a look back in time is taken and data for at least 2 points in time (in the past) with a minimum of 5 years apart are required. Better yet, is to have data for a longer period, e.g. have it every 5 years for 20 years, with a total of 4 data points.
2. **Goals:** Many of the indicators have EU or national targets that they can be connected to. This gives the city a good understanding of their standing and contribution.

Generally, it is also valuable to have and analyse direct and indirect indicators in conjunction. Since indirect indicators are often given as a percentage (share), which is a value that is not indicative of the magnitude or significance of a flow, a value that is rather informed by direct indicators, both types of indicators together give each other context.

Finally, as for the sector and its circularity assessment, there is not a single circularity sector score derived for evaluation. Lonca, Bernard and Magni (2019, 8) make the point that "aggregate indicators have the benefit to facilitate the dissemination of information to the public as well as to policy makers (Meyerson et al., 2005). But the reverse is also true. MFA-based indicators at the global economy level lack of clarity concerning flows of individual materials or substances potentially misses for elaborating CE policies (Mayer et al., 2018)." By maintaining clarity of the flows and not weighing the different strategic objectives, the cities can pursue their own respective priorities.

In that same line, there is also not one score per SO, which would have required a weighing of the single indicators addressing it, simply because it was impossible to know in advance what kind of data can be found for them and what the cities wish to evaluate per SO.

4. MFA Method

This part will present the backbone of the Sector-Wide and Urban-Wide Circularity Assessment methods, namely how materials (both resources and wastes) that circulate through economic sectors and the city will be accounted for. The current chapter will further detail how this method was chosen and developed as well as provide necessary guidelines for evaluation managers of CityLoops in order to apply it.

4.1. How the method was developed

Developing this method followed a number of iterations and tried to juggle between scientific rigor and usability by city officials and evaluation managers.

The first iteration, focused on developing a method that would be able to be consistent for measuring sector-wide and urban-wide circularity as well as identify circular hotspots in Task 4.5, which entailed to find the minimum common denominator between these tasks. As presented before (Chapter 2), the central piece that unified all these tasks was the economic sectors (or in other words, NACE codes) as they could cater simultaneously to all.

This approach focused on developing the best imbrication of data and flows nesting sectors within cities. Nevertheless, this approach also brought forward some challenges as it did not allow for any inconsistency from the final user (in CityLoop's case the urban administrations). Indeed, all flows needed to be mutually exclusive and be part of one sector and only the addition of sectors could enable assessing material flows/stocks at a city level. Due to unavailability of data, potential challenges of double counting and wanting to maintain the method user friendly, it was decided to abandon this method.

Another iteration of the method development considered developing a tailored approach, which would enable cities to use the circular economy to tackle their context specific challenges and ambitions (as such consider CE as means to an end rather than an end in itself). This approach would combine on the one hand different accounting scopes and techniques (inspired by the Greenhouse Gas Protocol) and on the other selected objectives of what implementing circular economy could achieve (see Table 8).

Table 8: Different scopes and layers of a possible method iteration

	A/ Simplified	B/ Economic	C/ Spatial	D/ Environmental Impacts	E/ Temporal
Scope 1					
Scope 2					
Scope 3					

These two entry points developed a matrix which could enable cities to specifically focus only on the topics that they consider as most essential or which most align with the current political situation. In the case of this methodological framework, Scope 1 would measure only direct material flows from a territorial-based approach. Scope 2 would also focus on a territorial-based approach in addition to considering the same material flows as in Scope 1, it would also include all associated (auxiliary) resource and waste flows. In other words, while Scope 1 would only measure finished construction materials (or ready to use), Scope 2 would also include all the necessary materials that were included for local extraction and manufacturing processes of the construction materials. Finally, Scope 3 would use a consumption-based approach considering all resource and waste flows that were mobilised along the supply chains of a city's consumption (both direct and indirect, both locally and globally). While consumption-based accounting is still (very) new for cities as IO tables are not available at a city level, a study comparing the territorial and consumption-based approaches for Brussels estimated that indirect flows were 3 to 4 times higher than direct ones (Athanassiadis et al. 2018).

In the columns of Table 8, cities could choose to focus on different challenges to be answered through a circular economy. The simplified version (A) would only consider a synthetic overview of material flows/stocks through a Sankey diagram. The economic (B) column would associate monetary value to material flows (similarly to a Material Flow Cost Analysis) to prioritise actions not necessarily on mass terms but on economic factors such as local value added, employment, etc. Column (C) adds a spatial component to flows and stocks by adding their origin and destination thus mapping the different stages of supply chains as well as their associated infrastructures. This spatial component enables cities and users to comprehend their dependence on a global hinterland and the economic activities taking place there. These could be relocalised to the city of study to increase self-sufficiency, but also to implement territorial symbiosis strategies. Column (D) is very similar to column (B), while it goes beyond to translate material flows to their associated environmental impacts (as these are not proportional). Focusing on this column would enable urban administrations to use circular economy strategies to become carbon neutral, for example. Finally Column (E) would add a temporal perspective (both retrospective and prospective) to measuring flows and stocks in order to identify patterns over time, material regime shifts, but also to forecast future resource use and waste flows in order to plan for appropriate infrastructure.

While cities could choose between the cells of this matrix, the overall matrix was conceived so that there should be a bare minimum that is comparable and which would constitute the baseline for their circularity assessment. Some of the minimum components of this bare minimum would be proper system definition including space and time boundaries, an analysis of flows and stocks relevant to the economic sector and city, and finally provide some city profile information that could help contextualize all previous information. The challenge with this methodological framework is that when many cities embark on their circular economy journey, they do not necessarily know what they want to achieve or what the benefits are that they can yield through circular economy (especially given the novelty of some solutions). In addition, it is difficult to foresee at this stage what the insights and results from some accounting methods would yield. Therefore, such a tailored approach could be overwhelming both for cities and for people applying all of these methods. As such, this ambitious framework needed to become more modest and straightforward for its application (although some tailoring elements were kept).

A third iteration of developing this method was to review all of the accounting methods that were present in Deliverable 4.1, the literature review and evaluate how closely they fit to assessing circularity but also how easy they are to be used by non-experts. The latter also considered the availability of data as well as the calculation steps required to apply an accounting method. A more detailed evaluation of the most promising methods, which included the UMAN model (H2020 UrbanWins project), the MUSIASEM method used in several H2020 project including the MAGIC-NEXUS project, the Activity-Based Material Flow Analysis used in H2020 REPAiR project and the Eurostat Economy-Wide MFA, will be presented here below.

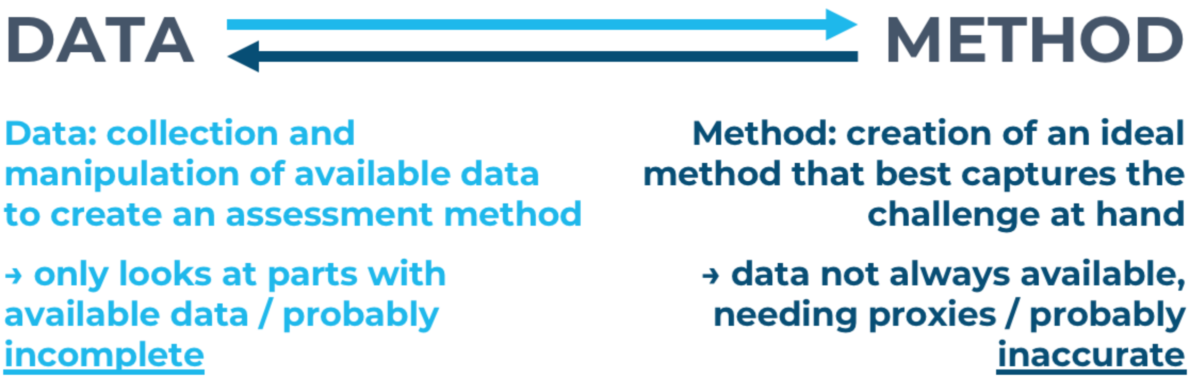


Figure 16: Data vs. Method

The final iteration in the creation of the SCA method was informed by the in-depth review of accounting methods and realising that all methods are as good as their underlying data. In reality, each of the presented methods were constructed or heavily relied on available material flow data. This implies that the development of any accounting method should be grounded with the availability of reliable and accurate data. In that sense, the development of the here presented method had to steer away from the best theoretic assessment of circularity in cities and adapt to data that would be easily available and able to be collected by urban administrations. The dilemma between developing a theoretically ideal method and one grounded on accurate and available data is illustrated in Figure 16.

To conclude, in the beginning of the method development, the idea or ambition was that a method is formulated that is general and could be applied to any sector of a city. Due to the intricacies of the various sectors, scopes, and materials, this led to carrying out a scoping exercise of available data at the European, national, subnational, and city level. Numerous "global", which is to say large scale encompassing, sources were reviewed, including Eurostat's database, with results of this exercise presented in the following sections. However, finally, a universal method was not being created after all, but rather two methods that are specific to the construction and biomass sectors and that can work well with available data.

4.2. Evaluation of existing MFA methods

In this section, the most promising elements from four main methods that were deemed to best fit urban material flow analysis and which could also inform on circularity at a sector and urban level, are briefly outlined. A more detailed review of these four accounting methods (as well as others) can be found in Deliverable 4.1 (Hoekman and Bellstedt 2019). The four methods included the Economy-Wide Material Flow Accounting (EW-MFA), Urban Metabolism Analyst (UMan), multi-scale integrated analysis of societal and ecosystem metabolism (MuSIASEM), and finally Activity-based Spatial MFA (AS-MFA).

Firstly, EW-MFA is the oldest and most established accounting method (approximately 20 years old) and has been followed at a European, and member state level for a number of years. This method is a statistical data compilation of some major parts of the economy including extraction, imports, processed materials, exports, material accumulation, etc. Its advantage is that it builds on existing (or transformed) Eurostat datasets that have been refined over time. Statistical offices from member states are now familiar with finding and processing material flow data following a specific materials nomenclature and correspondence tables exist between this nomenclature and other useful and frequently reported nomenclatures (CPA, PRODCOM, CN, etc.). Most importantly, EW-MFA is used (and slightly modified) for monitoring the CE progress of the EU and member states and automatically produces indicators (DMC, NAS, Circularity Material Use rate, etc.) which are frequently used. The biggest disadvantages from this accounting framework are that while it provides a good overview of flows, it does not necessarily link them with value chains, nor does it reveal consumption and production patterns. It provides a "black-box" which can be difficult to use for developing circularity roadmaps and disaggregation into sectors. Due to its inception at a national level, EW-MFA has also chosen to draw upon existing datasets at national level which are often missing at an urban level and for which some downscaling of data would be needed.

Secondly, the Urban metabolism analyst method does a great job in linking various datasets (using different nomenclatures) as well as linking material flows to specific products. This connection enables better link consumption patterns with material flows as well as adding products' lifespans in order to create a dynamic model which attempts to forecast demand for resources and generation of waste. The link between material flows and manufactured products also enables the use of LCA to estimate their environmental impacts and as such combines MFA with LCA. While this method is very promising and has already been applied to around 10 EU cities (either through the H2020 UrbanWins project or through academic research), it was difficult to use for measuring circularity in CityLoops as the documentation of some of its pieces were not accessible, such as the three databases of material composition, product lifespan and life cycle phase. Furthermore, it is a rather complex method that requires expertise for using it. (In the UrbanWins project, partners collected the data and A. Prof. Leonardo Rosado ran the model). Therefore, the UMan method was removed from further consideration, since the cities and the evaluation managers of CityLoops are meant to be fully autonomous in carrying out their sector circularity method.

Thirdly, the multi-scale integrated analysis of societal and ecosystem metabolism method, is one that, as the name suggests, looks by default at multiple scales by studying the "performance of socio-economic activities (for households, enterprises, economic sectors, national economies, world economy)" (Giampietro, Mayumi, and Ramos-Martin 2009). An advantage of MuSIASEM is that it also focuses on the economic and social components of the system, which are often lacking in other methods. However, although this method also exists for a couple of years already, there is very little work on an urban level. Moreover, it was found to be too difficult for cities to carry out by themselves, as it requires such a deep level of analysis and understanding of the socio-economic structures.

Finally, the Activity-based Spatial MFA (AS-MFA) developed within the European Horizon 2020 REPAiR project offered great additions to accounting for circularity as on the one hand it explicitly focused on economic activities and on the other hand it focused on spatialising them and their associated flows, thus opening the black box. Nevertheless, this method only focused on waste streams and not on all material flows entering and exiting the economy/city, which meant that it only looked on the output side of the system.

To summarise, Table 9 provides a synthesis of the advantages and disadvantages of these four methods. Based on this review, the best features from each of these accounting methods were considered, in order to create the most relevant and easy-to-use method for urban policy makers and urban administrations. It considered the simplicity and ease of constructing indicators from the Eurostat EW-MFA, the combination of different nomenclatures from the UMAN model, the multi-scale analysis of MuSIASEM, and it took into account the spatial and economic activity components from the Activity-based Spatial MFA. As such, the method proposed here is a hybrid of existing methods and uses the best features of each one of them in order to best capture circularity at an economic sector and urban level.

Table 9: Synthetic analysis of advantages and disadvantages of four selected accounting methods

	Advantages	Disadvantages	Existing use
EW-MFA	Used at a national level, has indicators, robust	Black or grey-box, not very applicable at a city-level	Eurostat base method
UMan	Links with economic sectors, links flows with products, measures environmental Impacts of products	Quite some approximations done, needs expert work/calculations	H2020 Urban Wins
MuSIASEM	Looks by default at multiple scales, links material and energy flows	Very detailed. Little work on urban level.	H2020 MAGIC NEXUS
AS-MFA	Uses economic activities, spatialises flows/actors	Focuses only on waste and not entire chain. Not fully finalised.	H2020 REPAiR

4.3. Review of available material flow data

As mentioned in the section describing how the accounting method was developed (Chapter 4.1), the final iteration of the method construction consisted of looking for available and relevant data. The data also needed to fit the database structure that was developed in Task 4.2, illustratively shown in Figure 17. Therefore, the main type of datasets that were pursued were related to datasets and connected nomenclatures containing information on reference spaces, processes, and materials. The following available information was found:

- **Reference spaces:** There is spatial information on city boundaries, but also geolocalisation of actors and infrastructures. Various spatial nomenclatures exist from Eurostat, including e.g. NUTS levels.
- **Processes:** There are economic or natural activities which generate, affect or transform material flows and stocks (e.g. precipitation or extraction). Various activity catalogues can be used (for instance, the statistical classification of economic activities in the European Community, abbreviated as NACE).
- **Materials:** There is plentiful information on raw materials, semi-finished and finished-goods, by-products, waste and pollution flows that are flowing in and out of the sector and city. Various nomenclatures describe materials from the EW-MFA list, to PRODCOM (manufactured goods), EWC (Waste), NST (Transportation), CN (imports and exports), CPA (products by activity), etc.

At this stage, it is important to highlight the plethora of nomenclatures that are used to classify these three categories of data, which can be overwhelming and seem counterproductive as they divide efforts. In most cases, each nomenclature was developed to serve a very specific reporting purpose but not necessarily to provide a systemic overview of material flows and stock of a sector or city. Fortunately, a lot of effort was put to link these nomenclature both at a theoretical level by developing the schematic diagram of Figure 18 for example, or on a practical one by developing correspondence tables.

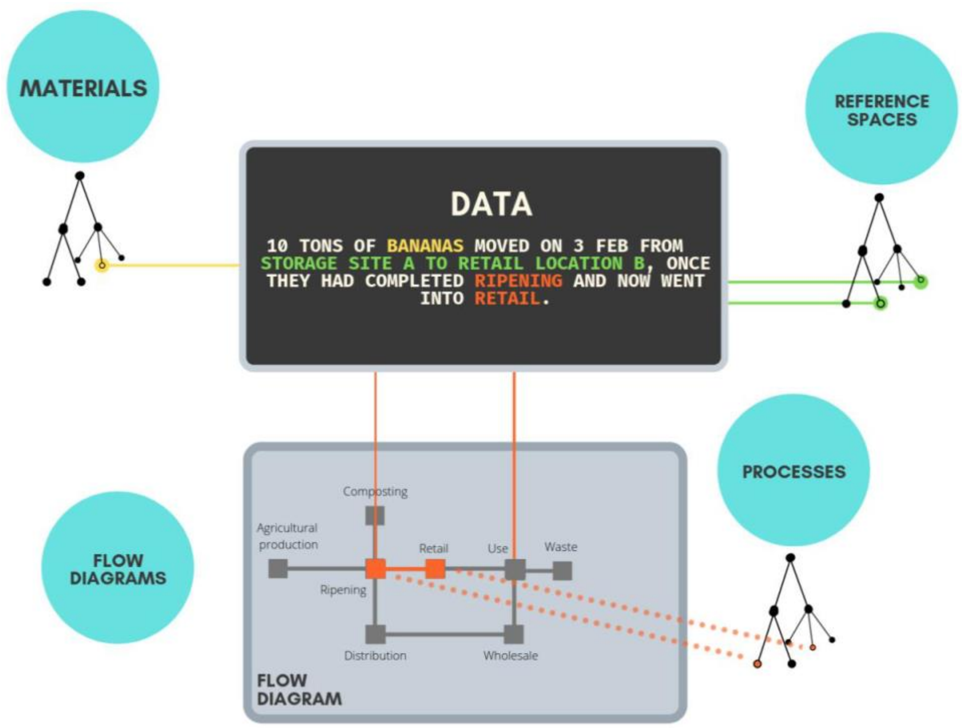


Figure 17: A simplified overview of the Stocks And Flows Database structure

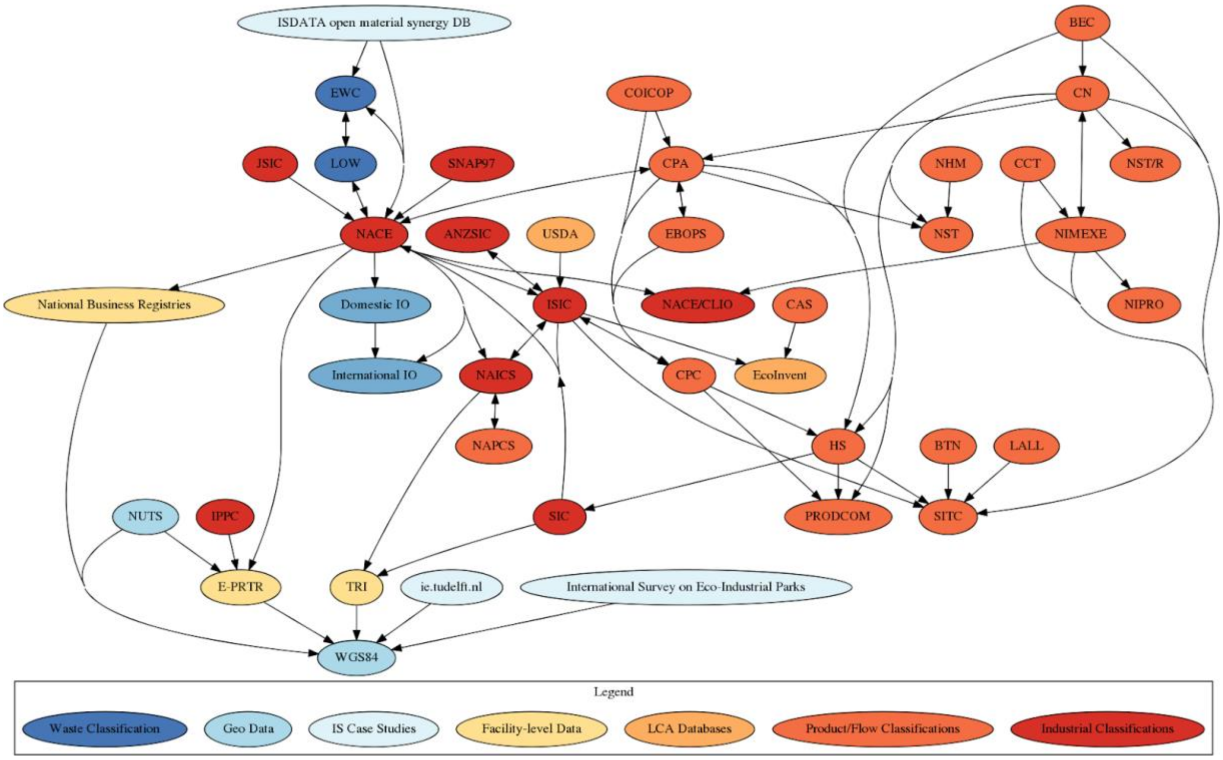


*Figure 18: Schematic overview of frequently used nomenclatures in Material Flow Analyses (both in EU and worldwide) and how they connect to each other (*Isdata-Org/What-Links-to-What *[2016] 2016)*

4.3.1. Spatial boundaries

In all traditional material flow accounting methods, one of the first steps is to define a system boundary, both in space and time, where flows enter and exit from, and stocks stay within. In the case of CityLoops, the system boundary coincides with urban administrative boundaries as this is where most information/data is available but also where their jurisdiction often ends.

At a European level, various spatial levels were created to collect data on, in order to highlight specific territorial aspects of regions and cities. These levels zoom further in from member states level as they enable them to compare similarly inhabited or similar areas of land. The main hierarchical categorisation of territorial statistics is the so-called Nomenclature of Territorial Units for Statistics (NUTS) classification going from the country to smaller and smaller regions and territories namely NUTS 1, 2 and 3 respectively. Table 10 provides the name and number of each of these NUTS levels for the seven demonstrator cities of CityLoops.

Table 11 states the respective names and codes of the NUTS levels that the cities are nested in. As can be seen from that table, the biggest cities, such as Porto and Seville sometimes coincide with their NUTS 3 boundaries, but in most cases that smallest NUTS level is still too big and a smaller territorial scale is needed. This is where Local Administrative Units (LAUs) can be taken advantage of since they are compatible with NUTS levels (through specific correspondence tables). In this case, almost all cities have a corresponding LAU, except Porto which has several (Table 12). That table contains what appear to be the boundaries that best reflect the urban administrations for the seven demonstrator cities of CityLoops.

Table 10: Official titles of NUTS levels and the respective amounts of each for the cities of CityLoops

City	Country	NUTS1	#	NUTS2	#	NUTS3	#
Apeldoorn	Netherlands	Landsdelen	4	Provincies	12	-	40
Bodø	Norway	-	1	-	1	Hagskýrslu-svæði	2
Høje-Taastrup	Denmark	-	1	Regioner	5	Landsdele	11
Mikkeli	Finland	Manner-Suomi, Ahvenananmaa / Fasta Finland, Åland	2	Suuralueet / Storområden	5	Maakunnat / Landskap	19
Porto	Portugal	Continente + Regiões Autónomas	3	Grupos de Entidades Intermunicipais + Regiões Autónomas	7	Entidades Intermunicipais (Comunidades Intermunicipais + Áreas Metropolitanas) + Regiões Autónomas	25
Roskilde	Denmark	-	1	Regioner	5	Landsdele	11
Seville	Spain	Agrupación de comunidades autónomas	7	Comunidades y ciudades Autónomas	19	Provincias + islas + Ceuta, Melilla	59

Table 11: Name and code of each NUTS level for the 7 demonstrator cities of CityLoops

City	Country	NUTS1	NUTS1_code	NUTS2	NUTS2_code	NUTS3	NUTS3_code
Apeldoorn	Netherlands	OOSTNEDERLAND	NL2	Gelderland	NL22	Veluwe	NL221
Bodø	Norway	NORWAY	NO0	Nord-Norge	NO07	Nordland	NO071
Høje-Taastrup	Denmark	DANMARK	DK0	Hovedstaden	DK01	Københavns omegn	DK012
Mikkeli	Finland	MANNER-SUOMI	FI1	Pohjois- ja Itä-Suomi	FI1D	Etelä-Savo	FI1D1
Porto	Portugal	CONTINENTE	PT1	Norte	PT11	Área Metropolitana do Porto	PT11A
Roskilde	Denmark	DANMARK	DK0	Sjælland	DK02	Østsjælland	DK021
Sevilla	Spain	SUR	ES6	Andalucía	ES61	Sevilla	ES618

Another scale for spatial entities that can be relevant for selection for the cities and their boundaries are what is codified as spatial units by Eurostat, namely cities, greater cities, and functional urban areas:

- **City:** a local administrative unit (LAU) where the majority of the population lives in an urban centre of at least 50 000 inhabitants.
- **Greater city:** an approximation of the urban centre when this stretches far beyond the administrative city boundaries.
- **Functional Urban Area:** consists of a city and its commuting zone. (This was formerly known as the larger urban zone (LUZ)).

Table 13 lists the codes for the cities, greater cities and functional urban areas for the CityLoops cities. It can be seen that only the larger cities have those codes, whereas the smaller ones do not. It is important to note that for each of these levels, there are numerous corresponding LAUs. For instance, Seville counts one LAU at a city level (688,592 inhabitants), 10 LAUs at a greater city level (880,726 inhabitants) and 46 LAUs at a FUA level (1,549,641 inhabitants). As such depending on the city boundaries chosen for the analysis, a different number and selection of LAUs will need to be considered.

Table 12: Name and code of the Local Administrative Units corresponding to the 7 demonstrator cities of CityLoops

City	LAU	LAU_code	LAU population	Area (km²)
Apeldoorn	Apeldoorn	GM0200	162,445	340
Bodø	Bodø	*unknown*	42,102	2,863
Høje-Taastrup	Høje-Taastrup	169	50,686	78
Mikkeli	Mikkeli	491	53,818	3,230
Porto	Bonfim/Campanhã/Paranhos/Ramalde/União das freguesias de Aldoar, Foz do Douro e Nevogilde/União das freguesias de Cedofeita, Santo Ildefonso, Sé, Miragaia, São Nicolau e Vitória/União das freguesias de Lordelo do Ouro e Massarelos	131202/ 131203/ 131210/ 131211/ 131216/ 131217/ 1312018	237,591	41
Roskilde	Roskilde	265	87,577	212
Seville	Sevilla	41091	688,592	141

Finally, a last spatial boundary which could be considered when collecting data, is Metropolitan Regions. Although, as can be seen in Table 13, only Porto and Seville are considered as metropolitan regions.

Table 13: Cities and greater cities and metropolitan regions codes for CityLoops cities

	Cities and greater cities			**Metropolitan regions**	
City	City (C)	Greater City (K)	Functional Urban Area (L)	MREG_CODE	NUTS_ID
Apeldoorn	NL014C1		NL014L3	-	-
Bodø	-	-	-	-	-
Høje-Taastrup	-	-	-	-	-
Mikkeli	-	-	-	-	-
Porto	PT002C1	PT002K1	PT002L2	PT002M	PT11A
Roskilde	-	-	-	-	-
Seville	ES004C1	ES004K1	ES004L3	ES004M	ES618

4.3.2. Processes

After having found information on the system boundaries, the next step was to find information on the processes which transform flows from one state to another. These can be seen as nodes from the local and global value and supply chains that exist within and go beyond cities. Knowing which processes exist within a city can help discover whether some flows are present in the city (e.g. if there are no mines in a city, it follows that there is no extraction of metallic and non-metallic minerals). Conversely, it enables to localise and disaggregate bulk information on flows which can be frequently reported (such as a total of extraction or a total of production, etc.) into more contextual economic activities. As mentioned in the section “Evaluation of existing MFA methods”, adding processes (or activities) as part of the accounting method helps to open up the “black box”.

The main source of information for processes, will come from economic activities data which follow the NACE nomenclature (see Table 1 and Table 2). The information sought for these processes can be of different nature including geolocalisation of these processes, number of employees, GVA produced, etc. These pieces of information will also be helpful later on for downscaling information from larger areas (such as NUTS 2 entities) in case of local data unavailability. In general, economic activities data are quite abundant and frequently published at most spatial scales (as can be seen in Figure 20).

4.3.3. Materials

Information on materials (from raw to semi-processed to processed) is the central anchor for each MFA, as it is the quantity values that are reported that can be included in flow diagrams (see Figure 17) and Sankey diagrams. Two main characteristics are sought for the SCA: material quantity and quality. Material quantity helps to provide orders of magnitude of the flows, while quality helps to better describe the state of the flows. In fact, 1 tonne of raw materials has a different economic and technical value (as well as environmental impact) than 1 tonne of processed goods. While resources, goods and wastes are all materials, it is essential to better describe at which stage/process of their life cycle they are located. As mentioned earlier, several nomenclatures exist to describe and classify materials at their various stages (or associated to a specific economic activity).

Definitions of materials

Below some definitions for different states of materials can be found:

- Substance =“*any (chemical) element or compound composed of uniform units. All substances are characterized by a unique and identical constitution and are thus homogeneous. Using this definition makes clear that “wood” is not a substance. It is composed of many different substances such as cellulose, hydrogen, oxygen, and many others. Chemical elements and compounds both are correctly addressed as substances*” (Brunner and Rechberger 2004).
- Goods = “*Goods are defined as economic entities of matter with a positive or negative economic value. Goods are made up of one or several substances”. “Sometimes the words product, merchandise, or commodity are used synonymously for “goods””* (Brunner and Rechberger 2004).
- Material = “*material serves as an umbrella term for both substances and goods*” (Brunner and Rechberger 2004).
- By-product: “*a result from a production process that was not the primary aim of that process. Unlike waste, it must be able to be used afterwards. The directive allows the European Commission to set criteria to be met by substances so as to differentiate by-products from waste*” (European Commission 2020a).
- Waste: “*any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force*” (Eurostat 2019d).
- End-of-waste: “*End-of-waste criteria specify when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material). According to Article 6 (1) and (2) of the Waste Framework Directive 2008/98/EC, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions*” (European Commission 2020b).

Classification of materials

Depending on the use of the reporting and the state of the materials, different nomenclatures are used to classify them and in most cases, these nomenclatures are linked through correspondence tables see Figure 18. The most prominent and relevant (for CityLoops) nomenclatures include:

- The CPA (classification of products by activity) classifies products (goods and services) through a direct and unique link to NACE codes. Similarly to NACE codes, CPA has a hierarchical structure with six levels. This classification is of great interest as it nests perfectly with NACE codes and covers all of them (Eurostat 2013). **In that sense, it is a good overall classification, yet it could lack some details when wanting to further zoom in for one process.**
- PRODCOM classification focuses on industrial production statistics which are annually recorded through the PRODCOM survey (both in monetary value and quantity terms). "The PRODCOM survey is based on a list of products called the PRODCOM list which currently comprises about 4000 headings relating to industrial products and some industrial services. These products are detailed at an eight-digit level. The first four digits refer to the equivalent class within the Statistical classification of economic activities in the European Community (NACE), and the next two digits refer to subcategories within the Statistical classification of products by activity (CPA)" (Eurostat 2019b) **This classification is of great use when looking at the first parts of the flow diagram (extraction and manufacturing)**.
- The NST 2007 (Standard Goods Nomenclature for Transport Statistics) nomenclature reports all "goods transported by four modes of transport: road, rail, inland waterways and sea (maritime). As NST 2007 considers the economic activity from which the goods originate, each of its items is strongly connected to an item of the European Union product and activity classifications Classification of products by activity (CPA) and Statistical classification of economic activities (NACE)" (Eurostat 2019c). **This nomenclature is especially important for imports and exports flows.**
- The CN (Combined Nomenclature), similarly to NST focuses on the transportation of materials, but more specifically on the context of (extra-EU) trade. The CN nomenclature can also be translated to CPA and NST classification and therefore also to NACE codes. **This nomenclature is especially important for imports and exports flows (mostly coming from outside of the EU)**.
- The EW-MFA nomenclature, which classifies materials into eight main material types (biomass, metal ores, non-metallic minerals, fossil energy materials/carriers, Other products, Waste for final treatment and disposal, Domestic processed output, and Balancing items), some more detailed than others. "It is a hierarchical classification with main material flow categories (1-digit level); i.e. MF.1 to MF.8. Each main category is further broken down, maximal down to 4-digit-level:
  - 1-digit: material category
  - 2-digit: material class
  - 3-digit: material group
  - 4-digit: material sub-group

(...) The main material categories MF.1 to MF.4 correspond to the following types of material flows: *domestic extraction, physical imports,* and *physical exports*. The material categories MF.5 and MF.6 solely apply to *physical imports* and *physical exports.* Material category MF.7 applies exclusively to *domestic processed output*; while MF.8 solely applies to *balancing items*" (Eurostat 2018, 22). Physical imports and exports are flows of products for which one commonly employs product classifications such as the Classification of Products by Activity (CPA) or Combined Nomenclature (CN). In EW-MFA traded products are not classified by product classifications, but are assigned to material classes, groups and sub-groups according to the main material the product is composed of. For this, a correspondence between the CN product classification and MF classes has been established (see correspondence tables). This nomenclature is strictly related to the accounting method and as such data is not collected on its own, but needs to be reclassified and compiled from existing Eurostat datasets. **This nomenclature is the preferred one in the case of this accounting method, as it covers the full spectrum of flows and classifies them into material categories that are the most widely used for MFA and circularity assessment at an EU level. Nevertheless, in some cases it will be valuable to enrich it with the other nomenclatures presented here above and below for more detailed analyses.**

- The COICOP (Classification of individual consumption by purpose), "is a classification developed by the United Nations Statistics Division to classify and analyze individual consumption expenditures incurred by households, non-profit institutions serving households and general government according to their purpose. It includes categories such as clothing and footwear, housing, water, electricity, and gas and other fuels" (Eurostat 2019a). There is a correspondence between COICOP and CPA (and therefore NACE) nomenclatures in order to link consumption by activities. **This nomenclature is especially important for reporting consumption and use activities from households and governments.**

Classification of wastes

Grouping of waste can be done by material properties such as whether they are solid, liquid, biodegradable, organic, inert etc. or by waste treatment processes such as bio-chemical conversion (composting, bio-methanisation), thermal processes (gasification, incineration, pyrolysis) or simple landfilling.

A more interesting grouping for the CityLoops project is by origin, from the economic activity, since that is what will be studied. In order to know what to account for and what to include and exclude, wastes and materials should be considered from that perspective. The simplest way to talk about it, is from the side of waste, because there is some understanding about what and which amounts come out and what a problem is in a city. Fortunately, in the CityLoops consortium there is an understanding that waste occurs higher up the chain too, not just in use or at the consumer stage, but along the entire supply chain. This means that the to be included wastes are then also industrial and agricultural wastes and not only municipal solid waste and thus materials entering those various points need to be studied.

In the EU, different waste categories have been defined, as well as an European List of Waste (LoW) (Commission Decision 2000/532/EC) that provides an EU-wide common terminology for waste classification to ease waste management, including for hazardous waste. Most of the chapters from this list can be linked to economic activities, although some are grouped together, for instance Chapter 20 *"Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions"*. **This classification will be used for all wastes and their valorisations, so the final part of the value chain/Sankey diagram.**

Summary of nomenclatures to be used for the accounting method

To conclude this part, presenting in which format material data has been classified in and collected, a synthetic Figure (Figure 19) showcases the nomenclatures used for each step of the value/material chain, highlighting the most relevant (in bold) in terms of data accuracy, frequency of reporting and level of detail.

The following section presents all the relevant datasets that are present in Eurostat (and are compiled with different nomenclatures) for the sector- (and partially urban-)wide circularity assessment.

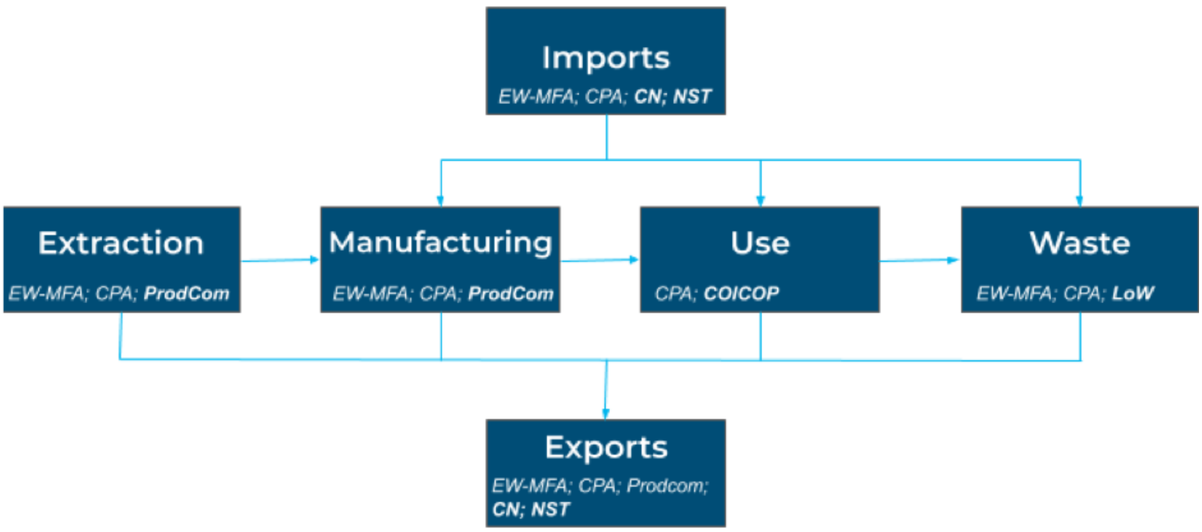


Figure 19: Available and relevant (in bold) nomenclatures for each step of the value/material chain

4.3.4. Eurostat datasets

The Eurostat database (https://ec.europa.eu/eurostat/data/database), provided by the European Commission, was also evaluated in the effort to determine data availability and quality necessary to construct our circularity accounting method. This very collection, which was deemed most promising due to the nature of it being about the European context, its standardised data collection effort across reporting entities and spanning considerable time frames over many themes, contained 8,037 unique datasets as of June 23, 2020. This database was cleaned up, reviewed, tagged and will be imported to the [Metabolism of Cities Data Library](https://data.metabolismofcities.org/library/datasets/) (https://data.metabolismofcities.org/library/datasets/). Details on how these single steps were carried out and what they brought to light, can be found in the following paragraphs.

In order to facilitate the revision, it was necessary to **clean up** the database that had been imported into "**Eurostat manager**" (https://cityloops.metabolismofcities.org/eurostat/). This meant that datasets of which multiple instances existed, e.g. "Population connected to at least secondary wastewater treatment", which was listed three times in various subfolders, were removed. As a result, the total records went from 9,949 to 8,037.

Thereafter, the **review process** began with the Eurostat manager. A lengthy number of keywords and rules were used to filter and eliminate or accept for. The list of keywords that was eliminated is too lengthy and not interesting enough to include, but the keywords for inclusion are listed in Table 14. It shows that the focus was on certain materials, economic factors, and population. Moreover, preference was given to the data on NUTS2 or NUTS3 level, since they would be more appropriate as smaller spatial scales, in the case that there is no data on the city level and they yield more precise results in the case of downscaling. Since the indicators for the analysis had not yet been determined at the time of review, some datasets were left aside, since they could be related to social indicators and well-being, if needed, such as life expectancy, work-life balance, job quality, unemployment, and poverty. There was also already a focus on CityLoops' materials flows to some extent, because for example computers, which would be relevant if focus was on WEEE (electronic waste), were left out.

Table 14: Keywords that were filtered and mostly included for in the Eurostat database review

▪ waste ▪ recycling ▪ secondary raw materials ▪ landings of fishery ▪ gross weight of goods transported to/from main ports ▪ circular ▪ water ▪ pollutant ▪ environmental	▪ naio_ (national input output) ▪ metropolitan regions ▪ cities and greater cities ▪ Functional Urban Area ▪ eco-innovation ▪ EEA ▪ JRC ▪ NUTS 3 ▪ NACE Rev. 2 ▪ NACE Rev.2

After the review process, the relevant datasets were **tagged**. Six spatial scales and the layers that are used for the data collection (see Chapter "Design of Layers") were used for tags. The spatial scales that were tagged were those of the NUTS levels, as well as the two Eurostat own groups of "Cities and greater cities" and "Metropolitan regions".

- **NUTS:** If "NUTS3" or "NUTS 3" is in the title, it was tagged. Same was done for NUTS2 and NUTS1.

- **Cities and greater cities (urb_):** The dataset codes starting with “urb_”. It was checked if the CityLoops cities are represented in this group, with Table 13 yielding the results. Added a “cities and greater cities” tag to all datasets that have “urb_” at the beginning of their dataset ID.
- **Metropolitan regions (met_)**: Another category from Eurostat, with the dataset codes starting with “met_”. . Added a “metropolitan regions” tag to all datasets that have “met_” at the beginning of their dataset ID.

Next to the layers and spatial scales, “**secondary datasets** were taken notice of as well. There are some Eurostat datasets that do not seem to be important immediately, but which could support the project nevertheless. These were termed secondary datasets, since they are of secondary importance. For example, the dataset of “Individuals who ordered goods or services over the internet for private use [isoc_r_blt12_i]” with the label "Online purchases: from sellers from other EU countries" could provide information on the consumption behaviour of individuals and even speak to the purchase of goods from abroad, which could be deemed undesirable from a self-sufficiency or local circular economy perspective. Another examples of a secondary dataset are the ones about people having access to the internet or “Individuals using the internet for interacting with public authorities”, since they could be relevant for transferability of tools and individuals having access to information. For example, if people do not have access to the internet, a computer or are not computer literate, then the best apps, websites or online outreach programmes are useless. Similarly, the dataset on “Individuals using the internet for selling goods or services [tin00098]” could provide insight into the likelihood of people engaging in selling their used items for reuse or repurposing. A stark difference existed here in 2019, where in the Netherlands 36% of people sold goods or services online, in Portugal only 9% and the value for the EU28 was 20%.

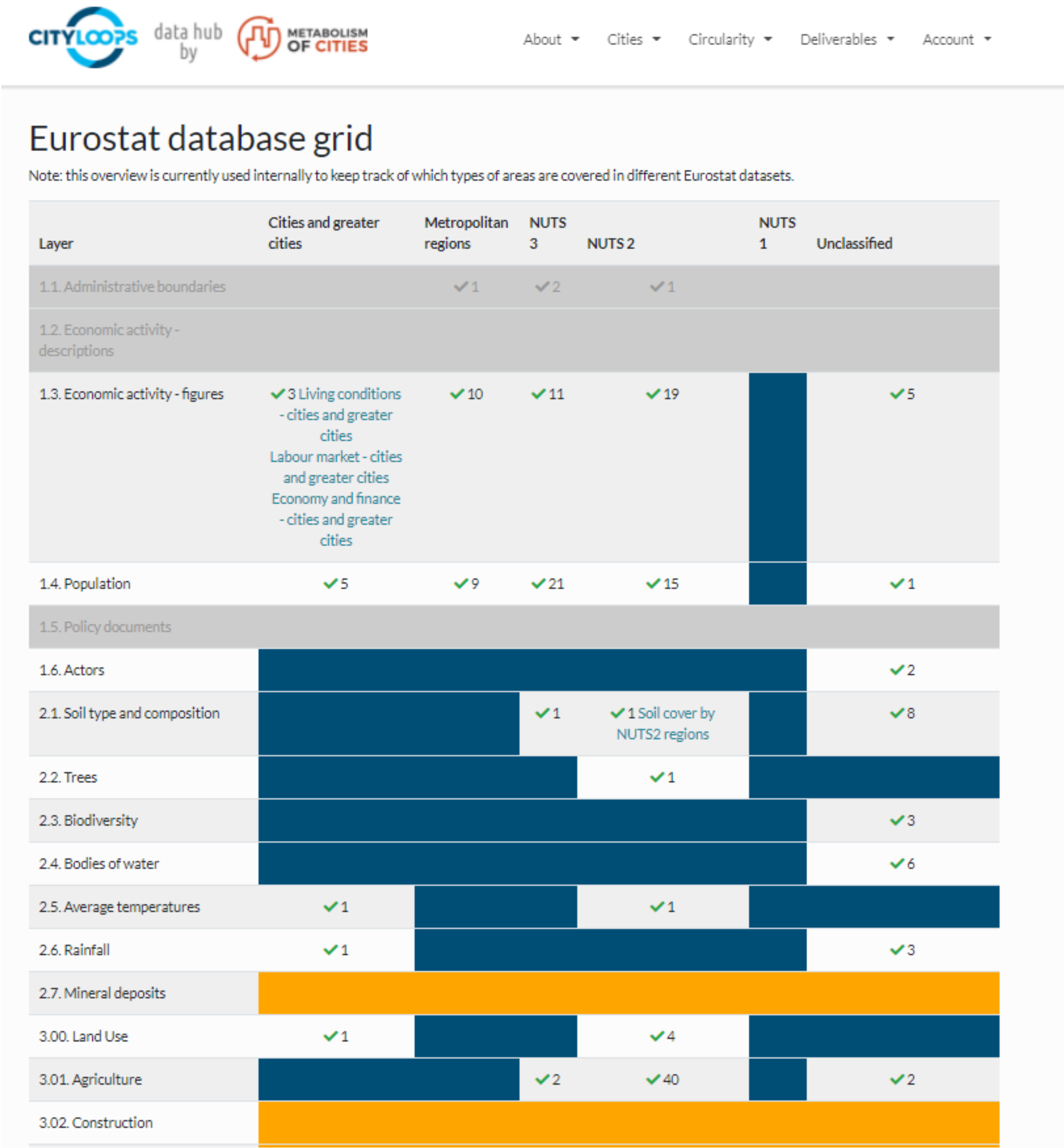
Eurostat grid

The most visible result of the tagging was that the **Eurostat grid** could be created (https://cityloops.metabolismofcities.org/eurostat/grid/). The grid acts as an overview to illustrate for which layers as well as the six different spatial scales, Eurostat datasets exist and have been tagged. There were a couple of “rules” for making the grid:

- Include only “accepted” datasets from the Eurostat manager
- Include datasets in the respective layer row(s)
- Spatial scales
  - Sort according to the tags of NUTS, cities and greater cities and metropolitan regions
  - If a dataset is not in any of the spatial columns, put it in “unclassified”.
- Colours
  - Grey out the row for which it is known that no such data is produced by Eurostat.
  - Add green checkmark and amount of datasets if there are some
  - If there are datasets in a layer, make rest of row blue
  - If there is no dataset on any spatial scale, make the row orange

Figure 20 and the Eurostat grid itself show that there are quite a number of relevant datasets for some spatial scales and layers, for example on NUTS3 and NUTS2 level and for population, but that there are also considerable gaps. When clicking on any cell which has data, the name of the Eurostat datasets appear and can be retrieved easily by searching on their website.

The Eurostat grid can be used by urban administrations, as a starting point, to guide them to relevant datasets during their data collection process. While some of the CityLoops cities are also considered as "Cities" from a Eurostat perspective, these cities could directly use these datasets. When datasets are only available at bigger spatial scales, cities can use a relevant downscaling technique to approximate the sought after value at their spatial scale.



Eurostat database grid

Note: this overview is currently used internally to keep track of which types of areas are covered in different Eurostat datasets.

Layer	Cities and greater cities	Metropolitan regions	NUTS 3	NUTS 2	NUTS 1	Unclassified
1.1. Administrative boundaries		✓1	✓2	✓1		
1.2. Economic activity - descriptions						
1.3. Economic activity - figures	✓3 Living conditions - cities and greater cities Labour market - cities and greater cities Economy and finance - cities and greater cities	✓10	✓11	✓19		✓5
1.4. Population	✓5	✓9	✓21	✓15		✓1
1.5. Policy documents						
1.6. Actors						✓2
2.1. Soil type and composition			✓1	✓1 Soil cover by NUTS2 regions		✓8
2.2. Trees				✓1		
2.3. Biodiversity						✓3
2.4. Bodies of water						✓6
2.5. Average temperatures	✓1			✓1		
2.6. Rainfall	✓1					✓3
2.7. Mineral deposits						
3.00. Land Use	✓1			✓4		
3.01. Agriculture			✓2	✓40		✓2
3.02. Construction						

Figure 20: Screenshot of top part of Metabolism of Cities' Eurostat grid (https://cityloops.metabolismofcities.org/eurostat/grid/)

4.4. A hybrid Material Flow and Stock Accounting method

The material accounting part of the SCA tracks materials through space and time using Eurostat nomenclatures, in order to ensure compatibility with national and European efforts of measuring physical flows and progress towards circularity. After having reviewed numerous accounting methods, as part of Deliverable 4.1, it was decided to follow and enrich the Economy-Wide Material Flow Analysis (EW-MFA) from Eurostat, as it is already used by European member states and by the European Circular Economy monitoring framework. However, in order to contextualise this method at the urban level, some additional spatial and economic features had to be added. As such, the method presented here attempts to open the black box of traditional economy-wide MFA studies and better integrate economic sectors as well as their value chain/life cycle steps.

Similarly to EW-MFA, the **here presented method consists more of a compilation of data which combined with indicators provides systemic and synthetic insights for the circularity of sectors,** rather than a calculation-heavy method which requires specific (disciplinary) expertise. **It attempts to maximise the amount of *circularity insights* for the *least* amount of data collected while remaining scientifically sound and easily transferable and comparable to national and EU statistics.**

Some essential elements need to be introduced here in order to better understand the inner workings of this method. **To assess the circularity of sectors, the main materials are considered throughout their (local) supply chain going from extraction to manufacturing, use, waste collection, and finally to waste treatment.** Some additional loops are considered such as reuse and remanufacturing (recycling is considered as part of waste treatment). Imports and exports are then linked to most of the stages mentioned above.

The accounting technique used is territorial-based (Scope 1 from Table 8), to reduce complexity for users, meaning it only considers direct material flows entering, being stocked and exiting the city under study. **This approach clearly underestimates the real quantity of flows that are required to satisfy the consumption and production levels of these cities. Therefore the efforts would need to be much more ambitious than the ones necessary to *become circular* under this accounting framework.** The results from this accounting method should only be seen as a starting point for cities to build upon depending on their future ambitions.

In terms of material scopes, no auxiliary materials are considered. For instance, when talking about fruits, neither packaging materials are considered, nor the energy and water used to harvest and transform them or treat their waste. When the materials considered can be used directly after extraction/harvesting, no other materials are added in their supply chain. This is the case for most biomass materials (except dairy and animal products), and some construction materials (wood, sand and gravel). In the case of composite materials, their primary materials are considered for extraction (and as imports for manufacturing). For instance, there is no extraction of concrete, but extraction of its constitutive materials, e.g. cement (which in turn is composed of limestone, clay, sand and a small amount of gypsum), sand, gravel, and water (a very small fraction also are put in making concrete, but are disregarded at this stage). Vice versa, in the case of "natural" products, no manufacturing processes are needed. For instance, sand manufacturing is not considered (in contrast to concrete manufacturing, which produces different concrete products from ready to pour concrete, to concrete bricks, etc.).

A particularity of the sector-wide circularity assessment method compared to EW-MFA is that the number of materials considered for each sector is smaller (in fact, EW-MFA focuses on material groups and not economic sectors). As a reminder, only 11 materials for the construction sector (wood, steel, aluminium, concrete, sand & gravel, soil, bricks, glass, gypsum, asphalt and insulation) and 9 materials for the biomass sector (cereals, vegetables, fruits, dairy, fish, live animals, fodder crops, horticulture, timber) are included. This choice was made to account for a vast majority of the direct material consumption of EU-28 (for each of the sectors), as well as contain the materials for which there is a demonstration action in CityLoops. Such a selection needed to be done, as analysing the sectors as a "black box", would provide less actionable results, and because doing a separate MFA for all materials (beyond the 11 and 9 selected ones) of the two sectors would be too time consuming and contribute a smaller margin in terms of circularity.

Once a synthetic Material Flow Analysis has been carried per each of the 11 or 9 materials, they can be added up to form a sector-wide Material Flow and Stock Analysis (MFSA) Sankey diagram. In some cases, some parts of the sector-wide MFSA can be completed top-down (when data is available or downscaled from higher spatial scales) and others are informed by the addition of bottom-up accounting of flows.

The material stock is only measured at a sector level (and not per material). This is done to give an indication of the available materials in the city, which could be "mined" for future uses. While measuring the material stock is especially relevant for the construction sector, it would also be possible to do so for the biomass sector. In both cases, the measurement of the stock will be rather simplified by developing a top-down accounting, multiplying the material composition of at least one component (for instance a building, one infrastructure, etc.), with the number or linear/square meters from that component. A more detailed bottom-up accounting is also encouraged (but voluntary), which consists of exactly the same procedure as before but adding more instances of each component and more importantly by spatialising them, in order to develop a resource cadastre map.

Finally, another divergence from the EW-MFA method is that **in the proposed accounting framework, there is no material balancing**. In fact, while it would have been a great addition, since the auxiliary materials are not included in the accounting of the SCA, a balancing of the total inflows and outflows is not possible.

To summarise, the MFSA heavily builds on EW-MFA's data sources and structuring, supply chain thinking, indicators and nomenclatures, however, it diverges to make it appropriate for the urban and sector scales and to simplify the workload for the cities, while still being comprehensive. The following sections detail the different aspects of this method to demonstrate how they work when applied and how they are linked, especially when it comes to its final outputs.

4.4.1. Data collection

The core element of this method is a structured data collection process, which later enables its processing into three main analytical outcomes: Sankey diagrams, maps, and indicators. The structuring elements employed for data collection are layers. This chapter explains how they were designed and what the single layers entail. Part 2 (Handbook) further explains how the collection of data is carried out through the CityLoops Data Hub.

Design of Layers

To coherently collect and store necessary data to assess the circularity of sectors, three main layers were designed. The choice of layers was inspired by a prominent urban metabolism article (Kennedy et al. 2014) which collected data for 27 megacities around the world and its further adaptation of the layer structure (Musango, Currie, and Robinson 2017). In these documents, four and five layers were presented respectively (Layer 1: Context, Layer 2: Biophysical characteristics, Layer 3. Urban metabolism parameters, Layer 4: Role of utilities, and Layer 5: Policy frameworks). After some brainstorming, it was decided to slightly modify these layers by including Layer 5: Policy in Layer 1: Context, and by adding infrastructures instead of the role of utilities. The result is visible in the Metabolism of Cities Data Hub (https://data.metabolismofcities.org/).

These layers were tested by more than 50 volunteers from around the world, who collected data for numerous cities during participating in a series of online courses in English and Spanish (https://education.metabolismofcities.org/courses/). Based on the feedback collected from the participants and for the sake of minimising the amount of data requested to produce the analytical outputs, some additional changes were made. Finally, only three layers were set up for the data collection process, each serving a very specific purpose.

Layer 1: Urban context

The first layer includes contextual information of cities about system/city and other administrative boundaries, population, economic activities, policies and land use (see Table 15). All information harvested in this layer considers the entire city, for which most information is required at four different spatial scales, namely the city, NUTS 3, NUTS 2, and country level. The data collected in Layer 1 goes beyond the two focus sectors, as it will also be used during the Urban Circularity Assessment. Its aim is to provide insights into the city to contextualise the flows and stocks (eventually enabling comparison to other scales or other cities).

One of the main originalities of this method is that it is coupled with an online and interactive website that can host all collected data, the Data Hub. As such, when users collect data about e.g. city boundaries, they upload the necessary shapefiles, thus georeferencing their city and all the uploaded data that are associated to this reference space (or system boundary).

Data on economic activities, including employment and GDP/GVA are crucial for all circularity assessments of WP4 (sector, urban and hotspot) as they do not only attach economic features to material flows, but also are invaluable proxies when local data is not available (more information at the downscaling info box in Section 4.4.2). In addition, when some material flow data are not available, it is also possible to look at economic activity information to determine whether the economic activity even takes place in the city and know therefore if there is an associated flow in the area. Lastly, economic data can also be used to form indirect indicators such as resource productivity.

Table 15: Mandatory and optional information of Layer 1: Urban Context

Layer 1: Urban Context	mandatory optional
1.1. Boundaries	m
1.1.1. City boundaries	m
1.1.2. NUTS3 boundaries	m
1.1.3. NUTS2 boundaries	m
1.1.4. Country boundaries	m
1.2. Population	m
1.2.1. City population	m
1.2.2. NUTS3 population	m
1.2.3. NUTS2 population	m
1.2.4. Country population	m
1.3. Economic activity - descriptions	o
1.4. Economic activity - figures (employees and GDP per NACE codes)	m
1.4.1. City employment per NACE codes (at least level 2)	m
1.4.2. NUTS3 employment per NACE codes (at least level 2)	m
1.4.3. NUTS2 employment per NACE codes (at least level 2)	m
1.4.4. Country employment per NACE codes (at least level 2)	m
1.4.5. City GDP or GVA per NACE codes (at least level 2)	m
1.4.6. NUTS3 GDP or GVA per NACE codes (at least level 2)	m
1.4.7. NUTS2 GDP or GVA per NACE codes (at least level 2)	m
1.4.8. Country GDP or GVA per NACE codes (at least level 2)	m
1.5. Policy documents	o
1.6. Land use	m

Similarly, data for population are also important contextual information that enable to situate flows, facilitate comparisons, be used as proxies (when economic data are not available) and finally enable flows/stocks values and indicators to be expressed in per capita terms.

The last contextual information required is land use. Providing (if possible) a (vector) map of land use helps situate flows. In fact, quantities of flows *per se* do not mean much. For instance, it can be expected that a city having land that is mostly covered by agricultural areas will probably extract and circulate more biomass flows than a densely built city of the same population or size. In addition, land use can determine whether some economic activities *really* take place on the ground of the city.

Layer 2: Urban economic activities per material

While the first layer focused on including general information at a city level, Layer 2 and 3 focus directly on the sector under study (construction and biomass respectively) and more specifically on data for the chosen materials of each sector. In fact, from this point onwards, **Layer 2 and 3 are subdivided per sector and their respective materials**. Practically, this implies that in Layer 2 of the construction sector, users will be collecting information on the economic activities for all the life cycle/value chain stages of the 11 selected materials and similarly for the biomass sector this task will be carried out for the 12 selected materials (see Figure 21).

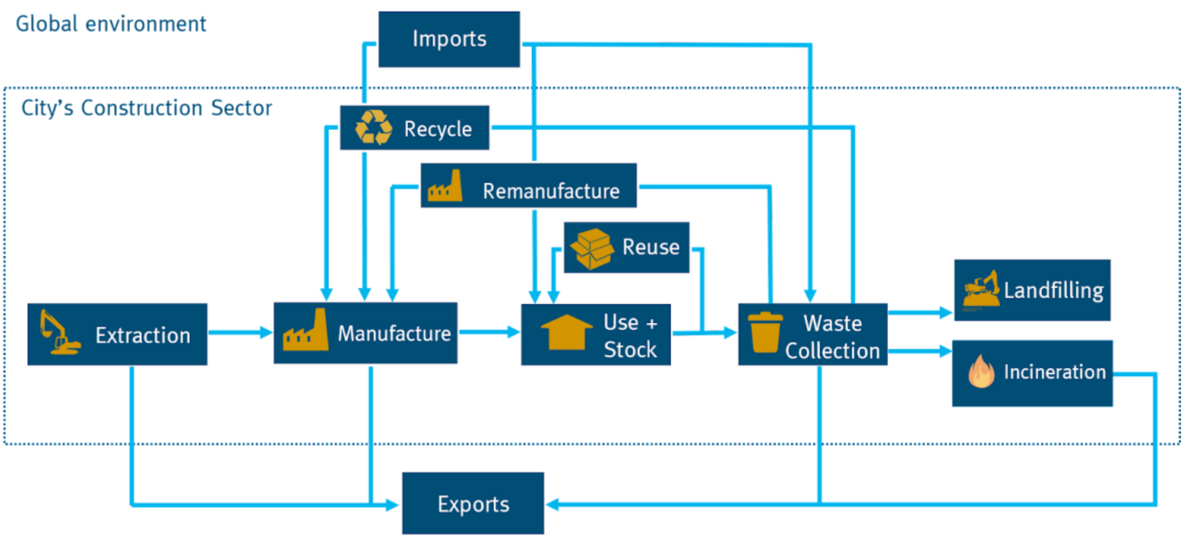


Figure 21: Generic value chain of construction materials

While some information for these two sector-specific layers can be directly used and transferred from Layer 1, other types of information are exclusive to Layer 2. For instance, when the information is material specific the employment and GDP per relevant economic activity can be reused. As an example, if information on *Manufacture of concrete products for construction purposes* (C23.6.1) was collected in Layer 1 then it can be reused for the concrete value chain of Layer 2 dedicated to the construction sector. However, for some materials this becomes slightly more complex. In the case of sand & gravel, while its extraction was covered by NACE code (B8.1.2) in Layer 1, in Layer 2, this information needs to be divided up by material that is using sand & gravel (concrete, glass or sand & gravel as a final product for foundations). In reality it might be difficult to segment which part of the extracted sand & gravel was finally used in concrete or sand & gravel as a final product (especially their actors and infrastructures), but as the value chains are now distinguished per materials it is also essential to distinguish as best as possible one economic activity that is in different value chains to avoid double-counting.

Table 16: Mandatory information of Layer 2: Urban economic activities per material of the construction sector

Life cycle / Value chain stages	Materials	
	Concrete	Sand & gravel
2.1. Extraction	B8 - Other mining and quarrying / B8.1.2 - Operation of gravel and sand pits; mining of clays and kaolin / 08.11 Ornamental and building stone, limestone, gypsum, chalk and slate E36 - Water collection, treatment and supply	B8.1.2 - Operation of gravel and sand pits; mining of clays and kaolin
2.2. Manufacturing	C23.5.1 - Manufacture of cement / C23.6 - Manufacture of articles of concrete, cement and plaster / C23.6.1 - Manufacture of concrete products for construction purposes / C23.6.3 - Manufacture of ready-mixed concrete / C23.6.4 - Manufacture of mortars	N/A
2.3. Use	F41 - Construction of buildings / F42 - Civil engineering	F41 - Construction of buildings / F42 - Civil engineering
2.4. Waste Collection	E38.11.19 Collection services of non-hazardous recyclable waste, other	E38.11 Collection of non-hazardous waste /
2.5. Waste Treatment	E38.11.19	
2.5.1 Landfill	E38.21 Treatment and disposal of non-hazardous waste	E38.21 Treatment and disposal of non-hazardous waste
2.5.2 Incineration	N/A	N/A
2.5.3 Recycling	E38.32.39 Other non-metal secondary raw materials	N/A
2.5.4 Backfilling	E38.32. Recovery of sorted materials	N/A
2.5.5 Remediation	N/A	N/A
2.6. Reuse	N/A	E38.32 Recovery of sorted materials
2.7. Remanufacture	N/A	N/A
2.8. Imports	H49.2 - Freight rail transport / H49.4.1 - Freight transport by road / H50.2 - Sea and coastal freight water transport / H50.4 - Inland freight water transport / H51.2.1 - Freight air transport	H49.2 - Freight rail transport / H49.4.1 - Freight transport by road / H50.2 - Sea and coastal freight water transport / H50.4 - Inland freight water transport
2.9. Exports	H49.2 - Freight rail transport / H49.4.1 - Freight transport by road / H50.2 - Sea and coastal freight water transport / H50.4 - Inland freight water transport / H51.2.1 - Freight air transport	H49.2 - Freight rail transport / H49.4.1 - Freight transport by road / H50.2 - Sea and coastal freight water transport / H50.4 - Inland freight water transport

Apart from this distinction of economic activities per materials, Layer 2 goes one step further by providing more information on the actors behind these economic activities and when/if possible geolocalises them. By putting economic activities on a map, it quickly becomes apparent which actors need to be present when planning for a circularity roadmap at a sectoral level. Geolocalising the actors could also help to spatialise the flows in Layer 3 and enable potential material exchange between companies (bridging demand and supply of materials in an industrial symbiosis fashion).

Table 16 exemplifies the economic activities (and their corresponding NACE codes) that are related to concrete and sand & gravel, two materials of the construction sector. In this table, the relevant extraction activities for each material are put forward in sublayer 2.1. In the case of sand & gravel, the extraction activities related are quite straight forward. For concrete, however, all its primary materials have to be included water, gravel & sand and the primary materials for cement (clay, sand, gypsum). As mentioned before, there are no economic activities for sand & gravel manufacturing, whereas there are many for concrete. Similarly, all other cells of the following table are filled up, by looking for the most appropriate NACE codes for each value chain stage per material.

Once all the relevant economic activities for each material are identified, it is possible to illustrate its respective value chain, for which Layer 3 is going to fill the material flow data (see example for concrete in Figure 3). In addition, by superposing the value chains of each material for each sector, it becomes possible to develop an overall value chain for the entire sector.

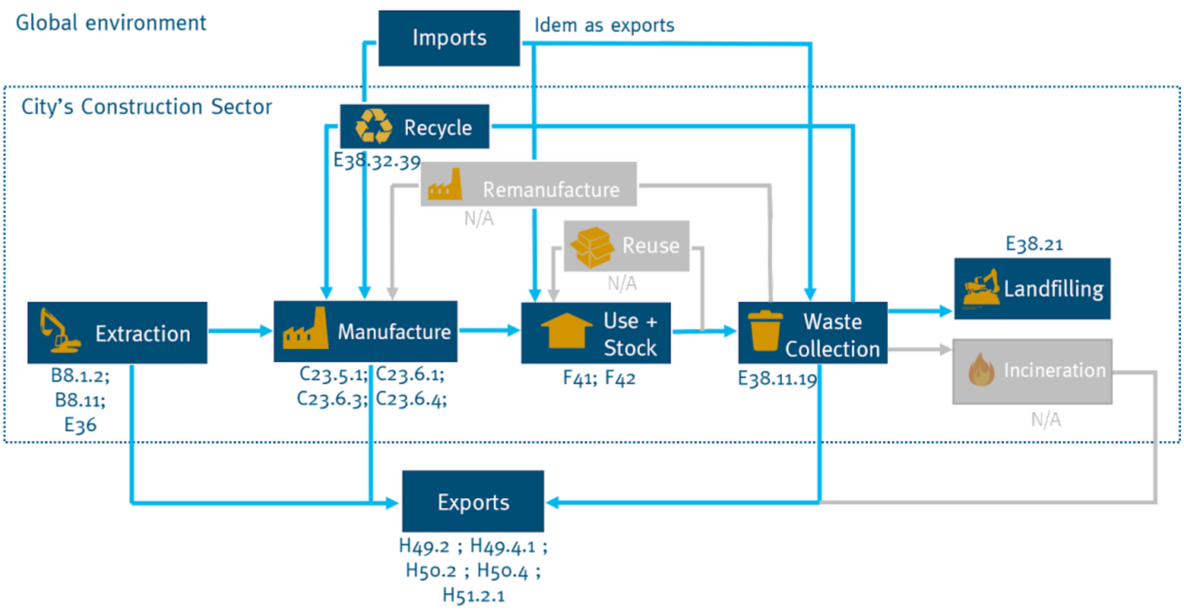


Figure 22: Value chain of concrete using relevant NACE codes

Layer 3: Flows (and stocks) per material

Layer 3 is the physical counterpart to Layer 2 and requires adding of material flows and stocks values to the constructed value chain for each of the materials of the sectors. In other terms, **while Layer 2 provided information on the nodes/boxes of the value chain, Layer 3 will provide information on the flows/stock of the diagram**.

The material values for both flows and stocks are following the nomenclatures which were presented before (see Chapter "Classification of materials"). The easiest way to translate the value chain diagrams into material flows and stocks, is by using the CPA nomenclature, which simply adds products that are nested within economic activities.

Nevertheless, in some cases, CPA codes do not cover all material flows and other material nomenclatures have to be used to describe them. In fact, the previous figure (Figure 22), simplified the diagram to include all steps of the value chains but did not include all possible flows to enhance legibility. In reality, a more complete picture of this diagram, including all flows/stocks which need to be included in Layer 3, are presented in Figure 23.

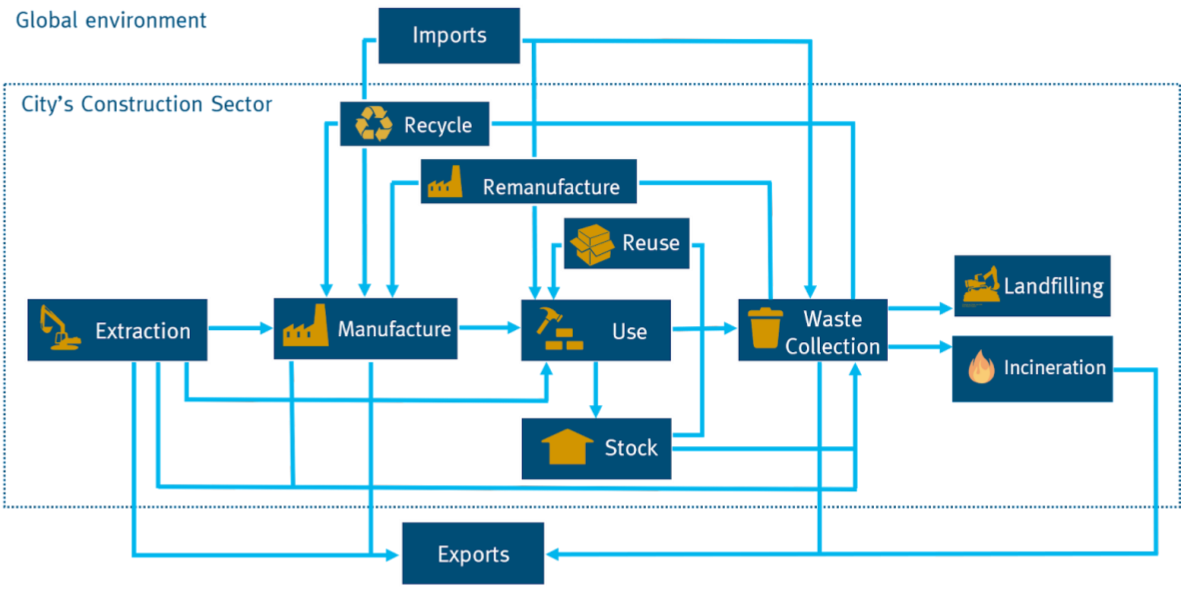


Figure 23: Generic flow diagram for construction materials

Some of the notable additions of this diagram are more comprehensive links of flows between each of the economic activities, for instance the addition of extraction and manufacturing waste flows, and the separation of the stock from the action of construction. Similarly to Table 16, it is possible to construct a Table for the mandatory information for Layer 3 (Table 17). The latter is a bit less detailed than Table 16, to keep data collection simple. However, the source and destination of each flow (whereas before just the activity was included) are then dealt with in the Sankey diagram and the table template for that. Some additional elements in this table are the material nomenclatures, which can be used to find and collect data.

Similarly to Layer 2, all sublayers of Table 17 are mandatory. The mandatory ones enable to cover all the flows present in Figure 23 and as such it is possible to produce a synthetic Sankey diagram per material and by adding up all the materials, a synthetic Sankey diagram for the sector.

To further open up some "black boxes" of the flow diagram, some flows are then split up for the Sankey diagram. For instance, in the current flow diagram all waste flows are first bundled up as waste collection, and then they are subdivided according to their waste treatment. However, in this way, it becomes impossible to discern from which life cycle stage waste ends up in a certain valorisation method. Thus, it is difficult to directly target economic activities that need to reduce the waste sent to incineration or landfill. For this purpose, this is dealt with in the Sankey generating stage and not the data collection phase where it can be detailed how each generated waste flow is treated. This was made as such, as it might be difficult for cities to know which treatment each type of waste receives.

Table 17, provides an example for the material "concrete" and gives information on the material nomenclature for which data on concrete can be found, as well as denotes all non-applicable (N/A) fields.

Table 17: Mandatory and optional information of Layer 3: Flows and stocks per material of the construction sector; with optional information marked as grey

Life cycle / Value chain stages	Nomenclature	**Material:** Concrete
3.1. Extraction		Sum of all (mandatory) extraction flows
3.2. Manufacturing	-	-
3.3. Use (construction/renovation)	CPA	41 Buildings and building construction works, 42 Constructions and construction works for civil engineering
3.4 Stock		Measurement of material stock
3.4.1 Reuse (stock to use)	CPA	Same as 3.2.1
3.5. Waste flows		Sum of all waste flows
3.6. Imports and exports	NST	Sum of all (mandatory) flows to exports and from imports

For the material stock, a separate calculation is made and as mentioned before, it is only measured at a sector level. Information collected for the material stock are the number of building environment elements (number of buildings, length of roads, etc.) and a material composition (share of construction materials that constitutes these elements) per element. Optionally, cities can choose to spatialise their material stock, which would include the same elements as before, but also a shapefile with the built environment's respective location.

4.4.2. Data processing

Once all data is identified (in form of reports, spreadsheets, maps, etc.), correctly uploaded to the CityLoops Data Hub (https://cityloops.metabolismofcities.org/) and the appropriate sublayer, the next step is to process the data. In other terms, it means to make the data more machine readable in order to automatically generate relevant visualisations such as line/bar/area/pie charts, choropleths, geolocalisation and ultimately a Sankey diagram. To do so, it is necessary for the system to understand which spatial boundaries, which time period, and which materials are considered.

The first step in data processing is to process the relevant shapefiles that will be used as the city boundaries. The data processing tab of the CityLoops Data Hub ([e.g. for Apeldoorn]) goes through the processing of shapefiles which consists of visual confirmation that the uploaded shapefile previews correctly and then identification of the column which contains the names of the reference spaces. Once the shapefile containing the city boundaries is processed, it can be set as the city boundary and all processed maps and geospatial spreadsheets can be visualised in one master map (see for example Figure 24).

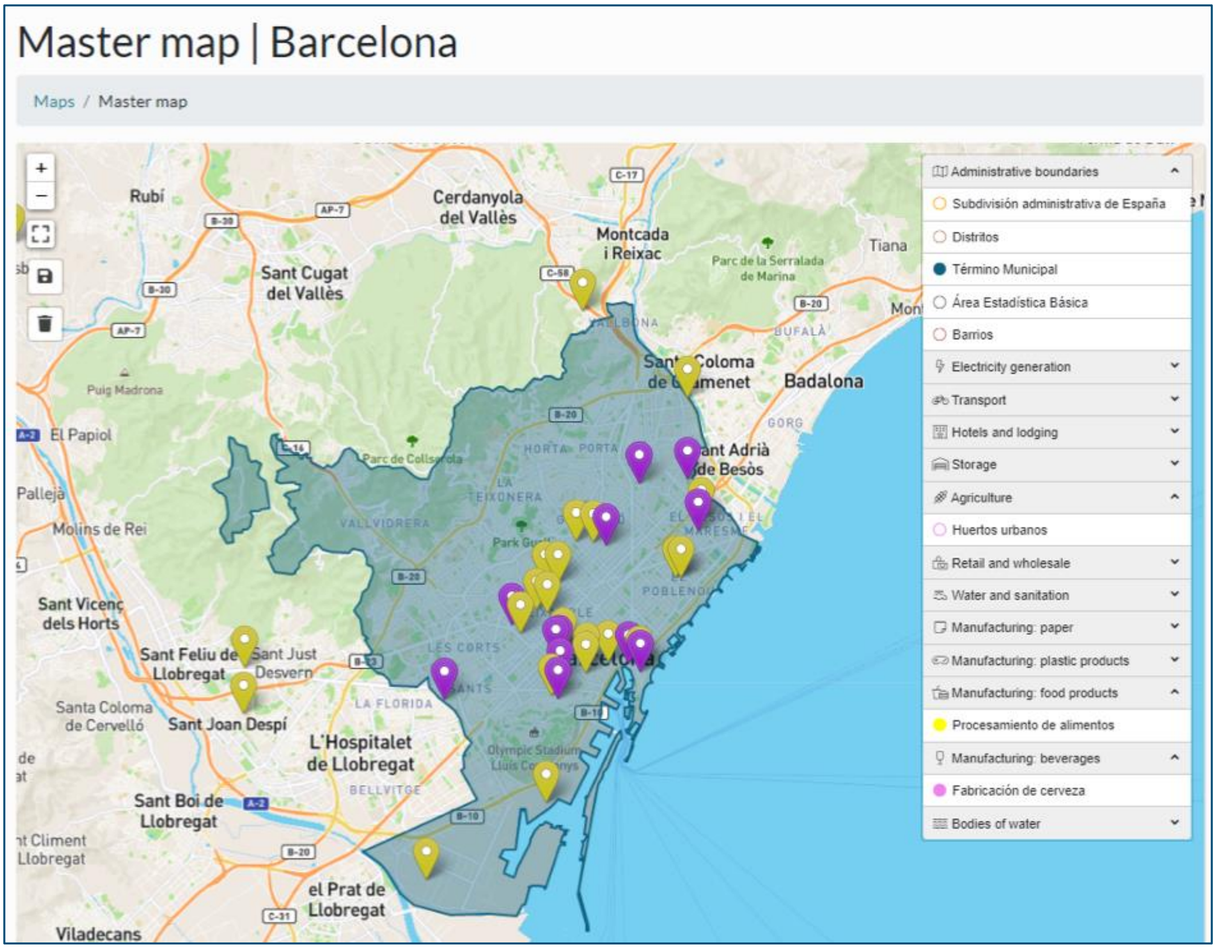


Figure 24: List of food manufacturing plants in Barcelona illustrated in its Master map (https://data.metabolismofcities.org/dashboards/barcelona/maps/overview/)

The geospatial spreadsheets are especially relevant for Layer 2 as it can map actors, infrastructures, economic activities, etc. (see example Figure 24). To process those, information collected should be formatted according to Table 18.

Table 18: Formatting template for geospatial spreadsheets

Name of company/infrastructure	Latitude	Longitude
Company A	y°	x°
Infrastructure X	y'°	x'°

Nevertheless, the most important data to be processed for SCA are the flows and stocks data. To do so, another formatting template is provided and needs to be used to transform reports and spreadsheets to actionable visualisations. Table 19 provides two different examples for processed data precising:

- the period for which this flow was recorded (the time period can be as flexible as necessary),
- the material name, which should coincide with the (11+12) materials for the construction and biomass sector,
- a material code (so far an adapted EW-MFA nomenclature (https://staf.metabolismofcities.org/materials/25935/, called Energy, materials and products (EMP) catalogue) is being used, but others can also be used),
- the quantity and unit measured of the flow (in most cases the unit used will be tonnes)
- the reference space where the flow occurred (in most cases the city boundaries, but it can also be a district or even an infrastructure, which has been geolocalised),
- finally, a comment section is available to add more details, remarks or precautions.

Table 19: Formatting template for stocks and flows data with example data

Period	From (date)	To (date)	Material name	Material code	Quantity	Unit	Reference space	Comments
2013	2013-01-01	2013-01-31	Sand and gravel	EMP3.8	1000	t	Porto	Sand
2014	2014-01-01	2014-12-31	Fruits	EMP1.1.8	800	t	Porto	Apples

All the necessary template files that need to be used for processing the collected data can be found in the processing tab of each city (see for example in the screenshot for Apeldoorn, https://cityloops.metabolismofcities.org/dashboards/apeldoorn/hub/processing/datasets/, in the Figure of "Step 2: Data processing" in Part 2).

DOWNSCALING DATA

As it was discussed during the 1st stakeholder engagement workshops, which took place in each CityLoops demonstrator city, to assess preliminary data availability, some data might not be available at city scale. For instance, imports and exports data are hard to find at a city level, yet they are crucial to ensure a comprehensive overview of the two sectors. When this occurs, it is recommended to make approximations. The preferred way in the SCA method is to downscale (or sometimes, but more rarely, upscale) data from a higher spatial scale (e.g. national level) to the city scale using a proxy. It is precisely for this reason that data for Layer 1 are collected on many different scales (to ensure that data is at least available on one of them).

The proxy to be used can vary depending on the flow to be downscaled. For instance, for all flows related with economic activities, the most appropriate data is number of employees, followed by GDP or GVA. In fact, it can be considered that economic activities throughout the country under study employ the same ratio of people per tonne of material transformed. This is not necessarily true for GDP or GVA as in some cases a territory can have a high GDP only because a headquarter is present, but not necessarily a productive plant. For some extractive activities (especially in the biomass sector), land use can also be a good proxy if it can be supposed that land productivity is similar within a country. Lastly, when residential flows/stocks are considered, population can be considered as the best proxy.

Finally, in order to downscale data, a simple proportionality rule can be applied (see equation), and as a rule of thumb, data that is available at the closest spatial scale (in terms of size) to the city boundary is preferred.

$$Data_{city} = Data_{higher\ spatial\ scale} * (proxy\ value_{city} / proxy\ value_{higher\ spatial\ scale})$$

4.4.3. Data analysis

The last element of the hybrid Material Flow and Stock Accounting method developed in this report is the analysis of the results produced by the processed data. These come as online visualisations and a number of indicators which together form a sector circularity dashboard (which is still under construction) for the cities. The results from this analysis can also be grouped to form an online report that can dynamically link all the visualisations made.

Data visualisations

Three main data visualisation families can be produced with the data processed: traditional charts, maps, and Sankey diagrams. Traditional charts can be used to visualise individual material flows and stocks datasets. These help to turn "*boring*" tables into understandable insights. As it is visible from the top of Figure 25, different charts can be implemented from a single dataset and used to point out a particular insight.

In the previous sections, examples of maps were illustrated and these can be of two kinds. Either geolocalisations of actors, infrastructures, etc. or choropleth maps, which display the spatial distribution of a flow or stock.

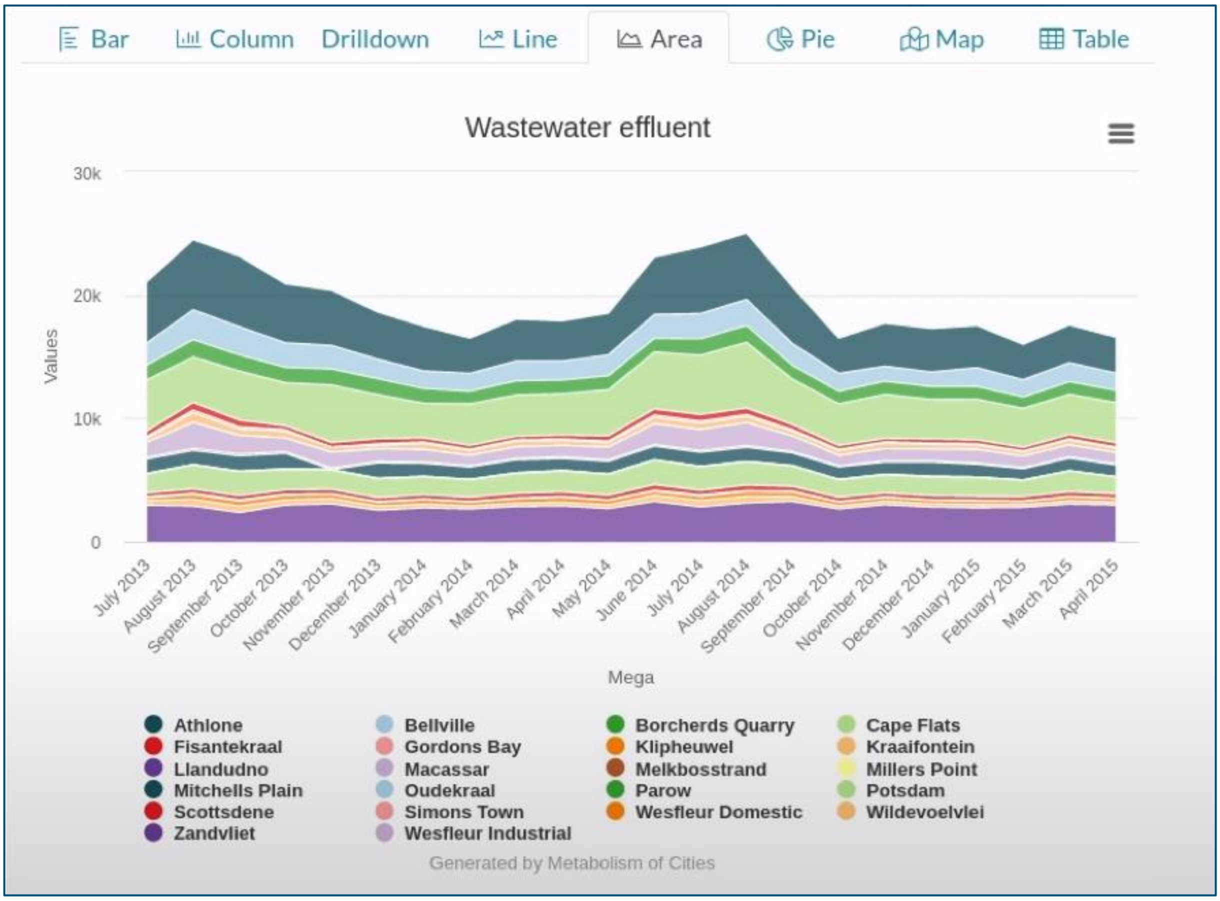


Figure 25: Examples of data visualisations from the Metabolism of Cities Data Hub

The final type of data visualisation that can be produced through the processed data is a Sankey diagram. Two different Sankey diagrams will need to be produced, one at a material level (11 for the construction sector and 12 for the biomass sector) and one at a sectoral level. Both will use the flow diagram presented in Layer 2 and 3 in order to build the structure of the diagram and the processed data will serve to provide the thickness of the flows. To facilitate the construction of these Sankey diagrams, template files will be developed in order to automate their visualisation. These template files will only be used for mandatory collected data from Layer 3 and as such not overburden urban administrations with another data collection and processing step.

Indicators

The final element that will be developed in the Data Analysis step is calculating the indicators presented in the previous sections (see Chapter 3.3.2). Similarly to the Sankey diagram, all necessary data to calculate the indicators will have been collected and processed through

Layer 1, 2 and 3. For instance measuring the Direct Material Consumption indicator will consist of adding extraction flows to imports flows and subtracting export flows. Information from Layer 1 could be helpful to create composite indicators such as DMC/cap or DMC/GDP. The calculation and analysis of the indicators in conjunction with the material flow and stock accounting develop a solid understanding of how circular the construction and biomass sectors are at a certain point in time, as well as identify some pressure points. It becomes not only possible to create a material overview of the sector, but also to evaluate whether the sector is progressing towards a more circular state. To conclude, this sector-wide circularity assessment is an important support tool to urban administrations which are starting or scaling up their circularity journey.

Part 2: Sector-Wide Circularity Assessment – Handbook

Welcome to the Handbook for the Sector-Wide Circularity Assessment (SCA), a combination of an urban material flow and stock accounting method and indicators that evaluate the "circularity of a sector". The SCA is a method that was developed for the EU Horizon 2020 CityLoops project and this handbook will outline it, by answering the following questions:

- Why should cities carry out the SCA?
- What is the SCA?
- What are the outputs of the SCA?
- What are the steps of the SCA?

This handbook is meant to give an introduction to and an overview of the SCA. It is complementary to the online data collection, processing and analysis courses that are given to the CityLoops cities from February to June 2021, which encompass video instructions and weekly meetings (https://cityloops.metabolismofcities.org/instructions/). This document should therefore be seen as a light version or living document until it becomes a fully-fledged handbook at the end of the CityLoops project. It should be understood as such, since the CityLoops Data Hub (https://cityloops.metabolismofcities.org/), the repository for the data and the connected dashboard, have not been fully built yet, so some functionality, structure and design will still change. Moreover, the method has not been tested yet and necessary clarifications will only become evident after a first application of it. Lastly, the cities' yet to be gained experience with data (non-)availability and choice of indicators could also have an impact on the method and thus the handbook.

In this handbook, Part 2 of Deliverable 4.3 "Sector-Wide Circularity Assessment (SCA) Method", sometimes reference is made to "Part 1: Sector-Wide Circularity Assessment – Method Development", which can be seen as a background document to this handbook, detailing the development of the method and all its components. Both documents, Part 1 and Part 2, as well as others that these build on can be found in the Deliverables section of the CityLoops Data Hub: https://cityloops.metabolismofcities.org/reports/

Why should cities carry out the SCA?

Before explaining the SCA in detail, it is helpful to start with an inspirational WHY - why should cities carry out the SCA - for cities to understand the reasons and benefits of a method that helps them assess the circularity of a sector and be motivated to take advantage of it:

- **Make data visible:** At its most basic level, the SCA makes data that cities have or have access to visible, by digging them out of drawers and locally stored files on computers and putting them in a centralised place.

- **Break silos:** Looking for and making data visible also opens up silos that city departments often operate in due to their organisational nature and working structures. Breaking silos (of information) can uncover data that other departments were not aware of, can benefit from and potentially allow for better communication around data needs. It can also highlight areas where it is possible to start collaborating on, ideally creating synergies, but that is its own point.
- **Put material into context:** The materials that the cities deal with in the Demonstration Actions are, on their own, not representative of the whole sector that they are in. By analysing a number of other material (flows) that in this group embody the sector better and gaining information on the sizes of those, the material of interest to a single city or DA can be seen in context and its significance understood.
- **Understand the big picture:** By studying a number of materials, along various elements of the value chain, throughout a sector, and ideally over more than a year, cities will, possibly for the first time, see the big picture of a sector in their city. They will also gain insights about the sectors' complexities, main challenges and efforts that are needed to be carried out in order to achieve their objectives and goals.
- **Establish a status quo:** If they do create this big picture for the first time, they will simultaneously establish a first status quo. This baseline will give them a starting or reference point for their analysis, efforts and policy making in the future and also for the evaluation framework in CityLoops that the assessment is primarily designed for.
- **Inform policy making:** With the status quo and the big picture, a city is given a basis from which they can optimise planning and develop policies that are holistic, context-specific, and informed and supported by hard values. In an iterative process, they could even carry out the assessments over and over to track the efficacy of their implemented policies.
- **Put DAs into context:** Aside from having the materials in a larger context, the DAs themselves also need to be understood as part of a larger "ecosystem". This ecosystem is made up of stakeholders and supply chains that are uncovered through the SCA, by spatialising and disaggregating as much as possible the metabolic flows and stocks and economic activities, infrastructures, and actors associated with them.
- **Upscale DAs:** By obtaining insights on both the material and waste flow sizes and the economic landscape in the city, cities will be able to develop informed circularity upscaling plans (WP7). They will be able to determine where the DAs can be further expanded and how much capacity there is. It may also help to directly support the implementation of the demonstration actions themselves through indicating relationships and pressure points.
- **Unlock circular hotspot analysis:** Determining the circularity of a single sector lays the groundwork and unlocks the ability to do a "circular hotspot analysis" (later in WP4). The hotspot analysis will uncover the sectors to be prioritised, since one of their material flows or part of the value chain is significant, either in terms of size or economic importance, and very linear.

What is the SCA?

The Sector-Wide Circularity Assessment is a combination of (1) an urban material flow and stock accounting method and (2) indicators that evaluate the circularity of a sector. It seeks to create an understanding of an urban sector, its economic significance, material flows and stocks, related infrastructure, and stakeholders to capture, assess and present its situation around closed material loops and harmful resource use.

For its application, three steps have to be carried out (see “What are the steps of the SCA?”). In order to better understand the overall picture, the various SCA aspects are described as follows:

Context

To describe the urban and sector context, the SCA requires some main status quo characteristics. For this, data on population, land use and city boundaries need to be collected. By employing those local values, the analysis becomes context specific and relevant to the local sector.

System scope

The “system” that the SCA considers is the sector in a city. The SCA is not only going to be applied to demonstration actions (DA) of the CityLoops project, but the entire sector (see “Sectors") that they are connected to. The sectors are geographically limited to the city boundaries, although their in- and outflows from outside of those boundaries are accounted for (i.e. imports and exports). This is to stress that it is not a “global sector” that is studied (for instance, the global construction sector).

Sectors

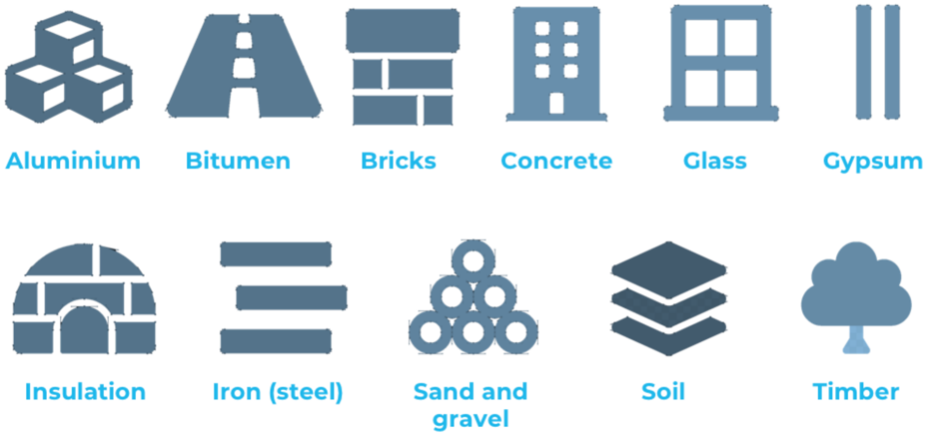
The SCA was developed for two sectors: construction and biomass. The sectors are defined by the materials that represent them (see “Material scope”). To be informed on the local size and (economic) significance of a sector, the numbers of companies and employees as well as GDP, gross value added (GVA) and names of the associated stakeholders are collected.

Material scope

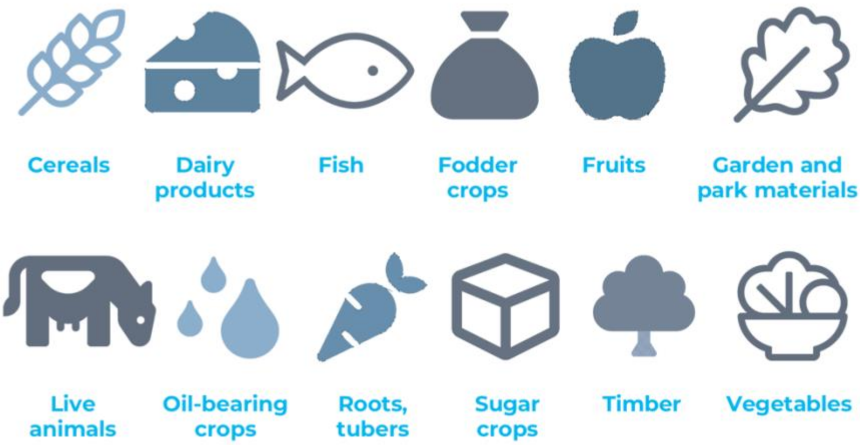
The material scope of the SCA focuses on the materials that typically make up the main share of a sector by nature, while ensuring that they encompass the materials that are dealt with in the demonstration actions in the CityLoops project. While it could be argued that the materials should be limited to those of the DAs or a single city focuses on a single material, the scope needed to be broadened to properly represent these two sectors. The additional materials that were selected beyond those of the DAs, were calculated to make up a vast majority (> 65%) of the sector’s mass[i].

[i] More detailed information on the calculation can be found in Chapter 3.2.2 of Part 1.

The ***construction sector*** is made up of 11 materials namely aluminium, bitumen/asphalt, bricks, concrete, glass, gypsum, insulation (plastics based), iron (steel), sand and gravel, soil, and timber.



The ***biomass sector*** is represented by 12 materials: cereals, dairy products, fish, fodder crops, fruits, garden and park materials, live animals, oil-bearing crops, roots & tubers. sugar crops, timber, and vegetables.



Indicators

Since the goal of the method was to be aligned with and satisfy the definition of CityLoops' circular economy and circular city definition, the indicators used to evaluate the circularity aim were selected to build on those. The sectors are linked to strategic objectives that attempt to represent if overall the material loops were closed and overall consumption of resources is reduced. A set of indicators was selected for each sector. The list of indicators can be found in "Step 3: Data analysis".

What are the outputs?

There are three main outputs that the SCA can produce: sector understanding, a data dashboard, and a report.

Sector understanding

Arguably the most important, albeit the least tangible outcome of the SCA is the understanding of the sector and its circularity. This really is the final product of the SCA that will especially be internalised by the person(s) carrying out the analysis, but that is ideally captured and consequently shared and made available to the public by various means.

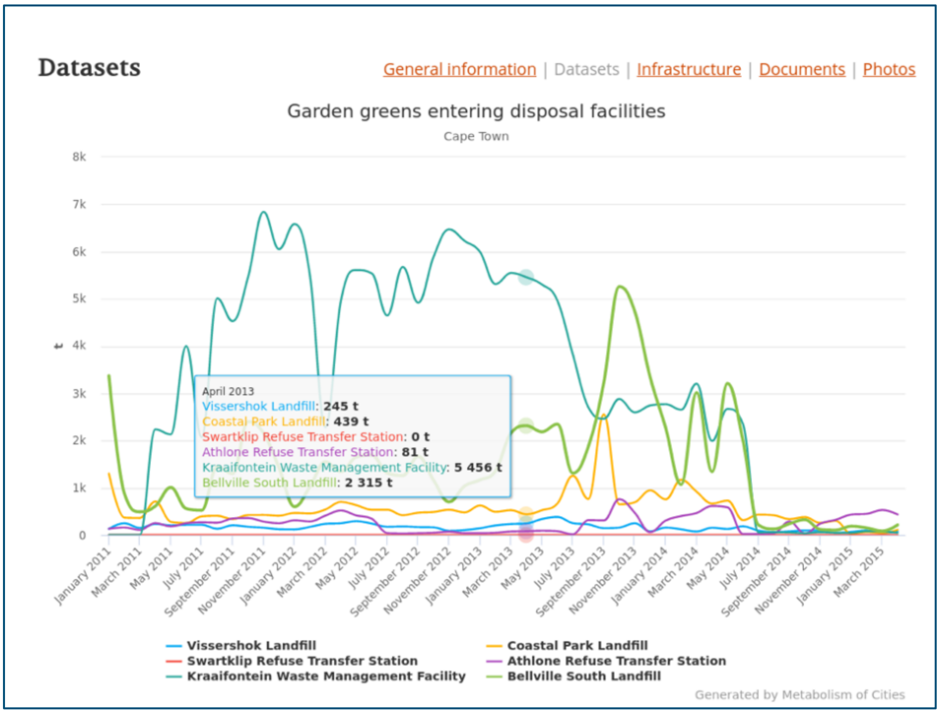
This understanding of the sector level includes detailed knowledge around the size of the sector in terms of economic output, employees, specific parts of the value chains that are covered in the city, location of infrastructure, and diversity of stakeholders. Moreover, the sector can be apprehended in terms of the composition and magnitude of material flows that move through it. Even without indicators, a physical understanding of the system is generated. Yet, the indicators that are fed by the various data points eventually reveal and allow for an assessment of a sectors' circularity (and the progress towards it), which can be checked for single so-called strategic objectives. Overall, the SCA exposes what happens in the sector of that city and uncovers a metabolic status quo.

Data dashboard

To represent the metabolic functioning of the sector, a data dashboard will be created for each sector and eventually per city, after the Urban Circularity Assessment (UCA) has been developed. The dashboard will link to all collected and processed data and bring them to life in the form of visualisations and indicators.

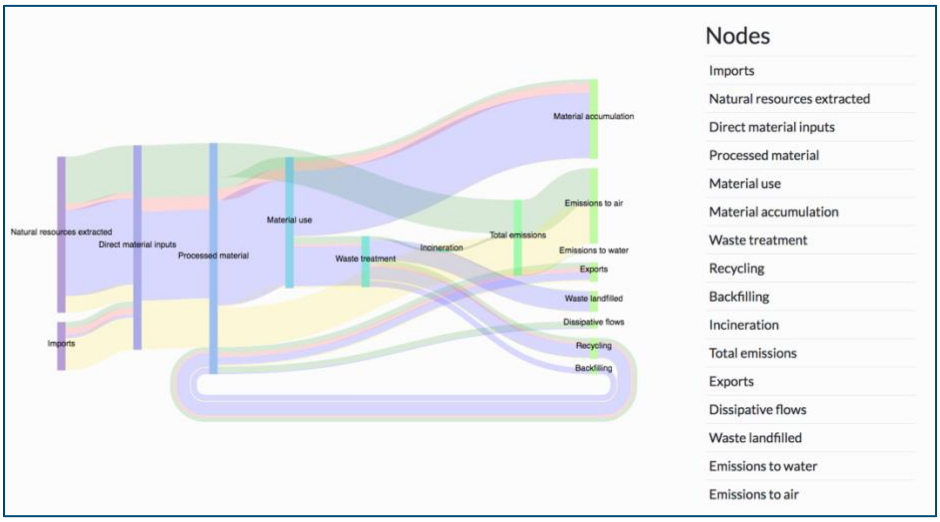
Placeholder for dashboard that is yet to be developed

Those visualisations will illustrate the data of the sector, depending on the type of data, either in traditional diagram styles such as bar or pie charts or as synthetic Sankey diagrams. The Sankey diagram will play a central role in the dashboard and depict not only the proportions of the flows, since they are in relation to each other, but also contain the actual values for that city's sector.



Line diagram of a single dataset.

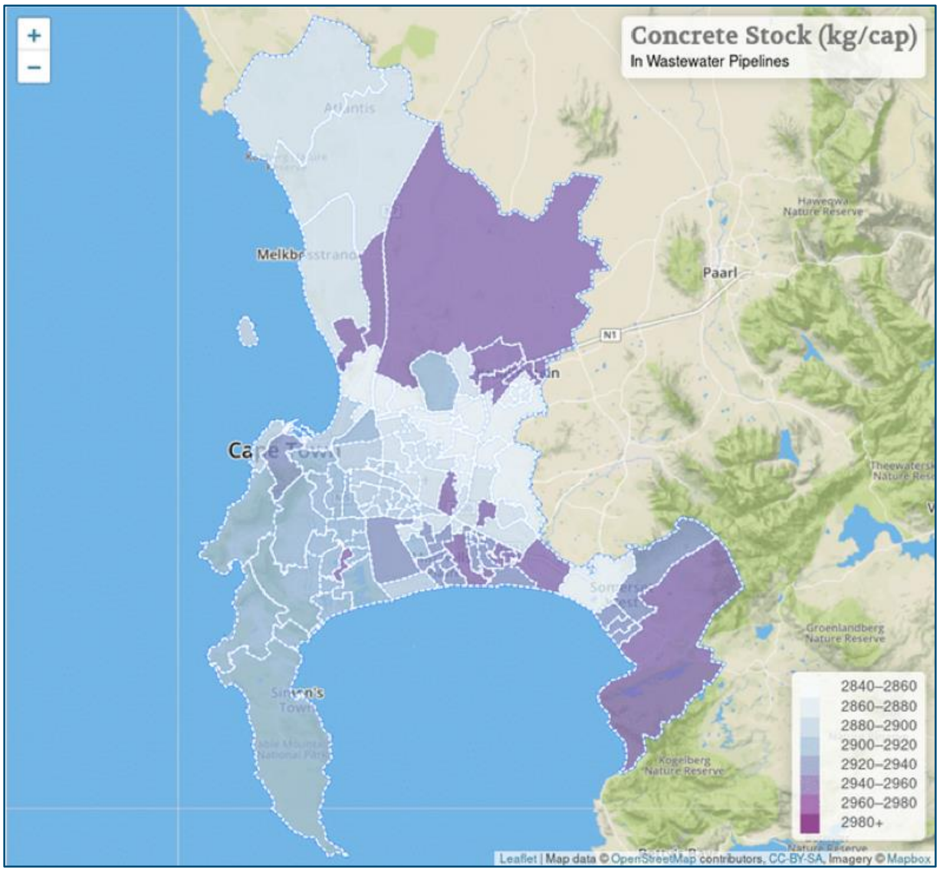
***Helps cities to** gain in-depth insights into single materials in a material group or development over time.*



Sankey diagram displaying the various material flows and their pathways

***Helps cities to** get a quick overview of the significance of all materials in a sector for one year.*

The geospatial data is made available and visualised in the form of maps. There are a number of map types. Some show areas on a map, such as those that illustrate land use, whereas others depict the location of certain infrastructure, as for example mines or recycling plants. They all come together in the "master map", see the one of Porto, for example: https://cityloops.metabolismofcities.org/dashboards/porto/maps/overview/



Material stocks mapped in various districts of a city, here the concrete stock in Cape Town

Helps cities to *better explore the urban mine and manage secondary resources.*

Infrastructure mapped in the city

Helps cities to *see either clusters or single locations of infrastructure and actors of a sector.*

Infrastructure mapped in the city of Porto

Helps cities to *identify (missing) actors and initiate potential industrial symbiosis strategies.*

The indicators of the dashboard have their own illustrative function. They are an essential part of the SCA in any case, because otherwise it would not be possible to determine how the quantified flows and stocks are faring. They give away the status quo and a first baseline from where cities can focus on improving their circularity in the future. Since the indicators and strategic objectives are linked to the Sustainable Development Goals (SDG), the dashboard features them as well.

While indicators can provide information as to how circular the sector is, there is not a unique circularity value or single score that says that city ABC is XY circular. There are not any aggregated scores for the strategic objectives either. This is because the indicators are already limited in number and the system has to be seen holistically and evaluated at its various parts to determine the situation of its leverage points, instead of being masked in a combined value.

Report

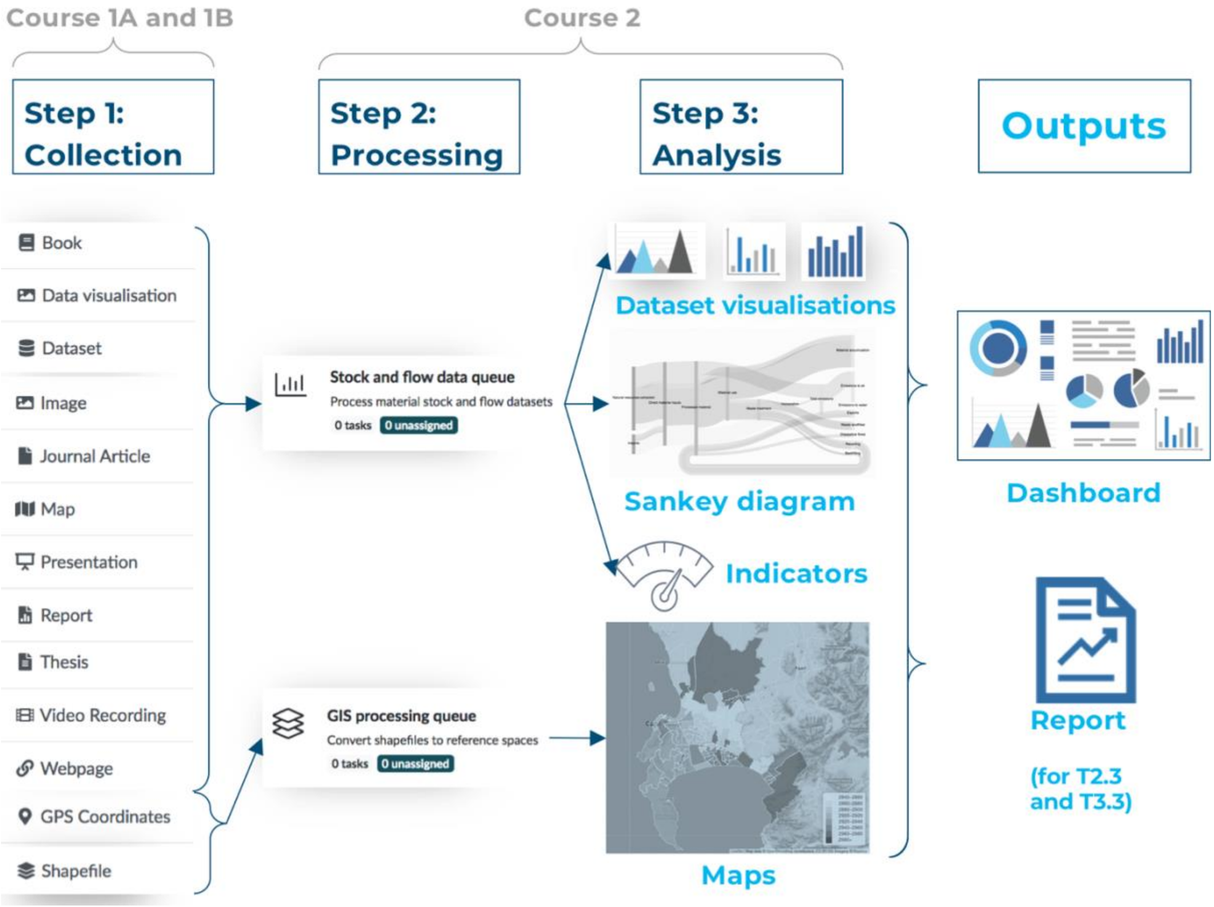
Upon taking the courses for data collection, processing and analysis, it is on the person responsible for a city to create a final report for the sector. A template for this report will be provided and it is anticipated that it will be around 10-15 pages long (without references). The template can be filled in on the Data Hub and will benefit from a semi-auto generation of the structure and placeholders for the visualisations there. After filling in the text and assigning figures to the placeholders, the report can eventually be exported as one comprehensive report in standard file formats (Word, PDF).

The final report will contain the following:

- some general stats around the city and the sector,
- many visualisations from single datasets as well as flow diagrams that are generated on the site,
- insights from the data analysis course, including the indicator evaluation,
- reflections on how the demonstration actions (DA) put in place can alter the degree of circularity
- reflections on how to upscale and expand these DAs to get a sector more circular.

What are the steps of the SCA?

The SCA requires three steps to be followed, which are (1) data collection, (2) data processing, and (3) data analysis. The graphic below illustrates the outputs of the single steps as well as the overall outputs.



Step 1: Data collection

Step 1 is all around data identification and collection, following a data collection structure (Layers) to assess the situation around data availability and the completeness of data and do the field work for Step 2.

Step 2: Data processing

Partly in parallel to the data collection in Step 1, partly thereafter, **Step 2** revolves around processing the data (and modelling the flows and stocks). That means that the collected and uploaded data will be converted so that it can be loaded into a single database in the online Data Hub for easier handling going forward. This process will help to identify data gaps and includes the approximation of data in the case where there is none for the city scale.

Step 3: Data Analysis

Following the collection and processing, **Step 3** is where it all comes together for the analysis. Taking all the processed information, a system-wide look will be taken across the inflows and outflows to better understand what is going on in the sector. Data visualisations (incl. Sankey diagrams) and the indicators will be evaluated to connect the various parts of earlier work and get new insights.

There is much more to these single steps and the following part therefore describes the HOW - how is the method carried out - conducting the three necessary steps, including the tools and data necessary for them.

Step 1: Data collection

Data collection is the first step of the SCA and almost all the necessary data will be collected first before processing it in any way. The reason for doing all the data collection in one step, is to assess completeness of data for the sector and therefore also identify gaps, which can be filled with downscaling calculations (see info box in Step 2). The more comprehensive and accurate the data, the better the potential for a good understanding of the sector and circularity assessment.

There is already a lot of existing data, hence in principle, there is no need to generate or collect primary data. Cities have their own economic data and local waste management companies, regional and national statistical offices, urban/provincial/state administrations etc. have even more available data (see info box "Existing data"). But finding, collecting and cataloguing it correctly (for future use), is the more challenging part.

EXISTING DATA

A great deal of existing datasets and data portals already exist on the internet. The Metabolism of Cities community has been collecting and cataloguing datasets on the Metabolism of Cities Data Hub in the "Library section" (https://data.metabolismofcities.org/library/datasets/) and the data portals in the Metabolism of Cities Library https://library.metabolismofcities.org/list/dataportals/. The items are listed with a brief description and meta information.

Eurostat datasets
A special group of existing datasets are the ones from Eurostat. There are 8,037 unique datasets across a wide range of themes. Metabolism of Cities has already reviewed, identified and tagged the relevant ones and put them in the "Eurostat grid" https://cityloops.metabolismofcities.org/eurostat/grid/.

During the data collection process: two types of data are required, namely numerical data (those in spreadsheets) and spatial data (e.g. maps and points on maps that come from geospatial spreadsheets and so-called shapefiles). To make it easier to follow what is needed, and understand what themes certain datasets belong to, it was necessary to structure the data collection. For this, "Layers" were introduced. There are three distinct layers:

- Layer 1: Urban context
- Layer 2: Urban economic activities per material
- Layer 3: Flows (and stocks) per material

Those Layers, which will be described in more detail just below, are set up in the CityLoops Data Hub (see info box), which is where Step 1 will take place.

CITYLOOPS DATA HUB

The CityLoops Data Hub (https://cityloops.metabolismofcities.org/), previously also referred to as the repository, is a subsite of Metabolism of Cities that exists specifically for the 7 CityLoops (CL) cities of the project. This place serves as the central location for data that can be accessed openly and collaborated on with any (freely) registered user, which allows for fairly easy data management. On this subsite, the system is structured and ready with various layers and sublayers for each city to be filled by the respective evaluation managers and other people working on that city, as several people can work on the same city. There will be construction / biomass materials specific layers (as part of WP 2 and 3).

The visualisations of the single datasets and system diagrams will be displayed within single cities' dashboards, respectively. The cities can take advantage of this interactive platform, which also includes a forum, and can engage with users in online collaboration and community building.

The "Circularity" tab of the menu will be the go-to place for the cities, since the tools (data inventory, dataset library, data processor) for data collection and management will be found there.

In short, the CityLoops Data Hub, is the place where the data is collected, stored, processed, visualised and analysed. Eventually, it is here where a data dashboard for each city is created. The Data Hub is not fully set up yet and some abilities are hidden for now.

- Link to the CityLoops Data Hub: https://cityloops.metabolismofcities.org/
- Forum: https://cityloops.metabolismofcities.org/hub/forum/

Layer 1: Urban context

Layer 1 is about providing context for the city. It seeks data on the cities placement in their region, through geodata, spatial boundaries, population numbers, economic activities at city level, policy documents, and land use. Since Layer 1 is on the overarching scale of the city, it is the same for the construction and biomass sectors.

Layer 1: Urban Context	mandatory optional
1.1. Boundaries	m
1.1.1. City boundaries	m
1.1.2. NUTS3 boundaries	m
1.1.3. NUTS2 boundaries	m
1.1.4. Country boundaries	m
1.2. Population	m
1.2.1. City population	m
1.2.2. NUTS3 population	m
1.2.3. NUTS2 population	m
1.2.4. Country population	m
1.3. Economic activity - descriptions	o
1.4. Economic activity - figures (employees and GDP per NACE codes)	m
1.4.1. City employment per NACE codes (at least level 2)	m
1.4.2. NUTS3 employment per NACE codes (at least level 2)	m
1.4.3. NUTS2 employment per NACE codes (at least level 2)	m
1.4.4. Country employment per NACE codes (at least level 2)	m
1.4.5. City GDP or GVA per NACE codes (at least level 2)	m
1.4.6. NUTS3 GDP or GVA per NACE codes (at least level 2)	m
1.4.7. NUTS2 GDP or GVA per NACE codes (at least level 2)	m
1.4.8. Country GDP or GVA per NACE codes (at least level 2)	m
1.5. Policy documents	o
1.6. Land use	m

The Table shows the data needs for each of the sublayers, having a two or three digit level, e.g. “1.6. Land use” or “1.2.1 City population”. On the “Community Portal” part of each city, each sublayer details the data needed and in some cases the appropriate file type is even preselected. For example when collecting data on administrative boundaries, it states that shapefiles are required, because it helps to draw system boundaries. Another example is that for the collection of data on land use, again shapefiles of land use are needed, but also data on soil type and composition, and mineral deposits.

Although some of the sublayers may seem like a lot of extra or even unnecessary data, this data is in fact crucial to be used as proxies for downscaling or upscaling information when data is not available at a city/sector scale, or as a proxy to estimate data for a missing year. Layer 1 data can also be used to make the comparison between cities more contextualised. The layers that are not useful for such calculations, but that are helpful to have for the understanding of the city context, namely the descriptions of economic activities and policy documents, are optional layers.

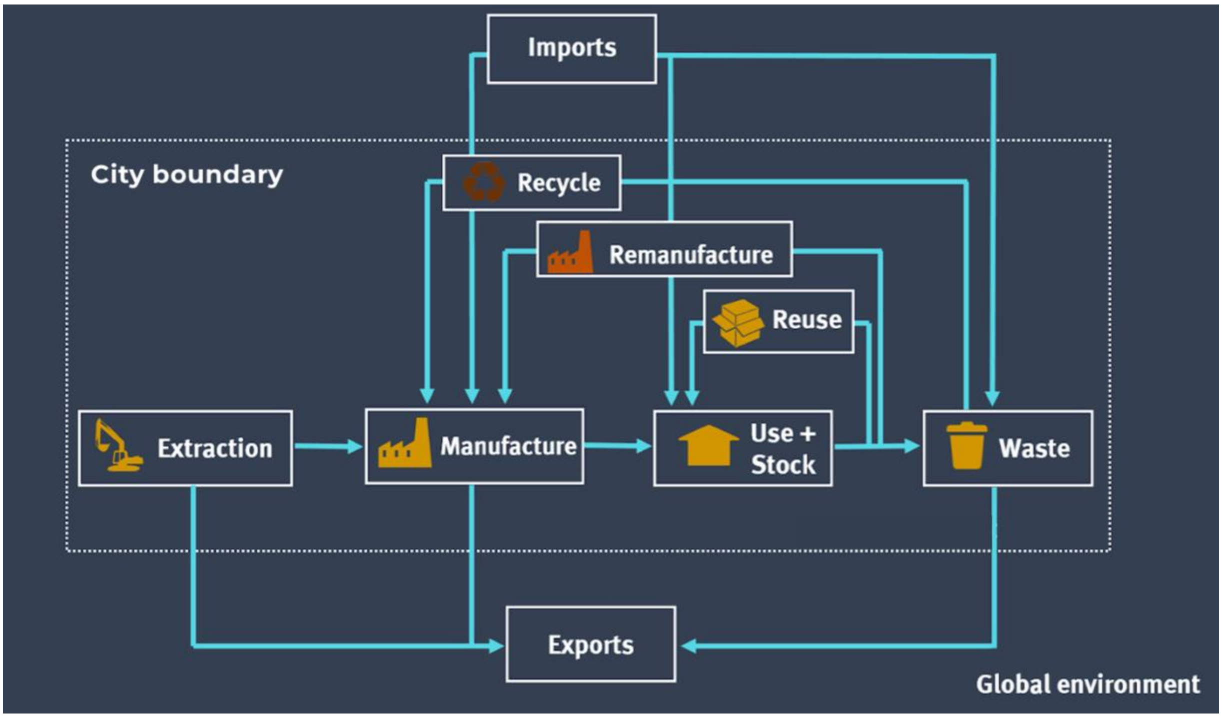
Layer 2: Urban economic activities per material

Layer 2 is about gaining insights on the economic activities per material in order to develop their respective value/material chains. While in Layer 1 data on economic activities were already collected, Layer 2 focuses only on the relevant activities per material and adds some additional (geospatial) information which better describes the actors/companies behind these flows. Since Layer 2 is material specific, it is not the same for the construction and biomass sectors, but sector specific.

Although Layer 2 and its sublayers are sector specific, the type of data to be collected are nevertheless the same and data for all the single life cycle/value chain stages of the 11 selected materials of the construction sector and 12 selected materials of the biomass sector need to be collected. Preliminary value chains have already been built for each material of the sectors and in Layer 2, it will be confirmed if those economic activities take place in the city. Tracing the generic value chain (see graphic below), for each value chain stage, the following information has to be found per each material and value chain stage:

- Number of companies per NACE code
- List of companies per NACE code
    - Geo-localisation of infrastructure for: waste collection and treatment, and extraction (mandatory)
    - Geo-localisation of infrastructure and actors other than the above (optional)
- Number of employees per NACE code
- GDP or GVA per NACE code

Aside from being useful for further downscaling from bigger spatial scales, this data will also help to translate flows to economic terms (and vice-versa), which will be especially relevant for the CHA. The data on the actors and their geo-localisation will enable cities to determine who and where the actors are, but also to identify if crucial circularity actors are missing from the territory which can assist them in policy making and planning future actions. The usual providers of this kind of data are the Chamber of Commerce, economic agency of the city, and national (or regional) statistical offices.



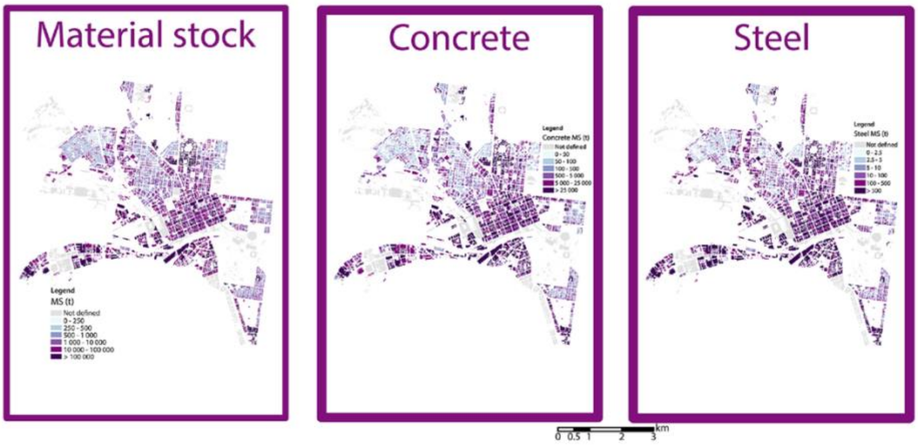
Layer 3: Flows (and stocks) per material

Layer 3 is all about adding the material quantities on the in Layer 2 assessed value chains. For all value chain stages of all materials that are applicable in the city, the respective masses have to be provided in tonnes/year. This way, the extraction flows, manufacturing flows, consumption flows, composition and addition to (artificial) stocks (e.g. building stocks), waste flows, import and export flows are all quantified. As this is again done for the selected sector materials, Layer 3 is also sector specific.

In order to facilitate this work, the cities will work with material codes from existing European and international nomenclature catalogues (see Annex 3-7). The material codes have already been pre-selected, again for every value chain stage and each material. As an example, Table 17 in Part 1 lists all material codes from different catalogues for the construction material "concrete". The Table below further exemplifies the kind of data that is desirable (a full structured list can be found in the Layer 3 section of Part 1). Those in grey are optional data, such as the modes of transportation in the case of imports and exports, which come from NST statistics.

The usual data providers for the various information are environmental agencies (national/local), public and private waste companies, transportation agencies (national/local), chamber of commerce, national/regional statistical office, and open data portals. In the case, where there is no data available on the city level, it is possible to use the data of the EW-MFA material flows, which give tonnes of materials flows (per EW-MFA codes & indicators) at a national level and downscale them using proxies (see Step 2).

Value Chain Stage	Nomenclature	Data need
Extraction	EW-MFA and PRODCOM	▪ Tonnes of extracted materials for relevant EW-MFA category codes
Manufacturing	PRODCOM	▪ List of products/manufactured per Prodcom list (per NACE code) ▪ Tonnes of products manufactured
Use	HBS - household consumption	▪ List of products consumed by households (per COICOP code) per NUTS 2 or 3 level (ideally at a city level) ▪ Tonnes of products consumed
Stock	Cadaster - Material stock for construction sector	▪ Number of buildings in the city ▪ Average composition of buildings in the city ▪ Shapefile of all buildings in the city – with year of construction, height, latest renovation year – List of building typologies – Material composition per building typologies ▪ Shapefile of all road and infrastructures – with year of construction, latest renovation year – List of infrastructure typologies – Material composition per infrastructure typologies
Waste	EWC	▪ Tonnes of waste per EWC category ▪ Tonnes of waste per EWC category per NACE code (if possible with GPS coordinates) ▪ End-of-life valorisation of Tonnes of waste per EWC category
Export	NST - transport	▪ Tonnes of materials exported per NST category at minimum at a NUTS 2 level – Details of the country of export – Details of the mode of transportation (rail/road/boat/airplane)
Import	NST - transport	▪ Tonnes of materials imported per NST category at minimum at a NUTS 2 level – Details of the country of import – Details of the mode of transportation (rail/road/boat/airplane)



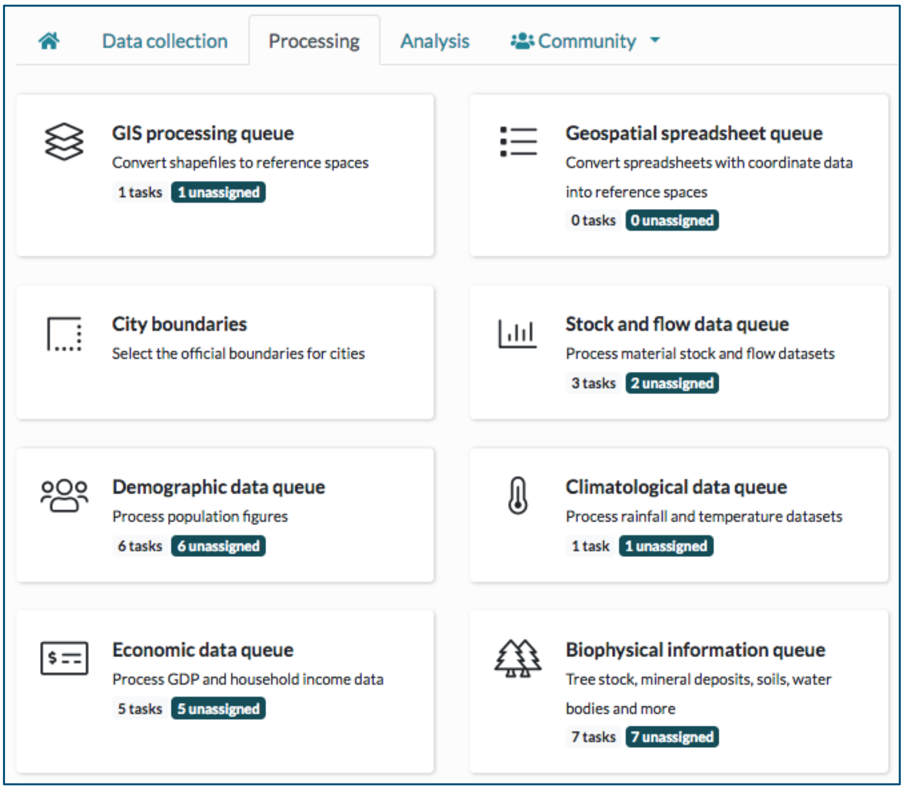
Material stocks of the City of Melbourne (Stephan and Athanassiadis 2017)

***Helps cities to** better explore the urban mine and manage secondary resources.*

ADDING DATA TO THE CITYLOOPS DATA HUB
The following steps need to be carried out to add data to the CityLoops Data Hub: ▪ Open your city's Community Portal, with either option a) or b). – In the main menu of the CityLoops Data Hub, click on Circularity and choose your city under "Data uploading". – Choose your city here: ▪ Apeldoorn ▪ Bodø ▪ Høje-Taastrup ▪ Mikkeli ▪ Porto ▪ Roskilde ▪ Sevilla ▪ Choose the correct sublayer for which you want to upload data ▪ Under "upload new item", select the data format that you wish to upload ▪ Fill in the correct info for the fields: name, authors, description, URL etc. ▪ Click "Save" Congratulations! The data item has been submitted and a new entry recorded. A task to process this item has been automatically created by the MoC bot.

Step 2: Data processing

Step 2 is about data processing and continues the work of the SCA by following Step 1: data collection. The goal of Step 2, is that all of the collected data (from Step 1) are processed. The documents that were uploaded in its various data formats, such as Excel, PDF, shapefiles, CSV are taken and converted to a standardised format for which templates are provided (see Community Portal image below). This allows data to be entered into the Metabolism of Cities database, so that interactive charts or maps can be *automatically* created and customised, to visualise data in the best possible way.



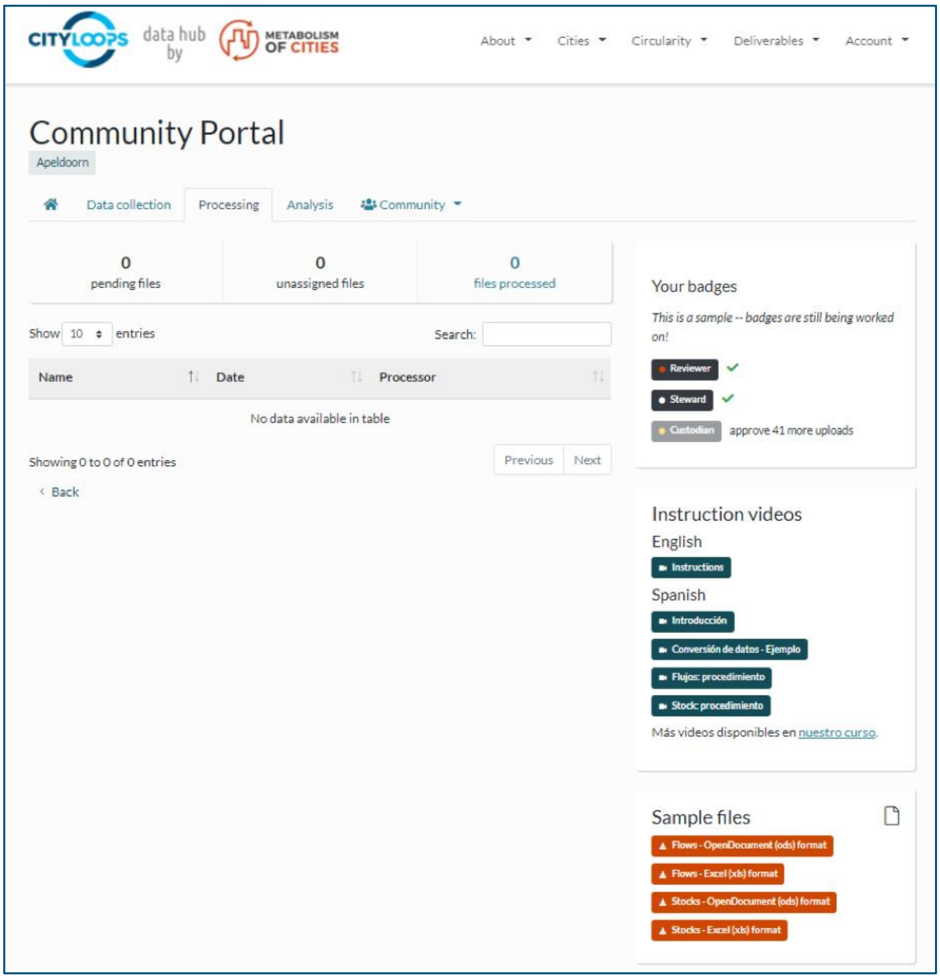
Data processing tab of a city on the Metabolism of Cities Data Hub

While the “Processing” tab on the Metabolism of Cities Data Hub shows a number of different processing queues, depending on the Layer, two general types of data and their respective processing steps can be distinguished:

1. GIS data or shapefiles: This type of data produces maps that represent areas (e.g. a park or a suburb) or points on a map (e.g. location of a supermarket or recycling centers).
2. Spreadsheet data, such as geospatial and other numerical data: This type of data allows for the creation of single dataset visualisations (e.g. the development of waste amounts collected over the years).

The spreadsheet data needs to be put into a standard format, for which there are template files. All these necessary template files can be found in the processing tab of each city (see for example below, in the screenshot for the Community Portal of Apeldoorn, https://cityloops.metabolismofcities.org/dashboards/apeldoorn/hub/processing/datasets/).

Once these two data types of data are processed, the data can be synthesised, which is also a part of the data processing step. For the synthesis, data points from various single datasets are taken and filled into a data template. The synthesis is required to generate the Sankey diagram that can be seen as a summary of the sector and the data processing step.



Community Portal of Apeldoorn with the sample (template) files for data processing

GETTING DATA WHERE THERE IS NONE

In the case where there is no existing data on an urban or sector scale, there is a solution to still carry out the SCA. The preferred way to get data is to "downscale" data from a higher spatial scale, as for example with "top-down" data from a regional or national level. This can be done with the help of a proxy. Employee numbers, GDP, land use, or population are examples for means to get an approximation, with the formula here showing how data on the city scale can be calculated. As a rule of thumb, data that is available on a close spatial scale, e.g. NUTS 3 or NUTS 2 is preferred to higher scales, as their data is more relevant.

$$Data_{city} = Data_{higher\ spatial\ scale} * (proxy\ value_{city} / proxy\ value_{higher\ spatial\ scale})$$

Other options to get data where there is none or little: primary data collection, upscaling (from a lower spatial scale, e.g. a neighbourhood or using bottom-up data from the demonstrators), or proxies from literature.

Step 3: Data analysis

Step 3 concludes the SCA method with a data analysis part, following the data collection and processing steps. The processed information in its standardised data format, maps and visualisation are taken and studied. That is to say, the data analysis deals with the generation of indicators and interpretation of indicators, as well as data (incl. data quality) and the derived maps and visualisations (incl. the Sankey diagrams). The goal is to finalise the sector understanding and generate insights on the status of closed material loops and harmful resource use, to communicate it (via the dashboard and the report) and ultimately to find ways to translate these data into sources of information for policy making and monitoring.

A number of different aspects have to be analysed in this step and guiding questions such as the exemplary ones below are used for facilitation.

Analysis of the single datasets (visualisations)

- What do we see in the graphic?
- What is the share of the single materials?
- Is there a clear trend for a material? How did it increase or decrease over time?
- Which material seems problematic?
- How complete is the data?
- What kind of other data would be beneficial to have?
- How big is the sector under study compared to the other ones?

Analysis of the maps

- Where in the city are relevant infrastructure located?
- Are all the necessary infrastructures to make flows more circular available in the city?
- Are there (industrial) clusters that can be taken advantage of?
- Can you foresee any industrial symbiosis between some of the economic activities present in your territory?
- Are there any insights about urban mining that can be extracted from the material stock map?

Analysis of the Sankey diagram

- What is the most prominent material in terms of extraction?
- Is your city consuming materials that are directly extracted from your territory or do you import them?
- Is your city treating its waste locally or exporting it?
- How much waste is your city importing?
- How big is your stock?
- What is the quantity of materials that are staying within the material loop?

Generation and analysis of the indicators

Indicators were selected to support the strategic objectives (SO) for the construction sector and the biomass sector respectively. To arrive at an informed assessment of circularity, there is at least one unique indicator per SO that is mandatory to assess, except for the SO on energy (SO23). Depending on the ambition of cities, they can choose additional indicators that they want to evaluate depending on their context specific needs.

The table here lists the construction and biomass sector indicators, with numbers for each sector indicating importance or relevance for the SCA: 1 = core/mandatory, 2 = relevant/important, 3 = optional. A total number of 8 mandatory and 16 additional indicators for the construction sector and a total number of 9 mandatory and 15 additional indicators for the biomass sector exist.

For the calculation of indicators, the cities will follow the specific methodology for each indicator, laid out in the indicator protocol that also specifies a description, unit and data needs. For the analysis, it can then be asked:

- Which indicators were met?
- How did they perform over the years?
- Where is room for improvement?
- What is the status of the SOs?

#	Strategic Objective	Indicators supporting this Strategic Objective	Construction sector	Biomass sector
22	Reduce harmful raw material consumption	35:Domestic material consumption (DMC)	1	
		35a: Domestic material consumption (DMC) of virgin materials	3	
23	Reduce overall energy demand and increased share of renewable energy	41:Total energy demand	3	
		45:Share of renewable energy in total energy demand	3	
		47:Local biomass for energy generation	-	3
24	Increase share of renewable and secondary raw materials in overall material demand	48:Share of renewable raw materials in domestic material consumption	3	
		49:Share of secondary materials in domestic material consumption	-	1
		44:Circular Material Use Rate	1	-
25	Increase self-sufficiency / self-reliance	50:Share of local secondary materials in raw material demand	3	
		51:Imports of materials	2	

		52:Export of waste materials	3	
		52a: Export of waste materials to incineration	3	
		52b: Export of waste materials to landfill	3	
		52c: Export of waste materials to composting	-	3
		54:EU self-sufficiency for raw materials	1	
26	Increase quantity of materials available for the next cycle	56:Quantity of materials subjected to reuse	2	
		57:Quantity of materials subjected to repair	2	-
		58:Quantity of materials subjected to remanufacturing	2	-
		59:Quantity of materials subjected to recycling	2	-
		60:Quantity of material for anaerobic digestion	-	1
		66:Quantity of material for composting	-	1
		65:EOL-RR (End of Life Recycling Rate)	1	-
27	Reduce waste generation	62:Amount of sector specific waste that is produced	1	
		61:End of Life Collection Rate	3	
		64:End of Life Processing Rate	1	
28	Reduce incineration and landfilling activities and amounts subjected	67:Incineration rate	1	
		67a:Incineration rates per material fractions	2	
		68:Landfilling rate	1	
		68a:Landfilling rates per material fractions	2	

Analysis of the next steps

- How can you use/embed the current analysis in your urban administration (for monitoring)?
- How can DAs be scaled up?
- Which other DAs do you think you should implement to make your sector more circular (based on the Sankey diagram and the indicators)?
- What are some data that you need to refine in the future?
- Which materials would you need solutions for?
- What are some avenues for future analysis, including stock and spatialisations? What else would you like to explore?;

FAQ

There are a number of questions that have already been asked by the cities, and others that can be anticipated to be frequently asked. The FAQ collects these for the three categories of method, data hub, and courses.

Method

What is the difference between the sector circularity assessment and the urban circularity assessment?

The sector circularity assessment (SCA) is the one that the cities will do for the construction and biomass sectors. The city/urban circularity assessment (UCA) is for the city scale. It is NOT part of the courses in early 2021 and will only be done in 2022, after the UCA method has been developed.

What are the data requirements?

In order to know the data requirements, have a look at the Layer description in the Handbook or on the CityLoops Data Hub (https://cityloops.metabolismofcities.org/).

I have a document with total population and population by sex, what should be processed?

For now only create a dataset with TOTAL POPULATION. However, we are adding a new option so that multiple different datasets can be added based on a single source document. Once that is in place you can also add the population by sex.

Data Hub

How do I sign up to the Data Hub?

Signing up by creating an account is easy and can be done by following these steps:

1. *You can go to the Community Portal and click on "Join us" or use this link https://cityloops.metabolismofcities.org/hub/join/?next=/hub/*
2. *Enter your full name, email address and password. (While optional, we encourage people to add a profile photo and their interests, as this makes a user profile that much nicer.)*
3. *Click "register" and you are done. You should be automatically signed in. If you are not, you can now sign in here.*

Should you ever forget your password, no problem, as there is a password reset function.

How can I reset my password?

You can simply use the [password reset function](https://cityloops.metabolismofcities.org/accounts/passwordreset/) (https://cityloops.metabolismofcities.org/accounts/passwordreset/).

Does the data collection tab contain the variables for both the city and the sector assessment?

The data collection tab is NOT yet the one that is specific for CityLoops, but the one that is also used on the general Metabolism of Cities Data Hub (https://data.metabolismofcities.org/). But yes, some of them will be the same for the sector and the city scan, whereas others will be more refined for the sector.

Can everyone see the data and have access to it?

At the moment, yes. There could be different clearances for the users introduced, e.g. the public can only see the actual data on the Data Hub, whereas the evaluation managers and possibly other registered users (others from the CityLoops project) get to log into the site and have access to the "data manger", where they can either only view it or also edit it, use the forum, upload data etc.

I don't want for everyone to see the data. Is there a workaround?

Yes. Instead of uploading the data file, you can also upload a file to a password secured google drive, basecamp etc. folder and simply paste the link to that file when adding that there is data for a layer.

I've just uploaded a publication or dataset for a city, but the progress bar or document number has not changed. Why is that?

Everything is fine and your submission counts. That this is not reflected is an issue of site performance. That page is not generated live, but instead a copy is saved and the data is updated every so many hours, because otherwise it takes too long to generate the page.

Course

How many hours do the courses take in total?

The time that it takes to carry out the SCA is something that can momentarily only be estimated, until it has been trialled by the CityLoops cities. Based on the courses that were given by Metabolism of Cities, the workload was estimated to take a total of 290-350 hours for all three steps (120-150 hours for data collection, 120-150 hours for data processing, and 50 hours for data analysis).

Why is the course so long?

Feedback from the course participants revealed that continuous drips of time were better than one intense sprint. Moreover, it takes time to contact data providers and get data from them, so it is better to stretch the course out.

Is there anything that I need to do before the course?

There is nothing that NEEDS to be done, but if cities want to do some preparatory work, they can try to find out:

- how waste data is reported in their city? By EWC codes? Other codes? Per NACE activity? Who reports this?
- *who collects the waste reporting from single companies?*
- *if city uses NACE codes at all or how do they report on the economic activities? (Perhaps the chamber of commerce or an economic department would know.)*

Can I already take another course?

There are already 3 courses that will be similar to the ones that the cities will take. There is a Spanish data collection course that was given in Aug-Sep 2020, an English data collection course, and a Spanish data processing course. Amongst other things, these courses were created to test out this platform with some volunteers from around the world. However, do note that these courses are available outside of CL and are not CL specific (those will be created very soon). If you wish to follow any of them, you will do so on your own and we will not have the time to support you. We would actually ***prefer that you don't take this existing course****, because things will change until then and we don't want you to be confused (when taking the course with us) or have any unnecessary work.*

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Annex 1 – Construction sector codes

Highlighted in blue, are the NACE Rev. 2 codes provided by ECSO.

Codes for narrow construction sector:

F - Construction
- F41 - Construction of buildings
  - F41.1 - Development of building projects
    - F41.1.0 - Development of building projects
  - F41.2 - Construction of residential and non-residential buildings
    - F41.2.0 - Construction of residential and non-residential buildings
- F42 - Civil engineering
  - F42.1 - Construction of roads and railways
    - F42.1.1 - Construction of roads and motorways
    - F42.1.2 - Construction of railways and underground railways
    - F42.1.3 - Construction of bridges and tunnels
  - F42.2 - Construction of utility projects
    - F42.2.1 - Construction of utility projects for fluids
    - F42.2.2 - Construction of utility projects for electricity and telecommunications
  - F42.9 - Construction of other civil engineering projects
    - F42.9.1 - Construction of water projects
    - F42.9.9 - Construction of other civil engineering projects n.e.c.
- F43 - Specialised construction activities
  - F43.1 - Demolition and site preparation
    - F43.1.1 - Demolition
    - F43.1.2 - Site preparation
    - F43.1.3 - Test drilling and boring
  - F43.2 - Electrical, plumbing and other construction installation activities
    - F43.2.1 - Electrical installation
    - F43.2.2 - Plumbing, heat and air-conditioning installation
    - F43.2.9 - Other construction installation
  - F43.3 - Building completion and finishing
    - F43.3.1 - Plastering
    - F43.3.2 - Joinery installation
    - F43.3.3 - Floor and wall covering
    - F43.3.4 - Painting and glazing
    - F43.3.9 - Other building completion and finishing
  - F43.9 - Other specialised construction activities
    - F43.9.1 - Roofing activities
    - F43.9.9 - Other specialised construction activities n.e.c.

Additional codes for broad construction sector:

Manufacturing activities:

C16.2 - Manufacture of products of wood, cork, straw and plaiting materials
- C16.2.1 - Manufacture of veneer sheets and wood-based panels
- C16.2.2 - Manufacture of assembled parquet floors
- C16.2.3 - Manufacture of other builders' carpentry and joinery
- C16.2.4 - Manufacture of wooden containers
  - C16.2.9 - Manufacture of other products of wood; manufacture of articles of cork, straw and plaiting materials

C23.3 - Manufacture of clay building materials
- C23.3.1 - Manufacture of ceramic tiles and flags
  - C23.3.2 - Manufacture of bricks, tiles and construction products, in baked clay

C23.5 - Manufacture of cement, lime and plaster
- C23.5.1 - Manufacture of cement
- C23.5.2 - Manufacture of lime and plaster

C23.6 - Manufacture of articles of concrete, cement and plaster

C23.6.1 - Manufacture of concrete products for construction purposes
C23.6.2 - Manufacture of plaster products for construction purposes
C23.6.3 - Manufacture of ready-mixed concrete
C23.6.4 - Manufacture of mortars
C23.6.5 - Manufacture of fibre cement
C23.6.9 - Manufacture of other articles of concrete, plaster and cement

C23.7 - Cutting, shaping and finishing of stone

C23.7.0 - Cutting, shaping and finishing of stone

C25.1 - Manufacture of structural metal products

C25.1.1 - Manufacture of metal structures and parts of structures
C25.1.2 - Manufacture of doors and windows of metal

Real estate activities:

L68.1 - Buying and selling of own real estate

L68.1.0 - Buying and selling of own real estate

L68.2 - Renting and operating of own or leased real estate

L68.2.0 - Renting and operating of own or leased real estate

L68.3 - Real estate activities on a fee or contract basis

L68.3.1 - Real estate agencies L68.3.2 - Management of real estate on a fee or contract basis

Architectural and engineering services:

M71 - Architectural and engineering activities; technical testing and analysis

M71.1 - Architectural and engineering activities and related technical consultancy

M71.1.1 - Architectural activities
M71.1.2 - Engineering activities and related technical consultancy

Annex 2 – NACE in EU countries

NACE Rev.2 has multiple national implementations (Joinup 2020).

- Austria: http://portal.wko.at/wk/format_detail.wk?AngID=1&StID=372762&DstID=17
- Cyprus: http://www.mof.gov.cy/mof/cystat/statistics.nsf/All/AB7D287A01F6123FC22578170036B4A4/$file/NACE_Rev2_5%20DIG_EN_100408.pdf?OpenElement
- Czech Republic: http://www.czso.cz/csu/klasifik.nsf/i/klasifikace_ekonomickych_cinnosti_(cz_nace)
- Denmark: http://www.dst.dk/pukora/epub/upload/11119/bi3.pdf
- Estonia: http://metaweb.stat.ee/view_xml.htm?id=2791059&siteLanguage=en
- Finland: http://www.stat.fi/meta/luokitukset/toimiala/001-2008/index_en.html
- France: http://www.insee.fr/fr/methodes/default.asp?page=nomenclatures/naf2008/naf2008.htm
- Greece: http://dlib.statistics.gr/Book/GRESYE_02_2004_00010.pdf
- Italy: http://www.istat.it/it/archivio/17888
- Lithuania:
- http://www.stat.gov.lt/uploads/klasifik/EVRK/EVRKred2.htm
- Luxembourg: http://www.environnement.public.lu/dechets/informations_pratiques/code_nace.pdf
- Poland: http://www.stat.gov.pl/klasyfikacje/pkd_07/pkd_07.htm
- Portugal: http://www.ine.pt/ine_novidades/semin/cae/CAE_REV_3.pdf
- Romania: http://www.listafirme.ro/caen.asp
- Slovakia: http://www.statistics.sk/pls/wregis/ciselniky?kc=5205
- Slovenia: http://www.stat.si/eng/vodic_oglej.asp?ID=42&PodrocjeID=14
- Spain: http://www.ine.es/jaxi/menu.do?type=pcaxis&path=/t40/clasrev&file=inebase
- Sweden: http://www.sni2007.scb.se/
- The Netherlands: http://www.cbs.nl/en-GB/menu/methoden/classificaties/overzicht/sbi/default.htm

Annex 3 – NST Nomenclature

Nomenclature of the standard goods classification for transport statistics (Eurostat n.d.).

METADATA

Standard goods classification for transport statistics, 2007

--- Further files and information --- Layout: Hierarchic

Top of classification Back to classification list

Show Code Select language of the data: English

Detail	
01	Products of agriculture, hunting, and forestry; fish and other fishing products
02	Coal and lignite; crude petroleum and natural gas
03	Metal ores and other mining and quarrying products; peat; uranium and thorium
04	Food products, beverages and tobacco
05	Textiles and textile products; leather and leather products
06	Wood and products of wood and cork (except furniture); articles of straw and plaiting materials; pulp, paper and paper products; printed matter and recorded media
07	Coke and refined petroleum products
08	Chemicals, chemical products, and man-made fibers; rubber and plastic products ; nuclear fuel
09	Other non metallic mineral products
10	Basic metals; fabricated metal products, except machinery and equipment
11	Machinery and equipment n.e.c.; office machinery and computers; electrical machinery and apparatus n.e.c.; radio, television and communication equipment and apparatus; medical, precision and optical instruments; watches and clocks
12	Transport equipment
13	Furniture; other manufactured goods n.e.c.
14	Secondary raw materials; municipal wastes and other wastes
15	Mail, parcels
16	Equipment and material utilized in the transport of goods
17	Goods moved in the course of household and office removals; baggage and articles accompanying travellers; motor vehicles being moved for repair; other non market goods n.e.c.
18	Grouped goods: a mixture of types of goods which are transported together
19	Unidentifiable goods: goods which for any reason cannot be identified and therefore cannot be assigned to groups 01-16.
20	Other goods n.e.c.

Annex 4 – PRODCOM Nomenclature

Nomenclature of PRODCOM (Eurostat, n.d.).

METADATA

PRODCOM List 2010

--- Further files and information ---

Top of classification

Layout: Hierarchic

Back to classification list

Show Code

Select language of the data: English

Detail	
07.10	Mining of iron ores
07.29	Mining of other non-ferrous metal ores
08.11	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
08.12	Operation of gravel and sand pits; mining of clays and kaolin
08.91	Mining of chemical and fertiliser minerals
08.93	Extraction of salt
08.99	Other mining and quarrying n.e.c.
10.11	Processing and preserving of meat
10.12	Processing and preserving of poultry meat
10.13	Production of meat and poultry meat products
10.20	Processing and preserving of fish, crustaceans and molluscs
10.31	Processing and preserving of potatoes
10.32	Manufacture of fruit and vegetable juice
10.39	Other processing and preserving of fruit and vegetables
10.41	Manufacture of oils and fats
10.42	Manufacture of margarine and similar edible fats
10.51	Operation of dairies and cheese making
10.52	Manufacture of ice cream
10.61	Manufacture of grain mill products
10.62	Manufacture of starches and starch products
10.71	Manufacture of bread; manufacture of fresh pastry goods and cakes
10.72	Manufacture of rusks and biscuits; manufacture of preserved pastry goods and cakes
10.73	Manufacture of macaroni, noodles, couscous and similar farinaceous products
10.81	Manufacture of sugar
10.82	Manufacture of cocoa, chocolate and sugar confectionery
10.83	Processing of tea and coffee
10.84	Manufacture of condiments and seasonings
10.85	Manufacture of prepared meals and dishes
10.86	Manufacture of homogenised food preparations and dietetic food
10.89	Manufacture of other food products n.e.c.
10.91	Manufacture of prepared feeds for farm animals

Annex 5 – CPA Nomenclature

Nomenclature of CPA: Statistical Classification of Products by Activity in the European Community, 2008 version (Eurostat, n.d.).

METADATA

Statistical Classification of Products by Activity in the European Community, 2008 version

--- Further files and information ---

Top of classification

Layout: Hierarchic

Back to classification list

Show Code

Select language of the data: English

Detail	
A	PRODUCTS OF AGRICULTURE, FORESTRY AND FISHING
B	MINING AND QUARRYING
C	MANUFACTURED PRODUCTS
D	ELECTRICITY, GAS, STEAM AND AIR CONDITIONING
E	WATER SUPPLY; SEWERAGE, WASTE MANAGEMENT AND REMEDIATION SERVICES
F	CONSTRUCTIONS AND CONSTRUCTION WORKS
G	WHOLESALE AND RETAIL TRADE SERVICES; REPAIR SERVICES OF MOTOR VEHICLES AND MOTORCYCLES
H	TRANSPORTATION AND STORAGE SERVICES
I	ACCOMMODATION AND FOOD SERVICES
J	INFORMATION AND COMMUNICATION SERVICES
K	FINANCIAL AND INSURANCE SERVICES
L	REAL ESTATE SERVICES
M	PROFESSIONAL, SCIENTIFIC AND TECHNICAL SERVICES
N	ADMINISTRATIVE AND SUPPORT SERVICES
O	PUBLIC ADMINISTRATION AND DEFENCE SERVICES; COMPULSORY SOCIAL SECURITY SERVICES
P	EDUCATION SERVICES
Q	HUMAN HEALTH AND SOCIAL WORK SERVICES
R	ARTS, ENTERTAINMENT AND RECREATION SERVICES
S	OTHER SERVICES
T	SERVICES OF HOUSEHOLDS AS EMPLOYERS; UNDIFFERENTIATED GOODS AND SERVICES PRODUCED BY HOUSEHOLDS FOR OWN USE
U	SERVICES PROVIDED BY EXTRATERRITORIAL ORGANISATIONS AND BODIES

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Annex 6 – Definitions of Waste

Waste

In the EU, waste is generally defined as "any substance or object which the holder discards or intends to or is required to discard" (European Union, Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives). It is a material in a certain state or loop, but still a material.

- EU definition from waste framework directive 2008: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098
- EU definition from waste framework directive 2018: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018L0851

Municipal (solid) waste

"(a) mixed waste and separately collected waste from households, including paper and cardboard, glass, metals, plastics, bio-waste, wood, textiles, packaging, waste electrical and electronic equipment, waste batteries and accumulators, and bulky waste, including mattresses and furniture;

(b) mixed waste and separately collected waste from other sources, where such waste is similar in nature and composition to waste from households;"

"Municipal waste does not include waste from production, agriculture, forestry, fishing, septic tanks and sewage network and treatment, including sewage sludge, end-of-life vehicles or construction and demolition waste." (EU waste framework directive 2018)

Construction and demolition waste

Construction and demolition waste (CDW) = "Rubble and other waste material arising from the construction, demolition, renovation or reconstruction of buildings or parts thereof, whether on the surface or underground."

Remark: It consists mainly of building material and soil, including excavated soil. It includes waste from all origins and from all economic activity sectors.

(Joint OECD/Eurostat Questionnaire 2002 on the State of the Environment, section on Waste)

From the EWC, everything that falls under NACE F has been chosen (codes 17 01 - 17 09) and 01 01 and 01 04 for construction industry waste from NACE sectors B and C.

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018XC0409(01)&from=EN

Biowaste

As per the steering group of CityLoops, it was decided in April 2020 that organic waste shall be referred to as biowaste to align with the official European Commission documents, such as the one described by the European Commission (2020c).

Biowaste = "biodegradable garden and park waste, food and kitchen waste from households, offices, restaurants, wholesale, canteens, caterers and retail premises and comparable waste from food processing plants;"

From the definition it can be seen that it is not just biowaste from households

From the EWC, the codes 2, 3, 15, 19 and 20 have been chosen to be included for biowaste.

Food waste

Food waste = "all food as defined in Article 2 of Regulation (EC) No 178/2002 of the European Parliament and of the Council (*2) that has become waste;

(*2) Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety (OJ L 31, 1.2.2002, p. 1)"

Annex 7 – European List of Waste

Main chapters of European List of Waste (LoW) (European Commission 2018, 22)

CODE	CHAPTER DESCRIPTION
01	WASTES RESULTING FROM EXPLORATION, MINING, QUARRYING, PHYSICAL AND CHEMICAL TREATMENT OF MINERALS
02	WASTES FROM AGRICULTURE, HORTICULTURE, AQUACULTURE, FORESTRY, HUNTING AND FISHING, FOOD PREPARATION AND PROCESSING
03	WASTES FROM WOOD PROCESSING AND THE PRODUCTION OF PANELS AND FURNITURE, PULP, PAPER AND CARDBOARD
04	WASTES FROM THE LEATHER, FUR AND TEXTILE INDUSTRIES
05	WASTES FROM PETROLEUM REFINING, NATURAL GAS PURIFICATION AND PYROLYTIC TREATMENT OF COAL
06	WASTES FROM INORGANIC CHEMICAL PROCESSES
07	WASTES FROM ORGANIC CHEMICAL PROCESSES
08	WASTES FROM THE MANUFACTURE, FORMULATION, SUPPLY AND USE (MFSU) OF COATINGS (PAINTS, VARNISHES AND VITREOUS ENAMELS), ADHESIVES, SEALANTS AND PRINTING INKS
09	WASTES FROM THE PHOTOGRAPHIC INDUSTRY
10	WASTES FROM THERMAL PROCESSES
11	WASTES FROM CHEMICAL SURFACE TREATMENT AND COATING OF METALS AND OTHER MATERIALS; NON-FERROUS HYDRO-METALLURGY
12	WASTES FROM SHAPING AND PHYSICAL AND MECHANICAL SURFACE TREATMENT OF METALS AND PLASTICS
13	OIL WASTES AND WASTES OF LIQUID FUELS (EXCEPT EDIBLE OILS, 05 AND 12)
14	WASTE ORGANIC SOLVENTS, REFRIGERANTS AND PROPELLANTS (EXCEPT 07 AND 08)
15	WASTE PACKAGING; ABSORBENTS, WIPING CLOTHS, FILTER MATERIALS AND PROTECTIVE CLOTHING NOT OTHERWISE SPECIFIED
16	WASTES NOT OTHERWISE SPECIFIED IN THE LIST
17	CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)
18	WASTES FROM HUMAN OR ANIMAL HEALTH CARE AND/OR RELATED RESEARCH (EXCEPT KITCHEN AND RESTAURANT WASTES NOT ARISING FROM IMMEDIATE HEALTH CARE)
19	WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTE WATER TREATMENT PLANTS AND THE PREPARATION OF WATER INTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIAL USE
20	MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSTITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS

CityLoops is an EU-funded project focusing on construction and demolition waste (CDW), including soil, and organic waste (OW), where seven European cities are piloting solutions to be more circular.

Høje-Taastrup and Roskilde (Denmark), Mikkeli (Finland), Apeldoorn (the Netherlands), Bodø (Norway), Porto (Portugal) and Seville (Spain) are the seven cities implementing a series of demonstration actions on CDW and soil, and OW, and developing and testing over 30 new tools and processes.

Alongside these, a sector-wide circularity assessment and an urban circularity assessment are to be carried out in each of the cities. The former, to optimise the demonstration activities, whereas the latter to enable cities to effectively integrate circularity into planning and decision making. Another two key aspects of CityLoops are stakeholder engagement and circular procurement.

CityLoops started in October 2019 and will run until September 2023.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 821033.