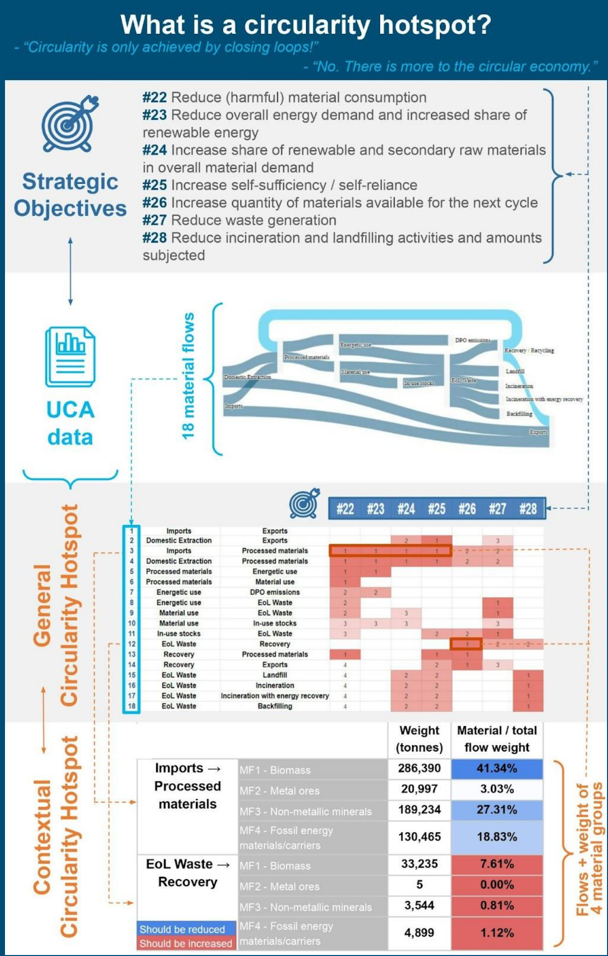
CIRCULARITY HOTSPOT ANALYSIS METHOD

Deliverable 4.5

Metabolism of Cities



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Abstract	The document presents the Circularity Hotspot Analysis, a method for cities to identify urban circularity hotspots for four material categories. Firstly, the aim of the method is presented, before explaining how general circularity hotspots can be found with the help of combining strategic objectives for the circular economy with material flows. The next section outlines the related material flow analysis data inputs and how their weights and shares are employed, to produce intermediate outputs. Lastly, the outputs, including the qualitative approach to determine the final ones in the form of contextual circularity hotspots are discussed.
Keywords	Circularity hotspot analysis; Impact assessment; Solutions; Circular city;
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Executive Summary

Cities (within the CityLoops project) strive to take actions and make transitions towards a circular economy. In order for them to design roadmaps and action plans to implement and carry out their endeavours, they need to make informed decisions and to determine where to invest their efforts, based on their status quo, local context and policy goals. The aim of the Circularity Hotspot Analysis (CHA) method is to assist cities in this process, by providing them with a method, to apply on their own, to reveal and understand circularity hotspots and take action on them by planning and implementing context-specific best practices and policies. From the CityLoops project perspective, the aim of the CHA method is to inform the development of upscaling plans (WP7) for partner cities.

For the identification of circularity hotspots, the CHA capitalises and extends on the results of existing elements of the CityLoops project, namely the circular city definition and its seven connected strategic objectives (of vision element 3) as well as system boundaries and the material flow data part of the Urban Circularity Assessments, which were data and resource intensive. It combines and crosses these pieces of information to generate two types of circularity hotspots, general and contextual ones.

The general hotspots, which are universal/theoretical, are disclosed by the relationship of strategic objectives and the material flows that directly impact them. This intermediate output is then combined with the weight per material group per selected flows (provided by the UCA) and the shares of their relative weight on an overall lifecycle stage (for instance processed materials).

The intermediary outputs of the general hotspots and shares will be used by local experts to combine them with context specific knowledge, thus producing contextual circularity hotspots. The local and quantitative assessments produced previously, are considered by local experts to identify impactful and realistic opportunities to increase circularity in their urban context. Thereafter, best practices and policies for the most promising urban materials and actions to promote the use of sustainable and resource-efficient practices, tailored to the specific context of each city, can be proposed.

Contents

Acronyms and Abbreviations

CHA	Circularity Hotspot Analysis
DE	Domestic Extraction
DMCcorr	Domestic Material Consumption corrected
EoL	End-of-Life
GDP	Gross Domestic Product
GVA	Gross Value Added
MoC	Metabolism of Cities
NACE	Nomenclature statistique des activités économiques dans la Communauté européenne (Statistical Classification of Economic Activities in the European Community)
PVs	Photovoltaics
SCA	Sector-wide Circularity Assessment
SOs	Strategic Objectives
UCA	Urban Circularity Assessment

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1. 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 enables to address the second part of the second objective of WP4 and is a deliverable of Task 4.5: Circularity Hotspot Analysis (CHA). (The first objective was addressed through Deliverable 4.3 "Sector-Wide Circularity Assessment Method", while the second objective was also already addressed through Deliverable 4.4 "Urban Circularity Assessment Method".)

The **aim of the task** at hand was to develop a method that identifies sectors (now materials, see below) and actions in a municipality that have the highest circularity potential or in other words, those that perform the worst in terms of strategic objectives and are promising for change. In turn, the **aim of the CHA method**, which is meant for cities (of the CityLoops project) to apply on their own, is to reveal and understand circularity hotspots and take action on them by implementing and planning context-specific best practices and policies.

Task 4.5 is not independent, as can be seen in Figure 1, depicting its relationships to the other tasks in WP4, showing how other tasks feed into Task 4.5 Circularity Hotspot Analysis and rely on the outputs of Task 4.5. Therefore, the CHA method development partly builds on the four previous deliverables in WP4:

- *"Deliverable 4.1: Urban Material Flows and Stocks Accounting: A Review of Methods and Their Application"*: Deliverable 4.1 demonstrated the findings and insights from a literature review on the different urban material flow and stock accounting methods, and provided an overview of other projects that deal with such methods.
- *"Deliverable 4.2: Development of an Urban Material Flow and Stock Database Structure":* Deliverable 4.2 documented the development of a database structure that caters to the data used and generated by the accounting methods.

- *“Deliverable 4.3: Sector-Wide Circularity Assessment Method”:* Deliverable 4.3 presented the SCA accounting method and indicators that assess the circularity of a (construction or biomass) sector.
- *“Deliverable 4.4: Urban Circularity Assessment Method”:* Deliverable 4.4 presented the urban material flow and stock accounting method paired with system-wide indicators to assess the material circularity of a city.

These previous deliverables and as well as the carrying out of the two methods developed by a number of cities steered the development of the Circularity Hotspot Analysis method. Two elements specifically influenced the original definition of the CHA, which was to “*combine information about the metabolic flows and stocks data with economic data (GDP, GVA and employment per NACE code) in order to rank economic sectors by order of priority.*” Firstly, the focus steered away from sectors, because the data input needed (for example from the UCA) is not structured and built up of several single sectors, as originally planned. This is because of the understanding that materials and employees cannot be subjected to a single sector only, to avoid double counting. Instead of sectors, the focus is on materials and material circularity, an understanding that was developed and formulated in Deliverable 4.3. Secondly, due to unavailability of economic data (GDP, GVA, and employment per NACE code) according to the activity groups of domestic extraction, imports & exports, waste etc. on the city level and even less per material or material category, neither activity groups nor materials can be ranked and compared with the help of economic data. It is important to note that these datasets were extensively sought-after during Tasks 4.3 and 4.4 and remain to this date non-existent.

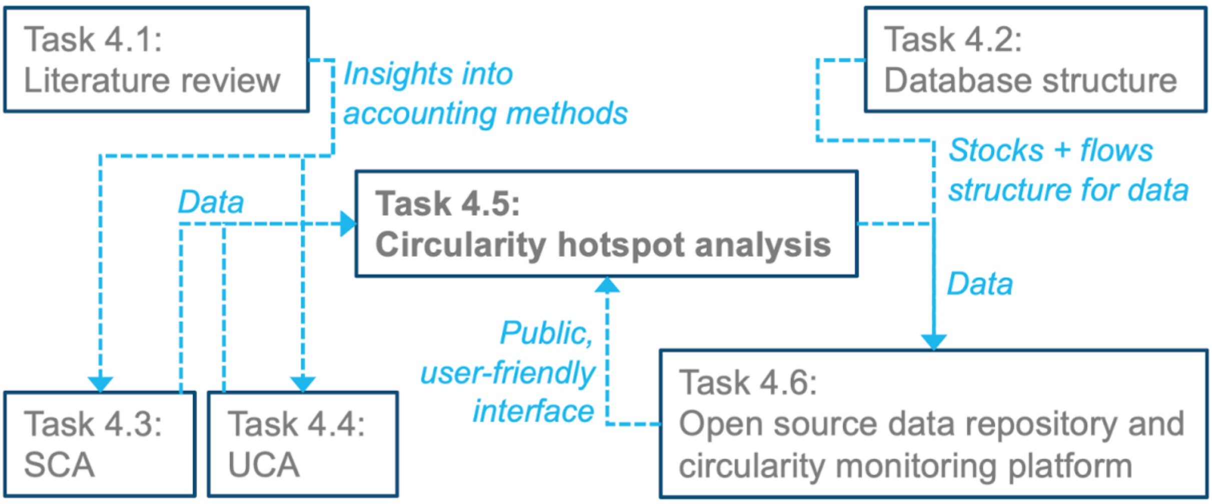


Figure 1 - Relationship of tasks in WP4 and the information and/or function that they provide

Consequently, while the CHA was not developed as originally intended, it builds on previous deliverables and results, with a focal point on the material flow data and the translation of circularity through a number of strategic objectives. This new approach capitalises and extends the results of the UCA which were data and resource intensive.

Following this introduction, the document describes the resources and processes of the CHA method. First, the system boundaries are detailed. Secondly, in sub-chapters, it turns to the inputs required for the method, specifying the relationship of strategic objectives and material flows, definition of Circularity Hotspots, material flow data and the connection between them. Lastly, it outlines the intermediate and final outputs that can be obtained from the CHA.

The document does not detail the practical necessities for the application of the CHA method, such as use of the UCA templates for data handling and visualisation, but provides first ideas in info boxes. More details are to be shared during the facilitation of the method application for five of the CityLoops cities (Apeldoorn (the Netherlands), Bodø (Norway), Mikkeli (Finland), Porto (Portugal) and Seville (Spain)), guided by the team of Metabolism of Cities.

2. Resources and Process of the CHA

The CHA deals with a number of resources. On the input side, limited by system boundaries, it makes use of the relationships between strategic objectives and Sankey diagram flows, as well as material flow data. On the output side, the application of the analysis then produces a table with material flow shares and contextual circularity hotspots. All of these components and their connections are presented in this chapter.

2.1. System Boundaries

The system boundaries of the CHA method assist in delimiting the scope of the analysis in terms of space, time and materials. Since the prerequisite for carrying out the CHA method is that the Urban Circularity Assessment has been conducted, to have structured data available, its system boundaries are almost mirrored. That means the spatial boundaries of the CHA are the administrative boundaries of the municipality for which the UCA was carried out. The temporal boundary of this analysis is one year, the latest UCA reference year.

Table 1 - Material scope and how it is included in the method

Material categories	Scope
MF1 - Biomass	Represented as whole material category
MF2 - Metal ores (gross ores)	Represented as whole material category
MF3 - Non-metallic minerals	Represented as whole material category
MF4 - Fossil energy materials/carriers	Represented as whole material category
MF5 - Other products	Not included
MF6 - Waste for final treatment and disposal	Not included

The material boundary matches the EW-MFA classification system defined by Eurostat and remains at the most aggregated level with its main *material categories* (1-digit level) which vary from MF1 to MF8. Table 1 shows how materials are included in the CHA method. MF1 to MF4, biomass, metals, non-metallic minerals, and fossil energy carriers, are represented as a whole material category, meaning that the economy is distinguished into these four main materials and that e.g. all the aggregated biomass materials are considered as a whole for the calculations of the hotspot. MF5 other products as well as MF6 waste are not included in the calculations, because their allocation to their appropriate MF1 to MF4 categories does not exist directly and these categories apply to only physical imports and exports. Additionally, MF5 other products calculated total values of imports and exports are derived from downscaling using employees, according to the relevant employee numbers of NACE classes, which cannot be broken down to specific material categories. MF6 waste category total values are applied in imports and exports that do not affect selected material flows for circularity hotspot analysis, and in the UCA were used in calculating domestic material consumption corrected (DMCcorr).

2.2. Input

As has been stated at the beginning of this chapter, the inputs required for the CHA are the circular city definition, material flow data, structured flows from the Sankey diagram and a means to combine them all. The following paragraphs will describe them in more detail.

2.2.1. Definitions and Strategic Objectives

The CHA method requires definitions of the circular economy and a circular city to determine the direction and aim of the method and its analysis. It makes use of CityLoops' Circular City definition that was first presented by Vangelsten et al. (2020, 11) in "D6.1 Circular City Indicator Set" and is quoted here in the info boxes.

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.

For the CHA method, just like for the UCA, the focus lies on Vision Element 3 "Closing material loops and reducing harmful resource use", seen in Figure 2. The vision is further elaborated, expressed and supported through seven strategic objectives (SOs). These, listed in Table 2, reveal that circularity is about more than just closing material loops or flows. However, the SOs are intricately linked to material flows and the realisation of the strategic objectives depend on them, and their associated weights. Therefore, the relationship between them was explored with results in the next chapter.

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."

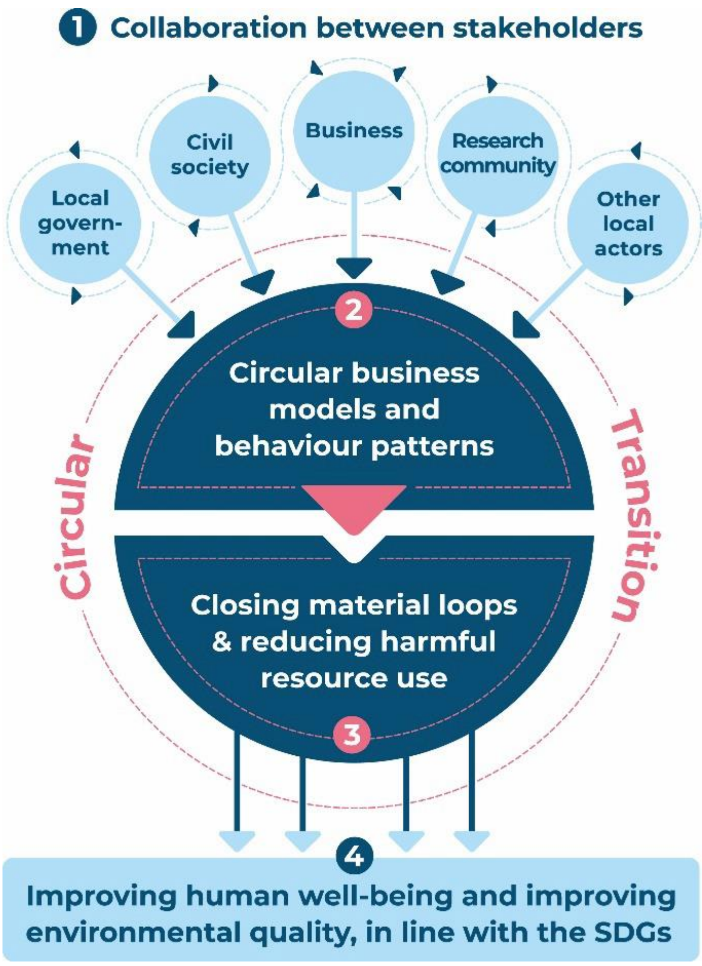


Figure 2 - The four Vision Elements of the Circular City vision and causal links for CE transition (Vangelsten et al. 2020)

Strategic Objectives and Sankey Diagram Flows

Strategic Objectives 22 to 28 simultaneously represent the means and ends of a city to close material loops and reduce harmful resources in order to transition towards a circular economy. They focus on both reducing harmful flows entering cities and increasing practices to close material loops (of post-use flows). To facilitate this transition and identify how and where to have more impact, it was important to integrate the larger strategic objectives (how to become circular) with the circularity assessment carried out at a city level (what is the circularity status quo). In other words, by using the 18 materials flows, which depict the functioning of an urban economy, to wider objectives of circularity, their intricate relationship is made explicit, enabling an identification of potential actions to make cities more circular.

The integration of SOs with the UCA can be carried out in two steps. First, a general or theoretic link where SOs are linked to UCA flows (which flows are in principle having more impact to implement SOs). This connection is highlighted in Table 2. Secondly, on top of the qualitative link, a quantitative link is being explored by using the mass values of the Sankey diagram for each city, further weighing and contextualising the impact of flows in achieving SOs.

To qualitatively link the SOs with the Urban Circularity Assessment (UCA) a matrix was developed and filled in. This matrix associated each SO with all the relevant Sankey flows from the UCA and weighted the latter (flows having the highest (1) to lowest (4) impact for achieving this SO). Table 2 showcases these relationships and the following paragraphs better explicit them.

Strategic Objective 22: Reduced (harmful) material consumption

1. Flow that is directly associated with reduced harmful material consumption
2. Flow that represents the effects of harmful consumption
3. Flow that is the effect of past and future harmful consumption
4. Flow that showcases the final effects of harmful consumption (pollution, etc.)

SO 23: Increased share of use of renewable energy in overall energy demand

1. Flow that is directly associated with increased use of renewable energy in overall energy demand.
2. Flow that is the effect of non-renewable energy use
3. Flow which represents future energy demand and potential future renewable energy production (PVs, …)

SO 24: Increased share of renewable and secondary raw materials in overall material demand

1. Flow that directly influences the increased share of renewable and secondary raw materials use (either through extraction i.e. biomass, renewable energy, imports (biomass, renewable energy, secondary raw materials) or through reuse of secondary materials).

2. Flow that can influence the share of renewable/secondary materials/energy (either by reducing the exports of renewable materials or by changing the treatment of waste flows).
3. Flow that could influence the share depending on the design and implementation of production or services.

SO 25: Increased self-sufficiency / self-reliance

1. Flow that has a direct impact on self-sufficiency (which decreases if exporting DE, decreases if importing, increases if using DE, and increases if using local secondary materials)
2. Flow that has a lesser impact on self-sufficiency and is generated due to decisions on how the stocks were conceived, managed and treated.

SO 26: Increased quantity of materials available for the next cycle

1. Flow that impacts directly the materials available for future use
2. Flow that indirectly impacts the material available for future use (what was used dictates what becomes available for the next cycle)

SO 27: Reduced waste generation

1. Flow that represents the direct flows to monitor for waste generation.
2. Upstream flow which is ultimately responsible for the waste flows generated
3. Downstream flow that may generate waste flows elsewhere or later

SO 28: Reduced incineration and landfilling activities and amounts subjected

1. Flow which has a direct impact on the SO

Table 2 - Relationship between material flows and strategic objectives

Materials Flows (18)		Strategic Objectives (7)						
		#22 Reduce (harmful) material consumption	#23 Reduce overall energy demand and increased share of renewable energy	#24 Increase share of renewable and secondary raw materials in overall material demand	#25 Increase self-sufficiency / self-reliance	#26 Increase quantity of materials available for the next cycle	#27 Reduce waste generation	#28 Reduce incineration and landfilling activities and amounts subjected
Imports	Exports							
Domestic Extraction	Exports			2	1		3	
Imports	Processed materials	1	1	1	1	2	2	
Domestic Extraction	Processed materials	1	1	1	1	2	2	
Processed materials	Energetic use	1	1					
Processed materials	Material use	1						
Energetic use	DPO emissions	2	2					
Energetic use	EoL Waste	2					1	
Material use	EoL Waste	2		3			1	
Material use	In-use stocks	3	3	3			3	
In-use stocks	EoL Waste	3			2	2	1	
EoL Waste	Recovery					1	2	2
Recovery	Processed materials	1			1	1		
Recovery	Exports	4			2	1	3	
EoL Waste	Landfill	4		2	2			1
EoL Waste	Incineration	4		2	2			1
EoL Waste	Incineration with energy recovery	4		2	2			1
EoL Waste	Backfilling	4		2	2	(1) for one more cycle		1

Definition of Circularity Hotspots

The circularity hotspot is a concept frequently used in the context of the circular economy but is loosely defined. In essence, most studies using circularity hotspots define flows, activities or spaces that present promising features for implementing circularity. In the case of this project, the hotspots are born and discovered from three main components (strategic objectives, material flows and material weights) in a two step analysis, the first of which was presented in the previous chapter and the second which is detailed in Chapter 2.3.2 and Figure 3.

- Step 1: Combining strategic objectives with material flows (without quantities) bears the **general circularity hotspots**.

- Step 2: Combining selected material flows with the weight quantities of the UCA, expert and local knowledge, reveals the **contextual circularity hotspots**.

Both types of hotspots are not geographical or otherwise location-based, but have a material flow focus and are, in principle, actionable.

The **general circularity hotspots** do not change depending on the city or territory. Analysing Table 2, it can be seen that the general circularity hotspots are those flows with a direct impact on several SOs and vice versa:

- Imports → Processed materials
- Domestic Extraction → Processed materials
- Recovery → Processed materials
- Flows related to EoL Waste

The **contextual circularity hotspots** are, as the name suggests, context and therefore city specific. Due to the CHA system boundaries, they occur in a city and focus on the material quantity and shares of the flows that are linked to the SOs. This information is crossed for the single material categories (MF1-4) of the general circularity hotspots flows and the information on which values should be increased or decreased respectively, to meet the SOs. In a workshop and consultation with locals this information needs to be taken and combined with local knowledge on land use, geology, economy, policy goals etc. to reveal the city's contextual circularity hotspots, favourable materials and flows for the municipality to work on and to help in decision-making for resource allocation, reaching strategic goals, and potential areas for collaboration and scaling up of circular economy initiatives.

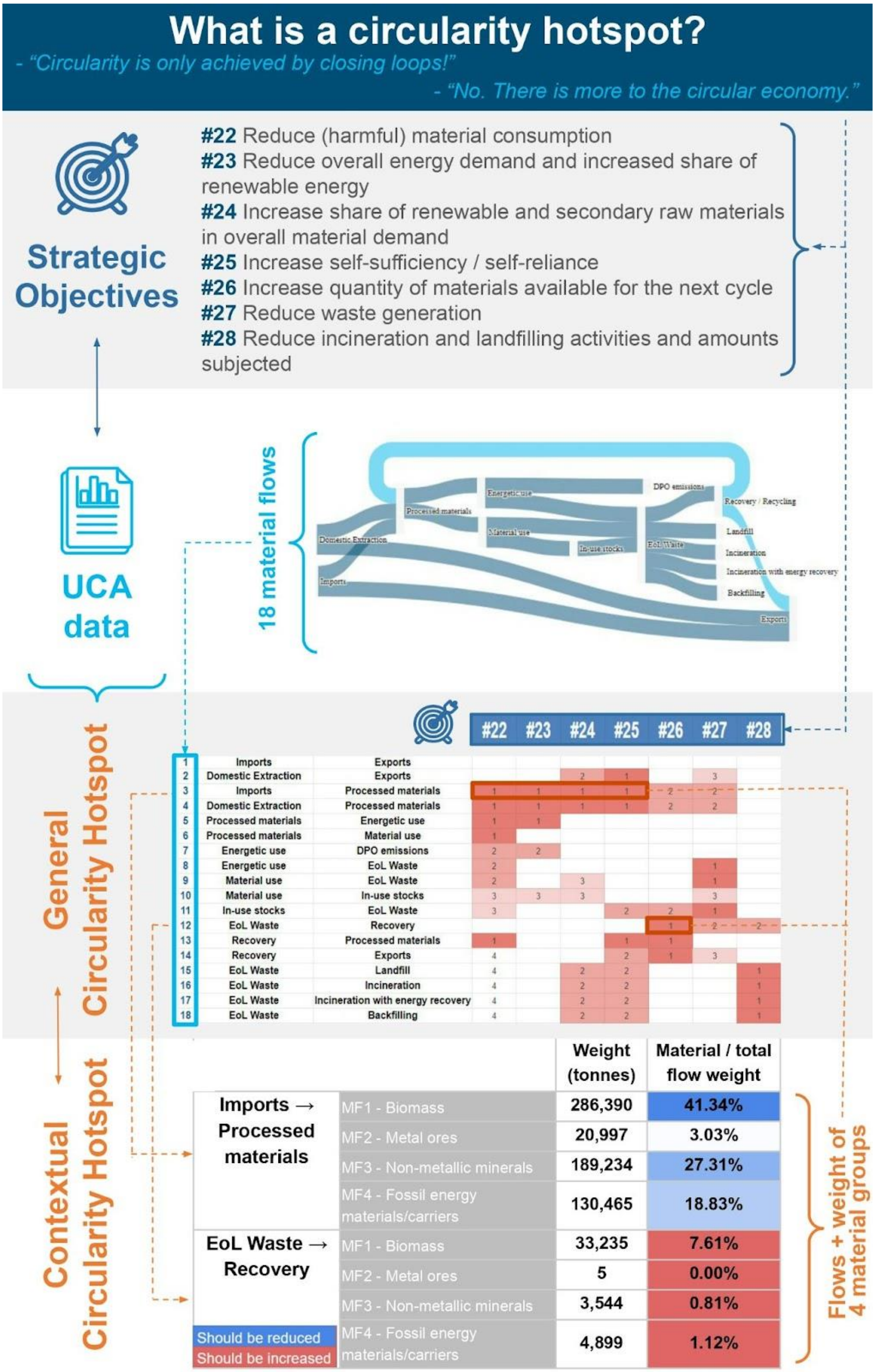


Figure 3 - Circularity Hotspots and their origin

2.2.2. Material Flow Data

To be able to perform the Circularity Hotspot Analysis, data representing the **entire physical economy of a municipality to determine which of its materials flows should be targeted with the intention to "close material loops and minimise as much as possible harmful resource use and waste generation locally"** is required. For that, an urban economy-wide material flow analysis should be carried out that provides structured material flow data, such as the collected and processed data from an Urban Circularity Assessment.

While it was considered and could be argued that the CityLoop's **Sector-wide circularity assessment (SCA)** outputs could also be taken advantage of for the CHA, these were not used for several reasons:

- **Incomplete economy:** The SCA only covers the biomass and/or construction sectors. Therefore, a circularity hotspot could only be revealed between these two sectors or their materials, but not the entire local economy, which is desired in the CHA.
- **Less accurate data:** The SCAs largely produced downscaled national data, as opposed to bottom-up local data. This would make the results on the hotspots less accurate.
- **Challenges in sector coverage:** It is almost impossible to gather comprehensive and accurate data on all the companies, organisations, and individuals operating within a particular sector, which can make it difficult to assess the circularity of the sector as a whole. Moreover, the sector-wide analysis may not fully capture the complexity of the material ecosystems that are involved in the sector, which can lead to incomplete or misleading conclusions about the potential circularity hotspots within a city.
- **Unbalanced flows and nodes:** The SCA does neither cover all materials nor all product flows accurately. As a result and due to data gaps in these assessments, the Sankey diagrams' nodes and flows are not fully balanced.

The Urban Circularity Assessment combats the issues of the SCA, by covering the entire local economy with a total of six material categories that have more reliable data at the city level, either due to bottom-up sources or better downscale proxies and with a balanced material flow analysis.

The focus of the UCA data is on the **four material categories** (see system boundaries) and **their flow amounts between and the total amounts of the 14 lifecycle stages** of the economy listed here and depicted as nodes in Figure 4:

- Imports
- Domestic Extraction
- Processed materials
- Energetic use
- Material use

- In-use stocks
- EoL Waste
- Recovery
- Exports
- DPO emissions
- Landfill
- Incineration
- Incineration with energy recovery
- Backfilling

While the node of “in-use stocks” is listed here, it should be noted that the CHA only takes into account the associated flows of that node (and of the flows of all nodes in general) and does not make use of the stock data from the UCA (which was assessed for buildings and a specific number of materials, depending on the city). The stock, which is situated between the use and waste nodes, exhibits a static behaviour by keeping the materials for more than a year. Therefore, it is argued that the stock does neither inhibit nor facilitate a circular economy, as it is only the flows entering into it or exiting from it that do so. Thus, it was concluded that the stock should not be included in the CHA.

The UCA associated flows and their actual weights are employed, as they directly affect strategic objectives for the achievement of a circular economy and therefore serve in the identification of contextual circularity hotspots. By using material flow data from the whole economy, the circularity hotspot analysis can identify the specific points where an intervention for circularity should take place for (1) the material categories as well (2) the material flows between the above nodes within a city and (3) the strategic objectives.

2.2.3. Table with Material Weights and Shares

On top of the general circularity hotspot analysis, it is essential to understand how flows and materials can affect strategic objectives positively or negatively. For this **material weights** and **72 material shares** were determined by analysing a total of 18 material flows for each material category (M1 to MF4). In this way, an additional weighing of materials was provided, which is both specific to the city’s main flow quantities that circulate the city and the economy, and also the amount of materials based on their weight shares. These were established as follows:

- **Material weights**
    - The single material category’s quantitative values were read out from the UCA results one by one per each flow. For example, 55,000 tonnes of biomass that are domestically extracted and going to processed material.
    - The summed up value of all material categories were also verified from the UCA material flows to obtain the total flow weight of one flow. For example, the total domestic extraction weight goes to processed material.

- **Material shares**
    - The amounts of the single material flows are divided by the total Sankey node (or lifecycle stage) weight to determine the share of it. For example, the share of the weight of imported biomass going to processed materials compared to the total of processed materials weight, see Figure 3.

As a final step, a table is created that lists both the weights and the shares. In the analysis part, the shares serve as the indicator of direction or importance, while the absolute value of weight of the flow is used as a check to determine if it is worthwhile to work on it. For example, a high share (50%) could call attention to a material flow that should be reduced, however if the weight of that flow is not considerably high (5 tonnes), then a lower share material flow (20%) with a higher material weight (200,000 tonnes) could be more favourable to work on. Table 3 provides an example below.

2.2.4. Sankey Diagram

Aside from the essential material flow data, the Sankey diagram and its underlying structure of flows are also an important input for the CHA. The role of the Sankey diagram is to visually depict the situation of the local economy, specified by the four coloured material categories and with some more detail about the waste treatment situation, which is crucial for a circular economy perspective. Aside from the visual function, the 18 flows (see Figure 4) provide a structure that can be crossed with two types of information, namely (1) the strategic objectives to obtain the general circularity hotspot and (2) the weights of the material categories to determine the contextual circularity hotspot.

In the UCA, the Sankey diagram was composed of 14 flows. Furthermore, it depicted the total of the materials. For the CHA, two changes were made. (A) The Sankey diagram is broken down by the economy's four main material categories of biomass, metals, non-metallic minerals, and fossil energy carriers. (B) On the right side of the diagram, where previously the EoL Waste and its flows went to the nodes of export, processed materials, and DPO waste, the waste output was specified. The flows were adjusted so that they now reflect the waste treatments:

- The materials that went from EoL Waste to Export and Processed materials are secondary materials that undergo a recovery process first, which was inserted as an additional node "Recovery", covering processes such as composting and recycling.
- The materials that went from EoL Waste to DPO waste were split up into "Landfill", "Incineration", "Incineration with energy recovery" and "Backfill" instead and replaced "DPO waste".

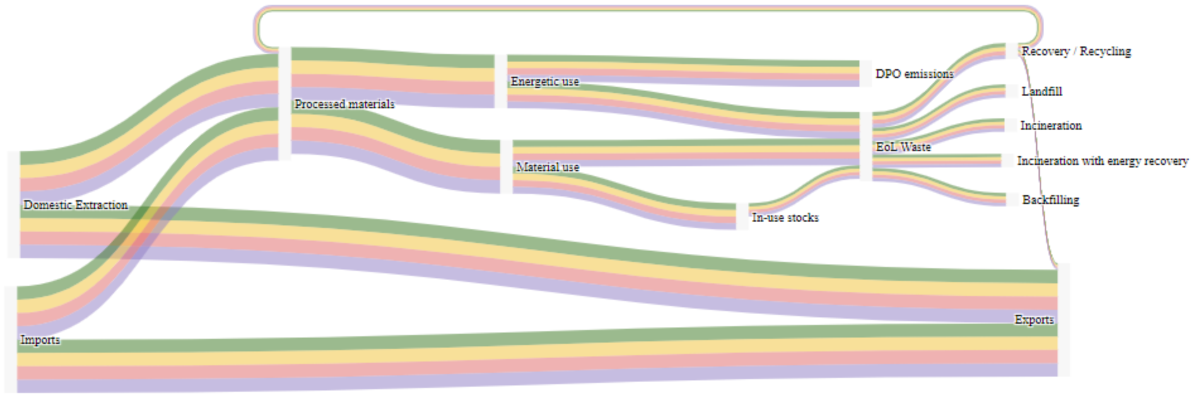


Figure 4 - Neutral Sankey diagram with four material categories and waste specification

2.3. Output

To conclude, by carrying out the CHA, a number of intermediary and final outputs are provided. Intermediary outputs are essential elements to obtain the final outputs. The intermediate outputs consist of the general circularity hotspots, which relates UCA flows to SOs (Table 2), a table with material weights and specific shares of those (within broader flows such as e.g. domestic extraction) that should be either increased or decreased to address a circularity hotspot, and Sankey diagrams that are disaggregated by material flow categories (biomass, metals, non-metallic minerals and fossil fuels).

2.3.1. Intermediate Outputs

While the intermediate outputs and their origin have already been presented in the previous chapters, the following ones provide practical examples for the table with material weights and shares as well as the Sankey diagrams. Moreover, it is explained in infoboxes how those can be generated.

General Circularity Hotspots

The general circularity hotspot table provides a broad relationship between UCA flows and the SOs. This table is important to kickstart discussions between stakeholders and enables them to better understand how one action on one flow could have a desired effect on (one aspect of their) circularity. This relationship stands *a priori* true for all territories. Furthermore, the general circularity hotspots facilitate a pre-selection of material flows that should be considered more closely, e.g. the flows from import to export do not seem to impact any of the SOs, while the flows from import to processed materials do.

Example of Table with Material Weights and Shares

To better illustrate the table of material flows with their weights and shares of nodes (Chapter 2.2.3), Table 3 provides an example of the UCA data for the city of Apeldoorn. It illustrates the weight in tonnes, the shares as part of processed materials, as well as if the flows should be reduced or increased. In the infobox, it is explained how cities can create Table 3 with their own UCA data.

Table 3 - Apeldoorn's material weights and shares for selected flows

2018	CHA TABLE						
	Material Weights and Shares						Should be reduced / Should be increased
				Weight (tonnes)		Material / total inflow	Material / Total flow
627085.37	Imports	Processed materials	MF1	286389.64		45.67%	41.34%
	Imports	Processed materials	MF2	20996.51		3.35%	3.03%
	Imports	Processed materials	MF3	189234.05		30.18%	27.31%
	Imports	Processed materials	MF4	130465.18		20.81%	18.83%
55838.51	Domestic Extraction	Processed materials	MF1	55838.51		100.00%	8.06%
	Domestic Extraction	Processed materials	MF2	0.00		0.00%	0.00%
	Domestic Extraction	Processed materials	MF3	0.00		0.00%	0.00%
	Domestic Extraction	Processed materials	MF4	0.00		0.00%	0.00%
9925.81	Recovery	Processed materials	MF1	8069.52		81.30%	1.16%
	Recovery	Processed materials	MF2	0.75		0.01%	0.00%
	Recovery	Processed materials	MF3	1574.25		15.86%	0.23%
	Recovery	Processed materials	MF4	281.29		2.83%	0.04%

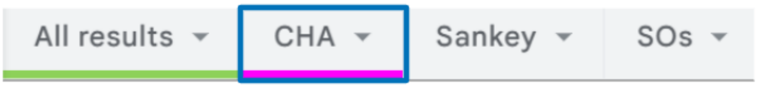
HOW TO GET THE CHA TABLE

Based on every city's Urban Circularity Assessment, a contextual circularity hotspot table can be formed with the latest reference year data. To achieve this, the following steps should be followed:

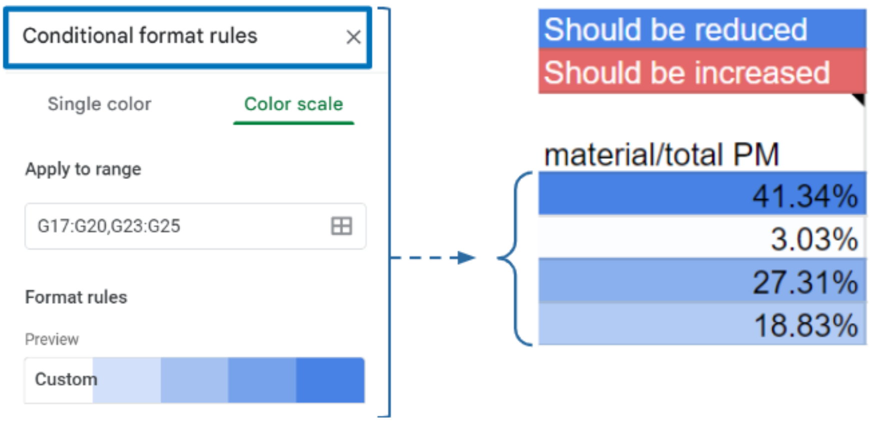
1. Duplicate the latest UCA reference year analysis sheet and rename it.

C.1 UCA - Analysis - Apeldoorn - Year 1 - 2018 → H. CHA - Apeldoorn - 2018

2. Add the CHA tab from the template sheet which will pull the data necessary from relevant cells.



3. Add conditional formatting to reveal what needs to be reduced and increased.



Example of Sankey Diagrams

The output from the circularity hotspot analysis is structured using Urban Circularity Assessment output data for each single material category, for a municipality with the latest reference year. Based on this output, a number of Sankey diagrams can be generated to make data better communicable and easier to understand the urban choreography of material flows, covering the entire system, from domestic extraction and imports to domestic processed outputs, waste, and exports, see Figure 5 with the example of the city of Apeldoorn.

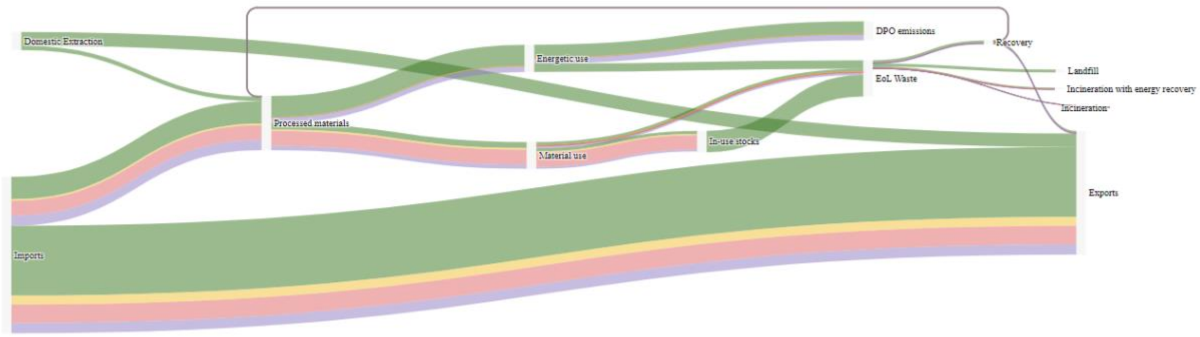


Figure 5 - Sankey diagram of Apeldoorn with all material categories and waste specification

These data for the single material categories (MF1-MF4) are also visualised separately using Sankey diagrams to clearly show the flows of each material and quantities through a system (Figure 6-9). It is useful to identify areas where there may be inefficiencies or opportunities for improvement as well as which flow(s) contribute most to a certain type of waste valorisation/recovery. As visible from these four different Sankeys, each material category has a very different functioning. For instance, some material groups have no recovery, others might have some domestic extraction and some others might be more responsible for emissions.

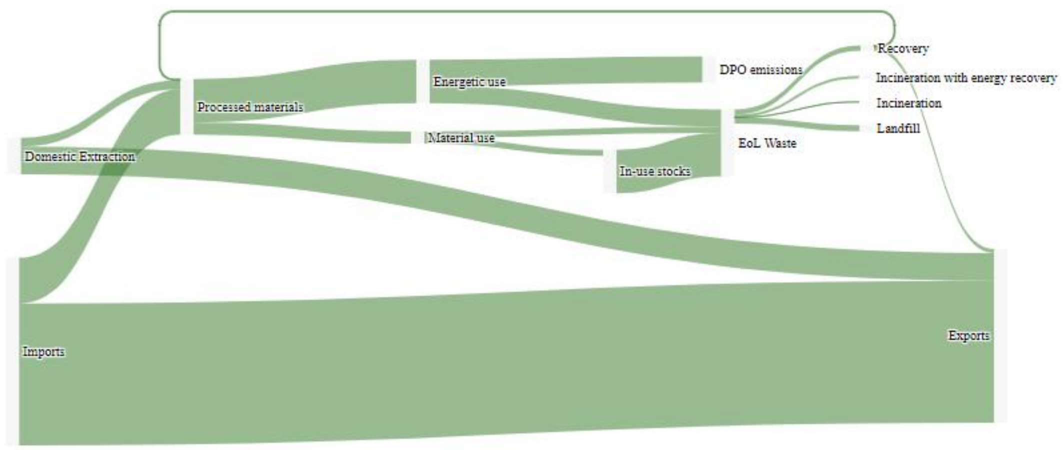


Figure 6 - Sankey diagram of Apeldoorn with MF1 Biomass category

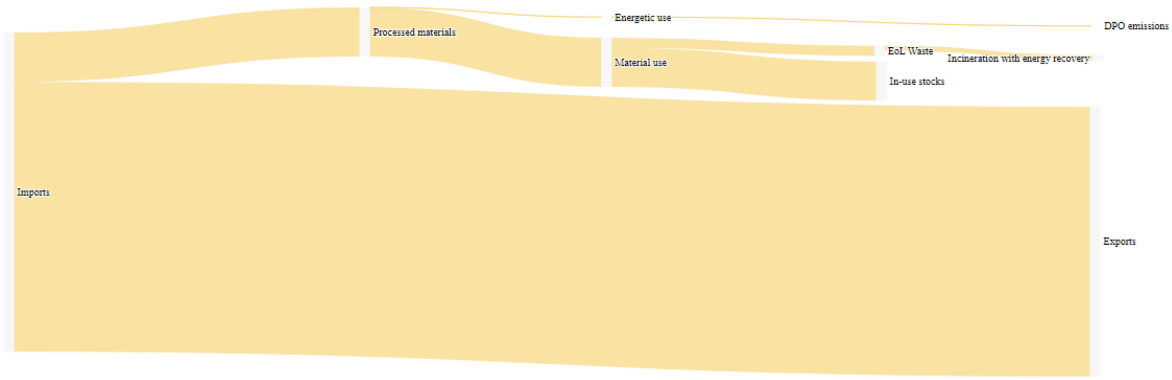


Figure 7 - Sankey diagram of Apeldoorn with MF2 Metal ores category

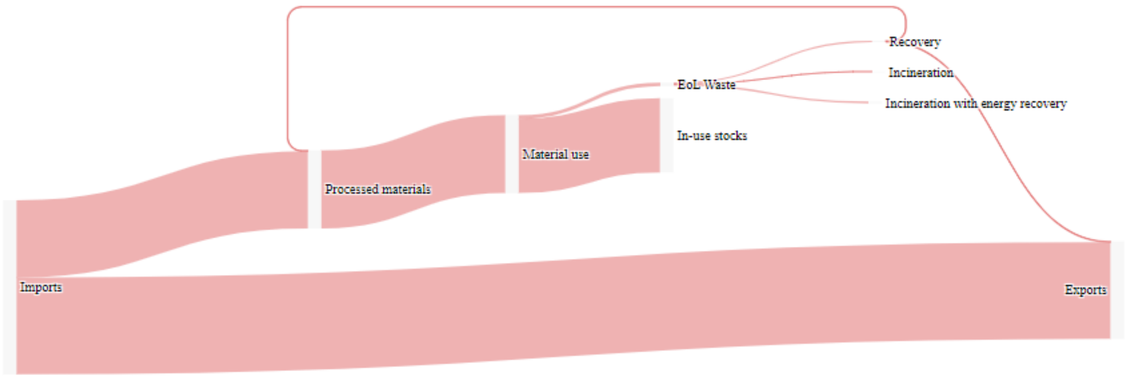


Figure 8 - Sankey diagram of Apeldoorn with MF3 Non-metallic minerals category

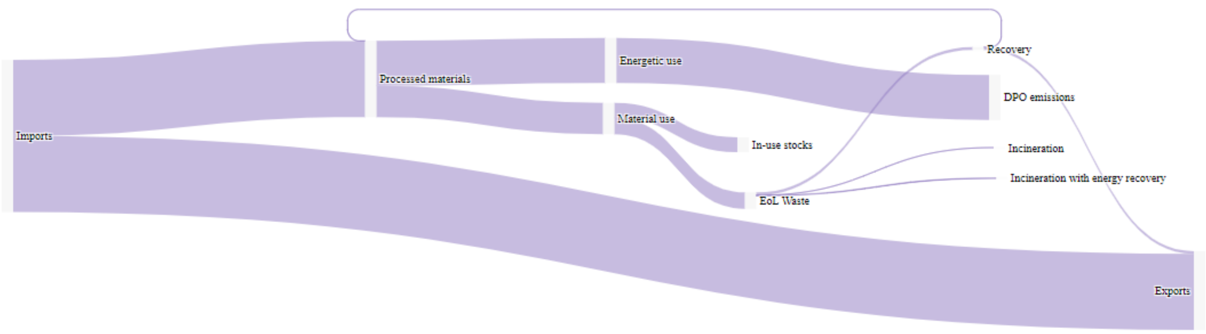


Figure 9 - Sankey diagram of Apeldoorn with MF4 Fossil energy materials/carriers category

HOW TO MAKE SANKEY DIAGRAMS

Sankey diagrams according to material categories with waste extension can be made through the following steps:

1. Use the latest H.UCA sheet and copy "CE_Calculation_final_step" tab from the template H.UCA worksheet made by MoC.

CE_Calculation_final_step ▾

2. Under UCA's Sankey flow calculations, CHA's Sankey flows with waste flows in total and material groups breakdown will show up automatically with your data.

Sankey		CHA with waste flows in total			
From	To		Flow Label		
Imports	Exports	3387.01	Imports --> Exports	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Domestic Extraction	Exports	174.14	Domestic Extration --> Expo	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Imports	Processed materials	627.09	Imports --> Processed mate	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Domestic Extraction	Processed materials	55.84	Domestic Extration --> Proc	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Processed materials	Energetic use	350.02	Processed materials --> Ene	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Processed materials	Material use	342.83	Processed materials --> Mat	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Energetic use	DPO emissions	242.27	Energetic use --> DPO emis	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Energetic use	EoL Waste	107.74	Energetic use --> EoL Wast	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Material use	EoL Waste	80.20	Material use --> EoL Waste	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Material use	In-use stocks	262.64	Material use --> In-use stock	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
In-use stocks	EoL Waste	248.93	In-use stocks --> EoL Waste	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
EoL Waste	Recovery	41.68	EoL Waste --> Recovery	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Recovery	Processed materials	9.93	Recovery --> Processed ma	rgba(0, 182, 237, 0.	rgba(239, 239, 239, 0.5)
Recovery	Exports	31.76	Recovery --> Exports	rgba(0, 182, 237, 0.	rgba(239, 239, 239, 0.5)
EoL Waste	Landfill	371.06	EoL Waste --> Landfill	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
EoL Waste	Incineration	0.05	EoL Waste --> Incineration	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
EoL Waste	Incineration with energy	24.07	EoL Waste --> Incineration v	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
EoL Waste	Backfilling	0.00	EoL Waste --> Backfilling	rgba(0, 77, 118, 0.5	rgba(239, 239, 239, 0.5)
Sankey		CHA with waste flows and material groups breakdown			
From	To	Value	Flow Label	flow_color	node_color
Imports	Exports	893.13	Biomass	rgba(56, 118, 30, 0.	rgba(239, 239, 239, 0.5)
Imports	Exports	115.21	Metal ores and metals	rgba(241, 194, 51, (	rgba(239, 239, 239, 0.5)
Imports	Exports	236.75	Non-metallic minerals	rgba(224, 102, 102,	rgba(239, 239, 239, 0.5)
Imports	Exports	130.47	Fossil energy carriers	rgba(142, 124, 195,	rgba(239, 239, 239, 0.5)
Domestic Extraction	Exports	174.14	Biomass	rgba(56, 118, 30, 0.	rgba(239, 239, 239, 0.5)
Domestic Extraction	Exports	0.00	Metal ores and metals	rgba(241, 194, 51, (	rgba(239, 239, 239, 0.5)
Domestic Extraction	Exports	0.00	Non-metallic minerals	rgba(224, 102, 102,	rgba(239, 239, 239, 0.5)
Domestic Extraction	Exports	0.00	Fossil energy carriers	rgba(142, 124, 195,	rgba(239, 239, 239, 0.5)
Imports	Processed materials	286.39	Biomass	rgba(56, 118, 30, 0.	rgba(239, 239, 239, 0.5)
Imports	Processed materials	21.00	Metal ores and metals	rgba(241, 194, 51, (	rgba(239, 239, 239, 0.5)
Imports	Processed materials	189.23	Non-metallic minerals	rgba(224, 102, 102,	rgba(239, 239, 239, 0.5)
Imports	Processed materials	130.47	Fossil energy carriers	rgba(142, 124, 195,	rgba(239, 239, 239, 0.5)
Domestic Extraction	Processed materials	55.84	Biomass	rgba(56, 118, 30, 0.	rgba(239, 239, 239, 0.5)

3. Import these calculations into a new Google sheet.

S. Sankey Apeldoorn — Saved to Drive

File Edit View Insert Format Data Tools Extensions Help Last edit was seconds ago

H12

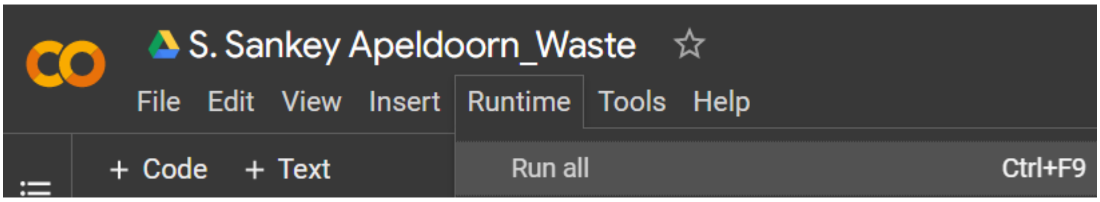
	A	B	C	D	E	F
1	From	To	Value	Flow Label	flow_color	node_color
2	Imports	Exports	893.13	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)
3	Imports	Exports	115.21	Metal ores and n	rgba(241, 194, 5	rgba(239, 239, 239, 0.5)
4	Imports	Exports	236.75	Non-metallic min	rgba(224, 102, 1	rgba(239, 239, 239, 0.5)
5	Imports	Exports	130.47	Fossil energy ca	rgba(142, 124, 1	rgba(239, 239, 239, 0.5)
6	Domestic Extraction	Exports	174.14	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)
7	Domestic Extraction	Exports	0.00	Metal ores and n	rgba(241, 194, 5	rgba(239, 239, 239, 0.5)
8	Domestic Extraction	Exports	0.00	Non-metallic min	rgba(224, 102, 1	rgba(239, 239, 239, 0.5)
9	Domestic Extraction	Exports	0.00	Fossil energy ca	rgba(142, 124, 1	rgba(239, 239, 239, 0.5)
10	Imports	Processed materials	286.39	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)
11	Imports	Processed materials	21.00	Metal ores and n	rgba(241, 194, 5	rgba(239, 239, 239, 0.5)
12	Imports	Processed materials	189.23	Non-metallic min	rgba(224, 102, 1	rgba(239, 239, 239, 0.5)
13	Imports	Processed materials	130.47	Fossil energy ca	rgba(142, 124, 1	rgba(239, 239, 239, 0.5)
14	Domestic Extraction	Processed materials	55.84	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)
15	Domestic Extraction	Processed materials	0.00	Metal ores and n	rgba(241, 194, 5	rgba(239, 239, 239, 0.5)
16	Domestic Extraction	Processed materials	0.00	Non-metallic min	rgba(224, 102, 1	rgba(239, 239, 239, 0.5)
17	Domestic Extraction	Processed materials	0.00	Fossil energy ca	rgba(142, 124, 1	rgba(239, 239, 239, 0.5)
18	Processed materials	Energetic use	272.86	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)
19	Processed materials	Energetic use	0.08	Metal ores and n	rgba(241, 194, 5	rgba(239, 239, 239, 0.5)
20	Processed materials	Energetic use	0.01	Non-metallic min	rgba(224, 102, 1	rgba(239, 239, 239, 0.5)
21	Processed materials	Energetic use	77.08	Fossil energy ca	rgba(142, 124, 1	rgba(239, 239, 239, 0.5)
22	Processed materials	Material use	77.44	Biomass	rgba(56, 118, 30	rgba(239, 239, 239, 0.5)

4. Copy and replace the new sheet's link into S. Sankey Google Colaboratory underneath Data.

Data

```
worksheet = gc.open_by_url('https://docs.google.com/spreadsheets/d/1cnhexBTlhYxCKGe39-ITzN5UVih-r8IB7q0QS0mRLnw/edit?usp=sharing').sheet1
```

5. Hit "Run all" underneath Runtime.



6. Lastly drag and drop nodes to show your city's circularity journey in the most legible way.

2.3.2. Contextual Circularity Hotspots

By using the intermediary outputs presented above, it is possible to explore contextual circularity hotspots in order to develop context specific actions and policies. In fact, it was judged counterproductive to develop a quantitative contextual circularity hotspot as not only numerous additional pieces of information would need to be mobilised (land use, employment, existing policies, funding, etc.), but also a local multi-criteria decision making process. As such, it was decided that all the intermediary outputs will be provided to a small number of local stakeholders, namely the UCA analyst and one or two transversal urban officers. They should be knowledgeable on the circular economy to e.g. be able to consider trade-offs, and be well-versed around (socio-)economic and environmental matters in the municipality. Through a collective intelligence workshop, they will use their local knowledge (actors, leverages, priority in politics etc.) to analyse and prioritise local hotspots and actions that are favourable, impactful and feasible.

As an example, in the case of Apeldoorn, by looking at the local Sankey diagrams and shares, it is visible that for example the following flows should be targeted in priority:

- the flow of imports to processed materials of biomass (41.34% of total imports with 286 thousand tonnes)
- and the same one for non-metallic minerals (27.31% of total imports with 189 thousand tonnes),
- as well as the flow of domestic extraction to processed materials of biomass (8.06% of total processed materials with 56 thousand tonnes), which is the only material that is extracted.

Nevertheless, the strategies for these two kinds of flows are very different. For instance, as Apeldoorn has a vast surface of biomass land and forest, more domestic extraction, which is currently rather low, might be proposed to reduce their imports. In the case of non-metallic minerals, while it would be possible to propose the same strategy, it might be wiser to propose an absolute reduction or substitution of non-metallic minerals (and not shift towards their local extraction).

The results of this workshop are therefore looking at the different absolute and relative numbers of materials flows in combination with the general circularity hotspot table, in order to underline which circularity hotspots are the most relevant, feasible and impactful. These contextual circularity hotspots will then be used as a basis to propose targeted actions (a catalogue of solutions will be provided during the application of the CHA method) and cities can carry this fact-based groundwork into the preparation of policies and road maps.

Bibliography

Vangelsten, Bjørn Vidar, Bjarne Lindeløv, Nhien Nguyen, Jens Ørding Hansen, Are Jensen, Nikolai Jacobi, Simon Clement, et al. 2020. 'Circular City Indicator Set (Deliverable 6.1)'. 6.1.

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.