Reflow | Co-creating Circular Resource Flows in Cities

constRuctive mEtabolic processes For materiaL flOWs in urban and peri-urban environments across Europe

Deliverable 3.1

Circular Principles and Indicators

Due date of deliverable: 29/05/2020
Actual submission date: 29/05/2020
Start date of project: 01/06/2019 Duration (36 Months)
Dissemination Level: Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement number 820937.

DELIVERABLE

Work Package	WP 3 Circular Engineering
Deliverable	D 3.1 Circular Principles and Indicators
Document Name	Circular Principles and Indicators
Due Date	M12: 29th May 2020
Submission Date	M12: 29th May 2020
Dissemination Level	P-Public
Deliverable Lead	Metabolic Institute (MET)
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Reviewers	Fab City Grande Paris, IAAC
Status	[X] Final [ ] Approved
Abstract (for public dissemination only)	D3.1 Circular Principles and Indicators lays out the key concepts and components of WP 3's Circular Urban Metabolism framework - (1) Circular Principles, (2) principle-level and pilot-specific key performance indicators, and (3) urban metabolism assessments - as well as the methodologies undertaken to derive them and the resulting outcomes. In doing so, it chronicles the activities undertaken and results derived by WP 3 within the first year of the REFLOW project.
Keywords	urban metabolism; circular economy; material flow analysis
Statement of Originality	This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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Revision History

Revision	Date	Author(s)	Organization	Description
D3.1 v0.1	30 April 2020	Liz Corbin, Antoine Coudard, Alysia Garmulewicz, Zoe Powell, Apurva Singh, Charlene Smith, Pilar Bolumburu	Metabolic, Materiom	First draft
D3.1 v0.2	18 May 2020	Liz Corbin, Antoine Coudard, Apurva Singh	Metabolic	Final draft

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Executive Summary

Cities account for 3% of the total land surface of the planet, yet use 75% of the total resources extracted by the world's economy (Pacione, 2009). This trend is projected to increase, as by 2050 urban dwellers are expected to represent 66% of the 9.5-billion human population (UN, 2017). Maximizing the circular and regenerative nature of urban resources while minimizing urban waste and impacts, has become both a pan-European priority and a key leverage point in transitioning the European economy to a regenerative and circular state.

A core concept upon which the REFLOW project is built is that of **urban metabolism**, which seeks to understand the flows of resources within a city and to provide a framework for studying the interactions between natural and human systems in specific peri-urban regions. At the core of the urban metabolism concept is the **material flow analysis** (MFA) methodology: an analytical method to quantify flows and stocks of materials, water, energy, and products in a pre-defined system in order to study biophysical aspects of human activity on different spatial and temporal scales. In REFLOW, the urban metabolism approach plays an important role. However, if the urban metabolism concept is key to tracking and monitoring key urban resource flows, the addition of circular principles that provide guidance on, and a vision for, how to reconfigure these flows is crucial. Thus, the **Circular Principles** described within the REFLOW project are an integral part of the metabolic approach and pave the way to transforming the project's participating cities in a regenerative and circular direction.

By combining the urban metabolism methodology with the Circular Principles, Metabolic and Materiom have generated the Circular Urban Metabolism framework: a framework for mapping, measuring, and facilitating interventions and strategies towards circular and regenerative European cities. Report **D3.1 Circular Principles and Indicators** lays out the key concepts and components of the Circular Urban Metabolism framework - (1) Circular Principles, (2) principle-level and pilot-specific key performance indicators, and (3) urban metabolism assessments - as well as the methodologies undertaken to derive them and the resulting outcomes.

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List of abbreviations and key words

Abbreviations:

CE: Circular economy

CP: Circular Principle

EFA: Energy flow analysis

EU: European Union

GHG: Greenhouse gas

KPI: Key performance indicator

LCA: Life-cycle assessment

MFA: Material flow analysis

STV: Single transferable vote

Definitions and Keywords:

Circular economy

A circular economy is an alternative to the present-day dominant linear industrial model of design, produce, purchase, consume and dispose. A circular model aims to redefine growth and generate positive societal and environmental impact. It entails a transition from using finite resources, to using renewable ones (designing the concept of waste out of the system), while building economic, natural, and social capita. Although starting from material resources as a point of departure in REFLOW, the focus of the circular economy gradually extends beyond these issues related to material management and covers broader aspects such as social impact and the evolution of urban governance structures. The social components of a circular economy are fundamental to consider within the transition.

Urban metabolism

Urban metabolism is a concept focusing on the quantitative assessment of urban resource flows. It is a process of identifying the collection of complex sociotechnical and socio-ecological processes by which flows of materials, energy, people, and information shape the urban space.

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Material flow analysis (MFA)

A material flow analysis is defined as 'a systematic assessment of the flows and stocks of materials within a system defined in space and time' (Brunner and Rechberger, 2003). It is a method that quantifies flows and stocks of resources in a defined system.

Environmental impact assessment

Environmental impact assessment (EIA) is a process of evaluating the likely environmental impacts of a material, product, or any type of proposed project or development, taking into account its entire life-cycle. It also considers the inter-related socio-economic, cultural, and human-health impacts, both beneficial and adverse.

Resource flows

A physical volume of material, energy, or water moving from one place to another in a specific timeframe.

ReflowOS

An online exchange platform acting as a Value-Based Network platform for recycled resources. ReflowOS has the ambition to create a marketplace to facilitate exchanges of materials, help locate and track materials and resources, and facilitate exchange through smart contracts.

Key performance indicator

A quantifiable measure used to evaluate the success of an organization, project or product in meeting objectives for performance.

Sankey diagrams

Sankey diagrams visualize material, energy, and other resource flows as arrow-like shapes with their width shown proportionally to the flow quantity they represent. They are often used to visualize results from a material flow analysis.

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Regenerative circular economy

An economy where materials flow in loops or cycles, human activity generates net-positive outcomes beyond system optimization, renewable energy is prioritized, economic growth is decoupled from resource use, and natural capital is invested in. The regenerative circular economy is considered a nested system spanning local, regional, national, and global scales of production and consumption, inspired at every level by living systems to help foreground change and support adaptive management of socio-ecological systems.

Ecosystem

Biological community of interacting organisms and their physical environment.

Planetary boundaries

Planetary boundaries is a concept involving Earth system processes with environmental impact thresholds that should not be crossed to avoid abrupt or irreversible environmental changes. Society must stay within these boundaries to continue to develop and thrive sustainably.

Socio-ecological systems

Social-ecological systems are complex adaptive systems composed of many diverse human and non-human entities that interact. They adapt to changes in their environment and their environment changes as a result.

Biodiversity

Biodiversity is the variability among living organisms from all sources, including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

Open source

Software for which the original source code is freely available for possible modification and redistribution. Hardware, methods, and datasets may also be open source.

System resilience

System resilience is the ability of a system to withstand a major disruption, whether predictable or not, while keeping its core functions intact in an acceptable range and recovering within an acceptable time frame.

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Biomaterial

A material intentionally made from substances derived from living (or once-living) organisms.

Feedstock

Raw material or resource needed in order to supply or fuel an industrial process. Within REFLOW, feedstock refers to recycled resources that re-enter the production chain as “new” supplies for the manufacturing processes.

Impact Areas

Twelve areas of impact co-identified and co-developed by the REFLOW consortium in order to highlight the most relevant impact categories in relation to the vision, objectives, and activities of the REFLOW project and pilots.

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1. Introduction

1.1 Scope and objectives

REFLOW is an EU H2020 project, running from 2019 to 2022, that seeks to co-create and test circular and regenerative solutions in urban and peri-urban areas across Europe. The ambition of REFLOW is to develop circular and regenerative cities through the re-localisation of production and the circular management of material flows - emphasizing a bottom up, citizen-driven approach. The project aims to provide viable strategies that leverage market, government, and citizen action that are in line with 2030 Sustainable Development Goals, in particular SDG 12: Sustainable Consumption and Production. At the project's core is the development, testing, and iteration of circular economy (CE) strategies in six pilot cities across Europe: Amsterdam, Berlin, Cluj-Napoca, Milan, Paris, and Vejle.

The primary elements of the REFLOW project are listed below, as well as their associated Work Packages:

- **Co-Creation Design & Framework** (Work Package 1): Design, deliver, and evaluate a series of CE practices that respond to urgent citizen and business needs. The aim of this work is also the alignment of the distributed ledger infrastructure (WP 2), circular engineering practices (WP 3), and governance and urban planning models (WP 4) into an overarching activity of business model ideation and prototyping.
- **Technical Infrastructure & Software** (Work Package 2): The integration of new technological solutions to facilitate the circulation of data and resources.
- **Creating & Managing Circular Flows** (Work Package 3): The mapping and measurement of each pilot city's urban metabolism through a core set of methodologies including material flow analysis (MFA) and environmental impact assessment. Results will help shape the circular economy strategies developed and tested by pilots.
- **Collaborative Governance & Urban Strategies** (Work Package 4): A set of new practices to redesign governance models towards more collaborative and distributed public-private-people alliances.
- **Pilots Framework** (Work Package 5): A structure that acts both as a tool and as a dashboard. It aligns the pilot cities from the understanding of their context, while recording the progress of their journey to discover how to become more circular.
- **Capacity Building** (Work Package 6): A set of capacity building activities to align the skills and needs of key stakeholders with the vision of each pilot city.

- **Communication** (Work Package 7): An ongoing communication strategy to inform and engage stakeholders and create a successful narrative for the transition to a circular economy.

A core concept upon which the project is built is the concept of **urban metabolism**, which seeks to understand the flows of materials, energy, and water within a city and to provide a framework for studying the interactions between natural and human systems in specific peri-urban regions. At the core of the urban metabolism concept is the **material flow analysis** (MFA) methodology: an analytical method to quantify flows and stocks of materials, water, energy, and products in a pre-defined system in order to study the biophysical aspects of human activity on different spatial and temporal scales.

1.2 Introduction to WP 3 Circular Engineering and D3.1

REFLOW activities associated with urban metabolism, material flow analyses, and environmental impact assessment are led by Metabolic and Materiom as part of Work Package (WP) 3: Circular Engineering. The purpose of WP 3 is to map and measure each pilot city's urban metabolism through a core set of methodologies including material flow analysis (MFA) and environmental impact assessment. The work is done in close collaboration with each pilot team and results are used to support the continual development and testing of the circular economy strategies within each pilot city. The core objectives of WP 3 are:

- To co-create principles and best practices for urban circular resource flows across the pilot cities.
- To co-identify, develop, and scale innovative solutions for urban circular resource flows across the pilot cities.
- To assess the environmental performance and impacts of pilot cities, their interventions, and strategies.

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Toward achieving the above mentioned objectives, Metabolic and Materiom have led three overarching tasks throughout the first year of REFLOW, including:

- **Circular Principles & Indicators**: Co-development, with pilot cities, of a set of principles and key performance indicators (KPIs) for circular urban resource flows. The purpose of the principles is to communicate key principles and best practices that partners should strive towards when building circular resource flows within cities.
- **Circular key performance indicators (KPIs)**: Support pilot cities in setting progressive circular economy targets and goals within their REFLOW Pilot Action Plans (REFLOW D5.1, 2020) as well as a core set of KPIs that enables pilot teams to monitor progress towards their pursuit. To ensure effective use of selected KPIs, WP 3 has worked closely with pilot teams to calibrate each KPI to the context, scale, and strategy of each pilot.
- **Urban metabolism**: To map and measure the urban metabolism of each pilot city and support the pilot teams in devising circular strategies and interventions that best address the unique context, challenges, and opportunities of their city. Results of the process include: a series of Sankey diagrams for each pilot (for example, a city-level MFA and a site-level MFA), a current state assessment of each pilot's urban metabolism (including volume, temporal, and spatial factors), and a circular intervention roadmap for each pilot city. At the time of writing, the Amsterdam pilot's city- and site-level scans have been completed, a city-level scan for the Milan pilot has been developed, while the remaining pilot scans will be completed in the upcoming year.

The processes taken thus far by WP 3 towards each abovementioned task are presented in this document **D3.1: Circular Principles & Indicators** as are the results derived. The document is organized in three main sections (mirroring the above mentioned three main tasks). The first section outlines the general scope, structure, and methodology undertaken to derive the Circular Principles and Indicators. The section includes a detailed explanation of the literature-based methodology and the co-creation process undertaken to derive the principles, as well as an in-depth explanation of each of the ten principles and their indicators, including exemplary case studies. The second section outlines the method and outcomes of our work with each pilot to develop KPIs and environmental monitoring measures for achieving the goals and targets set out by each pilot in **D5.1 Detailed Pilot Planning & Evaluation Framework** (REFLOW D5.1, 2020). The section includes the literature-based methodology and co-creation process we undertook to derive a final set of environmental KPIs with each pilot team in accordance with the unique context, goals, and activities of their pilot. The section also outlines in detail the outcomes of each step of the process, including: KPI shortlisting, KPI recalibration,

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stakeholder surveying, and final KPI setting. The third section introduces the urban metabolism process being undertaken within WP 3. It provides an introduction to the scientific method as well as an explanation of the methods that are being implemented within the REFLOW project.

It is important to note that the content contained within this report provides an overview of the activities and results of WP 3 throughout the first year of REFLOW. WP 3 seeks to mirror the iterative and co-creative nature of the REFLOW project and pilots, the outcomes included herein - namely, (i) the Circular Principles and Indicators, (ii) the Pilot environmental KPIs and monitoring measures, and (iii) pilot urban metabolism scans - will be revisited and adjusted where necessary throughout the next 12 months of the project to ensure they remain aligned with the evolving vision and objectives of the pilots.

2. Circular Principles

2.1 Introduction

In this chapter we present a set of Circular Principles and Indicators that can help guide cities in the transition toward a regenerative circular economy. The circular economy has been widely employed to mean an economy where materials flow in loops or cycles, human activity runs on renewable energy, economic growth is decoupled from resource use, and natural capital is invested in.

With the term regenerative circular economy, we aim to emphasize three main themes. First, we use the term regenerative to place emphasis on net-positive outcomes, and expand beyond the narrow focus of system optimization towards more generative, creative system outcomes. Second, our vision of a regenerative circular economy also foregrounds the importance of place-based and context-specific analysis and action. Rather than a one-size-fits-all approach to circular economy principles, we emphasize principles that frame the economy as a nested system spanning local, regional, national, and global scales of production and consumption. In particular, local and regional scales are where latent regenerative potential can be found. Third, we take inspiration from living systems by foregrounding change and adaptive management of socio-ecological systems. We propose learning from the way resources in natural ecosystems flow. This leads us away from a mindset of engineering tightly controlled closed loops of materials that are isolated from living systems, to designing our products to be nutrients for living systems at local and regional scales.

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We also acknowledge key barriers to a regenerative circular economy, some of which are particularly critical when focusing on local and regional scales. Any development of local and regional material supply chains, particularly those relying on sources of biomass, must avoid over-exploiting source ecosystems. Careful attention must be paid to understanding the carrying capacity of local ecosystems; with volume of resource extraction, rate of nutrient return, and interdependencies between human and ecosystem needs being of primary concern. A regenerative circular economy must avoid competition with food production. This means sourcing material feedstock in ways that are complementary to agricultural demands, such as developing materials from waste biomass. A regenerative circular economy must also avoid putting increased pressure on scarce water sources. There is a clear need for circular economic development to be tailored to the relative abundance and competing demand for resources, including biomass and water, in addition to the availability of renewable energy sources.

A barrier that cuts across all these challenges is knowledge about resource flows, particularly locality-specific knowledge about the volume and rate of resource availability, the composition and quality of resources, and the spatial dynamics of how resources move from one place to another overtime. For us to achieve truly regenerative circular cities, it will be essential to open up knowledge about urban resources - how they are (and can be) sourced, used, and recovered - as well as the means to measure the social, environmental, and economic value and impacts generated across the life-cycle.

If a regenerative circular economy is to take root in localities and regions worldwide, this knowledge must become widely accessible. This challenge relates to the need to scale a regenerative circular economy horizontally, rather than vertically. Instead of perpetuating an economic model where 'scale' means privatization and centralization of resources and productive capacity, we envision 'getting to scale' by propagating solutions through open loops of exchange powered by decentralized infrastructure.

If ideas and learning are shared openly and effectively, circular solutions can be replicated and scaled across localities and regions by adapting them to the local technical, cultural and environmental conditions.

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The REFLOW project is perfectly situated to accelerate the transition to a regenerative circular economy. Driven by pilot cities, there is a unique opportunity for place-based circular economy initiatives to take root. The following set of Circular Principles, indicators, and case studies are developed to support this effort.

The Circular Principles serve to distill the aims of a regenerative circular economy and provide meaningful guidance for its pursuit. For each principle a set of KPIs is offered so to make progress towards the principle measurable and therefore more achievable. Case studies are included for illustrative purposes and to make tangible the key concepts put forward within each principle.

The principles will be further co-developed in close collaboration with REFLOW pilots and project partners to ensure they sufficiently reflect and contribute towards the REFLOW shared vision as it evolves over the course of the project.

Graphic 1: The 10 Circular Principles.

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Table 1: An overview of the 10 Circular Principles.

Scale 1: Urban Resources	
1. Use life-friendly chemistry	A regenerative circular economy is one where materials and products are produced using chemical processes that are 'life-friendly,' that is, they promote human and ecosystem health.
2. Pursue efficient use of materials, energy, and water	To reduce the pressure put on natural ecosystems and keep within planetary boundaries, there is a need to enhance the material, energy, and water efficiency of products and processes.
3. Design for biological or technical loops	All materials should be designed to either cycle openly within the biosphere as biological nutrients, or be cycled within a technical closed loop by human systems. Waste and pollution is designed out, and instead, 'waste equals food' for the system (Braungart et al, 2002).
4. Build with abundant, accessible, and renewable resources	Materials and products should be produced and consumed at scales most effective for their cycling within biological or technical loops. The economy should be powered by renewable sources (defined as locally abundant solar, wind, water, and biomass waste).
Scale 2: Urban Ecosystems	
5. Manage connectivity	The level of connectivity in a circular economy can be both positive and negative, helping to facilitate recovery and adaptation, as well as spread disturbances. The level of connectivity between materials, food, clothing, housing, water, and energy systems must be managed to ensure that the development of one area does not undermine or compromise another.

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6. Incorporate system feedback	Developing a regenerative circular economy requires understanding and incorporating system feedback into decision-making. Identifying reinforcing and dampening feedback is critical, including variables that are slow to change yet produce large effects when thresholds are crossed. Inputs (resources) and outputs (waste) of a regenerative circular economy must be finely tuned to the regeneration and absorption rates of social-ecological systems - both source ecosystems and cycling ecosystems.
7. Foster diversity and redundancy	Biodiversity as well as cultural, economic, and institutional diversity are crucial to the ability of a regenerative circular economy to adapt to change. A diversity of scales of resource cycling increases the adaptive capacity and resilience of a circular economy. System redundancy also increases the potential for a circular economy to adapt to a changing world, where one part of the system can compensate for failure in another part.
Scale 3: Urban Governance	
8. Encourage learning and experimentation	A regenerative circular economy must be supported by continuous learning and experimentation. Open source and modular systems should be maximized in order to encourage experimentation, collective learning, and capacity building.
9. Enable openness and participation	Participation of a diversity of actors - human and otherwise - is important for a regenerative circular economy. Widespread participation in the production and cycling of resources should be encouraged to enhance system resilience. The development of common infrastructure that is transparent and decentralized is a key enabler for enhancing participation.
10. Promote polycentric governance	Governance systems should be nested, enabling collaboration across levels and scales. Governance should also be responsive to the nature of the resource system being utilized, and take into account interacting governance regimes from local to international levels.

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2.2 Methodology and co-creation process

Development of the Circular Principles and Indicators began with a comprehensive review of leading circular economy and socio-ecological systems frameworks. The principle frameworks referenced include: Principles for Building Resilience by the Stockholm Resilience Centre (Briggs, 2015), Biomimicry DesignLens (Biomimicry 3.8, 2020), Seven Pillars of the Circular Economy (Metabolic, 2017), and Circular Economy Operational Principles (Suárez-Eiroa et al., 2019). These frameworks were selected to provide a grounding in ecosystem science, circular economy, resilience thinking and regenerative socio-ecological systems. To build a unique set of guiding principles for the REFLOW project, we pursued where possible an integration of the mentioned frameworks. The resulting matrix was then further advanced through a series of development iterations wherein the WP 3 team integrated the principle frameworks and concepts being developed and deployed within the REFLOW project. Importantly, this phase saw referencing of D5.1 Detailed Pilot Planning & Evaluation Framework (REFLOW D5.1, 2020) and the D4.1 The REFLOW Handbook (REFLOW D4.1, 2019). Lastly, the resulting set of principles was further developed through a series of peer reviews wherein leading experts in circular economy, socio-ecological systems, and resilience thinking were invited to review the principles from a scope, content, and cohesion perspective. As a result of this process the Circular Principles present a unique set of principles that, together, distill the aims of a regenerative circular economy and provide meaningful guidance for its pursuit. Importantly the principles are grounded in scientific literature while equally emphasizing the key concepts and characteristics of the REFLOW project as co-developed by the consortium.

In order to make pursuit of the principles measurable, a set of indicators has been provided for each principle. To do so, the Metabolic and Materiom team worked together to review the KPI long list and identify a long list of indicators for each principle (based upon scope and relevance). As described in detail in Chapter 3 of this report, the KPI long List has been developed and deployed within the impact assessment processes of REFLOW, specifically those of WP 1, 3, and 5. For the purposes of the Circular Principles, a long list of relevant KPIs were identified for each principle then refined through two iterative work sessions in order to produce the short list of KPIs for each principle presented within this chapter.

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The case studies provided alongside each principle were derived through the collective expertise of the WP 3 team. The process began by developing a keyword search that encompassed the key material streams of each pilot, circular material and product innovation terminology, and those keywords tagged by the four frameworks mentioned above. We then systematically conducted our research through various media including online and offline literature reviews, as well as interviews with key communities and networks of relevance. After creating a library of possible case studies, we matched the most relevant case studies to each circular principle. It was important that the cases chosen showed not only a high degree of relevance to specific principles, but demonstrated strong connections between multiple principles. Attention was given to emphasizing the equal measurement of technological, social, and environmental case studies in order to achieve a well-rounded collection.

A draft version of the Circular Principles and case studies, was shared with the REFLOW consortium during the REFLOW Online Project Meeting in March 2020. Within the roundtable sessions, we shared the purpose and scope of the principles, each principle and set of case studies in detail, as well as the method we undertook to develop them. The aim of these round tables was to collect and incorporate feedback from the REFLOW consortium, in particular the pilots, on the accessibility of the principles and their relevance to REFLOW activities. By incorporating feedback into the second draft of the principles, we were able to ensure a strong connection between the principles, REFLOW pilots, and REFLOW activities.

Between M12 and M18 of the REFLOW project, the WP 3 team will further develop the Circular Principles and Indicators in close collaboration with REFLOW pilots. The focus of this work will be to explore with each pilot team how the principles can be integrated within and provide guiding support for their local initiatives and activities. Practically speaking, this process will take the form of a series of co-creation sessions where highly relevant principles will be identified and further explored, producing an iterative articulation of each relevant principle to more closely connect to and support the unique context, objective, and activities of the pilot. Where possible, pilot KPIs will be pinned to principles to make their pursuit measurable.

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2.3 Circular Principles

2.3.1 Principle one: Use life-friendly chemistry

Principle: *A regenerative circular economy is one where materials and products are produced using chemical processes that are 'life-friendly,' that is, they promote human and ecosystem health.*

Life-friendly chemistry is based on the following principles.

Table 2: Life-friendly chemistry principles (Dorfman, 2017).

1	*Break down products into benign constituents: Not only do nature's chemicals break down after their useful life, they break down to reusable building blocks. Enzymes are the key facilitators of biochemical breakdown.*
2	*Build selectively with a small subset of elements: React selectively through shape, maximize use of weak bonds, leverage paired opposites for self-assembly, and optimize element proportions and positions.*
3	*Do chemistry in water: Nature uses water as a polar solvent, but also leverages water to make and break molecular bonds. Water also plays a role in making the complex 3D shape of biochemical structures.*

The field of green chemistry is also instructive for the development of life-friendly materials and chemical processes. Green chemistry advocates the use of chemical products and processes that reduce or eliminate the use of hazardous substances. The goals of green chemistry are achieved through several dominant approaches, including: biocatalysis, catalysis, use of alternative renewable raw materials (biomass), alternative reaction media (water, ionic liquids, supercritical fluids), alternative reaction conditions (microwave activation), and new photocatalytic reactions.

The 12 green chemistry principles are outlined in Table 3.

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Table 3: Green chemistry principles (Anastas et al. 1998).

1	*Prevent waste: Design chemical syntheses to prevent waste. Leave no waste to treat or clean up.*
2	*Maximize atom economy: Design syntheses so that the final product contains the maximum proportion of the starting materials. Waste few or no atoms.*
3	*Design less hazardous chemical syntheses: Design syntheses to use and generate substances with little or no toxicity to either humans or the environment.*
4	*Design safer chemicals and products: Design chemical products that are fully effective yet have little or no toxicity.*
5	*Use safer solvents and reaction conditions: Avoid using solvents, separation agents, or other auxiliary chemicals. If you must use these chemicals, use safer ones.*
6	*Increase energy efficiency: Run chemical reactions at room temperature and pressure whenever possible.*
7	*Use renewable feedstocks: Use starting materials (also known as feedstocks) that are renewable rather than depletable. The source of renewable feedstocks is often agricultural products or the waste of other processes; the source of depletable feedstocks is often fossil fuels (petroleum, natural gas, or coal) or mining operations.*
8	*Avoid chemical derivatives: Avoid using blocking or protecting groups or any temporary modifications if possible. Derivatives use additional reagents and generate waste.*
9	*Use catalysts, not stoichiometric reagents: Minimize waste by using catalytic reactions. Catalysts are effective in small amounts and can carry out a single reaction many times. They are preferable to stoichiometric reagents, which are used in excess and carry out a reaction only once.*
10	*Design chemicals and products to degrade after use: Design chemical products to break down to innocuous substances after use so that they do not accumulate in the environment.*
11	*Analyze in real time to prevent pollution: Include in-process, real-time monitoring and control during syntheses to minimize or eliminate the formation of byproducts.*
12	*Minimize the potential for accidents: Design chemicals and their physical forms (solid, liquid, or gas) to minimize the potential for chemical accidents including explosions, fires, and releases to the environment.*

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Table 4: Circular Principle one case studies.

Case study 1: Beyond Benign	
Location	United States
Website	www.beyondbenign.org
About	Beyond Benign develops and disseminates green chemistry and sustainable science educational resources that empower educators, students, and the community at large to practice sustainability through chemistry.
Why is it relevant?	As a socially engaging resource, it is promoting positive effects on human health and well-being by portraying how green chemistry can be implemented in products and industry.
Case study 2: Healthy Materials Lab	
Location	United States
Website	www.healthymaterialslab.org
About	Healthy Materials Lab is a design research lab at Parsons School of Design, dedicated to a world in which people's health is placed at the centre of all design decisions. They are committed to raising awareness about toxic materials in building products and creating resources for the next generation of designers and architects to make healthier places for all people to live.
Why is it relevant?	● Fervent in imparting safe, renewable, and sustainable scientific principles through design-led practices. ● Encourages green chemistry practices through teaching and learning initiatives.

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Table 5: Circular Principle one key performance indicators.

Circular Principle one key performance indicators	
Changes of toxic contents in products and production processes	A decrease in toxic components in the composition share of a given product or production process. This indicator may be represented by the market share of the toxic components within the market sector supplying equivalent core components for the given product and production process.
Concentration of heavy metals and organic compounds in environmental media and in living species	Heavy metals are potentially toxic metals used in industrial processes, for example: arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. They may damage plant and animal life at low concentrations and tend to accumulate in the food chain.
Safety and health during chemicals production	The extent to which risk has been reduced as a result of actions taken in light of risk assessments (for example in terms of number of people at risk, potential environmental impact, probability of an accident, and size of risk zones). The number of incidents related to unforeseen risks (i.e., not identified in risk assessments) and the number of unacceptable risks that have not been adequately addressed.
Eco-toxicity measured through effective mass yield	This parameter is defined as the percentage of the mass of desired product relative to the mass of all non-benign materials used in the synthesis. It introduces the important issue of eco-toxicity.

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2.2.2 Principle two: Pursue efficient use of materials, energy, and water

Principle: *To reduce the pressure put on natural ecosystems and work within planetary boundaries, there is a need to enhance the material, energy, and water efficiency of products and processes.*

Nature-inspired chemistry and material development seeks to use low-energy processes, and minimize energy consumption by reducing the required temperatures, pressures, and time needed for chemical reactions. In order to economize on energy, material, and water needs, biomimetic design emphasizes multi-functionality, fitting form to function, and meeting multiple needs with one solution (Biomimicry 3.8, 2020).

System-wide strategies employed include service-based economy and sharing economy models. A service-economy model shifts from selling products to selling the service of a product. The ownership of the physical product remains with the producer, thus creating an incentive for the producer to design a product for ease of repair and remanufacture. A sharing economy promotes access to a common pool of goods and services that are provided or sold to customers and maintained by the owner. This promotes the maintenance and repair of products, and unlocks underutilized assets, thus decreasing waste. Other strategies include the promotion of local and seasonal products, and adjusting the sale of goods to consumer demand. Resulting in the use of fewer resources per product (Bocken et al., 2019), the aim of these strategies is dematerialization, or an overall reduction in the size of the resource system (Suárez et al., 2019).

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Table 6: Circular Principle two case studies.

Case study 1: Green Tomorrow House	
Location	Korea
Website	www.arup.com/projects/green-tomorrow
About	The first project in East Asia that has achieved the Leadership in Energy and Environmental Design (LEED) Platinum rating. Located in Yongin, the development includes a 423m² zero-energy house and a 298m² public relations pavilion and is designed to be a sustainability showpiece in Korea. Arup provided sustainable building design and LEED consultation for the project, working in conjunction with Samoo Architects.
Why is it relevant?	Promotes the development of sustainable design through innovative, environmentally conscious design.
Case study 2: Library of Things	
Location	United Kingdom
Website	www.libraryofthings.co.uk
About	Collections of things other than books that are being loaned like books, for no charge. A library of things can loan out kitchen appliances, tools, gardening equipment, electronics, toys and games, art, science kits, craft supplies, musical instruments, recreational equipment, and more.
Why is it relevant?	• Localised accessibility to shared tools, materials, and equipment which can benefit and strengthen sustainable/circular community values. • Promotes circularity through use of existing materials, slowing down the consumption of non-renewable raw materials by utilising existing ones.

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Table 7: Circular Principle two key performance indicators.

Circular Principle two key performance indicators	
Life time extension	The extent to which attempts to prolong the service lifetime of products is made.
Resource productivity	The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy.
Water productivity	Water productivity indicates how much economic output is produced per cubic meter of fresh water abstracted (in EUR per m3 or PPS per m3). It serves as a measure of the efficiency of water use.
Reduction in life cycle energy use	Reduction in life cycle energy use by a material/product achieved by the project (%).
Ecological footprint	A global indicator that represents the amount of land and sea needed to regenerate the resources human populations consume, and to absorb the waste.

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2.3.3 Principle three: Design for biological or technical loops

***Principle:** All materials should be designed to either cycle openly within the biosphere as biological nutrients, or be cycled within a technical closed loop by human systems. Waste and pollution is designed out, and instead, 'waste equals food' for the system.*

In the biological cycle the reverse chain for biological nutrients returns those nutrients back to the biosphere via composting and anaerobic digestion. In addition, reverse cycles are not only confined within an industry, but also 'cascaded' across different industries (EMF, 2017). The technical cycle encompasses the recovery and restoration of products, components, and materials, closing the loop through strategies like reuse, repair, remanufacturing, and recycling (McDonough & Braungart, 2013; Millar et al., 2019). Products, components, and materials should be designed to be maintained at their highest utility and resource value at all times (EMF, 2015). This means increasing durability, repairability, repurposing, and reducing obsolescence (Reike et al., 2018), thus slowing down the flow of resources through the system (Stahel, 1981). Extended Producer Responsibility and industrial symbiosis initiatives can promote the maintenance of value and the upcycling of waste into a useful resource (Suarez-Eiroa et al, 2019).

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Table 8: Circular Principle three case studies.

Case study 1: Cupclub	
Location	United Kingdom
Website	www.cupclub.com
About	Returnable packaging service designed to hold both hot and cold drinks. CupClub offers a tailored end-to-end service helping to reduce single-use plastic packaging. Not only does CupClub make it easy to do the right thing, but the product itself is a step-up from disposable cups.
Why is it relevant?	● Material is recovered and fed back into the economy. ● Benefits to the ecoregion are created from reducing waste stream pollution and impact on nature, hence contributing to designing out waste.
Case study 2: Worn Again	
Location	United Kingdom
Website	www.wornagain.co.uk
About	Worn Again Technologies pioneer polymer recycling technology that can separate, decontaminate, and extract polyester polymers alongside cellulose from cotton from non-reusable textiles, PET bottles, and packaging - subsequently turning them back into new raw materials as part of a continual cycle.
Why is it relevant?	● Closing technical textile material loops. ● Utilising the abundant resource of existing non-reusable textiles in circulation today to meet annual demand.

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Table 9: Circular Principle three key performance indicators.

Circular Principle three key performance indicators	
Circular material use rate	The circular material use (CMU) rate measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M).
Total solid waste generation per capita	This indicator measures the urban solid waste volume generated per inhabitant and per day. Total solid waste generation per capita = total urban solid waste (in kg) / number of inhabitants.
Proportion of municipal solid waste that is sorted and recycled	Formally and informally recycled materials are those that (following local government permits and regulations) are diverted from the waste stream, partially recovered, and sent for processing into new products. Municipal waste recycling rate (%) = total amount of municipal waste recycled (year x) * 100 / total amount of municipal waste generated in tonnes (year x).
Recycled bio-waste per capita	Amount (kg) of bio-waste recycled per capita.

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2.3.4 Principle four: Build with abundant, accessible, and renewable resources

Principle: *Materials and products should be produced and consumed at scales most effective for their cycling within biological or technical loops. The economy should be powered by renewable sources (defined as locally abundant solar, wind, water, and biomass waste).*

According to complex systems theory, systems with a variety of scales are less brittle than the ones relying on a small number of large-scale items, because they leave more room for adaptation (Ulanowicz et al., 2009). The transition to a regenerative circular economy is an opportunity to develop material supply networks at local and regional scales based on widely accessible, abundant materials. Not only can this enhance the resilience of the overall industrial system, it can also enable resources to be more effectively cycled in ways that support local ecosystems. Nutrients can be sourced and released after end-of-life at appropriate levels of volume and concentration for local ecosystems.

While the production of technical materials is often done in a large-scale, centralized fashion, technical material waste is a locally abundant resource found all around the world. Cycling these materials within local and regional technical loops could lead to a more resilient, effective circular economy. Furthermore, biomaterials are distributed over large areas and can be harvested from a diversity of terrestrial and marine habitats (Kircher, 2018; Olson, 2001). The production of ingredients for biomaterials can also take place in artificial environments such as the cultivation of microalgae to produce oils, proteins, and carbohydrates as building blocks for bioplastics (Das, 2018). Biowaste from the byproducts of agricultural, forestry, and aquaculture systems is also abundant in many regions. A wide diversity of small and medium-sized business entrepreneurs in the biomaterial sector could play an important role in enabling greater system adaptation, through the development and prototyping of many diverse product alternatives. If these entrepreneurs were supported to develop their materials by sourcing feedstock from diverse sources for local and regional markets, a future circular economy would be less reliant on large volume flows from centralised industrial supply chains, benefiting overall system resilience.

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The same mindset of sourcing locally available materials can be applied to energy. While renewables present more diffuse sources of energy compared to oil and gas, many types are freely available and can meet the demands of local- and regional-scale economies. The challenge is to harness renewable sources of energy that are most suited to a respective locality.

Table 10: Circular Principle four case studies.

Case study 1: Ecobean	
Location	Poland
Website	www.ecobean.pl
About	EcoBean is a project powered by coffee. We turn waste left over from your daily cup of coffee, that would otherwise end up in the landfill, into clean energy products. EcoBean collects spent coffee grounds from over 100 locations and they reuse it to make Coffee logs or 'briquettes'.
Why is it relevant?	● The coffee logs are cost-effective in production. ● They also provide a sustainable alternative to conventional fossil fuels.
Case study 2: Piñatex	
Location	Philippines and United Kingdom
Website	www.ananas-anam.com
About	Piñatex is a leather-like material made from pineapple leaf fibre. It is a natural and sustainably-sourced material which supports cruelty-free production and provides an alternative to current manufacturing processes such as mass-production of leather (like chemical tanning) and synthetic material industries (which pollute local environments with run-off waste).

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Why is it relevant?	• The existing agriculture industry discards a large proportion of the 'undesired' components from plants, which have no current economic value. • The use of pineapple leaves has increased the application of waste components from plants significantly, changing the function of discarded plants from waste to abundantly resourceful. • It allows the farmers and producers to loop back into the biological waste system. • It will potentially have a dramatic effect on the air quality and local environment, avoiding discarding pineapple leaves by combustion.

Table 11: Circular Principle four key performance indicators.

Circular Principle four key performance indicators	
Share of renewable energy in gross final energy consumption	Percentage of energy from renewable sources as a proportion of overall energy consumption.
Raw material consumption	Measures the total amount of raw materials required to produce the goods used by the economy (also called 'material footprint').
Total material requirement (TMR)	Domestic extraction + Unused (domestic) extraction + Imports + Unused extraction in country of origin.
Self-sufficiency of raw materials for production in the EU	The share of a selection of key materials (including critical raw materials) used in the EU that are produced within the EU.
National recycling rate	Amount of material recycled in the economy.

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2.3.5 Principle five: Manage connectivity

Principle: *The level of connectivity in a circular economy can be both positive and negative, helping to facilitate recovery and adaptation, as well as spread disturbances. The level of connectivity between materials, food, clothing, housing, water, and energy systems must be managed to ensure that the development of one area does not undermine or compromise another.*

The nature and strength of interactions between actors in a system determines the level of connectivity. Connectivity can have positive and negative effects (Briggs, 2015). For example, highly connected social networks can spread information quickly and can support healthy communities. When a disruption takes place, such as a reduction in food supply or a natural disaster, highly connected communities can support each other and recover faster. Yet, connectivity can also mean that disturbances can spread quickly, such as with the spread of disease or financial exposure. For a regenerative circular economy, there is the need to manage connectivity to maximize the benefits and guard against the downsides.

An example is the need to manage the relations between material, food, water, and energy systems. The development of bioplastics that can be sourced from renewable sources of biomass present an opportunity for circular economy development. However, if they rely on food crops, such as corn, this could undermine food security. Furthermore, any disturbance to the agricultural sector, such as a changing climate, could have repercussions for both food and material supply chains. As the production of crops can draw heavily on water reservoirs, increasing corn production could compromise freshwater availability. The development of energy production from biomass may promote a regenerative circular economy as long as it doesn't rely on feedstock grown in a manner that depletes freshwater supplies or reduces soil fertility. Such scenarios underline the importance of understanding the dynamics of social-ecological systems in a local context where the production and consumption of materials, water, and energy are interrelated. It is imperative to examine the system interdependencies and vulnerabilities, understanding the effect that connectivity between these and other sectors could have on the overall regenerative capacity of a circular economy. In order to sufficiently monitor progress towards this principle, composite indicators need to be developed to measure

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the interlinked nature of a nexus approach towards sustainable development and a circular economy (FAO, 2014; Karnib, 2017; Nhamo, 2019). For example, composite KPIs for a Water-Energy-Food nexus can be created using the following indicators and weighing them through a multi-criteria-decision process:

- Proportion of available freshwater resources per capita (availability); Proportion of crops produced per unit of water used (productivity);
- Proportion of the population with access to electricity; Energy intensity measured in terms of primary energy and GDP
- Prevalence of moderate or severe food insecurity in the population; Proportion of sustainable agricultural production per unit area

Table 12: Circular Principle five case studies.

Case study 1: Fairtrade Foundation	
Location	United Kingdom
Website	www.fairtrade.org.uk
About	Fairtrade is about better prices, decent working conditions, local sustainability, and fair terms of trade for farmers and workers in the developing world. By requiring companies to pay sustainable prices, Fairtrade addresses the injustices of conventional trade, which traditionally discriminates against the poorest, weakest producers.
Why is it relevant?	• Ethical working environments throughout the supply chain leading to a positive, sustainable and stable workforce, ensuring there is sufficient food, shelter, and water for a life to thrive. • Allows those who are vulnerable within precarious working conditions to be rigorously represented and provided protective economic safeguarding to implement a circular and sustainable ethos.

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Case study 2: Fairphone	
Location	Netherlands
Website	www.fairphone.com
About	Fairphone is a social enterprise which aims to develop smartphones that are designed and produced with minimal environmental impact. They develop a mobile device that does not contain conflict minerals, has fair labour conditions for the workforce along the supply chain, and is a modular smartphone designed to be easily repaired and upgraded.
Why is it relevant?	● Limits the number of precious metals known to be incorporated in the manufacture of smartphones, which leads to the mistreatment of the labour force (these metals are known to be sourced in treacherous environments, where an insufficiently trained workforce are coerced/subjected to these conditions due to excessive demand). ● Promotes adequate wages relative to the work being implemented.

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Table 13: Circular Principle five key performance indicators.

Circular Principle five key performance indicators	
Prevalence of energy, water, and food insecurity	This indicator measures the different levels of stress experienced by a local population to access key resources and highlights the "nexus" interlinkages of the local energy, water, and food systems.
Eco-design indicators	This group of indicators measures the environmental considerations within a product system at the design stage. This is done to ensure an easier re-entry of materials back into the supply chain and reduced environmental impact throughout the product's life cycle. The indicators include number of reusable parts, reversible joints, parts with labels, inclusion of intelligent materials, and many more.
End-of-life recycling input rates	The EOL-RIR measures how much of the total material input into the production system comes from recycling products at the end of their life. This indicator measures a non sector-specific approach to the use of secondary materials in the production of new products in an economy.
Green Public Procurement	Public procurement accounts for a large share of consumption and can drive demands towards a circular economy. This indicator assesses if any procurement models on a system, supplier, or product level are in place within an organisation or government.
Diversion rate as a measure for EPR success	The amount of product successfully collected by the producers relative to the amount of product in a waste stream (percent or other measure).

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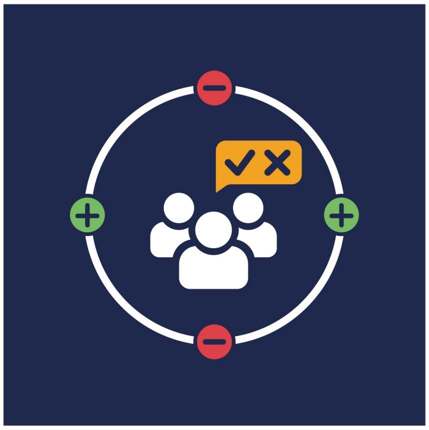
2.3.6 Principle six: Incorporate system feedback



***Principle:** Developing a regenerative circular economy requires understanding and incorporating system feedback into decision-making. Identifying reinforcing and dampening feedback is critical, including variables that are slow to change yet produce large effects when thresholds are crossed. Inputs (resources) and outputs (waste) of a regenerative circular economy must be finely tuned to the regeneration and absorption rates of social-ecological systems -both source ecosystems and cycling ecosystems.*

Developing a regenerative circular economy requires understanding and incorporating system feedback into decision-making. Reinforcing or positive feedback can accelerate change in a system, such as when the overuse of agricultural fertilizer contributes to a decline in soil fertility, thus requiring more fertilizer to make up for the deficit. Dampening or negative feedback can help maintain the current system state. For instance, good regulation can have a dampening effect on deforestation from illegal logging.

Understanding the sources of both reinforcing and dampening feedback and developing strategies for harnessing them can ensure that critical ecosystem services such as nutrient cycling and soil fertility are maintained for a circular economy. Many indirect species relationships can support ecosystem services. Soil fertility depends on complex interrelationships between chemical, biological, and physical conditions in the soil. Plant growth is affected by nutrient availability and the presence of soil organisms such as fungal mycorrhizal networks that contribute to soil structure (Abbott, 2017). A regenerative circular economy must consider these types of dependencies so as not to undermine the health and regenerative capacity of the ecosystem.

A part of integrating system feedback into decision-making is the identification of system variables that are slow to change, yet may have large-scale feedback effects once a threshold is crossed. Examples include CO_2 emissions or the amount of fertilizer used in agriculture. Once carbon emissions cross a certain atmospheric threshold, they may trigger large-scale changes in the earth system such as rapid sea-level rise. If the amount of nitrogen or phosphorus fertilizer used on agricultural land crosses a certain level, runoff can lead to river and ocean eutrophication, or dead zones, as algae blooms cut off oxygen to plants that help keep the system in nutrient balance (Briggs, 2015).

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Economic inputs (raw materials) and outputs (waste) are types of feedback that need to be managed in accordance with ecological regeneration and absorption rates. This is particularly critical for materials and products in the biological cycle. Positive examples include regenerative agricultural practices that return valuable nutrients to cropland in the form of human waste from surrounding urban environments (Pearson, 2007). Regenerative aquaculture techniques cultivate communities of multi-trophic species, where fish that are waste generating are grown with organisms like seaweed or shellfish that remove nutrients from the water, creating overall nutrient balance (Troell et al. 2003; Chopin et al. 2001). The effectiveness of these types of integrated systems highlights the importance of understanding and harnessing system feedback within a network of ecological relations.

Table 14: Circular Principle six case studies.

Case study 1: Natura	
Location	Brazil
Website	www.natura.com
About	Natura's R&D scientists study each ingredient to understand how to extract the maximum benefits for skin and hair. We work directly with over 30 local communities in the Amazon region - including more than 300 families - to help them develop sustainable business models that benefit the forest.
Why is it relevant?	● Benefitting the natural local and regional ecosystem. ● Material recovered and fed back into the economy, advocating sustainable, circular values.
Case study 2: EcoRegions Platform	
Location	United States
Website	www.ecoregions2017.appspot.com
About	Platform shows a map of the 846 ecoregions that represent our living planet. Ecoregions are ecosystems of regional extent, which are color-coded on the map to highlight their distribution and the biological diversity they represent. The map is based on recent advances in biogeography - the science concerning the distribution of plants and animals.

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Why is it relevant?	Allows a universal understanding of diverse ecosystems related to specific environments. Subsequently, this allows for increased awareness of the needs of a particular ecosystem or ecological system.

Table 15: Circular Principle five key performance indicators.

Circular Principle six key performance indicators	
Supply chain agility	Responsiveness and agility of the supply chain in response to external changes is a multi-dimensional concept which can be measured as the flexibility of three value chain activities: procurement, manufacturing, and logistics.
Environmental collaboration	The direct involvement of an organisation with its suppliers and customers in planning jointly for environmental management and environmental solutions. Environmental collaboration comprises a better understanding of each other's responsibilities and capabilities with regard to environmental management, which includes the exchange of technical information and requires a mutual willingness to learn about each other's operations in order to plan and set goals for environmental improvement.
Climate change strategy	Number of years since the city or organisation's climate change strategic plan was updated; and frequency of reviews and/or updates on the climate change strategy by cross-departmental groups, based on scientific evidence.
Sustainability reporting	Number of companies publishing sustainability reports and data. This indicator measures the success of SDG 12.6 which aims at encouraging the private sector to adopt sustainable practices and to integrate sustainability information into their reporting cycles.
Capacity-building for reliable data availability	The ability and capacity of countries, municipalities or organisations to significantly increase the availability of high-quality, timely, and reliable data relevant to decision making towards sustainability.

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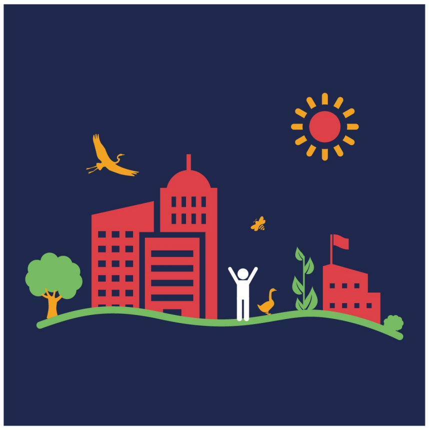
2.3.7 Principle seven: Foster diversity and redundancy



Principle: *Biodiversity as well as cultural, economic, and institutional diversity are crucial to the ability for a regenerative circular economy to adapt to change. A diversity of scales of resource cycling increases the adaptive capacity and resilience of a circular economy. System redundancy also increases the potential for a circular economy to adapt to a changing world, where one part of the system can compensate for failure in another part.*

In order to flourish in a changing world, a circular economy needs to be resilient and adaptive. Investing in biodiversity as well as cultural, economic, and institutional diversity is key to this adaptive capacity. Biodiversity enables an ecosystem to adapt to disruptions, such as climate change or land-use change, without losing core ecosystem service functions such as pollination, pest control, nutrient cycling, and waste assimilation (Briggs, 2015). Cultural diversity, including the use of indigenous knowledge and practices, can enable communities to respond to change and promote more appropriate, context-driven understanding. Economic and institutional diversity, including state and non-state actors such as NGOs, community groups, and businesses of varying sizes provide greater capacity to adapt to changes in environmental, social, and economic circumstances (Briggs, 2015).

A diversity of scales of economic production, consumption, and resource cycles is also important for a resilient system. System resilience is increased when a balance between efficiency (due to a small number of large-scale flows) and adaptiveness (due to a large and diverse network of small-scale flows), is achieved (Ulanowicz, 2009).

Redundancy is also an important feature of resilient systems. For a regenerative circular economy, 'functional redundancy' provides insurance by virtue of some parts of the system compensating when other parts of the system fail. 'Response redundancy' further increases a system's resilience whereby system components, such as institutional actors or communities, respond differently to change (Ulanowicz, 2009). This ensures the system can regenerate quicker after a disturbance or breakdown. Redundancy is particularly important to build in when incentivising innovation and the development of new systems, as some new ideas may fail while others succeed. For instance, being overly dependent on a particular actor, technology, or system of resource cycling may undermine the long-term success of circular economy development.

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Table 16: Circular Principle seven case studies.

Case study 1: Natural Systems Agriculture	
Location	United States
Website	www.landinstitute.org
About	The Land Institute is breeding new perennial grain and seed crops adapted to ecologically intensified polycultures that mimic natural systems, called Natural Systems Agriculture. Their goal is to develop an agricultural system that can produce ample food, reduce or eliminate impacts from the disruptions and dependencies of industrial agriculture, and inform cultural change through education.
Why is it relevant?	Promotes community independencies through the exploitation of the local ecology and adaptive biodiversity. This encourages the utilization of local resources through advanced cultivation of the surrounding landscape, removing the need to rely on non-renewable raw materials.
Case study 2: Malai	
Location	India
Website	www.made-from-malai.com
About	Biocomposite material made from entirely organic and sustainable bacterial cellulose, grown on agricultural waste sourced from the coconut industry in Southern India. They work with the local farmers and processing units, collecting their waste coconut water (which would otherwise be dumped, causing damage to the soil) and repurposing it to feed the bacterial cellulose production.
Why is it relevant?	• Biodesign for circular economy; minimising the use of non-renewable resources through biomimicry solutions. • Creating biomaterials through discarded waste specific to local abundance.

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Table 17: Circular Principle five key performance indicators.

Circular Principle seven key performance indicators	
Share of jobs in environmental industries	"Green jobs" are decent work opportunities that contribute substantially to preserving or restoring environmental quality. Specifically, work opportunities that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high-efficiency strategies; decarbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution.
Research and development expenditure in circular economy as a proportion of local GDP	The proportion of expenditure done on research and development focused on sustainability and/or circular economy compared to the local GDP.
Access to support for sustainability driven SMEs	The financial support for sustainable/circular economy businesses can be measured by the number of annual approved and regulated small business-loans or micro-credit per 100,000 population (Arup, 2015); or by the size of green funds/sustainability focused finance as a percentage of the loans industry in the city (GNO).
Species habitat index	Measures changes in the suitable habitats of species to provide aggregate estimates of potential population losses and extinction risk increases. Each species is assessed separately, and the index is calculated as a weighted average of the habitat changes for each species with weights determined by the proportion of global range found in the country.
Presence of diverse financing models for the cultural sector	The amount and diversity of financial support being provided to a locality's cultural sector. Three possible sources of finance for culture are: a) public (mainly from government or public institutions), which results in direct (subsidies and grants) or indirect (tax exemptions); b) private (from the market); and c) non-profit organisations or donors.

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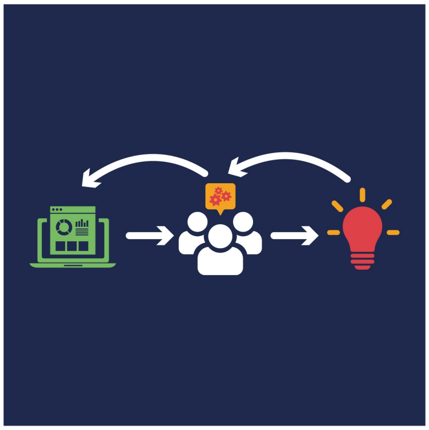
2.3.8 Principle eight: Encourage learning and experimentation



Principle: *A regenerative circular economy must be supported by continuous learning and experimentation. Open source and modular systems should be maximized in order to encourage experimentation, collective learning, and capacity building.*

Knowledge of complex systems is always partial and evolving (Briggs, 2015), creating the need for continual learning and experimentation. If a regenerative circular economy is to be resilient, and thus adaptive to change, continuous updating of present knowledge must be prioritized. Adaptive management and adaptive governance are practices that focus on identifying, testing, and assessing alternative hypotheses for how a system works, and work to integrate learning and collective action across scales of decision-making (Briggs, 2015). These practices focus on cross-sectoral learning, where multiple stakeholder groups are consulted and brought together to interpret data, learn from each other's perspectives, and propose different approaches to systems change. These kinds of holistic learning processes are fundamental to developing a regenerative circular economy that adapts to new information and unforeseen circumstances.

As a tool to enable learning and rapid experimentation, 'commons-based peer production' is a system of production that relies on digital infrastructure, where collaboration between large groups of people can provide information goods without the need for market pricing or managerial hierarchies (Benkler, 2006). Examples include Wikipedia, the Linux operating system, and various other open source software projects. Commons-based peer production can play an important role in enabling 'bottom-up' development by harnessing diverse local knowledge for a collective outcome (Langlois, 2008), allowing diverse people to self-organise available resources into dynamic collaborations and projects in a way that may outperform markets or bureaucracies (Benkler, 2016).

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A key driver of these benefits is modular architecture, where parts operate independently, yet support the functioning of the whole system through common interfaces (Simon, 1962). In open source software, contributors can modify and experiment with parts of the code system without causing changes in other modules. This allows a highly distributed collective to work together and produce innovative outcomes. Nature also builds with modular architecture through bottom-up synthesis, where a common set of chemical building blocks are used to assemble a diversity of natural materials that are tunable to local conditions (Kushner, 2011). Open source platforms and modular systems are tools that can encourage experimentation and collective learning towards a regenerative circular economy.

Table 18: Circular Principle eight case studies.

Case study 1: Faber Futures	
Location	United Kingdom
Website	www.faberfutures.com
About	Faber Futures is a London-based award-winning futures agency operating at the intersection of nature, design, technology and society. Their multidisciplinary practice engages industry, institutions, and multi-sector brands with ecologically driven models for holistic innovation. With sustainability at its core, their studio equips biotechnology start-ups, multi-sector brands, and institutions with innovative frameworks, tools, and networks to adapt to holistic systems for regenerative futures.
Why is it relevant?	● Approaching research as a continuous (rather than finite undertaking) can encourage the exchange of ideas and the development of regenerative practices instrumental in making regenerative impacts. ● This can lead to partnerships with a variety of stakeholders, including how to enhance citizen engagement and learn as a collective.

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Case study 2: Wikifactory	
Location	United Kingdom
Website	www.wikifactory.com
About	A social platform for collaborative product development. Designed for open source communities, designers, and product companies. Some of the key features are: ● Version control ● Tracking issues and improving them collaboratively ● Documentation tools ● 3D visualisation ● Permission systems ● Social features
Why is it relevant?	● The integrated support systems are built for both public and private projects which encourage users to experiment and collaborate on topics. ● Several ways of engaging with users which can also be defined by how you would like to learn, therefore there is a diversity of users with a wide array of inputs and topics being explored.

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Table 19: Circular Principle five key performance indicators.

Circular Principle eight key performance indicators	
Mainstreaming of environmental education	Extent to which (i) global citizenship education and (ii) education for sustainable development (including climate change education) are mainstreamed in (a) national education policies, (b) curricula, (c) teacher education, and (d) student assessment.
Citizens' awareness regarding urban nature & ecosystem services	The extent to which a project / initiative has used opportunities to increase citizen's awareness of urban nature and ecosystem services, and educate urban citizens about sustainability and the environment.
New forms of sustainable financing	The extent to which a project / initiative has contributed to, or inspired, the development of new forms of sustainable or green financing.
Allocation of expenditure of local authority for vocational training in circular economy practices	Proportion of training expenditure in the local authority budget allocated to vocational training sessions and/or exchange programmes focused on circular economy activities..
Research and development expenditure on circular economy as a proportion of local GDP	The proportion of expenditure done on research and development focused on sustainability and/or circular economy compared to the local GDP.

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2.3.9 Principle nine: Enable openness and participation

Principle: *Participation of a diversity of actors - human and otherwise - is important for a regenerative circular economy. Widespread participation in the production and cycling of resources should be encouraged to enhance system resilience. The development of common infrastructure that is transparent and decentralized is a key enabler for enhancing participation.*

The question of who gets to participate in a regenerative circular economy is fundamentally about social justice, sustainable economic development, and the inclusion of marginalized voices. Bringing all stakeholders together to co-create visions and strategies for a regenerative circular economy is vital to building trust and legitimacy in decision making processes (Briggs, 2015). If governments and businesses pursue closed loop strategies without considering the need to broaden participation, monopoly control over resources could disadvantage many economies and societies. A circular economy where resources and value flow in tightly controlled loops controlled by a minority would be unjust and unsustainable. A regenerative circular economy is one where all stakeholders, no matter their location or socioeconomic status, can participate in shaping systems of production, consumption, and cycling.

Key drivers of participation lie in aligning the circular economy agenda with global trends in mass customisation (Da Silveira, 2001), digital fabrication (Gershenfeld, 2012), open design (Tooze, 2014), (re)distributed manufacturing (ibid), and open source material development (Materiom, 2019). These movements and technologies are beginning to transform how, and by whom, products and materials are manufactured. They signal a wider democratisation of technological practices -namely, the rise of open access fabrication labs and the communities who use them to share materials, tools, technologies, and knowledge with like-minded peers (Tooze, 2014). When the production of materials and products moves from behind the closed doors of industry into the social realm, new opportunities and possibilities for enabling a more diverse set of narratives and actors, spaces, and practices within material development become possible.

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Exemplifying these trends, entrepreneurs and local communities are harnessing the accessibility and adaptability of the materials in the biological cycle for positive social and environmental impact. Biomaterial innovations including Piñatex, Malai and TotoMoxtle demonstrate the capacity of biomaterial entrepreneurship to empower local communities in generating local trade using local resources, in celebrating local heritage and knowledge, and in enabling new actors to participate within the material production system for economic and social benefit. Biomaterial innovations such as Merdacotta and Chip[s]Board demonstrate how traditional material production systems stand to benefit from the participation and expertise of non-traditional actors such as agriculturalists, fine artists, and designers. When paired with emergent trends in personal fabrication and digital manufacturing, the low-barrier nature of biomaterials brings about new opportunities between material development, product design, and technological production which, in turn, enables new actors to emerge and participate (Tooze, 2014; Kuznetsov, 2010). Broad participation in the making of biomaterials is further enabled by adopting water-based chemistry methods and low-pressure, low-temperature fabrication techniques.

Increasing participation in a circular economy means certification and data validity challenges are made more acute. Coordination between small producers may require significant investment in cooperative governance structures and collective physical infrastructure such as storage facilities. Distributed Ledger Technologies (DLTs), such as blockchain, may offer important ways forward for this set of challenges. By design, DLTs are built to accommodate a large and distributed set of actors, where trust and confidence in a common resource (be it a currency or database of supply network information) is developed through consensus mechanisms that govern decisions about the use, extraction, alteration, or addition to the resource. Blockchain is presently being used to bring greater transparency to existing supply chains as exemplified by the work of Provenance (Provenance, 2015). Given their decentralized nature and emphasis on transparency and trust building, DLTs may be particularly suited to be information infrastructure for new, more participative supply networks for a regenerative circular economy.

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Table 20: Circular Principle nine case studies.

Case study 1: Collective Intelligence Design Playbook	
Location	United Kingdom
Website	www.nesta.org.uk
About	Nesta is an organisation that approaches innovation in practical ways, demonstrating how collaboration can be achieved using emerging technologies and is connected by a diverse group of people who are passionate about challenges facing society. Their playbook is a downloadable toolkit which includes tools, tactics, and methods to harness the power of people, data, and technology to solve global challenges.
Why is it relevant?	● It shares knowledge from many data sources. ● It encourages widespread participation through activities made accessible to all. ● The toolkit is available to amend to the needs of the user for them to achieve their specific goals.
Case study 2: Open Desk	
Location	United Kingdom
Website	www.opendesk.cc
About	Open Desk provides furniture and furniture designs in the form of an online marketplace that serves as a platform for a global maker network. Their goal is to create inspiring workplaces which are adaptable to the user's needs. They have specifically chosen a distributed business model to support local designers, makers, and manufacturers; they can set their own fees as well as use local delivery services and take on localised decisions like material costs or local business taxes.
Why is it relevant?	● The global maker network can adapt designs to customer requirements and create an on-demand service that is less extractive and more resilient. ● It enables makers to manage their work independently, allowing them to connect to their local and regional customers as well as use local resources.

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Table 21: Circular Principle five key performance indicators.

Circular Principle nine key performance indicators	
Community involvement in planning and implementation phases	The extent to which citizens and other stakeholders have been involved in the planning and implementation phases of a given sustainability project or initiative.
Increase participation of vulnerable groups	The extent to which a sustainability project or initiative has led to an increased participation of groups that are not well represented in society.
Quality and frequency of dialogue; Number (and diversity) of stakeholders	The quality of dialogue is assessed based on aspects such as transparency, participation, engagement, etc. on a Linkert scale through a qualitative survey of participants.
Openness of participatory processes	The proportion of public participation processes in a given municipality per 100, 000 residents per year.
Integration of environmental justice principles in policy decisions	The number of Environmental Justice (EJ) principles integrated within policy. EJ is concerned with the fair distribution of environmental costs and benefits, bridging key goals of environmental protection and social justice. EJ implies a model of sustainable development that integrates economic development, poverty alleviation, and environmental protection.

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2.3.10 Principle ten: Promote polycentric governance

Principle: *Governance systems should be nested, enabling collaboration across levels and scales. Governance should also be responsive to the nature of the resource system being utilized, and take into account interacting governance regimes from local to international levels.*

Polycentric governance refers to 'nested institutions,' where institutions are connected through norms and rules across hierarchies and scales. Collaboration across institutional levels and scales can enable rapid and coordinated response in the face of uncertainty and change (Briggs, 2015). Polycentric governance enhances the resilience of governance institutions by improving learning and experimentation, broadening participation, improving connectivity, creating modularity, increasing potential for response diversity, and building redundancy that can minimize and correct errors in governance (Briggs, 2015).

Governance systems also need to be responsive to the nature of the resource system being utilized. A circular economy incorporates many diverse types of resources, some of which are amenable to being treated as private goods (such as minerals and plastics), while others are better governed as common-pool resources (fisheries, and forests). Common-pool resources often have many competing actors operating at multiple levels of scale, making multilevel governance arrangements necessary to avoid over-exploitation and collapse of the resource (Ostrom, 2005). It is important to take into consideration how goods should be governed when developing circular economy strategies. For example, strategies such as extended producer responsibility (Dubois, 2016; Kunz, 2018) and access or performance models that incentivise the return of material to the seller (Bocken, 2016) all assume that the goods in question are best governed under private markets. Privatizing common-pool resources can privilege one stakeholder group's interest while marginalising others (Ostrom, 1990). For example, the selling of land rights for extracting timber or other resources from the Amazon rainforest can undermine the rights of indigenous peoples. For the development of a circular economy to be ecologically regenerative and socially inclusive, natural resource commons must be appropriately governed, with inclusion of all relevant stakeholders.

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Table 22: Circular Principle ten case studies.

Case study 1: Bioregion Vestaland	
Location	Norway
Website	www.bioregionvestland.com
About	Bioregion Vestland is initiating a new sustainable large scale project with the business industries located in Western Norway. They are utilising design-driven research and development, focusing on the geography of the natural ecosystem to create solutions for human society. The goals are to create innovation for products and services that should discontinue the use of fossil-based plastics as well as create a corporate social responsibility for the bioregion.
Why is it relevant?	● It is a coordinated effort and collaboration between different institutional actors at different scales: e.g. municipality, local communities, businesses, etc. ● Focusing on the use of biological loops in value chains which are also circular, sustainable, and profitable for the local economy.
Case study 2: Exemplar	
Location	United Kingdom
Website	www.exemplarnet.org.uk
About	The ExeMPLaR project is an 18–month programme that focuses on the gradual accumulation of plastics in the region of South West UK. By addressing the causes of the problems as well as the efforts to solve them, the project is exploring the impact and costs to the environment. Meanwhile, it is enabling local stakeholders who are in turn supported by the Multidisciplinary Plastics Research Hub led by the University of Exeter across a few of their campus sites (which span a 100mile radius), to research and develop applications regionally for various purposes that would result in a higher value.
Why is it relevant?	● The project is enabling regional collaboration across organisations of different sizes and levels. ● It is also responding to the systems and strategies of the resource/waste stream, and building connections between its use internationally as well as locally.

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Table 23: Circular Principle five key performance indicators.

Circular Principle ten key performance indicators	
Proportion of cities with direct civil participation	Proportion of cities with a direct civil society participation structure for urban planning and management that operates regularly and democratically.
Policy learning concerning adapting policies and strategic plans	The extent to which the sustainability project and/or initiative has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming."
Quality of mechanisms that ensure inclusion, participation, equity, and empowerment	Do authorities have the capacity to ensure decentralization and encourage involvement of interested parties throughout the process of developing policies and strategies?
Percentage of projects in partnership with at least two others sectors (private, academic, civil society)	Percentage of sustainability projects or initiatives between the local government and at least two of the three following types of stakeholders: Businesses (and other private organisations); Academia; Civil society (professional associations, trade unions, local citizen associations, NGOs). The indicator is a process indicator reflecting the way the local authority works or does not work with other stakeholders as partners for delivering sustainable and integrated urban development.
Number of sustainability related science and/or technology cooperation agreements and programmes between countries, by type of cooperation	This indicator aims at collecting information and data on the national research and innovation landscape of countries focused on the circular economy and sustainability by listing all relevant science, technology, and innovation (STI) cooperation agreements and programmes between countries, in addition to acts, bills, regulations, and international agreements on circular economy and sustainability issues.

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3. Circular Indicators

3.1 Introduction to REFLOW impact assessment

There is no single road to take toward a circular city. The vision developed, levers pulled, and targets set by a city in pursuit of a circular transition must be done with close attention to the unique opportunities, challenges, and actors present. The pilot cities within REFLOW are no exception - with the City Action Plans included within D5.1 Detailed Pilot Planning & Evaluation Framework making clear a wide-ranging and diverse set of value chains, stakeholders, and policies which pilots see critical to engage in the transition to a circular economy. Aligning a diverse set of actors and value chains toward a common vision and roadmap has been a key challenge undertaken by each pilot throughout year one of REFLOW. As part of this process, Metabolic has worked closely with each pilot to identify and calibrate a set of environmental KPIs that make progress toward their circular vision more tangible and measurable. The purpose of the environmental KPIs co-developed by Metabolic and each pilot city is to help the pilot in assessing the progress and impacts achieved through their pilot activities, and for monitoring their transition towards a circular economy.

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The impact assessment process of REFLOW is spread across WP 1, WP 3, and WP 5: with WP 1 overseeing the KPI development and monitoring activities associated with social and economic impact, WP 3 overseeing the KPI development and monitoring activities associated with environmental impact, and WP 5 playing an important coordination role throughout. This type of structure creates a series of challenges. Firstly, it spreads the method and process of assessing project and pilot impacts across various work packages which poses a continuous risk of mis-alignment both in terms of methodology and timing. Secondly, it inaccurately silos the setting of impact goals and the measurement of outcome performance into three distinct categories: environmental, social, and economic. Theoretically, these three categories may look to offer a holistic approach to target setting and impact measurement that encompasses the triple bottom line of profit, people, and planet. However, in practice, the ability to silo any target or outcome as being distinctly economic, social or environmental in nature is exceedingly difficult. Indeed, a key outcome of the Impact Assessment workshop held at the M06 Co-Creation Session in Copenhagen in November 2019 was the REFLOW consortium's difficulty in adhering to these three discrete impact areas. Instead, the consortium opted to take a more fluid and dynamic approach; recognizing the hybrid nature of its targets - clean air and water, circular resource flows, renewable energy sources, etc. - and the potential impact each can achieve: social, socio-environmental, socio-economic, environmental, economic, etc. This hybrid approach is reflected in the 12 REFLOW Impact Areas co-defined by the REFLOW consortium and further detailed below.

In an attempt to mitigate the above two challenges, Metabolic worked with Copenhagen Business School (CBS) and Waag Society (work pack leader of WP 1 and WP 5 respectively) throughout the KPI refinement process of WP 3 to ensure its process and timeline was well aligned with those of WP 1 and WP 5. Where possible a holistic approach was taken whereby environmental, social, and economic impacts were mutually considered (as can be seen in steps 1, 2, 3, and 5 detailed below). Where definition, calibration, and monitoring of specific KPIs needed to occur it was agreed upon by Metabolic and CBS that Metabolic would focus on environmentally-focused KPIs while CBS would focus on socially- and economically- focused KPIs (as can be seen in steps 4 and 6 detailed below).

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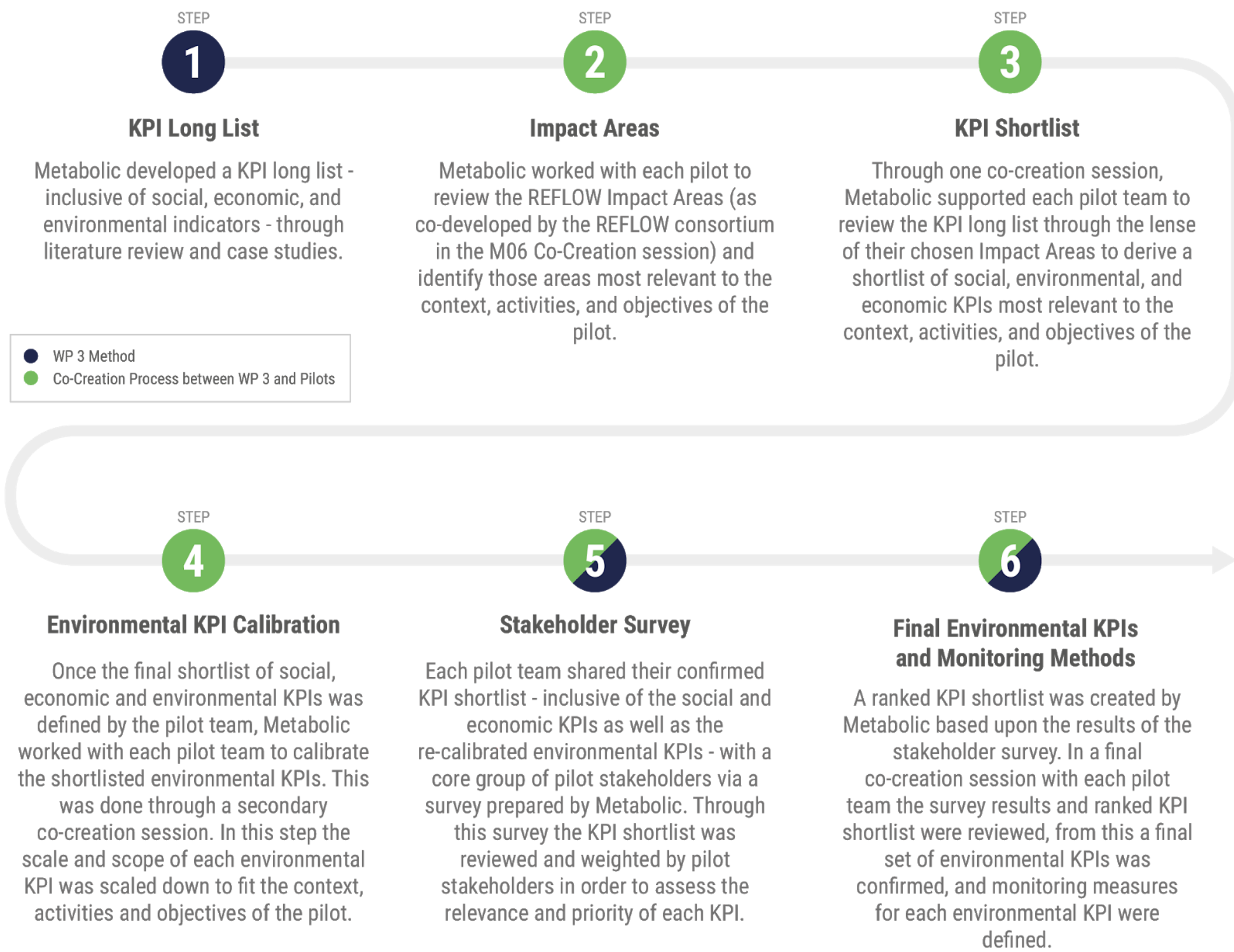
3.2 Methodology

A six step process was undertaken to help each pilot city arrive at a final set of environmental KPIs that is calibrated to the context, activities, and objectives of the pilot. The six step process was as follows:



Graphic 2: The six steps of the WP 3 KPI refinement process.

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3.2.1 KPI long List

A literature review was conducted to develop a comprehensive list of social, economic, and environmental KPIs developed and applied by leading institutions and municipalities across the EU when setting and monitoring progress towards circular, regenerative cities. A comprehensive review of literature and best practice for applying circular economy indicators to EU cities was completed by Metabolic - by combining practice with theory in this way we were able to develop a comprehensive KPI long list. The following steps were taken as part of the literature review:

1. Review of the circular economy indicators provided by EU directives.
2. Review of global environmental indicator datasets defined by international organizations.
3. Review of the "ScienceDirect" database for recent scientific literature to identify and analyze the indicators that have been used or considered to assess and quantify the environmental impacts/performance of European cities for the transition towards a circular economy.

Since the volume of scientific literature available on these databases is often overwhelming, we restricted these results to peer-reviewed publications and documents from international research organizations published in English. To evaluate the most commonly reported environmental indicators in literature, we also did a review of indicator datasets separate from the EU directives and national goals of the member states. These publications were identified in ScienceDirect and Google Scholar using keywords such as 'circular economy', 'environmental performance', 'environmental impact assessment' and more.

In addition to the above databases, it was noted that indicators to examine the emissions to air, including GHG, were not present in the EU CE directive. Indicators measuring emissions were found to be the most frequently used across all monitoring frameworks and datasets, therefore cannot be overlooked while establishing the KPI long list for the pilots. Critiques of the EU CE directive also mention the inclusion of eco-design and GHG emission indicators as a critical step towards linking the circular economy with the low-carbon economy, the EU Climate and Energy Objectives, and the Paris Agreement (EU, 2018).

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After a thorough evaluation of the selected sources, 26 academic papers, 15 international indicator datasets, and 3 meta studies were reviewed from which a total of 74 overlapping environmental indicators were retrieved. An additional 51 socio-economic indicators were added to the list by CBS, giving a final count of 120 indicators which together make the “KPI long list”.

For the KPI long list, all indicators have been considered equally important; no statistical or empirical evidence was used to develop a hierarchical weightage at this stage. The equal weighting strategy as mentioned above is the most commonly used method of indicator weighting worldwide (Gan, 2017). The layout of the KPI long list follows the following format:

Impact Area	Indicator	Definition	Unit	Citations

Indicators have been sorted under relevant Impact Areas, which will be introduced and discussed further in the next section. The citation section includes all reviewed literature and datasets where the indicator has been mentioned or used; this section also includes the original source of the indicator wherever applicable and possible.

3.2.2 Co-creation of REFLOW Impact Areas

Following the REFLOW M06 Co-creation session in Copenhagen in November 2019, all feedback from the Impact Assessment session was consolidated and analyzed to understand what types of impact the REFLOW consortium believed to be of highest priority and relevance in relation to the objectives and activities of REFLOW. Points were allotted to all the terms derived from the M06 session according to the number of occurrences in the workshop exercise. After sorting by number of occurrences, the terms with more than 3 repetitions were marked as priorities. This exercise gave us a set of 12 Impact Areas (broadly covering social, economic, and environmental impact) which the REFLOW consortium views as priority areas for the REFLOW project, specifically, and the transition towards circular cities more broadly. The 12 co-defined Impact Areas are detailed below. It is important to note that as the focus of WP 3 is on environmental impact assessment, Metabolic will be focusing on the first four Impact Areas that are more closely related to environmental impact.

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Table 24: REFLOW Impact Areas.

IMPACT AREAS		What future state do we hope REFLOW can help achieve for this Impact Area?
1	Materials and Resources	Both bio and technical resources are managed in ways that are regenerative by design. Accountability of resources is promoted through the tracking of resource flows.
2	Energy	Energy production is drawn from renewable sources and both private and public sectors adopt sustainable energy consumption practices.
3	Air Quality	The reduction of air pollution across urban areas promotes improved air quality.
4	Carbon Footprint	Cities have the technological, political, economic, and social support needed to reduce CO_2 equivalent emissions year-on-year.
5	Health and Well-being	The health and well-being of all living species - human and otherwise - are supported to thrive.
6	Equity and Inclusivity	Sustainable economic opportunities are made accessible to all, particularly to vulnerable communities.
7	Behavior and Lifestyles	Urban citizens are supported to adopt sustainable behaviours and lifestyles.
8	Community Participation	Local communities are empowered to adopt stronger roles within political and social decision-making processes.
9	Governance	Urban governance models and regulatory systems are increasingly adaptive and responsive to the needs of people and the planet.
10	Education and Training	Openly accessible education and training opportunities create new skills and competencies for a circular economy.
11	Employment	Circular jobs are accessible to all and generate significant social and economic value. A diverse set of local economic activities, in particular manufacturing, craftsmanship, and production, play a significant role in the urban economy.
12	Policy	Policy and policy change leads to greater positive impact through increased accountability.

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As a first step in the KPI refinement process, Metabolic supported pilots (through a co-creation session) to review and identify which of the REFLOW Impact Areas are most relevant to the context, objectives, and activities of their pilot. The identified Impact Areas were used by the pilots and Metabolic as a lens through which the KPI long list was analyzed.

3.2.2 Shortlisting of KPIs

Metabolic organised a co-creation session with each pilot in order to (i) review the KPI long list through the lens of those Impact Areas identified by the pilot as most relevant, and (ii) select which KPIs from the long list are of highest relevance and interest to the pilot team (given their context, activities, and objectives) thus creating a unique KPI shortlist for each pilot. The purpose of this exercise was to support the pilot cities in reviewing, assessing, and evolving the KPIs they originally set for themselves at the start of the project in light of how the ambition and activities of the pilot have progressed over the past year. To do so, the following steps were taken:

1. An initial call after the M06 Co-creation session in Copenhagen was organised by Metabolic with each pilot team in order to (i) introduce the KPI refinement process and timeline, (ii) share the 12 REFLOW Impact Areas developed at the M06 Co-Creation Session, and (iii) explain the way in which the KPI long list has been developed and structured.
2. Pilot teams reflected upon their initial set of KPIs using their City Action Plans (REFLOW D5.1, 2020) and an initial draft of the Theory of Change (as developed by WP 1).
3. Pilot teams reviewed the 12 Impact Areas and the KPI long list to complete two tasks:
    a. Highlight which Impact Areas are of highest relevance and interest to them.
    b. Pre-select all relevant KPIs using the highlighted Impact Areas as a lens. This step was done on the shared KPI long list spreadsheet through a color-coded scheme, where the pilot teams marked all pre-selected KPIs in yellow. These highlighted KPIs were used as a starting point for the co-creation session with Metabolic wherein the KPI shortlisting process was undertaken.

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4. In another co-creation session organised by Metabolic the pre-selected KPIs were reviewed with the pilot team in order to derive a KPI shortlist. For the environmentally-focused KPIs included within the shortlist, Metabolic worked closely with each pilot team to recalibrate the KPIs from their initial generic state (often set to a national level) to more accurately reflect the specificity of each pilot's context (often downscaling the generic KPI to fit a city-level scale or amending the scope of the KPI to better emphasise the unique focus of the pilot team). Any amendment necessary for the socially- and economically- focused KPIs will be led by CBS as part of WP 1.
5. The result of the second co-creation session is a refined KPI shortlist which contains social, environmental, and economic KPIs. For all environmentally focused KPIs Metabolic worked with the pilot teams to include within the shortlist a definition of the KPI, the unit and scale of data collection, and notes by the pilot team. A particularly important step within this process was the development of a definition for each environmental KPI with the pilot team. The definition process enabled each pilot team member to share and reflect upon what each KPI meant according to them. This supported an exploratory discussion between pilot team members and ultimately led to the development of a common definition for each KPI. As in step 4, any amendment, definition, or data collection assessment required for the socially- and economically-focused KPIs will be completed by CBS as part of WP 1. This KPI shortlist was shared and validated with pilot stakeholders through a survey and weighting process detailed in the following section.

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During the co-creation sessions, the following aspects were discussed with the pilot teams so to be kept in mind throughout the KPI shortlisting process:

- The type of KPIs to include: qualitative (perception based), quantitative (numerically benchmarked), or a composite of both.
- The ease of collecting data pertaining to the KPIs as well as the number of stakeholders needed to assess and collect information.
- Selecting KPIs that enable a clear evaluation and demonstration of any performance change related to the pilot's efforts.
- The potential time lag between actions and the intended impact, which may be short term (within the project period) or long-term (beyond the timeframe of the project period).
- The ability to determine the relationship (correlation or causality) between REFLOW-related activities and outcome performance.
- The degree of influence the KPIs have on the city or country's policy ecosystem.
- The degree of influence the pilot stakeholders may be able to exert to impact the performance of the KPIs.
- The overall needs of the stakeholders, such as policy makers, citizen groups, funders, etc.
- How the pilot team intends to use any information that may be generated by monitoring the selected KPIs beyond REFLOW-specific impact assessment activities.

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3.2.4 Stakeholder survey

An online survey was created for the purpose of (i) sharing, prioritizing and validating the KPI shortlist developed by each pilot team with their local stakeholders, (ii) collecting inputs on data availability, monitoring frequency, and stakeholder involvement in relation to the selected environmental KPIs, and (iii) getting buy-in from local stakeholders and agreement to monitor and evaluate the selected environmental KPIs. As in the previous step, collection and monitoring measures for all socially- and economically- focused KPIs will be led by CBS as part of WP 1. Using a common survey draft developed by Metabolic, six pilot-specific surveys were created by Metabolic using the shortlisted KPIs of each pilot.

The format of the survey is divided into two parts. The first part looks at ranking each KPI from most to least relevant in comparison to each other. While the second part asks a few questions related to KPI monitoring which have been derived from the Urban Sustainability Framework (World Bank, 2018). The methodology followed by Metabolic to analyze the survey results and generate a final set of environmental KPIs for each pilot team was as follows:

1. Pilot-specific surveys were created using the shortlist created by each pilot and circulated among the pilot teams and relevant stakeholders.
2. The results and feedback from the pilot teams and their stakeholders were collected to assess the suitability and relevance of the shortlisted KPIs as well as collect insights on possible monitoring techniques.
3. The results of the ranking question are used to generate a ranked list of KPIs using two different ranking methods, Single Transfer Vote count and Cumulative vote count (Pascuit, 2011).
4. A co-creation session was organized by Metabolic with each pilot team to discuss the outcomes of the survey and review in detail the environmental KPIs. For verification, the pilot teams were asked to confirm if the ranking of the KPI reflects the general consensus among the stakeholders who voted.
5. The result of this co-creation session are (i) a finalised shortlist of 2-5 environmental KPIs that each pilot team agrees to monitor, (ii) an agreed-upon process for how each environmental KPI will be monitored and evaluated by the pilot team and its stakeholders. As previously mentioned, the confirmation of what socially and economically focused KPIs each pilot team will move forward with, alongside a process for monitoring and evaluating each, will be carried about by CBS as part of WP 1.

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As part of the stakeholder survey, the ranking of KPIs was done to identify the most and least supported KPIs by pilot stakeholders. Multiple ranking methods were reviewed to assess the ideal method for ranking the shortlisted KPIs in the order of highest relevance to least. The review was done to find a ranking-based assessment method in order to avoid tethering the KPI refinement process to a win-lose model (Wilcoxon, 1945; Stanford, 2011). Additional criteria that the ranking method needed to meet were: the ranking question should not be complicated or require a lengthy explanation, it should promote an intuitive response, and it should not take multiple sessions for gathering inputs.

The final ranking method used was the Single Transferable Vote count method (Tideman,1995; Levin, 1995). It is a vote-counting procedure that uses the ranking as input to achieve proportional representation and to remove biases by taking into account the order of ranking given by each responder. The method asked users to rank their preferred KPIs from 1 to *x* (total number of KPIs in the shortlist) with *x* being the highest preference and 1 being the lowest. The method required voters to rank all the KPIs, meaning that,

- Every KPI is assigned a rank.
- There are the same number of possible ranks as the number of shortlisted KPIs.
- Different KPIs must be assigned different ranks.

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Votes were totaled, and a quota (the minimum number of votes required for selection) was derived by the droop quota equation (Newland, 1980). This process helped to create a well-balanced list of selected indicators; since no votes were considered 'wasted' on a lower-ranking indicator. An added benefit of this method was that only one ranking question needed to be answered for assessing all the KPIs and assigning rank. The "transfer" of votes works in the following manner:

- If a voter's first-ranked KPI achieves the quota, it is selected; and any surplus vote is transferred to other KPIs in proportion to the next back-up preference marked on the survey.
- This step is repeated until all KPIs achieve the minimum quota. The order in which they achieve the minimum quota defines the rank.
- If a KPI still remains that is unable to achieve a minimum number of votes, it stands to be eliminated. A sample calculation can be seen in Appendix 3.

Due to unforeseeable challenges related to COVID-19, the stakeholder survey process was launched at a time where many pilot stakeholders found it difficult to engage in completing the process. Because of this, the number of responses we received for each pilot survey was lower than initially expected. To mitigate this outcome, we felt it necessary to assess whether the ranked list produced by each survey using the above method was objectively unbiased. For this purpose another ranking method - the Cumulative Vote Count method - was implemented alongside the STV to see if the results showed a great degree of variation. The Cumulative Vote Count method counts the sum of the absolute amount of votes given in order of preference. This method is useful when the number of respondents is low, but the drawback of this method is that it does not show variation between KPIs that received one vote of *X* (highest) ranking or *x* number of votes of 1 (lowest) ranking.

Using both methods, a large variation was not noticed in the ranking results of any pilot's KPI shortlist. The top and bottom KPIs remained the same while slight changes in ranking were noticed in the middle KPIs. The only notable difference was seen if there was an outlier KPI that was voted "most relevant" by one or two people while the other majority of respondents voted it to be relevant only at a mid or low level.

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Overall, we believe the KPI refinement and co-creation process we undertook with each pilot team provided a comprehensive and thorough methodology for producing a final set of environmental KPIs for each pilot team to carry forward in the second and third year of the REFLOW project. The process is underpinned by peer-reviewed datasets and processes and is advanced through the inclusion of stakeholder insights and evaluations. However, no method is without its limitations. Here we take the opportunity to list those limitations of the process we have identified as a team:

- Overall: The process is, to an extent, dependent upon the number and diversity of stakeholders involved, which in our case was limited in each stage of the co-creation process. As this could lead to biased answers, the last step of the stakeholder survey was quite important to get feedback from a larger range of people. The process also could not involve end users such as citizens at this stage.
- KPI long list: While a comprehensive literature review was conducted, the development of the KPI long list was restricted by the time and budgetary constraints of the project. The WP 3 team plans to further expand the current long list to include many more KPIs as part of the second phase of the project.
- Impact Areas:
    - Each Impact Area holds a slightly different meaning to each pilot, while a common definition has been drafted a final definition has not yet been set. Creating a final set of common definitions could lead to better communication. The WP 3 team will work to do so in the second phase of the project.
    - Most pilot teams felt that all 12 REFLOW Impact Areas were important for a multi-pronged approach towards a circular economy, but they had to limit themselves to the Impact Areas their pilot's activities would have a direct impact upon. For example, a reduction in material and resource consumption might lead to a change in GHG emissions, but the pilot's activities have a direct impact on material consumption and an indirect impact on air quality. In this case the KPIs monitoring *Materials and Resources* were considered, but the KPIs monitoring *Air Quality* were not.

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- Shortlisting: The KPI shortlisting process was guided by the Impact Areas identified by the pilot team. This may have resulted in the pilot team excluding some KPIs that may have proven relevant regardless of being housed in unselected Impact Areas. The WP 3 team attempted to mitigate this limitation by suggesting KPIs from other Impact Areas if and when they proved potentially relevant.
- Survey:
  - Results and insights derived from the survey were limited by the number of responses we received. This proved particularly difficult due to unforeseeable challenges related to COVID-19.
  - Ranking of the KPIs was inherently a difficult task for all stakeholders, as many considered all the shortlisted KPIs equally important.
- Ranking method:
  - With the STV method, often a difference was seen in positions of mid-ranking KPIs if there was an outlier KPI which was voted “most relevant” by one or two people while the majority of respondents voted it to be relevant only at a low level. This did not have an impact on our results, as the intended purpose of the KPI ranking was not to create a win-lose model. The issue with STV counting has been addressed by many publications which propose using a modified STV method and quota equation (Aleskerov, 2013; Geller, 2004).
  - As an additional step towards verification of the results, the pilot teams were shown the survey results and asked to confirm if the ranking of the KPI reflected the general consensus among the stakeholders who responded.
  - An underlying assumption for the survey results and ranking was that there is no incentive for the responders to misrepresent their evaluations of the KPIs.

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3.3 Results

In this section, we share the results of the KPI refinement process detailed above in sections 3.2.1, 3.2.2, and 3.2.3. We do so by providing the a breakdown of steps and outcomes for each pilot including: selected Impact Areas, KPI long list selection, KPI shortlist recalibration, stakeholder survey results (inclusive of KPIs ranking and monitoring measures), final environmental KPIs, and key considerations when moving forward.

3.3.1 Amsterdam

City: Amsterdam
Pilot Team: *Amsterdam Municipality; Waag Society; Pakhuis de Zwijger; Alcon Advies; BMA Techne; Saxion* ***Pilot Description:*** *Amsterdam pilot focuses on textiles from households, such as clothes and home textiles. The pilot targets how textiles are used, discarded, and reused by citizens and companies. It explores how textile resources can be recovered and cycled back into the urban metabolism, and how to shift citizens' mindsets and behaviours about textiles.*

Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), the Amsterdam pilot selected the following Impacts Areas as most highly relevant for the pilot's REFLOW activities:

- Materials and Resources
- Behaviour and Lifestyles
- Community Participation
- Education and Training

The pilot placed a secondary emphasis on Energy, Governance, Carbon Footprint, and Equity and Inclusivity. The pilot determined that Air Quality, Health and Well-being, Employment, and Policy were not directly relevant to the REFLOW activities in Amsterdam.

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Among the four most relevant impacts categories, Materials and Resources was deemed highly important due to the low rate of textile waste separated, and the focus of the pilot to recover valuable textile materials. Behaviour and Lifestyles was selected as it is a key driver to modify the current metabolic flows of textiles in Amsterdam.

Community Participation and Education and Training were both selected because of the educational emphasis of the REFLOW activities and the future educational work of the pilot with the diverse communities of Amsterdam.

KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while the second round was co-iterated to select the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 (REFLOW, 2020). This refined KPIs list is compiled in Table 25. within each of the four Impact Areas. The Material and Resources KPIs are quantitative indicators targeting the monitoring of Amsterdam textile flows. The Behaviour and Lifestyles, Community Participation, and Education and Training offer a mix of quantitative and qualitative indicators focusing on involvement, quality of engagement, and educational and behavioural monitoring. Note that during the co-iterated second round, an additional KPI from the Policy Impact Area was added due to its relevance to Amsterdam pilot activities.

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Table 25: Amsterdam pilot refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Material and Resources	Circular material use rate (CMU)	The circular material use (CMU) rate measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M).	EUROSTAT 2018
	Life time extension	The extent to which the project attempted to prolong the service lifetime of the targeted product.	Bosch et al. 2017
	Proportion of municipal solid waste that is sorted and recycled	Formally and informally recycled materials are those that (following local government permits and regulations) are diverted from the waste stream, partially recovered, and sent for processing into new products. Municipal waste recycling rate (%) = total amount of municipal waste recycled (year x) * 100 / total amount of municipal waste generated in tonnes (year x).	World Bank 2018, IDB 2013, EBRD 2016; RFSC.
Behaviour and Lifestyles	Consciousness of citizenship	The extent to which the project has contributed to increasing consciousness of citizenship (qualitative).	Bosch et al. 2017
Community Participation	Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement.	World Bank 2018
	Quality and frequency of dialogue between and among domestic and external stakeholders.	The quality of dialogue is assessed based on aspects such as transparency, participation, engagement, etc. on a Linkert scale through a qualitative survey of participants.	UNDP, 2008
Education and Training	Adult education participation rate	Participation rate in education and training (project period) by sex, educational attainment level, age, and labour status.	EUROSTAT, 2019
Policy	Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming" (qualitative).	Bosch et al. 2017

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KPI shortlist recalibration

A selection process and recalibration process was performed jointly by Metabolic with the pilot team for the environmental KPIs (all included within the Material and Resources Impact Area). This process solely included environmental KPIs as socio-economic KPIs included in Behaviour and Lifestyles, Community Participation, Education and Training, and Governance are further developed within WP 1. A recalibration process was then required to tailor the refined environmental KPIs selected to the specific activities as defined in the Pilot Action Plans (REFLOW D5.1, 2020). This first iteration of environmental KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 26).

The circular material use rate is usually compiled at the country-level (EUROSTAT, 2018). Through the joint refinement effort, it was downscaled to the appropriate scale for Amsterdam REFLOW activities, that is, the key neighbourhoods involved in the pilot's activities. The KPI was also modified to include solely textile material as it is the focus of Amsterdam's pilot.

The life-time extension KPI was recalibrated in terms of its units. Originally a Likert scale, it was decided that the most appropriate unit would be the number of uses per life cycle for textile items as this metric is a core concern in unsustainable textile consumption (EMF, 2017). Additionally, this metric has been selected jointly with the pilot team as an experimental KPI. This KPI should be applied to the first beta users of the digital platform ReflowOS developed by WP 2, which focuses on tracking and tracing textile items.

The municipal recycling rate KPI was modified to include only textile waste recycling and its scale was amended to provide two levels: city-level and neighbourhood-level. This downscaling to the neighbourhood-level provides greater granularity to monitor the impacts of the Amsterdam pilot of its "REFLOW neighbourhoods". These neighbourhoods will be the focus of a core set of educational and outreach activities that aim to increase the local separation rate of household textiles.

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Table 26: Amsterdam pilot refined KPI list (calibrated).

Impact Area	Original KPI	Recalibrated KPI	New description
Material and Resources	Circular material use rate (CMU)	Textile material use rate	The circular textile use (CTU) rate measures, in percentage, the share of textiles recovered and fed back into Amsterdam - thus saving extraction of primary raw materials - in overall material use. The CTU rate is thus defined as the ratio of the circular use of textiles (U) to the overall textile use (T) of Amsterdam.
	Life time extension	Life-cycle use rate of textile items	Number of use cycles of textile items, in terms of times of reuse after initial discard within NL.
	Proportion of municipal solid waste that is sorted and recycled	Amount of textile sorted at a neighbourhood level	Textile sorted as a percentage of total municipal solid waste. Shows change in customer behaviour and total material available for recycling. Formally and informally recycled textile (following local government permits and regulations) diverted from the waste stream, partially recovered, and sent for processing into new products. Textile recycling rate (%) = total amount of textile waste recycled (year x) * 100 / total amount of textile waste generated in tonnes (year x).

Stakeholder survey results

The KPI co-refinement and finalization survey was completed by six respondents from the Amsterdam REFLOW pilot team from a variety of organizational backgrounds, ranging from a think tank, an educational institute, an entrepreneur, to a municipal actor, or citizen lab.

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KPI ranking

The refined set of Amsterdam calibrated environmental KPIs, alongside the selected socio-economic indicators were included in the stakeholder survey and were subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by Amsterdam REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **E1: Circular textile use rate**
2. **E2: Number of use cycles of textile items**
3. **E3: Amount of textile sorted at a neighbourhood level**
4. **S9: Education participation rate**
5. **S4: Increase in the consciousness of citizens**
6. **S7: Quality and frequency of dialogue**
7. **S10: Policy learning concerning adapting policies and strategic plans**
8. **S6: Number of people reached through REFLOW activities/campaign**
9. **S5: Number of stakeholders involved**
10. **S8: Availability of public information in local dialects for dissemination**

Monitoring measures

The respondents also provided their feedback on the three pre-selected environmental KPIs. The pie charts below illustrate the answers from the respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process.

Circular textile use rate

The Amsterdam REFLOW team believes that most data for this KPI will be generated directly by the project during its implementation. The monitoring process will require the contribution of a wide variety of stakeholders. Responses relating to the monitoring rate reflect the need to align on when monitoring should occur as 33% would monitor this KPI bi-annually while another 33% would record it at the start and end of the project. The vast majority of the pilot team believe that this KPI would have a direct impact upon their monitoring on the city textile waste policies. About half of the respondents believed that the impact from the REFLOW intervention would be reflected in this KPI in the short term while the other half believed it would be visible in the longer term.

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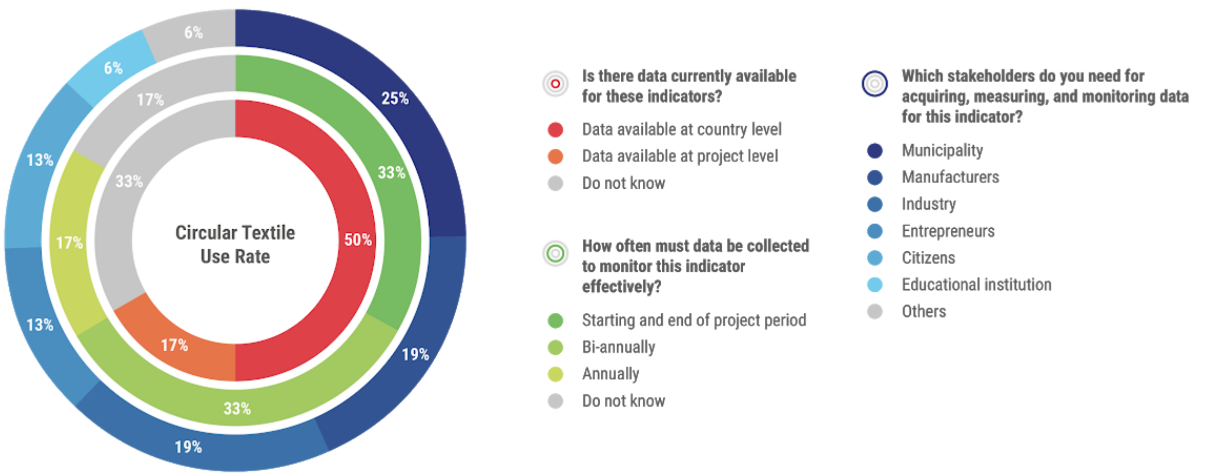
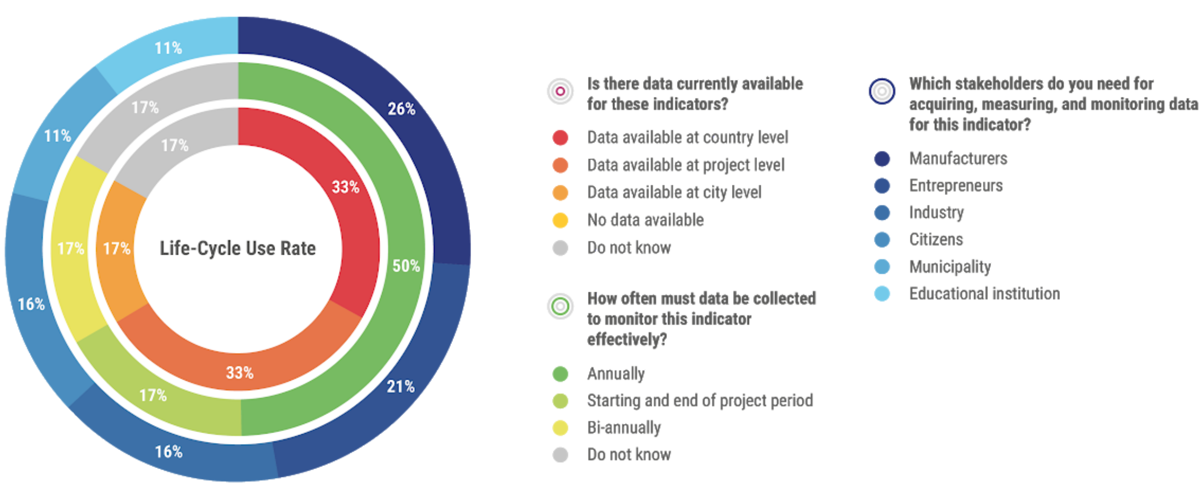


Graph 3: Responses to KPI: Circular textile use.

Life-cycle use rate

A little less than half of the respondents did not know or believed that no data currently was available for this KPI. Regarding the monitoring rate, half of the respondents believed it should be tracked on an annual basis. A large majority of the respondents believed that this KPI will have a direct impact on the city's textile policies, although half of them stated that the impact from the REFLOW intervention would be reflected in the long-term for this indicator. The monitoring process will require the contribution of a wide variety of stakeholders.



Graph 4: Responses to KPI: Life-cycle use rate.

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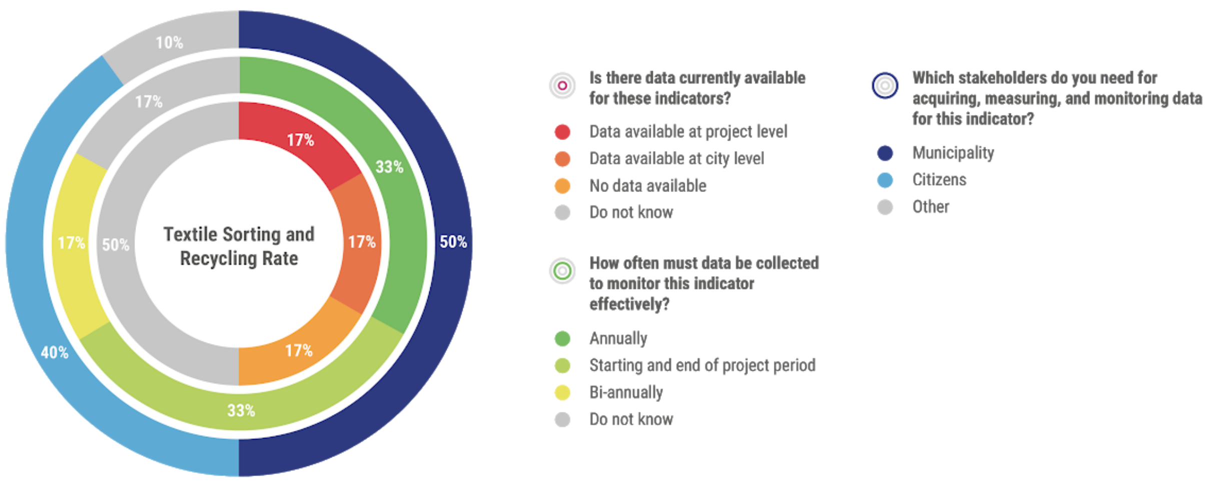
Textile sorting rate

About half of the respondents did not know whether data for this KPI was available. Responses relating to the monitoring rate reflect the need to align on when monitoring should occur as 33% would monitor this KPI annually while another 33% would record it at the start and end of the project. The municipality was cited most often as the stakeholder to collect this data. There was uncertainty about when the impact of the REFLOW interventions would be visible in this KPI, with half of the respondents not knowing. A majority of respondents believed the results from this KPI would have an indirect impact on Amsterdam's policies.



Graph 5: Responses to KPI: Textile sorting and recycling rate.

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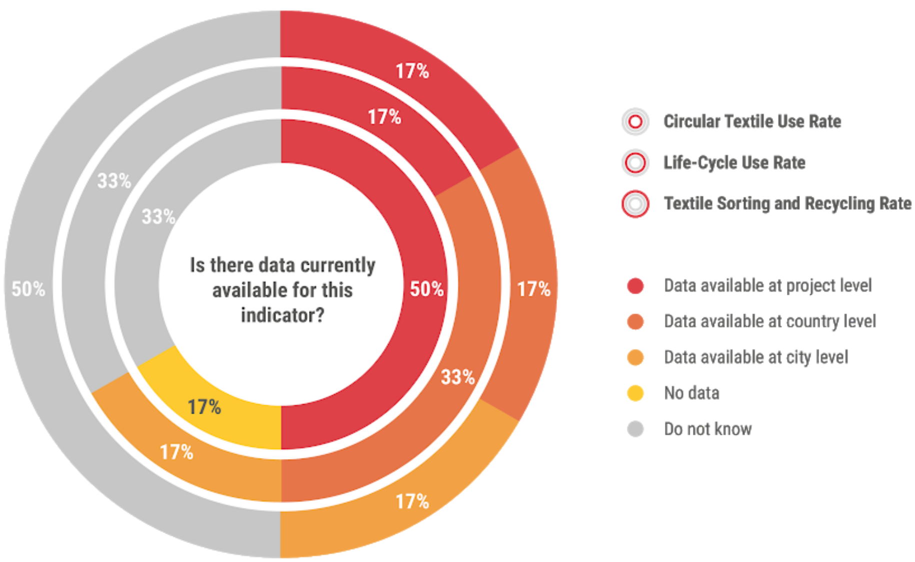
Key considerations when moving forward

Data availability

For the question regarding data availability, not many responders could provide insights as it depended on an active knowledge about the existence of relevant data sets within Amsterdam or the Netherlands. The information from the responses on the data availability on each KPI will be useful in case we need to compare or extrapolate data from the country level to a local level or vis-a-versa. The Amsterdam pilot aims to calculate the Circular textile use rate at the project level, as it is a composite KPI which needs input of data such as amount of textiles discarded and recovered, data for which might already exist at the city level.



Graph 6: Responses on data availability of all shortlisted environmental KPIs by the Amsterdam pilot.

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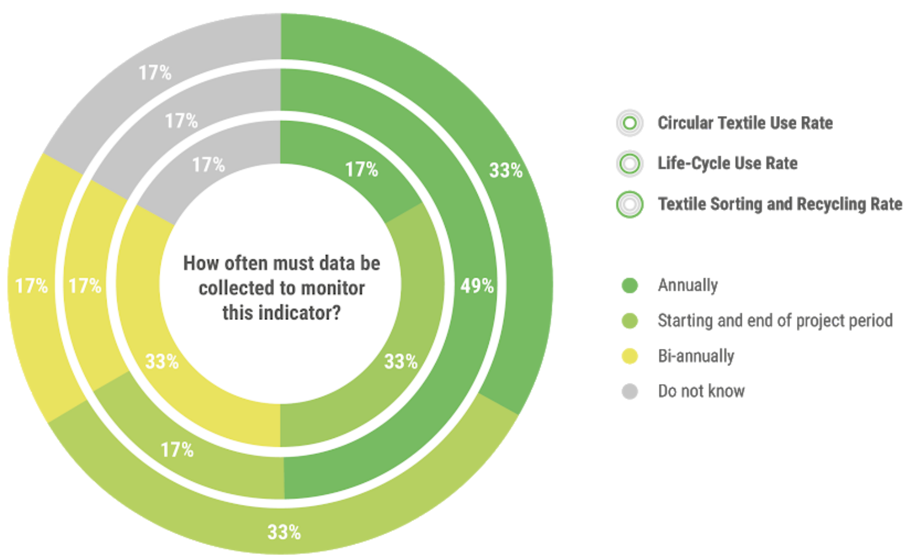
Regularity of monitoring

Graph 7 shows the frequency of data collection required for the monitoring of the three KPIs. Given the resources of the project, it was considered unrealistic to collect data bi-annually for any of the KPIs. After discussions with the pilot team it was decided that for Circular textile use rate and Life-cycle use rate, data will be collected at the beginning and end of the project period. The input on Life-cycle use rate is highly dependent on the ReflowOS, therefore requires a baseline to be measured when the OS is launched. Data on the sorting and recycling rate is currently collected by the municipality of Amsterdam annually, which has informed the decision to have an annual collection of data for this KPI. For the purpose of monitoring the change in performance of the selected KPIs at the starting and end of the project period, a baseline value will need to be calculated with the data currently available.



Graph 7: Responses on frequency of data collection on all shortlisted environmental KPIs by the Amsterdam pilot.

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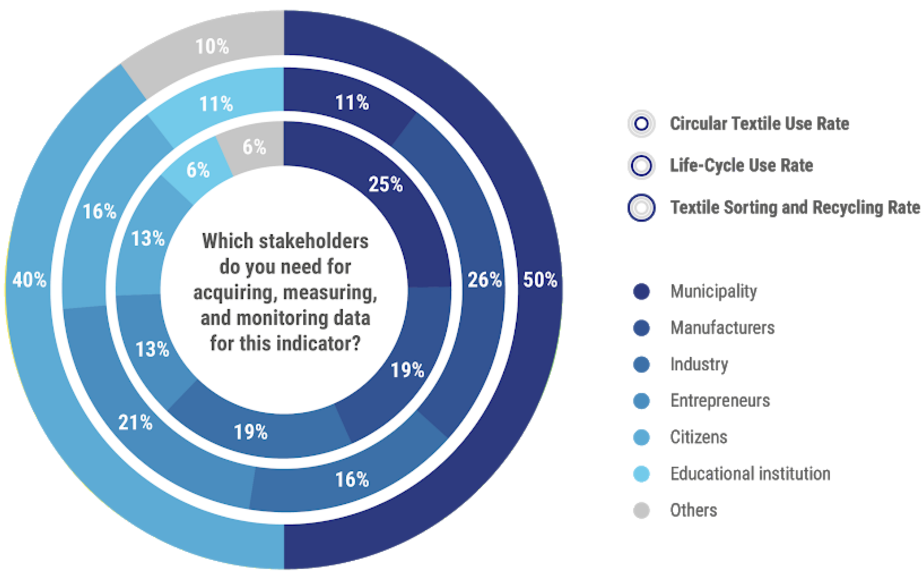
Stakeholders

Graph 8 shows the collective ecosystem of stakeholders required for measuring and monitoring the three environmentally-inclined KPIs for Amsterdam. The Circular textile use rate, which requires monitoring the amount of textiles that re-enter a productive material stream requires collaboration between multiple partners throughout the value chain, giving almost equal importance to the participation of the municipality, manufacturers, and industry. Life-cycle use rate aims to note the number of use cycles a textile item goes through after being discarded for the first time. This will require a greater involvement of the manufacturers and entrepreneurs as well as citizens and educational institutions. The textile sorting and recycling rate has unanimously been considered a task that requires the involvement of both the municipality and the citizens.



Graph 8: Responses on stakeholder required for all shortlisted environmental KPIs by the Amsterdam pilot

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Final environmental KPIs

Based on the results of the survey, a final co-iteration round was performed to review the environmental KPIs, discuss their impacts, and decide collectively on a monitoring approach. The final environmental KPIs for the Amsterdam pilot are shown below in Table 27. The municipality was established as a key stakeholder to lead the data collection process of two of the three KPIs. Their Circular textile use rate will be monitored at the beginning of the project thanks to the study performed by the municipality, and will be performed again at the end of the project. The Textile sorting rate KPI will be monitored annually using existing municipal data collection processes and infrastructure. The experimental KPI on Textile use rate will be supported by WP 2 through the testing of the ReflowOS, with support from the entire Amsterdam pilot.

Table 27: Amsterdam final environmental KPIs.

KPIs	Monitoring approach			
	Scale	Regularity	Stakeholders	Lead organization
Circular textile material use rate (%).	Neighbourhood	Beginning and end of project period, with expected projections.	Manufacturers, entrepreneurs, industries, community of Amsterdam, Sympany.	Municipality
Life-cycle use rate of textile items (number of use/lifecycle).	User - dependent on ReflowOS	Baseline from OS and then end of project period.	Manufacturers, entrepreneurs, industries.	WP 2 Leader
Textile sorted/recovery rate (%).	Neighbourhood	Annually.	Municipality, citizens, Sympany.	Municipality

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3.3.2 Vejle

City: Vejle
Pilot Team: *Municipality of Vejle; Vejle Kommune (Innovation og entreprenørskab); AffaldGenbrug Vejle; Danish Design Centre.* ***Pilot Description:*** *The Vejle pilot focuses on plastic waste produced across the municipality from a selection of public institutions, private companies, and households. The Vejle pilot will be designing new sustainable solutions to reduce the need for plastic and co-create circular strategies for plastic as a resource – together with local stakeholders from both public and private sector and citizens.*

Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), Vejle pilot selected the following areas as most highly relevant for the pilot's REFLOW activities:

- Material and Resources
- Community Participation

The pilot placed a secondary emphasis on Governance, Behaviour and Lifestyles, and Policy. The pilot determined that Energy, Air Quality, Carbon Footprint, Health and Well-being, Education and Training, Employment, Equity and Inclusivity were not directly relevant to the REFLOW activities in Vejle.

Among the most relevant Impact Areas, Materials and Resources were selected due to the pilot's core goal of reducing the current high use of virgin plastics by replacing plastic products with circular alternatives, and recovering plastic waste to use it as a new resource. Community Participation was selected as the active involvement of citizens, local companies, and the municipality as a key lever to co-create the tools necessary to transform the use of plastics in Vejle.

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KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while in the second round the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 were selected (REFLOW, 2020). This refined KPIs list is compiled in Table 28. within each of the four Impact Areas. The Material and Resources KPIs are quantitative indicators meant to monitor the flows of plastics within the local REFLOW sites, where the pilot will deploy their interventions and activities. The Community Participation offers a range of quantitative and qualitative indicators focusing on assessing the degree of involvement of the local population, the quality of the dialogue, and the effects of the projects in shifting values and mindsets for citizens involved within the local REFLOW activities. Additionally, an indicator on policy influence from the Governance Impact Area was selected during a joint iteration round due to its relevance for the municipal stakeholders of the REFLOW pilot team.

Table 28: Vejle refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Materials and Resource	Circular material use rate (CMU)	The circular material use (CMU) rate measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M).	EUROSTAT 2018
	Recycling rate of specific waste stream	Amount of specific material (plastic/wood/bio waste/C&D etc) recycled in the economy/city.	European Commission, 2018

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Impact Area	KPI	Description	Citation(s)
Community Participation	Increase consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship (qualitative).	Bosch et al. 2017
	Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement.	World Bank, 2018
	Stakeholder reach	Percentage of people in the target group that have been reached and/or are activated by the project.	Bosch et al. 2017
	Quality and frequency of dialogue between and among domestic and external stakeholders	The quality of dialogue is assessed based on aspects such as transparency, participation, engagement, etc. on a Linkert scale through a qualitative survey of participants.	UNDP, 2008
Governance	Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming" (qualitative).	Bosch et al. 2017

KPI long list recalibration

A selection process and recalibration process was performed jointly with the pilot team for the environmental KPIs (all included within the Material and Resources Impact Area). This process solely included environmental KPIs as socio-economic KPIs included in Community Participation, and Governance are further developed within WP 1. To tailor the KPIs included within the Material and Resources Impact Area to the specific activities as defined in the Pilot Action Plans (REFLOW D5.1, 2020) recalibration was required. This first iteration of environmental KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 29).

The Circular material use rate was adapted to only focus on plastic as this material is the sole focus of the pilot. Additionally, the KPI from EUROSTAT, was downscaled from its original scope (national-level) to the project-scope (REFLOW sites). Thus, this KPI will be applied to the REFLOW sites (nursing home, retails, schools, social housing) that are involved in the pilot activities.

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The Recycling rate was amended to include only plastic materials, and its application was downscaled from the city-level to the local REFLOW site to achieve greater granularity to monitor change of recycling rates where REFLOW activities are taking place.

Table 29: Vejle refined KPI list (calibrated).

Impact Area	Original KPI	Recalibrated KPI	New description
Materials and Resource	Circular material use rate (CMU)	Circular plastic use rate	The circular plastic use rate measures, in percentage, the share of plastics recovered and fed back into the REFLOW sites and into the city, - thus saving extraction of virgin plastic - in overall plastic use. This rate is thus defined as the ratio of the circular use of plastics to the overall plastic use.
	Recycling rate of specific waste stream	Plastic recycling rate	Amount of plastic recycled in the REFLOW sites and the city.

Stakeholder survey results

The KPI co-refinement and finalization survey was completed by seven respondents from the Vejle pilot team from a variety of organizational backgrounds, ranging from a waste plant actor, to municipal actor, and a non-governmental research organization.

KPI ranking

The refined set of Vejle calibrated environmental KPIs, alongside the selected socio-economic indicators were included in the stakeholder survey and were subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by Vejle REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **S5: Community involvement in the implementation phase**
2. **E2: Recycling rate of plastics at REFLOW sites**
3. **S3: Increase in the consciousness of citizens**
4. **S7:Policy learnings/Number of political decisions based on recommendations from REFLOW**
5. **E1: Circular plastic use rate**
6. **S6: Number of people reached through REFLOW activities**
7. **S4: Number of stakeholders**

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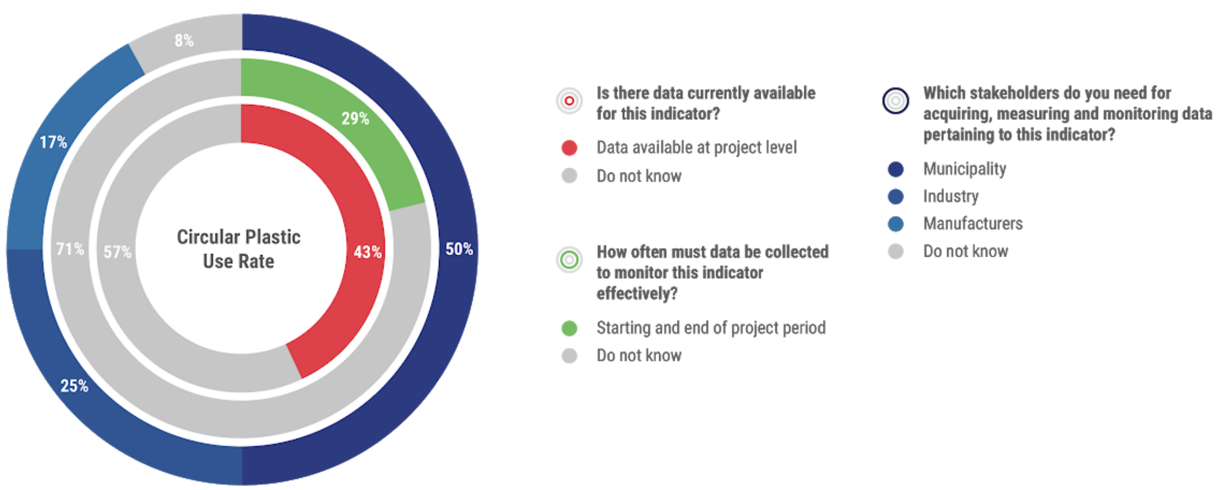
Monitoring measures

The stakeholder survey respondents provided feedback on the monitoring of the two pre-selected environmental KPIs. The pie charts below illustrate the answers from the respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process.

Circular plastic use rate

For the monitoring of the Circular plastic use rate, a majority of the Vejle pilot team did not know whether the data for this KPI was directly available. The municipality was cited most often as the key stakeholder best suited to collecting this data. A majority of respondents did not know at what rate it would be appropriate to monitor this KPI, while more than a quarter suggested it should be recorded at the start and end of the project. The vast majority of the pilot team believed that this KPI would have only an indirect impact upon their monitoring on the city's waste policies and that the impact from the REFLOW intervention would be reflected in this KPI in the long term.



Graph 9: Responses to KPI: Circular plastic use.

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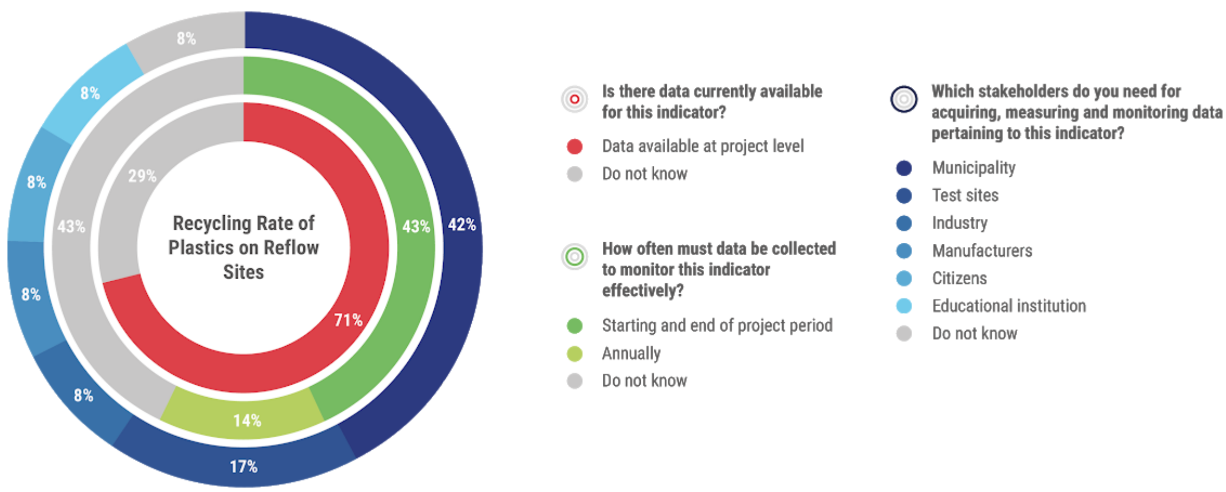
Plastic recycling rate

For the Recycling rate of plastic, a large majority of respondents believed that the data would be available at the project-level from REFLOW sites. The municipality was again cited most often as the key stakeholder best suited to collecting this data. Responses regarding the monitoring rate reflect the need to align on when monitoring of this KPI should occur. The vast majority of the pilot team believed that this KPI would have only an indirect impact upon their monitoring of the city waste policies. More than half believed that the impacts from the REFLOW intervention would be reflected in this KPI in the short term for its REFLOW sites. There was uncertainty about the monitoring rate of this KPI with little less than half not knowing when it should occur, another half believed it should be recorded on an annual basis.



Graph 10 - Responses to KPI: Recycling rate of plastics on REFLOW sites

Key considerations when moving forward

Data availability

As noted by a majority of respondents, the data for both finalised KPIs will be produced at the project level as the calculations will be done based on the data produced and monitored on-site. This highlights the need to set up a robust data collection and monitoring system on site that can relay relevant data periodically.

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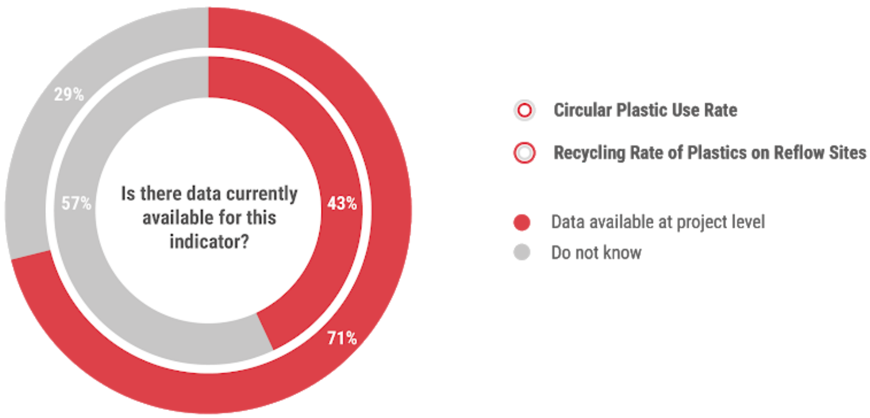
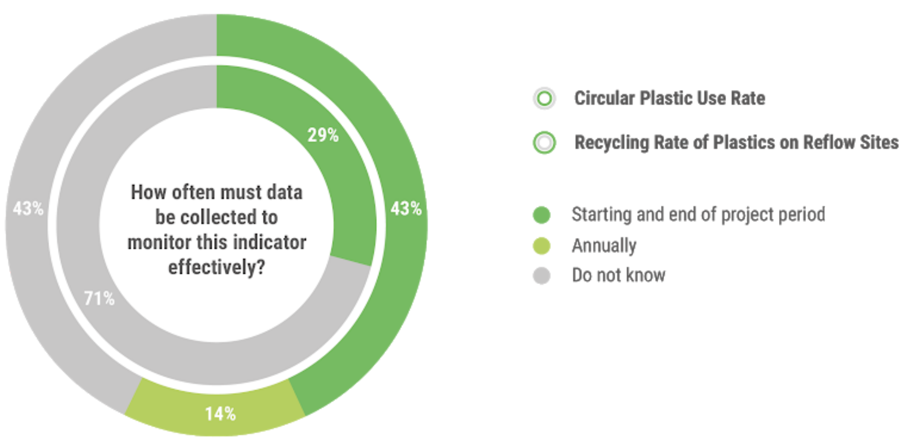


Graph 11: Responses on data availability of all shortlisted environmental KPIs by the Vejle pilot.

Regularity of monitoring

The frequency of data collection and monitoring for both KPIs was decided to be at the beginning and end of the project period, which highlights the need to set up a baseline of the current situation on the selected REFLOW sites within the Vejle pilot.



Graph 12: Responses on frequency of data collection on all shortlisted environmental KPIs by the Vejle pilot.

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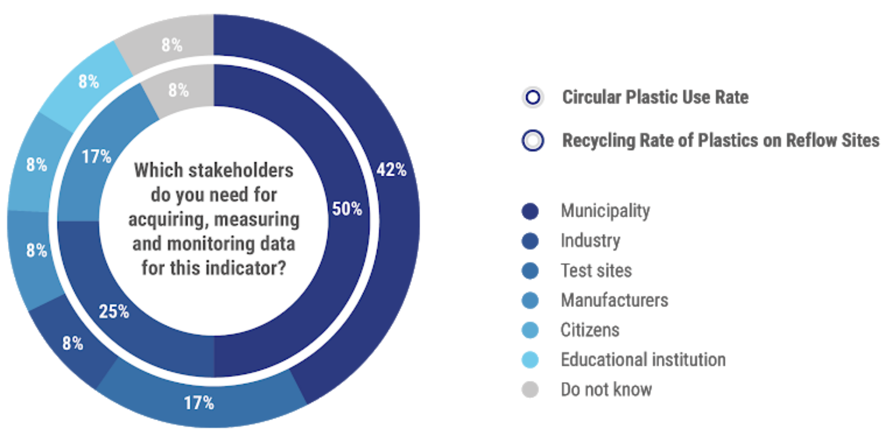
Stakeholders

Responses to the stakeholder involvement question for each KPI highlights the need for cooperation among multiple actors in order to push forward progress. The Recycling rate of plastics on REFLOW sites will require involvement of the municipality, industries, manufacturers, test sites, citizens as well as educational institutions. As the project progresses, it will be important to emphasise the level of involvement required by each stakeholder within the process for both KPIs.



Graph 13: Responses on stakeholders required for all shortlisted environmental KPIs by the Vejle pilot.

Final environmental KPIs

Based on the results of the survey, a final co-iteration round was performed to review the environmental KPIs, discuss their impacts, and decide on a monitoring approach. The final environmental KPIs for the Vejle pilot are shown below in Table 30. The municipality and the waste plant will lead the data collection process, which will also involve local industries and manufacturers. Both environmental KPIs will be monitored at the beginning and the end of the project and focus exclusively on the REFLOW sites engaged in the pilot activities.

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Table 30: Vejle final environmental KPIs.

KPIs	Monitoring approach			
	Scale	Regularity	Stakeholders	Lead organization
Circular plastic use rate (%)	REFLOW Sites	Beginning and end of project period	Municipality, Industries, Manufacturers	Municipality and Waste Plan
Plastic recycling rate (%)	REFLOW Sites	Beginning and end of project period	Municipality, Industries, Manufacturers	Municipality and Waste Plant

3.3.3 Milan

City: Milan

Pilot Team: *POLIMI, Comune di Milano, Municipality of Milan, OpenDot, WeMake*

Pilot Description: *The Milan pilot focuses on tracking food flows in its covered municipal markets to develop circular practices among the vendors of the markets. It aims to create market 'laboratories' to test new food prototypes, reduce food waste, and drive positively the local economy. This project will be performed with the participation of local residents, market vendors, and local businesses, thus reinforcing the markets as community hubs for Milan's neighbourhoods.*

Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), the Milan pilot selected the following Impacts Areas as most highly relevant for the pilot's REFLOW activities:

- Material and Resources
- Governance
- Health and Well-being

The pilot placed a secondary emphasis on, Policy, Community Participation, and Behaviours and Lifestyles. The pilot determined that Energy, Air Quality, Carbon Footprint, Employment, Equity and Inclusivity, and Education and Training Impact Areas were not directly relevant to the Milan pilot activities.

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Among the most relevant impact categories, Materials and Resources was selected as a key Impact Area as the pilot must track and understand the food flows going through Milan's covered markets to provide insights for the creation of interventions and the development of experimental prototypes in the market laboratories. The Governance Impact Area was chosen due to Milan's strong position in adaptive and forward-looking policy models regarding food, and for its relevance to the pilot's goal of developing circular and sustainable management models for the municipal markets. The Health and Well-being Impact Area was selected due to the importance of local food for Milan's residents.

KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while in the second round the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 were selected (REFLOW, 2020). This refined KPIs list is compiled in Table 31. within each of the four Impact Areas. The selected Material and Resources KPIs are quantitative and focus on the flows of food for the first two, while the third KPI assesses how dependent Milan municipal markets are to non-local food products. The Health and Well-being KPI will focus qualitatively on the promotion of healthy lifestyle for local residents. Although a secondary Impact Area, three KPIs were selected from the Community Participation Impact Area, mixing both qualitative KPIs focusing on awareness and dialogue quality and quantitative KPIs such as stakeholder reach. The Governance KPIs are both qualitative in nature.

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Table 31: Milan refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Materials and Resources	Circular material use rate (CMU)	The circular material use (CMU) rate measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M).	EUROSTAT 2018
	Food waste index	The indicator aims to measure the total amount of food that is wasted in tonnes. It complements SDG 12.3.1(a) on Food Loss. Both food indicators look to divide the food value chain and measure the efficiency of the food system.	SDG 12.3.1, FAO, 2018
	Material import dependency	The term 'material import dependency' shows the extent to which an economy relies upon imports in order to meet its material needs. The ratio of imports (IMP) over direct material inputs (DMI) in percentage. Material import dependency cannot be negative or higher than 100%. Values equal to 100% indicate that there are no domestic extractions during the reference year.	EUROSTAT 2018
Health and Well-being	Encouraging healthy lifestyles	Extent to which the project and associated activities serve to promote a healthy lifestyle among local residents (qualitative).	UNaLab, 2017
Community Participation	Increased consciousness of citizenship	The extent to which the project has contributed to increasing consciousness of citizenship (qualitative).	Bosch et al. 2017
	Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement.	World Bank, 2018
	Quality and frequency of dialogue between and among domestic and external stakeholders	The quality of dialogue is assessed based on aspects such as transparency, participation, engagement, etc. on a Linkert scale through a qualitative survey of participants.	UNDP, 2008
Governance	Citizens' awareness regarding urban nature & ecosystem services	The extent to which a project has used opportunities to increase citizen's awareness of urban nature and ecosystem services, and educate urban citizens about sustainability and the environment.	Bosch et al. 2017
	Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming" (qualitative).	Bosch et al. 2017

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KPI long list recalibration

A selection process and recalibration process was performed jointly with the pilot team and Metabolic for the environmental KPIs (all included within Material and Resources Impact Area). This process solely included environmental KPIs as socio-economic KPIs included in Health and Well-being, Community Participation, and Governance are further developed within WP 1. To tailor the KPIs within the Material and Resources Impact Area to the specific activities as defined in the Pilot Action Plan (REFLOW D5.1, 2020) recalibration was required. This first iteration of environmental KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 32).

The Circular material use rate and Material import dependency indicators were adapted to only focus on food as this resource is the sole focus of the pilot. Additionally, these KPIs from EUROSTAT, were downscaled from their original scope (national-level) to the project-scope, which is the municipal markets of Milan. Thus, these KPIs will be applied to the REFLOW food markets that are involved in the pilot activities. The Food waste index will also be applied at the municipal market-level.

Table 32: Milan refined KPI list (calibrated).

Original KPI	New KPI	New description
Circular material use rate (CMU)	Circular food use rate	The Circular food use (CFU) rate measures, in percentage, the share of food recovered and fed back into Milan's municipal market, thus saving production of primary food products in overall food consumption. The rate is thus defined as the ratio of the circular use of food to the overall food use.
Food waste index	Food waste index	The food waste index measures the total amount of food that is wasted in tonnes.
Material import dependency	Food import dependency	Total amount of food with local origin (peri-urban / metropolitan area, Lombardy Region area). Comparison between pre-intervention and post-intervention amounts.

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Stakeholder survey results

The KPI co-refinement and finalization survey was completed by six respondents from the Milan pilot team from a variety of organizational backgrounds, ranging from a university, to the municipality, to a technological business actor.

KPI ranking

The refined set of Milan calibrated KPIs[1] was included in the stakeholder survey and was subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by Milan REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **E1: Circular food use rate**
2. **E2: Food waste index**
3. **E3: Agri-food import dependency**
4. **S10: Policy learning concerning adapting policies and strategic plans**
5. **S6: Increased consciousness of citizens on the role of community hubs played by municipal markets**
6. **S5: Number of stakeholders engaged in co-design, co-creation and prototyping activities**
7. **S7: Number of people reached through REFLOW activities/campaign**
8. **S9: Citizens' awareness regarding peri-urban farming and agri-food local chains**
9. **S4: Number of customers of products derived from a local supply chain**
10. **S8: Quality and frequency of dialogue**

[1] Note that at the initiative of the pilot team, the socio-economic KPIs were calibrated and modified to match the specific context of the pilot. This is why the socio-economic KPIs ranked above appear slightly different from the uncalibrated list of selected socio-economic KPI in Table 31.

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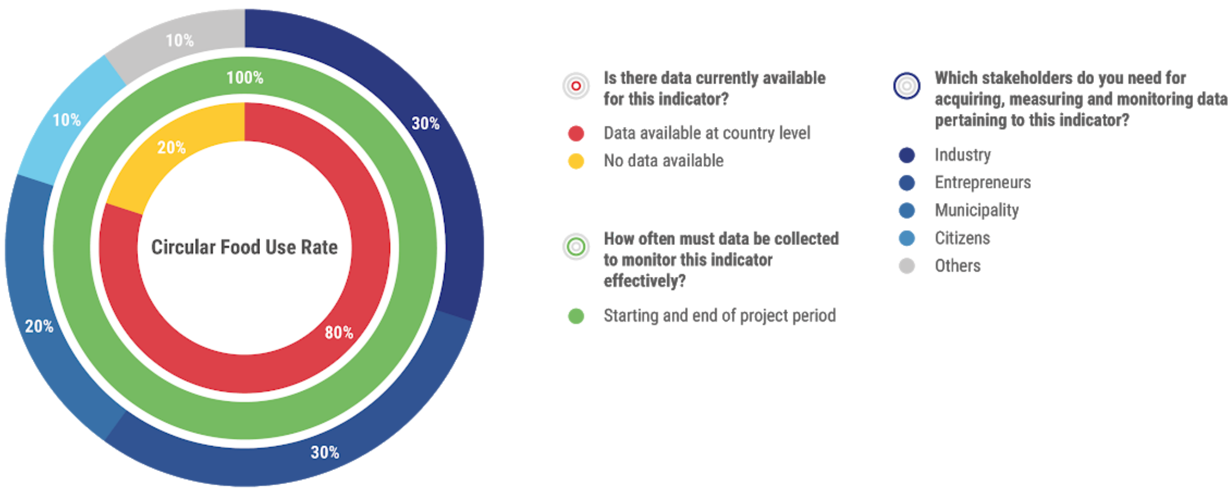
Monitoring measures

The respondents also provided their feedback on the three pre-selected environmental KPIs. The pie charts below illustrate the answers from the respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process.



Graph 14: Responses to KPI: Circular food use rate.

Concerning data availability for the selected three KPIs, a large majority of the respondents believe that the data will be collected directly during the project for the Circular food use rate and the Food waste index, while a little less than half believed that it would be the case for the Food import dependency indicator. Another small half believed that the Food import dependency data would be available at either the city-level or national-level.

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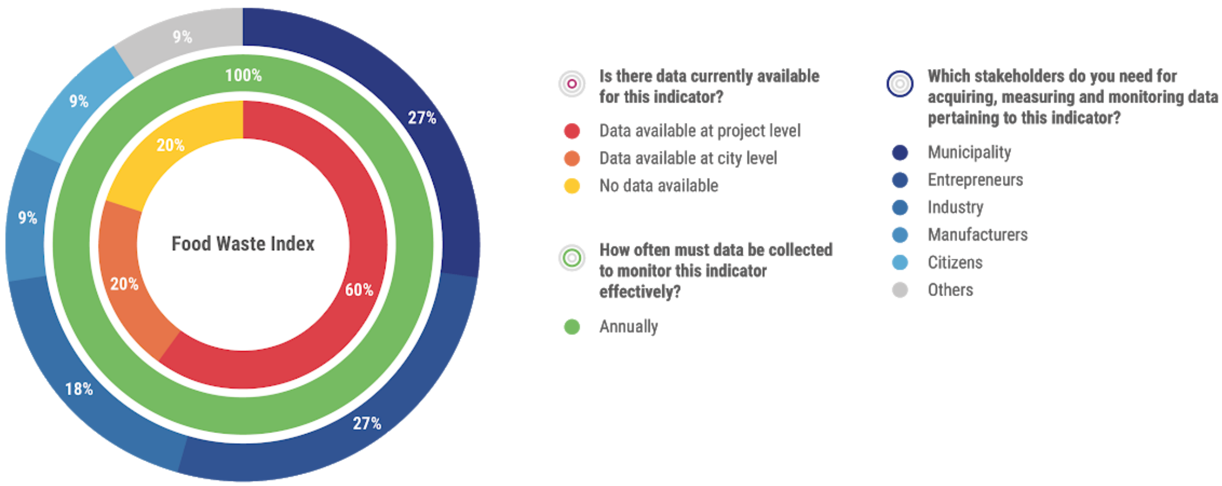
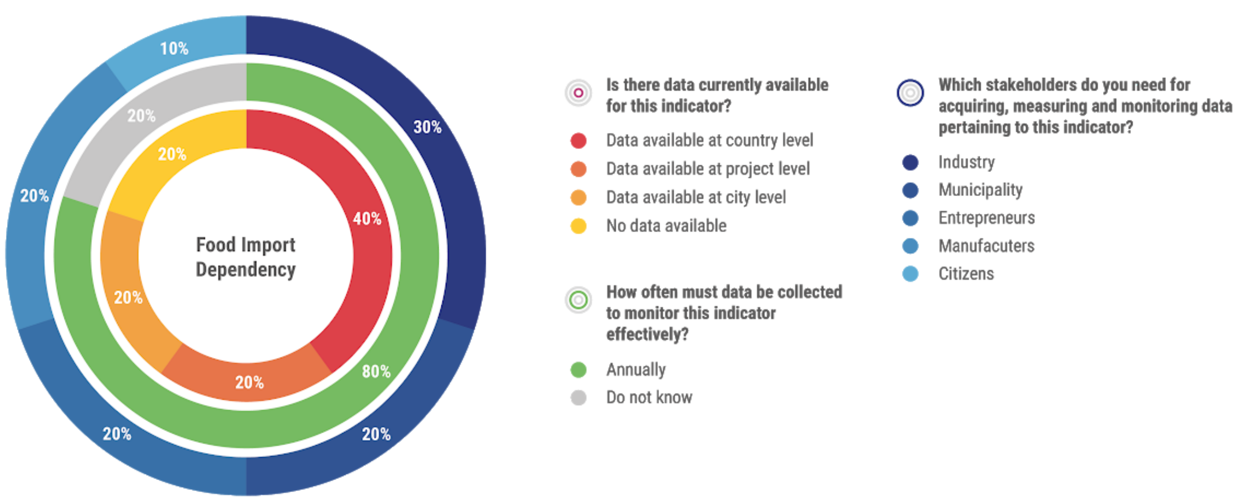


Graph 15: Responses to KPI: Food waste index.

All of the respondents agreed that the three KPIs should be monitored at the beginning and at the end of the project period. An overwhelming majority believed that the impacts of REFLOW activities would be reflected in the short term in the monitoring of the Circular food use rate and the Food waste index. Conversely, a majority believed that change in the Food import dependency indicator would also be visible in the long-term.



Graph 16: Responses to KPI: Food import dependency.

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A little less than half of the respondents believed that the monitoring of these three KPIs would not impact the city's policies on food, while one fifth believed it would have a direct impact, and a similar proportion believed that it would only have an indirect impact.

The municipality, entrepreneurs, and the local food industry are the stakeholders the most cited as the stakeholders required to monitor the three selected KPIs.

Key considerations when moving forward

Graph 17 shows the survey responses on the aspects of data availability, regularity of monitoring, and the stakeholders required for all 3 selected KPIs. The regularity of monitoring data for all KPIs was selected to be done annually with a 100% consensus from the pilot team. Moving forward, there is a need to set up a robust data collection and monitoring system with the selected REFLOW municipal markets that can relay relevant data annually. As Italy, and specifically Milan, are pushing towards circularity in the agri-food sector, data on Food important dependency and the Circular food rate may be available on the country level, which if available, can be used as a comparative benchmark to monitor the project's progress. Data for the Food waste index will be calculated at the project level, therefore requiring a baseline value to be calculated at the current state. Graph 17 also shows the collective ecosystem of stakeholders required for measuring and monitoring the three environmental KPIs for Milan. The Circular food use rate, which requires monitoring the amount of food recovered and fed back into Milan's municipal markets, requires collaboration between multiple partners throughout the value chain, giving almost equal importance to the participation of the municipality, entrepreneurs, industry, and citizens. The Food waste index and Food important dependency will also require the involvement of manufacturers and entrepreneurs in addition to the municipality to possibly bring change and innovation in production and distribution methods.

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Graph 17: Survey responses on (i) Data availability, (ii) Regularity of monitoring, and (iii) Stakeholders required for all shortlisted environmental KPIs by the Milan pilot.

Final environmental KPIs

Based on the results of the survey, a final co-iteration round was performed to review the environmental KPIs, discuss their impacts, and decide on a monitoring approach. The final environmental KPIs for the Milan pilot are shown below in Table 33.

The municipality will lead the data collection process, which will also involve local food industries, manufacturers, and entrepreneurs. All three of the environmental KPIs will be monitored at the beginning and the end of the project and focus exclusively on the REFLOW municipal markets engaged in the pilot activities.

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Table 33: Milan final environmental KPIs.

KPIs	Monitoring approach			
	Scale	Regularity	Stakeholders	Lead organization
Circular material use rate (%)	Municipal Food Market	Beginning and end of project period	Municipality, industry, entrepreneurs; and ReflowOS developers.	Municipality
Food waste index (Weight)	Municipal Food Market	Beginning and end of project period	Municipality, entrepreneurs, industries, waste company.	Municipality
Material import dependency (%)	Municipal Food Market	Beginning and end of project period	Industry, municipality, manufacturers and entrepreneurs.	Municipality

3.3.4 Paris

City: Paris
Pilot Team: *City of Paris, Volumes, ARS LONGA, E-STORE , Fab City Grand Paris* ***Pilot Description:*** *The REFLOW Paris Pilot focuses on building a circular economy through event waste management by creating a tracking system to coordinate the use and reuse of timber materials involved in temporary structures in the trade fair sector.*

Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), the Paris pilot selected the following Impacts Areas as most highly relevant for the pilot's REFLOW activities:

- Material and Resources
- Community Participation

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The pilot placed a secondary emphasis on Governance, Policy, Employment, Behaviour and Lifestyles, Carbon Footprint, and Education and Training. The pilot determined that Energy, Air Quality, and Health and Well-being were not directly relevant to the REFLOW activities in Paris.

Among the most relevant Impact Areas, Materials and Resources was selected as a key Impact Area as the pilot must track and understand the quantity and quality of flows of timber across events to provide insights for the creation of interventions and the development of circular solutions. Community Participation was prioritized as the active involvement of different actors in the local ecosystem (designers, event planners, site managers, waste management companies), citizens, and the municipality is a key lever to co-create the tools necessary to transform the use of timber in events in Paris.

KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while in the second round the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 (REFLOW, 2020) were selected within each of the four Impact Areas. This refined KPI list is compiled in Table 34.

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Table 34: Paris pilot refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Materials and Resources	Circular material use rate (CMU)	The circular material use (CMU) rate measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M).	EUROSTAT 2018
	End-of-life reuse/recycled input rate	The 'end-of-life recycling input rate' (EOL-RIR) measures how much of the total material input into the production system comes from recycling of "old scrap."	EC, 2018
	Export of waste materials	Waste exports to other economies, in physical weight (at border).	EUROSTAT, IRP, 2016, 2019; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
	Physical trade balance (PTB)	Physical imports minus exports in weight.	EUROSTAT, IRP, 2016, 2019; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
	Raw material consumption (RMC)	RMC measures the total amount of raw materials required to produce the goods used by the economy (also called 'material footprint').	EUROSTAT, IRP, 2016, 2019; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
	Products promoting sustainability - green purchasing of local authority	The indicator investigates the number of organisations, including public administrations that purchase products promoting sustainability of consumption. "Sustainable products" may include eco-labelled, organic, energy-efficient, certified timber, or fair trade products.	RFSC; European Common Indicators, 2003
	Life time extension	The extent to which the project attempted to prolong the service lifetime of products.	Bosch et al. 2017
Community Participation	Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement.	World Bank, 2018; EBRD;
	Increased consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship. The indicator provides a qualitative measure and is rated on a five-point scale.	Smiciklas, 2014; Bosch et al. 2017
	People reached	Percentage of people in the target group that have been reached and/or are activated by the project.	Bosch et al. 2017

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Governance	New forms of financing	The extent to which the project has contributed to, or inspired, the development of new forms of financing (qualitative).	Kabisch et al, 2016
	Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming" (qualitative).	Bosch et al. 2017
Employment	Establishment of new businesses	Number of new businesses established in the area surrounding the implemented project.	UNaLab, 2019
	Patents (innovation)	Patents related to recycling and secondary raw materials as a proxy for innovation. Number of patents related to waste management and recycling.	EC, 2018

KPI long list recalibration

A selection process and recalibration process was performed jointly between Metabolic and the pilot team for the environmental KPIs (all included within the Material and Resources Impact Area). This process solely included environmental KPIs as the socio-economic KPIs included in Behaviour and Lifestyles, Community Participation, Education and Training, and Governance are further developed within WP 1. To tailor the KPIs selected within the Material and Resources Impact Area to the specific activities as defined in the Pilot Action Plan (REFLOW D5.1, 2020) recalibration was required. This first iteration of environmental KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 35).

The Circular material use rate is usually compiled at the country-level (EUROSTAT, 2018). Through the joint refinement effort, it was downscaled to the appropriate scale for Paris REFLOW activities, that is, the key events involved in the pilot's activities. The KPI was also modified to address only timber material at the event scale as it is the focus of the Paris pilot.

The End of life reuse/recycle input rate, Export of waste material, Physical trade balance, and Raw material consumption indicators were all downscaled to the event level and to address timber in each case. While the focus will be timber, a general overview of all materials will be done by the pilot team.

Life time extension originally measures the impact a project has had on the extension of a product's useful lifespan through a qualitative analysis on a linkert scale. This has been calibrated to be measurable in a quantitative method by defining it as the number of event cycles a timber product goes through. The pilot team considers this KPI to be a potential direct indicator for effectiveness of incubated solutions.

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Table 35: Paris pilot refined KPI list (calibrated).

Impact Area	Original KPI	Recalibrated KPI	New description
Materials and Resources	Circular material use rate (CMU)	Circular timber use rate	The circular timber use (CTU) rate measures the share of timber recovered and fed back into the event - thus saving extraction of primary virgin materials - in overall material use. The CTU rate is thus defined as the ratio of the circular use of timber (U) to the overall timber use (T).
	End-of-life reuse/recycled input rate	End-of-life reuse/recycled timber input rate	The timber 'end-of-life recycling/reuse input rate' (EOL-RIR) measures how much of the total timber input into the event system comes from recycling of "old scrap" timber .
	Export of waste materials	Export of timber waste	Change in the export of timber waste at the event scale.
	Physical trade balance (PTB)	Timber stock	Total amount of timber structure and products stored for a recurring event.
	Raw material consumption (RMC)	Virgin timber input rate	Share of timber inputs from virgin timber production.
	Products promoting sustainability - green purchasing of local authority	Number of products promoting sustainability purchasing of local authority	The indicator investigates the ratio of public procurement in which there are environmental clauses for timber.
	Life time extension	Lifespan extension of timbre products - number of event cycles	Number of event cycles of products conceived with the incubation program.

Stakeholder survey results

The KPI co-refinement and finalization survey was completed by five respondents from the REFLOW team from a variety of organizational backgrounds, ranging from the municipal bodies, NGOs, SMEs, and FabLabs.

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KPI ranking

The refined set of 14 calibrated KPIs was included in the stakeholder survey and was subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by Paris REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **E7: Lifespan extension - number of event cycles per product**
2. **E2: End-of-life reuse/recycled input rate**
3. **E4: Timber stock: Total amount of timber structure and products stored for a recurring event**
4. **E1: Circular timbre use rate**
5. **S11: New forms of financing**
6. **S13: Establishment of new businesses**
7. **S12: Policy learning concerning adapting policies and strategic plans**
8. **S10: Number of people reached through REFLOW activities/campaign**
9. **E5: Virgin timber input rate**
10. **S8: Number of stakeholders involved**
11. **E3: Change in the export of timber waste at the event scale**
12. **S14: Patents related to recycling and secondary raw materials as a proxy for innovation**
13. **E6: Number of products promoting sustainability purchasing of local authority**
14. **S9: Increase in the consciousness of citizens**

During the final co-creation section, it was decided by the pilot team that amongst the environmental KPIs, only E1: Circular timber use rate, E2: End of life reuse/recycle rate, and E7: Lifespan extension will be pursued further. Virgin timber input rate, Timber stock, and Export of timber waste at the event level were all considered sub-components of the Circular timber use rate.

Monitoring measures

The respondents also provided their feedback on the seven shortlisted environmental KPIs within the monitoring section of the survey. The pie charts below illustrate the answers from respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process of the three finalised environmental KPIs.

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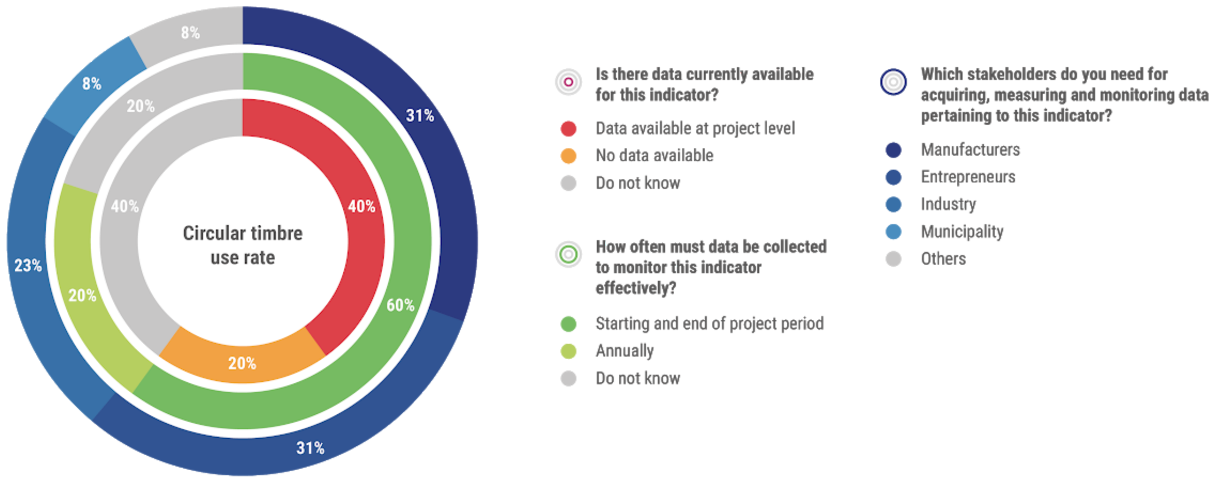
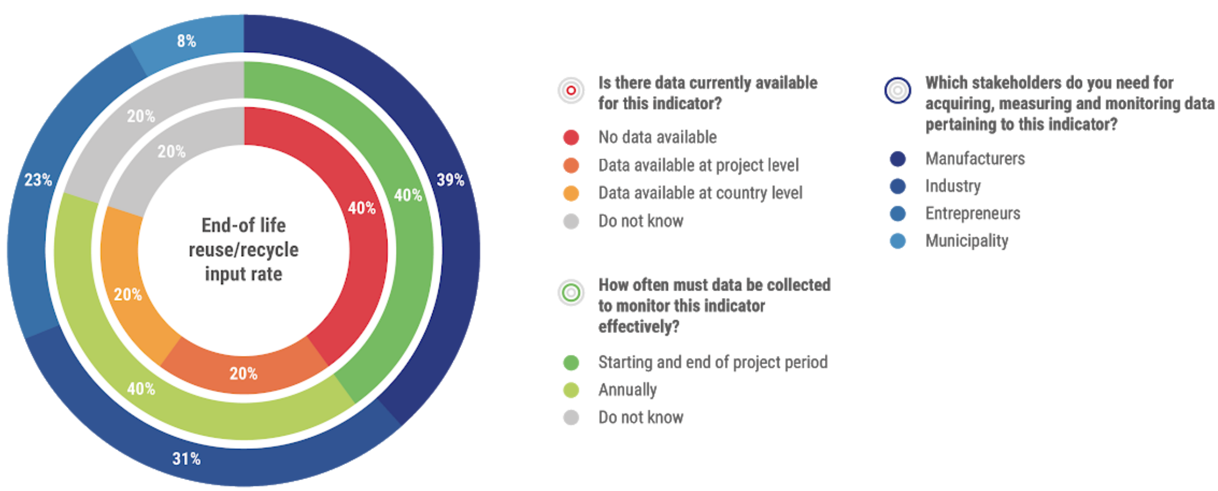
E1: Circular timber use rate



Graphic 18: Responses to KPI: Circular timbre use rate.

The Circular timber use rate was considered most useful if measured as a comparison between pre-intervention levels and post-intervention levels, thus the data collection should be done with a current baseline and then at the end of the project period. As this is a composite indicator, the data will be calculated at project level using data points collected within the selected events and from data points which may be available at the city scale.

E2: End-of-life reuse/recycled input rates



Graphic 19: Responses to KPI: End-of-life reuse/recycled input rates.

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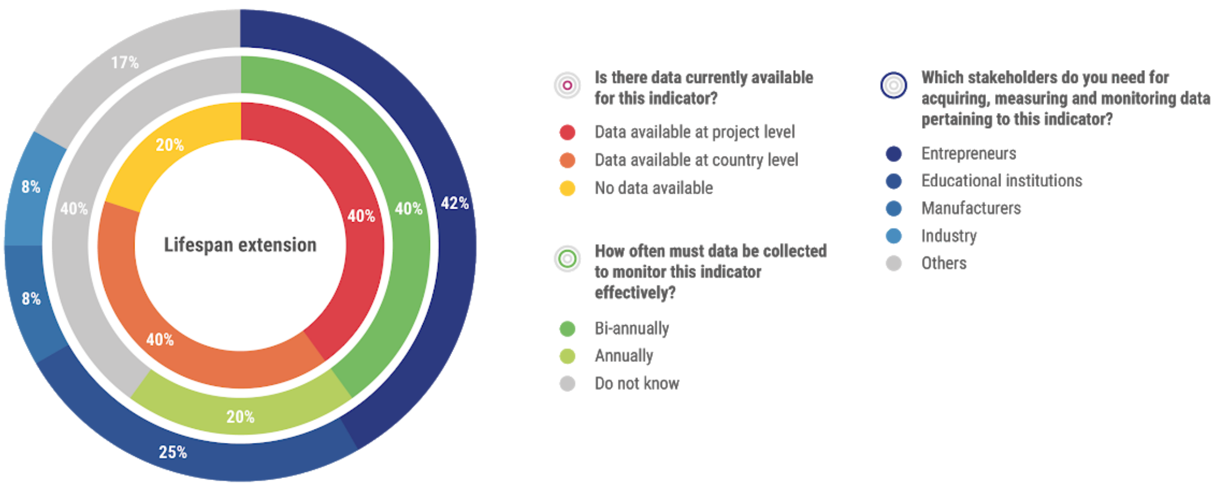
The data collection of the EOL-RIR, which measures how much of the total timber input into the event system comes from recycling of "old scrap" timber, will be done according to the occurrence of the events identified by the pilot on an annual basis. 40% of respondents commented on there being no data available currently, citing that data will have to be developed at the project stage. The stakeholders needed for the monitoring of this KPI include manufacturers, industry, entrepreneurs, and possibly the municipality.

E7: Life time extension - number of event cycles



Graphic 20: Responses to KPI: Lifespan extension.

The Life time extension of timber products looks at the number of event cycles a timber product conceived by the incubation program goes through. The data for this KPI will be collected following the development of products form workshops conducted through the pilot's incubation program and then according to the consequent occurrence of events where the product is possibly used. This KPI heavily depends on the involvement of entrepreneurs, educational institutes, and manufacturers to push innovation at the design stage of circular products.

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Key considerations when moving forward

Graph 21 shows the survey responses on the aspects of data availability, regularity of monitoring, and the stakeholders required for all 3 selected KPIs by the Paris pilot. Currently, data relevant to the KPIs is not available, but needs to be developed at the project level. Moving forward, as the event sector may remain affected in the coming year(s) due to the COVID-19 outbreak, it will be essential to develop a data collection strategy that can be safely implemented or to develop data points that can act as a proxy for live event data. The regularity of data collection and monitoring in the case of the Paris pilot is highly dependent on the schedule of the events as two out of the three KPIs - EOL-RIR and Lifespan extension - will be monitored during the consecutive occurrences of the events each year. The collective ecosystem of stakeholders required for measuring and monitoring the three environmental KPIs for Paris emphasizes the involvement of entrepreneurs, manufacturers, and industries for all three KPIs. The innovations in the product development stage required for Lifespan extensionEOL-RIR will require constant cooperation between Fab Labs, entrepreneurs, and educational institutions.

Graphic 21: Survey responses on (i) Data availability, (ii) Regularity of monitoring, and (iii) Stakeholders required for all shortlisted environmental KPIs by the Paris pilot.

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Final environmental KPIs

Based on the results of the survey, a final co-iteration session was performed to review the environmental KPIs, discuss their impacts, and decide on a monitoring approach. The final environmental KPIs for the Paris pilot are shown below in Table 36.

Table 36: Paris pilot final environmental KPIs.

KPIs	Monitoring approach			
	Scale	**Regularity**	**Stakeholders**	**Lead organization**
Circular timber use rate	Events	Beginning and end of project period	Manufacturers, industry, entrepreneurs.	ARS LONGA
End-of-life reuse/recycled input rates	Events	Data collected per event schedule, according to their occurrences	Manufacturers, industry, entrepreneurs.	City of Paris (Municipality)
Life time extension - number of event cycles	Events	Data collected per event schedule, according to their occurrences	Education Institutions, Entrepreneurs, Manufacturers, SMEs (driving the incubators and innovation).	TBD

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3.3.5 Cluj-Napoca

City: Cluj-Napoca
Pilot Team: *Cluj-Napoca Municipality, Cluj Metropolitan Area Association, National Institute for Research and Development of Isotopic and Molecular Technologies, ARIES Transilvania.* ***Pilot Description:*** *Through the REFLOW Pilot, the objectives for Cluj-Napoca are: to prove how the measures taken to date by the City have impacted the energy efficiency of selected buildings; to involve the identified stakeholders in implementing and furthering the measures already taken; to disseminate the information gathered at household and business level; to encourage different actors in the ecosystem to propose new ideas regarding renewable energy sources to be integrated in the City's strategy for a circular economy. All these will be complemented by educating citizens on the circular economy, its benefits and possibilities.*

Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), the Cluj-Napoca pilot selected the following Impacts Areas as most highly relevant for the pilot's REFLOW activities:

- Energy
- Carbon Footprint
- Behaviour and Lifestyles
- Community Participation

The pilot placed a secondary emphasis on Material and Resources, Governance, Education and Training, and Policy. The pilot determined that Air Quality, Health and Well-being, Employment, and Equity and Inclusivity were not directly relevant to the REFLOW activities in Cluj-Napoca.

Among the most relevant Impact Areas, Energy was selected due to energy efficiency being the core focus of the Cluj-Napoca pilot. The activities of the Cluj pilot also place a high priority on the change in consumer behaviour and lifestyle, which would involve community participation throughout the project period.

KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while in the second round the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 (REFLOW, 2020) were selected within each of the four Impact Areas. This refined KPI list is compiled below in Table 37.

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Table 37: Cluj-Napoca pilot refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Energy	Reduction in life cycle energy use	Reduction in life cycle energy use by a material/product achieved by the project (%).	Bosch et al, 2017; Smiciklas, 2014; ISO-14042, 2000
	Energy consumption	Total final energy consumption, in GJ per capita per year and average annual growth.	World Bank, 2017, 2018; IDB, 2014
Air Quality	Greenhouse gas emissions per capita	This indicator measures CO_2 emissions of the city, divided by city population.	SDGs, IDB, EBRD, WDI, CPI, World Bank, EU resource efficiency scoreboard, RSFC
	CO_2 emission - total	Measures the intensity of CO_2 emissions from the entire economy.	EPI; RFSC; Hertwitch, 2009; WRI climate analysis
Behaviour and Lifestyles	Consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship (qualitative).	Bosch et al, 2017; Smiciklas, 2014
Community Participation	Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement.	World Bank, 2018; EBRD;
	People reached	Percentage of people in the target group that have been reached and/or are activated by the project.	Bosch et al, 2017
	Availability of public information in local dialects for dissemination to local users	Availability of public information in local dialects for dissemination to local users.	UNDP Capacity Development, 2008
Governance	Participatory governance	The proportion (%) of citizens involved in participatory governance.	EIP-SCC, 2013; Bosch et al, 2017

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KPI long list recalibration

A selection process and recalibration process was performed jointly between Metabolic and the pilot team for the shortlisted KPIs (Table 37). This process included both environmental KPIs (Energy and Air Quality Impact Areas) and socio-economic KPIs (Behaviour and Lifestyles, Community Participation, and Governance Impact Areas). To tailor the KPIs selected within the Air Quality and Energy Impact Areas to the specific activities as defined in the Pilot Action Plan (REFLOW D5.1, 2020) recalibration was required. This recalibration process was done in collaboration between Metabolic and the Cluj pilot team. After this initial process, the Cluj pilot team worked together to recalibrate socio-economic KPIs (e.g. those KPIs included within the Behaviour and Lifestyles, Community Participation, and Governance Impact Areas). This first iteration of the shortlisted KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 38).

Reduction in life cycle energy use and Total CO_2 emissions were both calibrated to be measured on the building scale through REFLOW activities. Reduction of energy consumption has been considered a useful KPI by the pilot team as it is an ongoing objective of the municipality of Cluj-Napoca in the promotion of energy efficiency and climate change mitigation.

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Table 38: Cluj-Napoca pilot refined KPI list (calibrated).

Impact Area	Original KPI	Recalibrated KPI	New description
Energy	Reduction in life cycle energy use	Reduction in energy use	Reduction in energy use in the selected REFLOW building achieved by the REFLOW activities of the project.
Air Quality	CO_2 emission - total	CO_2 emissions	Reduction in carbon footprint of a building used as a mini-pilot.
Behaviour and Lifestyles	Increased consciousness of citizens	Number of citizens reached by dissemination actions	Raising awareness of the citizens with interventions in schools and other municipality owned buildings.
Community Participation	Number of stakeholders	Number of stakeholders involved	Number of stakeholders involved in REFLOW activities.
	People reached	Number of citizens reached by REFLOW dissemination actions	Number of citizens reached by REFLOW dissemination actions.
	Availability of public information in local dialects for dissemination to local users	Availability of public information in local dialects for dissemination to local users	Availability of public information in local dialects for dissemination to local users.
Governance	Participatory governance	Citizens activated by the CIIC meetings	Citizens activated by the CIIC meetings.

Stakeholder survey results

The KPI co-refinement and finalization survey was completed by five respondents from the Cluj pilot team from a variety of organizational backgrounds, ranging from research organisations, NGOs, and municipal bodies.

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KPI ranking

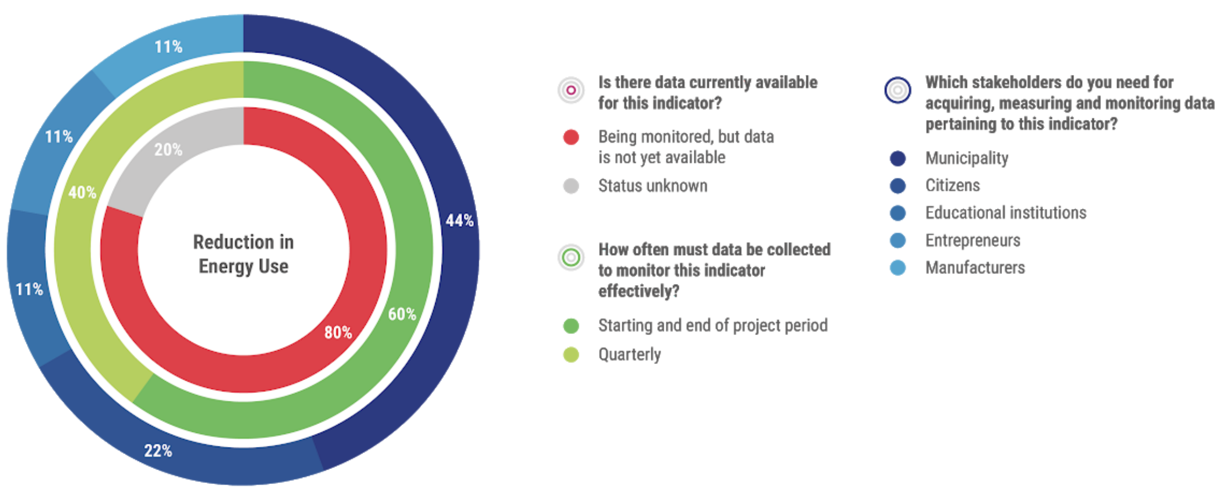
The refined set of seven calibrated KPIs was included in the stakeholder survey and was subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by the Cluj-Napoca REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **E1: Reduction in energy use**
2. **E2: Total CO_2 emissions**
3. **S3: Increase in the consciousness of citizens by REFLOW activities**
4. **S5: Number of people reached through REFLOW activities**
5. **S4: Number of stakeholders involved**
6. **S7: Participation: Citizens activated by the CIIC meetings**
7. **S6: Availability of public information in local dialects for dissemination**

Monitoring measures

The respondents provided their feedback on the monitoring measures for two selected environmental KPIs. The pie charts below illustrate the answers from the respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process.

E1: Reduction in energy use



Graphic 22: Responses to KPI: Reduction in energy use.

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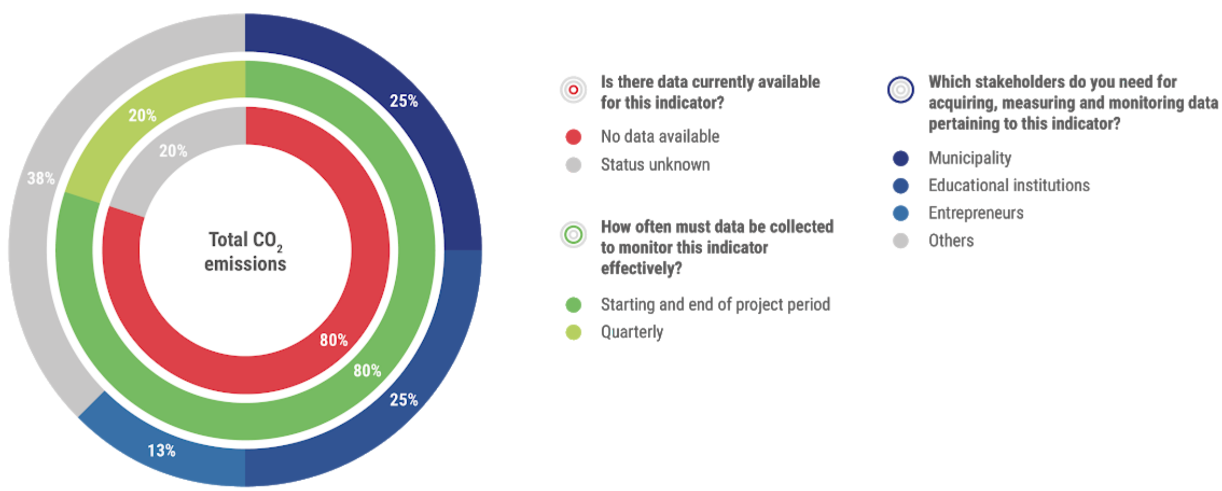
The Reduction in energy use KPI measures reduction in energy use measures in the selected REFLOW building achieved by the Cluj pilot activities. 80% of respondents reported that there is no data available currently that is being monitored. The key stakeholder needed for measuring and monitoring data for this KPI is the municipality who is committed to bringing energy efficient changes to the municipal buildings and street lighting. Citizens were considered the second most relevant stakeholder because of the impact of usage patterns and behaviours, which the pilot aims to address.

E2: Total CO_2 emissions



Graphic 23: Responses to KPI: Total CO_2 emissions.

The Total CO_2 emissions KPI measures the reduction in carbon footprint of a building used as a mini-pilot in the Cluj-Napoca pilot. Similarly to the previous KPI, there is no data available currently. The frequency of data collection was unanimously selected to be at the beginning and end of the project period. The stakeholders involved in the monitoring and measuring this KPI are the municipality, entrepreneurs, and educational institutions.

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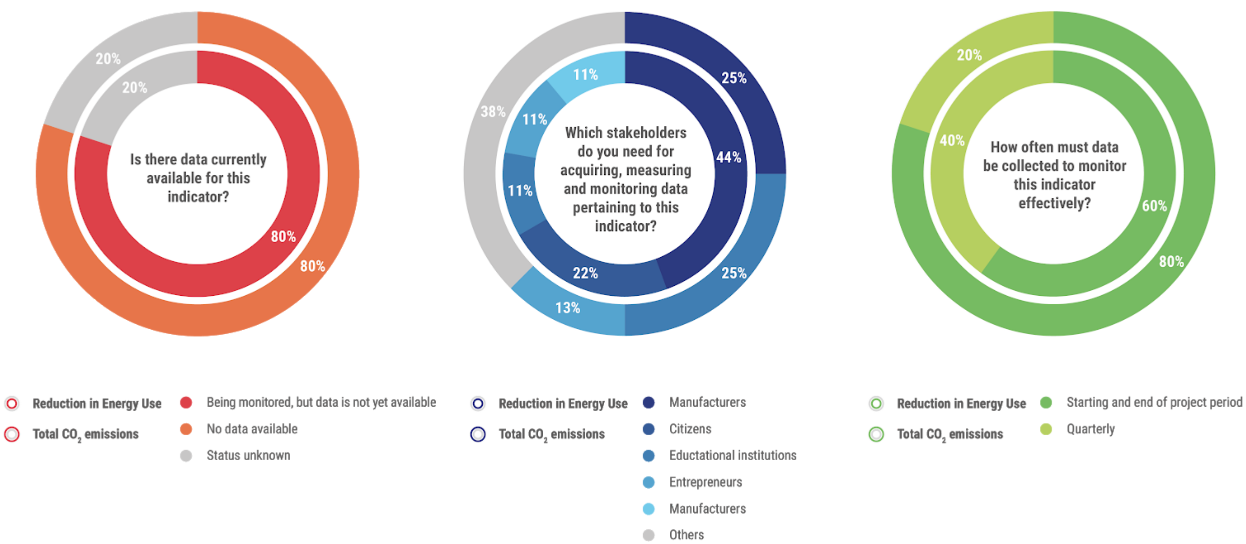
Key considerations when moving forward

Graph 24 shows the survey responses on the aspects of data availability, regularity of monitoring, and the stakeholders required for both selected KPIs by the Cluj-Napoca pilot. Since data for both KPIs is currently not available, and the intended regularity of monitoring for both is at the beginning and end of the project, therefore it is vital to calculate baseline values of the current state as a starting point. The collective ecosystem of stakeholders required for measuring and monitoring the reduction of energy use in the buildings selected within the Cluj-Napoca pilot is instinctively large: involving the municipality, citizens, educational institutions, entrepreneurs, and manufacturers. This KPI is dependent on a collective contribution towards the reduction of energy use from all processes involved in the selected buildings. The total carbon footprint of the selected buildings also involves inputs from the municipality, entrepreneurs, and educational institutions. Therefore, creating a platform for constant collaboration within the mentioned stakeholders will be vital to the process.



Graphic 24: Survey responses on (i) Data availability, (ii) Regularity of monitoring, and (iii) Stakeholders required for all shortlisted environmental KPIs by the Cluj-Napoca pilot.

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Final environmental KPIs

Based on the results of the survey, a final co-iteration session was held to review the environmental KPIs, discuss their impacts, and decide on a monitoring approach. The final environmental KPIs for the Cluj-Napoca pilot are shown below in Table 39.

Table 39: Cluj-Napoca pilot final environmental KPIs.

KPIs	Monitoring approach			
	Scale	Regularity	Stakeholders	Lead organization
Reduction in energy use	REFLOW site (building)	Beginning and end of project period	Municipality, Citizens, Industries, Manufacturers, Educational institutes	TBD
CO_2 emissions	REFLOW site (building)	Beginning and end of project period	Manufacturers, Entrepreneurs, Educational institutes	TBD

3.3.6 Berlin

City: Berlin

Pilot Team: *Berliner Wasserbetriebe, Agile Heap, Fraunhofer FOKUS, MCS Data Labs*

Pilot Description: *The Berlin Pilot is focussed on 'waste heat'. For citizens, the issue of waste heat is almost invisible, the Berlin Pilot would like to address this issue. To this end, properties that are easily accessible to civil society, such as makerspaces and coworking places, are to be equipped with waste heat technology in a particularly tangible way. The Berlin Pilot focuses on identifying where waste-heat potential lies in the metropolitan area. From that information, the Pilot aims at reducing time between stakeholders requesting advice about implementing waste-heat-technology and actually receiving such advice.*

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Impact Areas

Upon review of the co-defined Impact Areas (see Section 3.3), the Berlin pilot selected the following Impact Areas as most highly relevant for the pilot's REFLOW activities:

- Energy
- Carbon Footprint
- Governance
- Policy

The pilot placed a secondary emphasis on Air Quality, Community Participation, Education and Training, and Employment. The pilot determined that Health, Behaviour and Lifestyle, and Equity and Inclusivity were not directly relevant to the REFLOW activities in Berlin.

Among the most relevant Impact Areas, Energy and Carbon Footprint were considered the most important, as the Berlin pilot is focusing on identifying the energy potential of waste heat in the metropolitan area.

KPI long list selection

The pilot team subsequently used the most highly relevant Impact Areas as lenses to review the KPI long list in a two-round iteration process (see Section 3.3 for co-creation processes). The first round yielded a broad list of KPIs for each of the four Impact Areas, while in the second round the most feasible and relevant KPIs in regards to the Pilot Action Plan as defined in D.5.1 were selected (REFLOW, 2020) within each of the four Impact Areas. In addition to the KPIs shortlisted from the long list, Metabolic helped develop an additional KPI that measures recovery rate of waste heat. This refined KPI list is compiled in Table 40.

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Table 40: Berlin pilot refined KPI list (uncalibrated).

Impact Area	KPI	Description	Citation(s)
Energy	Circular energy use rate (CEU)	The circular energy use rate measures, in percentage, the share of energy recovered and fed back into the economy - thus saving extraction of primary energy - in overall energy use. The rate is thus defined as the ratio of the circular use of energy to the overall energy use.	EUROSTAT, 2018; EC, 2018
	EROEI	Energy return on energy input.	White, 2019
	Recovery rate of waste heat	Actual heat recovered in the neighbourhood wastewater over the theoretical recoverable heat from the wastewater. To calculate the theoretical limit, we need to look at the efficiency of the energy recovery system and the economic limit of the extraction process (break-even costs).	Developed with the Berlin Pilot
	Physical energy flow (PEFA)	PEFA records the flows of energy (in terajoules) from the environment to the economy (natural inputs), within the economy (products), and from the economy back to the environment (residuals).	EUROSTAT
	Energy productivity	The indicator results from the division of the gross domestic product (GDP) by the gross available energy for a given calendar year. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP. This can be calculated for a city and compared to its national average.	EUROSTAT, 2019, Europe 2020 RE indicators, 2019
	Energy dependence	The indicator shows the extent to which an economy relies upon imports in order to meet its energy needs. It is calculated as net imports divided by the gross available energy. Energy dependence = Net imports / Gross available energy.	Europe 2020 RE indicators, 2019
	Share of renewable energy in gross final energy consumption	Percentage of energy from a renewable source within the overall energy consumption.	SDG7.2, World Bank, 2018; EBRD, CPI, Europe 2020 RE indicators, 2019, RFSC
	Extraction of natural energy inputs	The flows of energy (in terajoules) from the environment to the economy (natural inputs); Natural energy inputs: flows from the natural environment into the economy such as fossil energy carriers in solid, liquid and gaseous form, biomass, solar radiation, kinetic energy in form of hydro and wind, geothermal heat etc.	EU Resource efficiency Scoreboard
	Residual energy amounts	Energy residuals: mainly energy in the form of dissipative heat arising from the end use of energy products, flowing from the economy into the natural environment.	EU Resource efficiency Scoreboard
	Use of waste for energy purposes	Production of waste-to-energy plants.	EU Resource efficiency Scoreboard

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Carbon Footprint / Air Quality	CO_2 emission - power	Measures the intensity of CO_2 emissions per kilowatt-hour of electricity and heat, as a blend of current-year intensity and a 10-year trend.	International energy agency, 2017
	Greenhouse gas emissions per capita	This indicator measures CO_2 emissions of the city, divided by the city population.	SDG, IDB, EBRD, WDI, CPI, World Bank, EU resource efficiency scoreboard, RSFC
Governance	Green public procurement (as an indicator for financing aspects)	The share of major public procurements in the EU that include environmental requirements; Percentage of procurement using environmental criteria compared to total procurement of the city administration, in a one year period.	RFSC; EU CE Monitoring Framework; SDG 16
	New forms of financing	The extent to which the project has contributed to, or inspired, the development of new forms of financing (qualitative).	Bosch et al., 2017; Kabisch, 2016
Policy	Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and "mainstreaming" (qualitative).	Bosch et al., 2017; Kabisch, 2016

KPI long list recalibration

A selection process and recalibration process was performed by Metabolic jointly with the pilot team for the shortlisted KPIs (Table 40). This process included both environmental KPIs (Energy and Air Quality) as well as socio-economic KPIs (Policy and Governance), which will also be further developed within WP 1. To tailor the selected KPIs to the specific activities as defined in the Pilot Action Plan (REFLOW D5.1, 2020) recalibration was required. This first iteration of KPIs therefore evolved into pilot and context-specific environmental KPIs (Table 41).

The calibration of the generic KPIs into pilot specific KPIs was done with comments from the Berlin pilot team over multiple discussions, where all KPIs were rescaled to be measured at a neighbourhood level agreeable to the Berlin pilot action plan.

One additional KPI was introduced to the list through co-creation with the pilot stakeholders to respond to the specific need to calculate waste heat potential in the city: Recovery rate of waste heat. To calculate the theoretical limit, the pilot team agreed that they need to look at the efficiency of the energy recovery system and the economic limit of the extraction process i.e. break-even costs. The theoretical limit of waste heat would be estimated by system-wide potentials via caloric equation (q=rho*cp*dT*V).

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The Circular Energy Use rate KPI is usually used at a scale of the national economy. For the purposes of the Berlin pilot, this KPI was scaled down to the neighbourhood level and focused specifically on heat from waste water in relation to total heat. Two socio-economic KPIs were suggested by the pilot stakeholders to measure the impact of their activities: Exploitation request rate and Implementations. The two respectively look at the increase in request rates for waste heat through the use of REFLOW platform and implementations triggered through REFLOW activities. The pilot partners believe that these could be realistic goals that can be reached during the project time by mapping wastewater heat potentials, web applications, and workshop activities.

Table 41: Berlin pilot refined KPI list (calibrated).

Impact Area	Original KPI	Recalibrated KPI	New description
Energy	Circular energy use rate (CEU)	Circular energy use rate (CEU)	Energy recovered and fed back into the city grid (thus saving extraction of primary energy).
	Energy return on energy input	REFLOW EROEI	The ratio of the amount of usable energy delivered from a particular energy resource to the amount of energy used to obtain that energy resource.
	Recovery rate of waste heat	Recovery rate of waste heat	Actual heat recovered in the neighbourhood wastewater over the theoretical recoverable heat from the wastewater.
	Share of renewable energy in gross final energy consumption	Share of heat energy in gross energy consumption	Percentage of energy contributed through waste heat recovery to the total gross energy consumption.
Air Quality	CO_2 emission - power	CO_2 emission change in power production	Measures the intensity of CO_2 emissions per kilowatt-hour of electricity and heat.
Outreach[2]		Exploitation - Request rate	Increase of wastewater heat requests due to sensitisation via ReFlow-plattform (heat potential mapping, workshops etc.).
		Exploitation - Implementation	Total of amount of triggered implementations during the project.

[2] A different term has been used for the Impact Area as the two KPIs have been developed through discussions with the Berlin pilot team. The two KPIs mentioned here cross multiple Impact Areas (Community participation, behaviour and governance).

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Stakeholder survey results

The KPI co-refinement and finalization survey was completed by five respondents from the REFLOW team from a variety of organizational backgrounds, ranging from research institutions, NGOs, SMEs, and municipal utility companies.

KPI ranking

The refined set of seven calibrated KPIs was included in the stakeholder survey and was subsequently ranked according to the single transferable vote count methodology (see Section 3.3.). The list below describes the ranking by the Berlin REFLOW pilot stakeholders. The ranking exercise included the socio-economic KPIs selected earlier in the process.

1. **S6: Exploitation request rate**
2. **S7: Total amount of triggered implementations during the project**
3. **E3: Recovery rate of waste heat**
4. **E2: Energy return on energy input (EROEI) rate**
5. **E4: Share of heat energy in gross energy consumption**
6. **E1: Circular energy use rate (CEU)**
7. **E5: CO_2 emission change in power production**

Monitoring measures

The respondents also provided their feedback on the five pre-selected environmental KPIs. The pie charts below illustrate the answers from the respondents regarding data availability, monitoring rate, impact time lag, and required stakeholders for the monitoring process.

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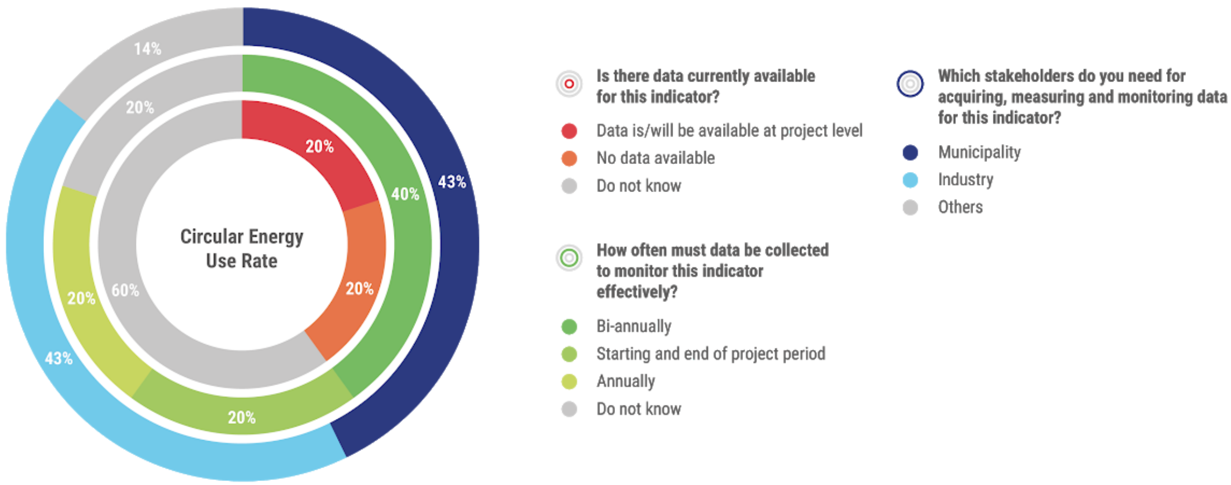
E1: Circular energy use rate



Graphic 25: Responses to KPI: Circular energy use rate.

The Circular energy use rate looks into the energy recovered and fed back into the city grid. Currently no data exists for this KPI as it is a composite KPI, for which the calculation will use other data points - such as total energy produced and energy recovered from waste heat, etc. - that will be collected at the neighbourhood level. 40% of respondents voted to collect data bi-annually for this KPI, but throughout the project it has been considered logistically unrealistic to collect data bi-annually for any of the KPIs. For this reason, it has been decided to measure this KPI either annually or as a comparison between the values at the beginning and end of the project period. For the stakeholders involved, it was clear by the responses that the involvement of the municipality and industry partners will be critical.

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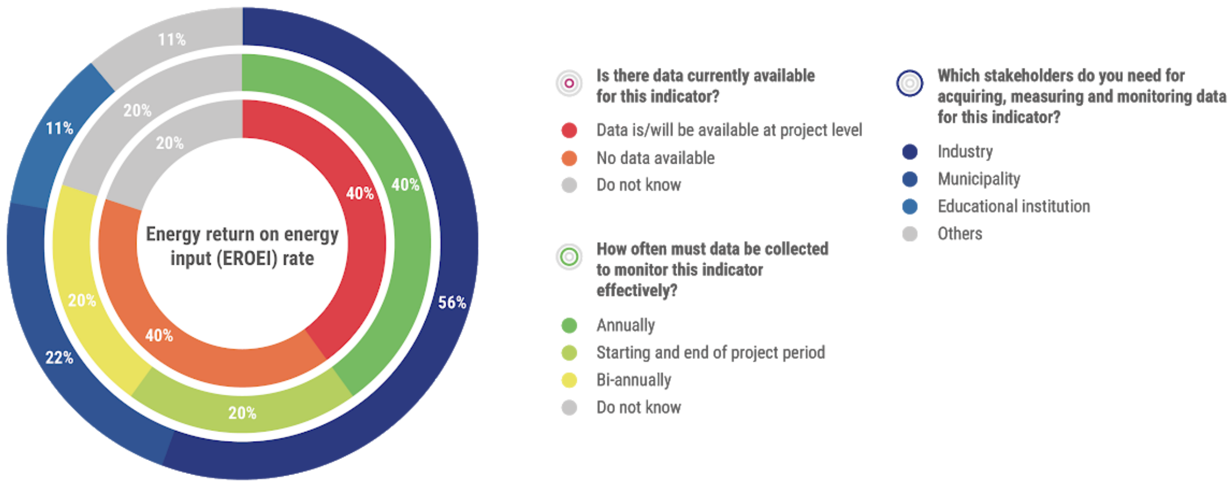
E2: Energy return on energy input (EROEI) rate



Graphic 26: Responses to KPI: Energy return on energy input rate.

The Energy return on energy input (EROEI) KPI measures the ratio of the amount of usable energy delivered from a particular energy resource, in this case waste heat to the amount of energy used to obtain that energy resource. The most commonly used data collection and monitoring processes come from single power plants, but this can be theoretically estimated for those waste water heat implementations triggered by the pilot. The KPI is expected to have a long term impact, above and beyond the time frame of the project. Therefore, similar to the Circular energy use, this KPI will also be monitored either annually or at the beginning and end of the project period but not bi-annually. While MCS datalabs will be taking a lead on this KPI, the involvement of the industry, municipality, and educational institutions is important to acquire and measure data as well as to create theoretical estimates.

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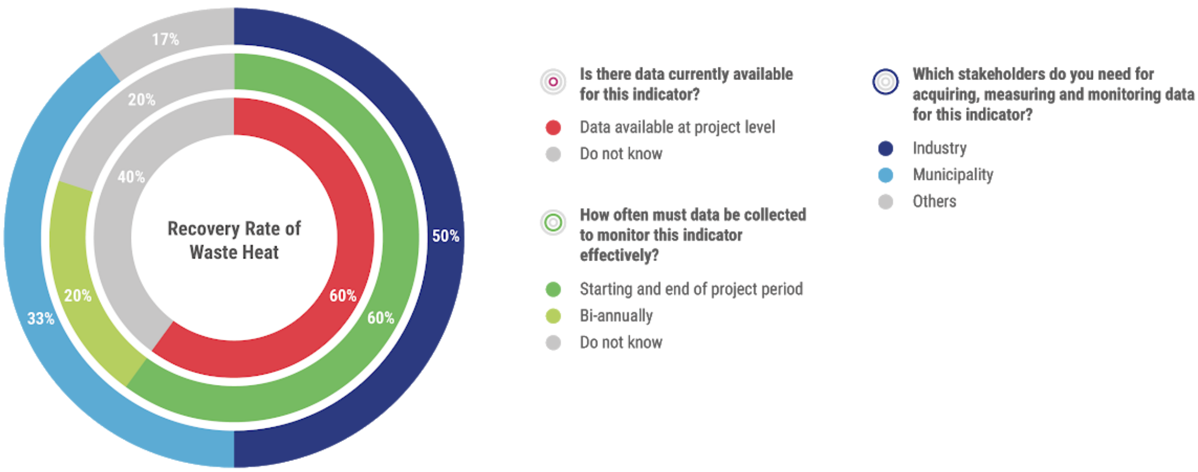
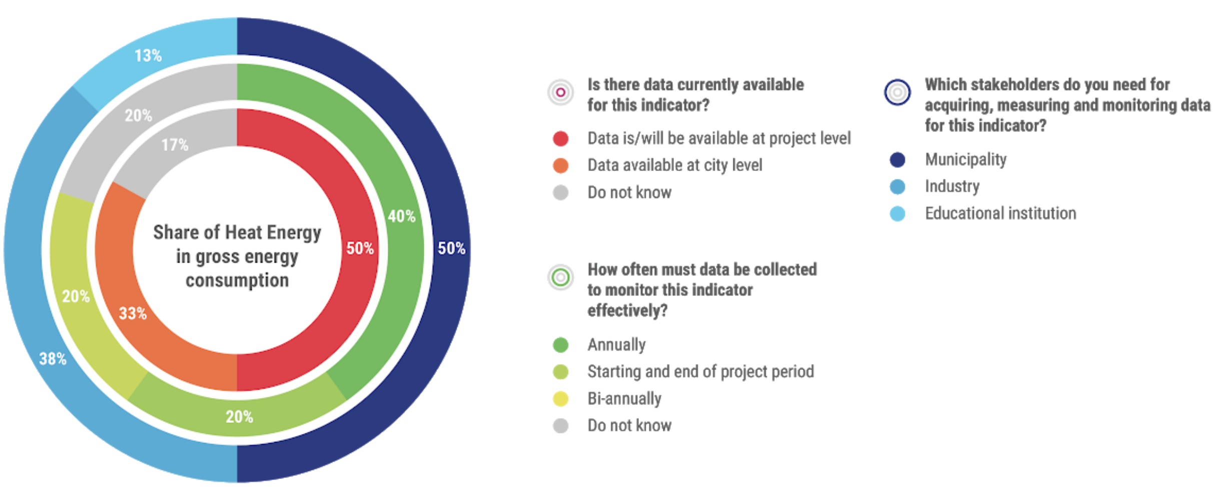
E2: Recovery rate of waste heat



Graphic 27: Responses to KPI: Recovery rate of waste heat.

To calculate the theoretical limit of recovery rate of waste heat, the pilot team agreed that they need to look at the efficiency of the energy recovery system and the economic limit of the extraction process i.e. break-even costs. The data in comparison to the theoretical limit will be developed, measured, and monitored at the project level within the addressable neighbourhoods. The values for the KPI will be compared at the beginning and end of the project period to measure the impact REFLOW pilot activities have had on the recovery of waste heat. Prototypes will be taking the lead on this KPI with support from the municipality and the industry.

E4: Share of heat energy in gross energy consumption



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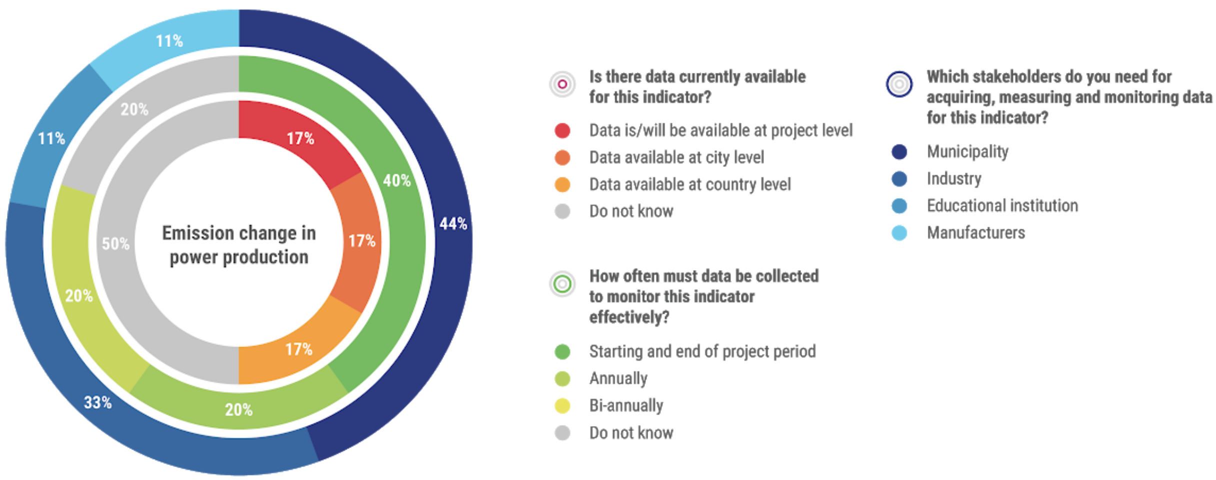
Graphic 28: Responses to KPI: Share of heat energy in gross energy consumption.

Data for the amount of heat energy added to the energy mix will be calculated at the project level, but to calculate the share it holds in the gross energy consumption, neighbourhood level or city level data will have to be used. The outcomes of this KPI have also been considered dependent on other renewable implementations within the neighbourhood, which may or may not be triggered through the actions of REFLOW. 40% of the respondents voted that the data should be collected annually. Fraunhofer will be taking the lead on monitoring this KPI, but will require the involvement of the municipality, industry, and educational institutions.

E5: CO_2 emission change in power production



Graphic 29: Responses to KPI: CO_2 emission change in power production.

The CO_2 emission change in power production KPI measures the intensity of CO_2 emissions per kilowatt-hour of electricity and heat produced. Data at country and city level is available as CO_2 emissions are quantifiable for the current energy production within Berlin, but will have to be calculated at the neighbourhood level or for the wastewater heat plants in relation to the REFLOW Berlin pilot. The substituted technology has been considered relevant to calculate the CO_2 reduction, which could be challenging for some implementations. As this is a long term change, the data will be collected at the beginning and end of the project period. Prototypes will be taking the lead on this KPI, with support from the municipality, Industry, educational institutions, and manufacturers.

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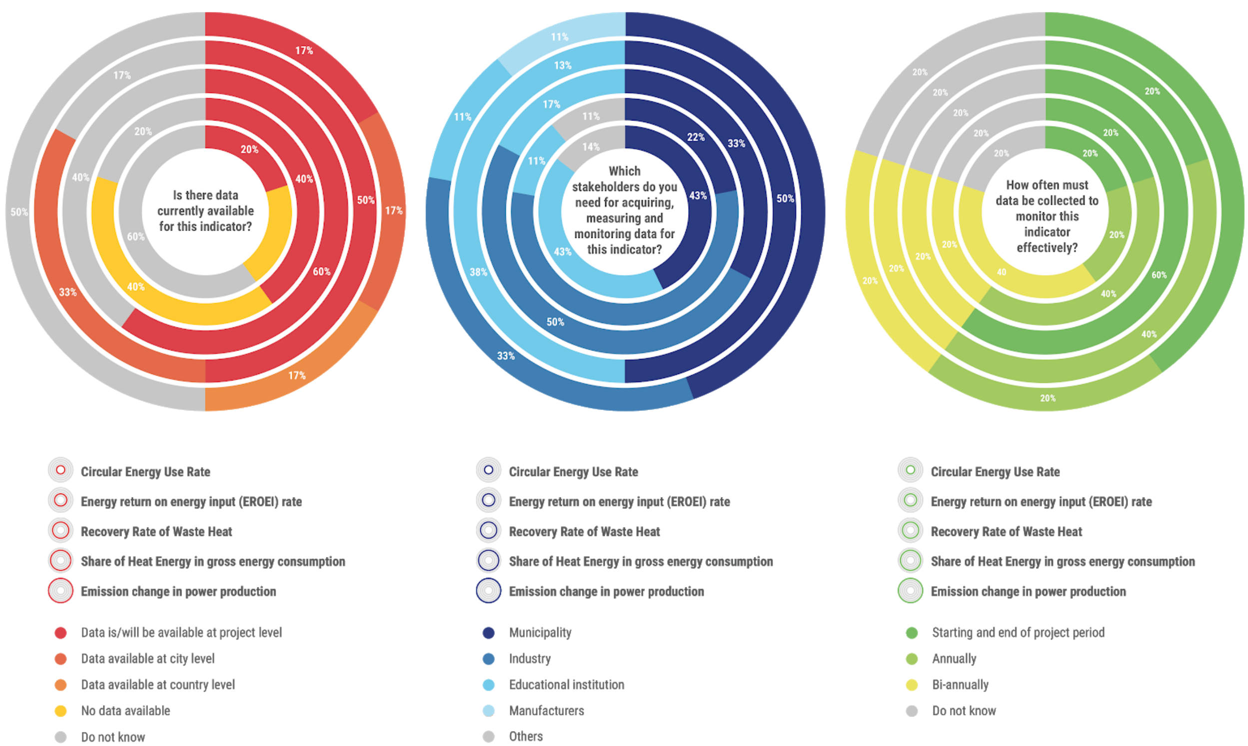
Key considerations when moving forward

Graph 30 shows the survey responses on the aspects of data availability, regularity of monitoring, and the stakeholders required for all five selected KPIs by the Berlin pilot. In response to the survey question on the time period of expected impact, most respondents supported the idea that many KPIs will have a long term impact that might show changes beyond the time frame of the project. This could have an impact on the progress seen within the next two years. It would be beneficial to develop projections based on the activities performed by the Berlin pilot. Many of the selected KPIs require the calculation of theoretical limits and estimates, which will be an important step moving forward. An additional comment was made by members of the pilot team on the need for relevant financial or economic parameters to precede the analysis of environmental KPIs E4 and E5 and the social KPIs S6 and S7, which will be further developed in WP1.



Graphic 30: Survey responses on (i) Data availability, (ii) Regularity of monitoring, and (iii) Stakeholders required for all shortlisted environmental KPIs by the Berlin pilot.

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Final environmental KPIs

Based on the results of the surveys, a final co-iteration session is to be performed in M12 to review the environmental KPIs, discuss their impacts, and decide on a monitoring approach. The current final environmental KPIs for the Berlin pilot are shown below in Table 42. The following table is yet to be finalised by the Pilot team.

Table 42: Berlin pilot final environmental KPIs.

KPIs	Monitoring approach			
	Scale	Regularity	Stakeholders	Lead organization
Recovery rate of waste heat	Neighbourhood	Start and end of project	Municipality, Industry, Others	Prototypes
Circular energy use rate (CEU)	Neighbourhood	Annually/Start and end of project period	Municipality, Industry, Others	MCS Datalabs
Share of heat energy in gross energy consumption	Neighbourhood	Annually/Start and end of project period	Municipality, Industry, Educational Institutions, Others	Fraunhofer
Energy return on energy input (EROEI) rate	Neighbourhood	Annually/Start and end of project period	Municipality, Industry, Others	MCS Datalabs
CO_2 emission change in power production	Neighbourhood	Annually/Start and end of project period	Municipality, Manufacturers, Educational institutions, Industry	Prototypes

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4. Urban metabolism process

4.1 Introduction

4.1.1 Cities as key nexus for the circular economy and urban metabolism approach

Cities currently account for 2% of the total land surface of the planet, but use 75% of the total resources extracted by the world's economy (Pacione, 2009). Urban spaces are therefore a key nexus of resource flows - from material to energy, water to waste. This trend is projected to increase, as by 2050 urban dwellers are expected to represent 66% of the 9.5-billion human population (UN, 2017). Reducing urban waste and environmental impacts has become both a priority and a key leverage point to transition the economy into a regenerative and circular state.

Urban metabolism is a concept focusing on the quantitative assessment of urban resource flows that has gained attention over the last two decades (Mugando et al., 2017).

Urban metabolism as a concept and its application has crossed many scientific fields, with studies spanning from the fields of industrial ecology, urban ecology, and urban geography to the fields of political ecology and ecological economics. In its most traditional form urban metabolism includes the systemic assessment of the urban inputs, outputs, and stocks of energy, water, nutrients, materials, and waste.

The most cited definition of the concept stems from Kennedy et al. (2007) body of work: "The sum of the technical and socio–economic processes that occur within the city, resulting in growth, production of energy, and elimination of waste." This definition has however been criticized due to its sole quantitative focus on energy and waste (Mugando et al., 2017). Curry and Mugando (2016) suggested therefore a more holistic and multidisciplinary definition, defining urban metabolism as: *"[a] collection of complex sociotechnical and socio-ecological processes by which flows of materials, energy, people, and information shape the city, service the needs of its populace, and impact the surrounding hinterland"*.

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4.1.2 Historical roots

The historical roots of the urban metabolism concept are hard to trace. Wolman (1965) is often coined with the metabolic metaphor, where the resource consumption of cities to meet the input of energy and materials needed to exist and enable growth is compared to a living organism and its metabolic needs (Wolman, 1965; Kalmykova & Rosado, 2016). However, recent studies (Lederer & Kral, 2015) have suggested that this philosophical approach was developed as early as the end of the 19th century - providing the German chemist Theodore Weyl and his publications "*Essays on the metabolism of Berlin"* as a key example. Although the filiation of the concept remains vague, the fundamental approach to consider cities as metabolic systems has had crucial impacts in the scientific field and caused a mindset shift on how environmental, social, and economic factors interact together to shape the urban ecosystem.

4.1.3 Practical application

The mapping of urban resource flows and their determinants has evolved through the years and become increasingly more comprehensive (Graphic 31). These recent developments have enabled the identification of leverage points that can be used to create interventions that reduce the throughput of material, energy, and water through urban spaces, make cities more resilient and efficient with their resources, and even usher in the concept of regenerative and circular cities.

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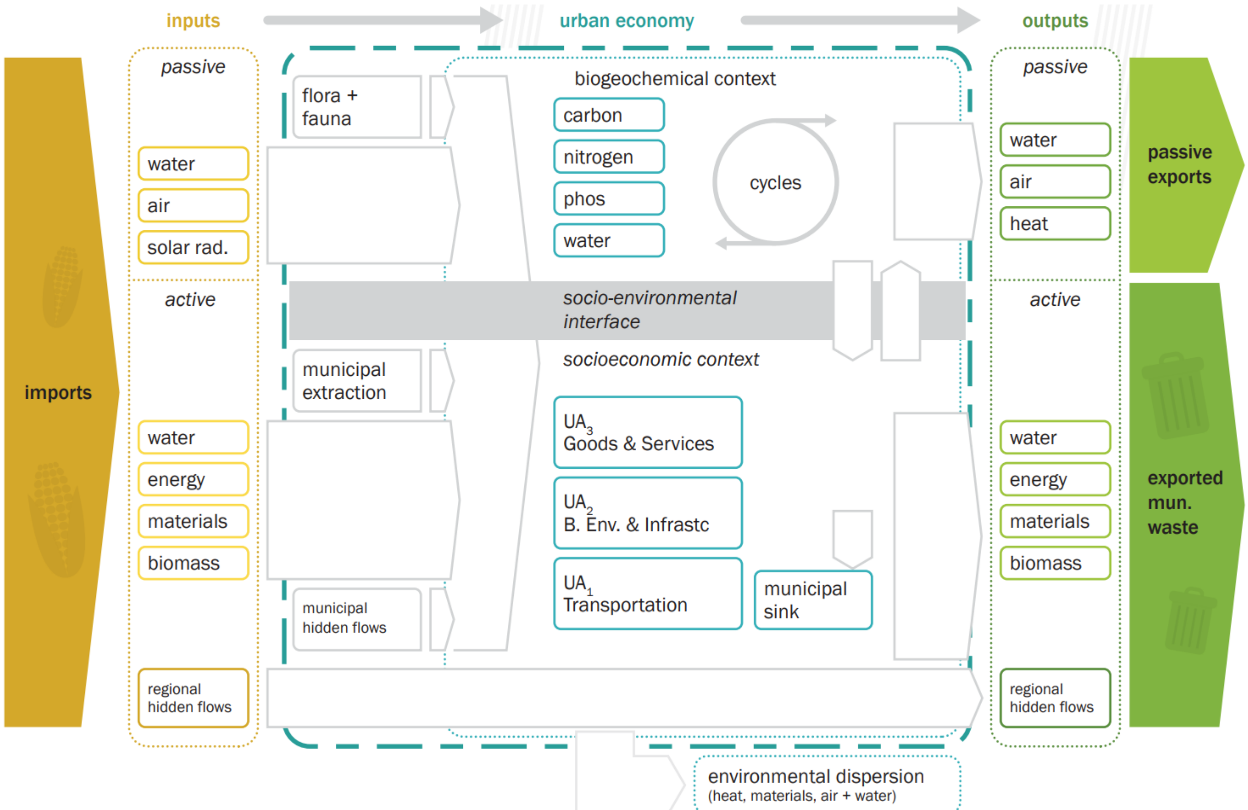

Graphic 31: Urban metabolism framework diagram (Ferrao & Fernandez, 2013:40).

4.2 REFLOW and the circular metabolism approach

4.2.1 Circular urban metabolism

In REFLOW, the urban metabolism approach plays an important role. However, if urban metabolism is key to track and monitor urban resource flows, the addition of circular principles that provide guidance on and a vision for how to reconfigure these flows is crucial. Thus, within the REFLOW project, the Circular Principles (described in detail in Chapter 2) have been made an integral part of the metabolic approach, hence the use of the term 'circular urban metabolism'. The 10 Circular Principles pave the way to transform the REFLOW pilot cities towards a regenerative and circular state.

A circular urban metabolism should strive to close its biological and technical loops (CP3). Its biological resources should cycle back to the local biosphere, while its technical resources should be kept within the city's boundaries at a high value, therefore ensuring efficient use of resources (CP2). A circular urban space should rely on resources that are abundant and renewable (CP4), especially using chemical resources that are fundamentally safe and healthy (CP1). A circular urban metabolism is a metabolism founded in diversity and positive redundancies (CP7), that manages connectivity between key resources like energy, water, food, and materials in an optimally balanced way, to avoid burden shifting and negative externalities (CP5). Additionally, understanding system feedback is key for a successful circular urban metabolism and its integration within its local ecosystem (CP6). Finally, cities that adopt a circular urban metabolism approach are continuously learning and iterating on their approach (CP8), in an open and participative way (CP9), through polycentric governance models (CP10).

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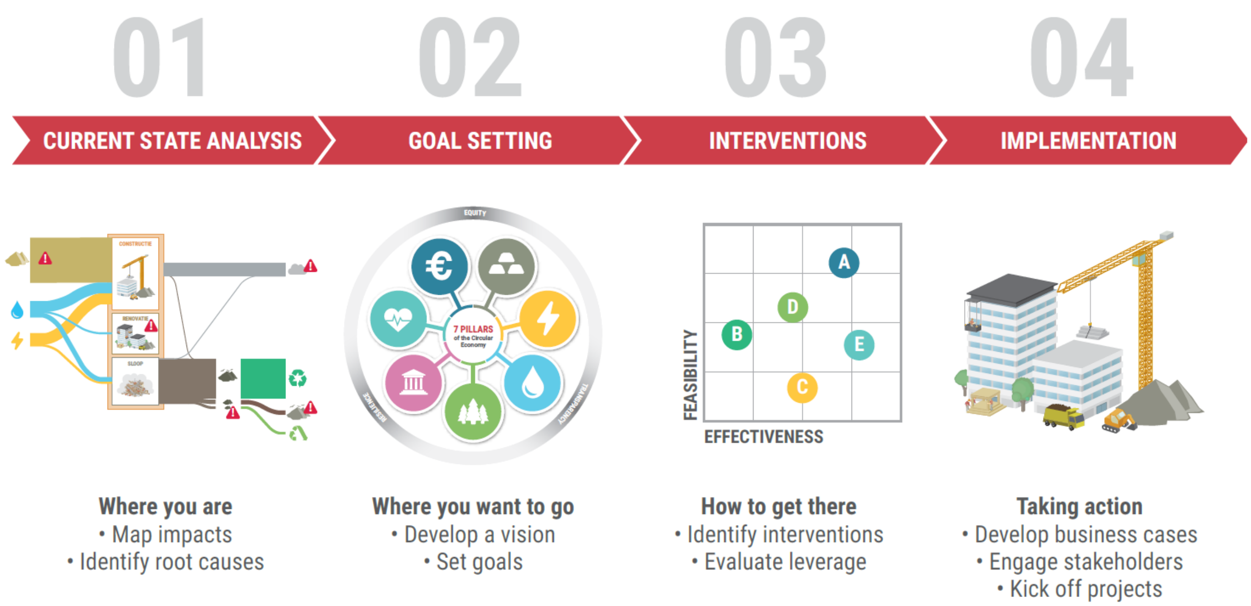
Practical approach to achieve a circular urban metabolism

To achieve a circular urban metabolism, cities can adopt a practical four step approach that encompasses a current state analysis, goal setting, intervention development, and implementation.



Graphic 32: From analysis to implementation of circular metabolism strategies (Metabolic, 2019).

Current state

This step refers to the assessment of the current urban metabolism of the focus city. The urban flows (food, energy, water, materials, construction and demolition waste, municipal waste) of the city must be mapped throughout its key economic sectors and their mass quantified. For the selected flows included in the assessment, their environmental impacts must be assessed so as to identify the most problematic hotspots and their root causes that should be addressed by the city. A Material Flows Analysis (MFA) is usually the main methodology used to systematically quantify the urban resources flows of a given city.

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Material Flows Analysis methodology and environmental impact assessment

The main methodology used to assess the metabolism of REFLOW pilot cities is material flow analysis (MFA)[3]. An MFA can be defined as a systematic assessment of the flows and stocks of materials and energy within a system defined in space and time (Brunner & Rechberger, 2004). More broadly in the urban metabolism context, an MFA is essentially a "model of the interrelation between the economy and the environment, in which the economy is an embedded subsystem of the environment and – similar to living beings – dependent on a constant throughput of materials and energy" (Hinterberger et al., 2003). As such, this tool enables the assessment and modeling of the key materials and energy flows selected by the REFLOW pilot cities (plastic, timber, energy, textile, food, waste heat) that move into, out of, and within them.

From a mathematical perspective, the guiding principles of an MFA is that all the inputs and the outputs of a system must be accounted for and the overall mass balance of the system must be correct. The correct mass balance is represented by the following relation:

$$Input = Output + \Delta Stock$$

The setting of the system boundaries is an important first step in the process as it defines where the inputs and outputs inventories start and end. An MFA also has a temporal scope and may be dynamic (future projections with scenarios) or static (total flows accounted for in a given period). In REFLOW, the usual time frame is one year and the MFA is static: it provides a snapshot of the studied metabolic flow for a given year.

An MFA provides several key insights into a city's metabolism. It provides a high-level view of what is happening in a sector, company, supply chain, or region regarding material and energy flows. Specifically, regarding cities, it provides a view of the different economic sectors that use resources within a city. Additionally, it gives an indication of the relative size of the different resource flows going through a city. Gaining a sense of the order of magnitude of flows can help decision-makers in setting priorities when developing circular interventions and strategies. An MFA has the additional benefit of illustrating how the different economic sectors and key stakeholder groups forming the urban fabric of a city are interconnected. Thus, it shows which of them must come together around a specific intervention to usher in change to their urban

[3] For the case of Cluj and Berlin pilots, an Energy Flow Analysis (EFA) will be conducted rather than an MFA given their sole focus on energy flows.

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metabolism. Finally, an MFA highlights how (usually little) circular a city is in practice and how dependent the city is on virgin materials imports, and finally how linear its waste streams are - as opposed to waste being cycled back through recycling or reuse.

An MFA can be used at multiple scales: from a country- (EUROSTAT, 2018), to a region-, to a city-, and finally to a site- level (e.g. a factory or building). In the context of REFLOW, the MFA methodology will be used both at the city-level and at the level of the specific sites selected by the REFLOW pilot teams as presented in section 4.2.2. At the time of writing, the MFA approach has already been fully implemented for the Amsterdam pilot (city-level and site-level), and a first iteration has been performed for the Milan pilot's city-level MFA. The method will also be applied to Vejle and Paris (city-level and site-level), Cluj-Napoca and Berlin (city-level), and Milan (site-level) in the coming year as further explained in section 4.2.2.

An additional step for the current state analysis is to quantify and analyze the environmental impacts associated with the flows studied in the MFA. A life-cycle perspective is adopted at this stage, where the environmental impacts of the urban resource flows studied are assessed at each stage of the value chain (raw material extraction, production, transport, consumption, collection, and waste management). Therefore the flows are not only analyzed from an urban metabolism point-of-view, but also from a value chain point-of-view. This additional layer of analysis is necessary because, to only focus on the resource flows by mass - that is the total mass present within the city boundaries - excludes an understanding of any associated, but often hidden upstream flows and their impacts (e.g. flows and impacts associated with raw material extraction, production processes, distribution and transport throughout the value chain) (Kalmykova & Rosado, 2016). A holistic understanding of the environmental impacts is essential for adequately prioritizing management strategies for the most problematic flows. Kalmykova & Rosado (2016) illustrate in an example why it is crucial to weight mass flows going through cities against their environmental impacts:

> ***"Take for example aggregate: aggregate is, by mass, one of the most important resources consumed in a city, however, its environmental impact is much lower than that of the small urban flows of rare metals."***

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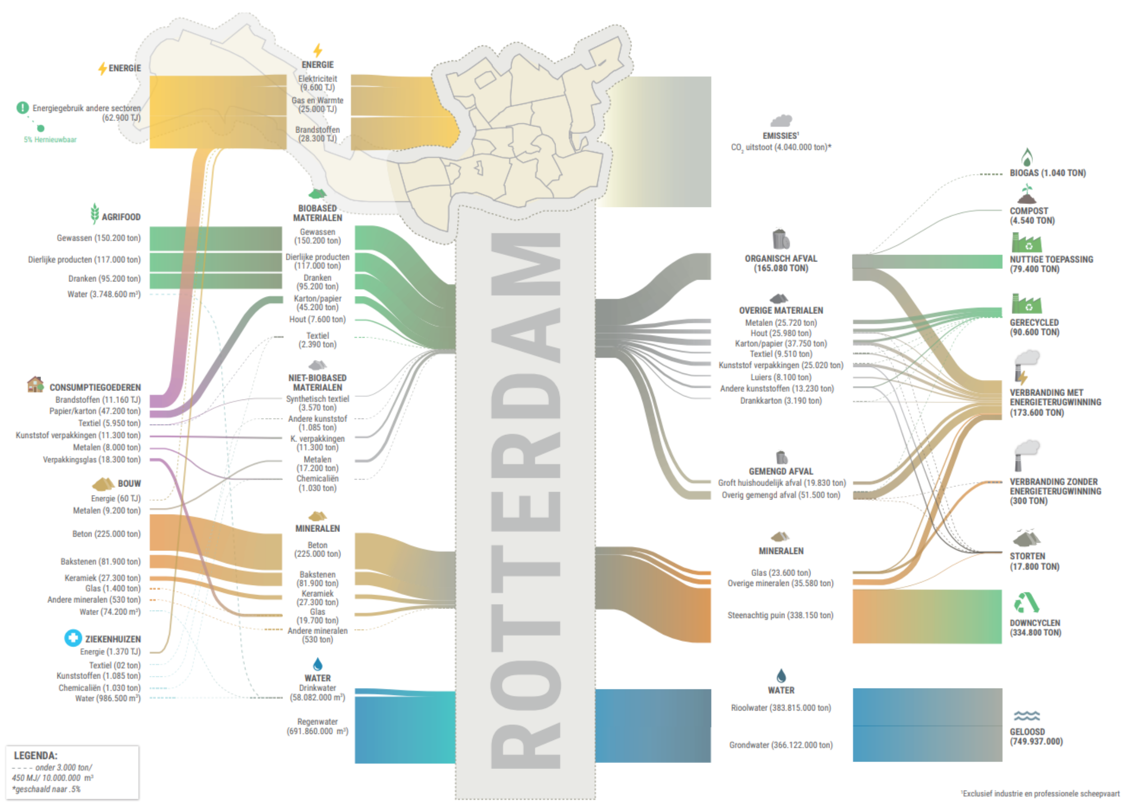
Once identified, the priority urban material streams can be managed through reduction, substitution, or efficiency strategies (Kalmykova & Rosado., 2016). In practice, once the mass flows are classified and quantified, their value chain is unravelled to include the upstream flows (extraction, production, processing, distribution) as well as the downstream ones (end-of-life waste management). Life-cycle assessment databases are then selected and used to quantify the different environmental impacts of these mass flows at each stage of their value chain.

Finally, a common hotspot identification process is performed specifically regarding the circular performance of the urban metabolism. The analysis identifies common urban resource stocks that can be re-integrated back into the economy in order to increase the circularity of the urban metabolism. Lastly, the analysis gives special attention to the end-of-life (waste) flows present in the urban metabolism. It is key to understand how waste streams are currently treated (incineration, landfilling, digestion, recycling) to comprehend how linear the current urban metabolism is.



Graphic 33: Current state of Rotterdam urban metabolism illustrated by a material flow analysis (Metabolic, 2017).

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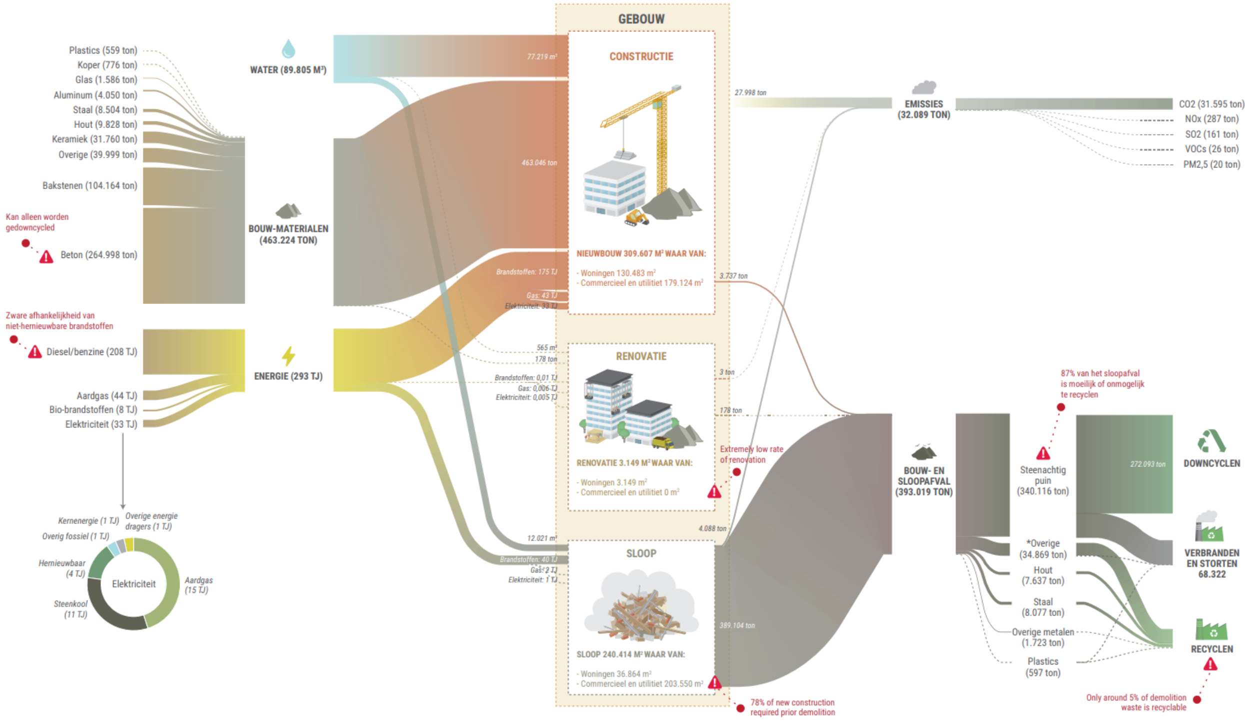

Graphic 34: An MFA focusing on the Construction and Demolition sector: A key sector of Rotterdam's urban metabolism (Metabolic, 2017).

Goals setting and interventions: Implication for circular management

Once the current state is well understood, the definition of the core goals of the city and the vision of a future circular state must be developed. To be able to track progress towards the newly defined vision, key performance indicators (KPIs) must be identified and their associated monitoring processes must be established. Finally, interventions that address the key hotspots and environmental impacts associated with urban resource flows must be developed.

Implementation

Once a vision, goals, KPIs and interventions are defined and key stakeholders are aligned, the implementation phase can begin. The implementation phase can adopt different forms. Two case studies are briefly presented below, one for the city of Rotterdam (Netherlands) focusing on construction and demolition waste and one for the city of Charlotte (USA) focused on organic flows.

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Rotterdam CE Logistic Hub

After a current state analysis that highlighted the construction and demolition waste streams as a problematic but promising flow in terms of circular practices, the city of Rotterdam has been developing and building a Materials Hub in an available warehouse in the city. In addition to reducing transport impacts, the goal of the hub is to facilitate urban mining within the city, functioning as a logistics point for storing and reusing secondary materials from demolition. This project also builds on the "Urban Mining Tool" previously developed by Metabolic, which predicts the quantities of materials flowing from planned demolitions and constructions in the Netherlands.

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Charlotte CE Innovation Hub

The current state analysis for the city of Charlotte revealed high volumes of organic waste being sent to landfill. As closing the biological loop is of key importance for circular urban cities (CP1), Charlotte has developed a new program directly tackling this challenge. The Charlotte Materials Innovation Lab (MIL) is a university-affiliated student-startup incubator program focused on new value propositions for organic waste. The aim is to reduce the total amount of organic waste in the city by generating and supporting innovative local initiatives for high-value upcycling of specific organic waste streams. The city is establishing a Materials Innovation Lab that will house the equipment needed for experimentation and testing.

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4.2.2 REFLOW pilot cities and their urban metabolism scans

The circular urban metabolism approach described above has been central in the development of the metabolism scan approach developed for each REFLOW pilot city in WP 3. In collaboration with WP 5, the urban metabolism scanning activities were defined by WP 3 with each individual pilot and adapted to their needs and local context.

Amsterdam

The Amsterdam pilot is focused on the flow of textiles within the city. It places an emphasis on clothes and home textiles consumed and discarded by households.

City-Level

A city-wide MFA has been carried out by Metabolic in collaboration with the pilot team, with special data support provided by the waste management department of the municipality. The results of the MFA have supported the framing of the pilot's challenges, scenarios, and activities described by the pilot team in D5.1 (REFLOW D5.1, 2020). Since then, further iterations of the MFA have been generated as the latest data has become available, increasing the granularity of the waste flows (see Graph 35 at the end of this chapter). This iterative process will continue to support the pilot throughout its planning and programming activities.

Site-Level

The pilot team is interested in working with a selection of neighbourhoods in Amsterdam. As a result, neighbourhood-level textile waste scans will be carried out that focus on the following neighbourhoods: Noord, Nieuw-West, and Zuidoost. The goal of the scans is to track annual change for each of the selected neighbourhoods in terms of total volume of textile waste, its composition, and the contamination rate (non-textile, spoiled textile in textile containers). These scans will enable cross-neighbourhood comparisons - for example analyzing how "REFLOW neighbourhoods" fare compared to Amsterdam's neighbourhoods that are less involved in the project. A temporal assessment of the neighbourhood's evolution in terms of textile collection will also be carried out to understand the impacts of REFLOW activities. Finally, the scans will provide information for a spatial analysis of waste flows from neighbourhood collection to the final destination of waste.

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Milan

The Milan pilot is focused on the flow of food in the city. It has a particular interest in the numerous covered municipal markets that are scattered around Milan. Assessing the flow of food at the market-level is therefore key for the pilot team.

City-Level

A city-wide food MFA was carried out by Metabolic to map the flows of food across the value chains that supply Milan residents with food products. This MFA will be re-iterated to increase its granularity regarding the consumption patterns at the household-level, the supply of food from food markets, as well as to identify the regional origins of the food consumed in Milan.

Site-Level

The Milan pilot is especially interested in the municipal food markets, as they represent a key hub in local neighbourhoods. For one selected food market, a mapping of food flows will be carried out and their mass quantified through an MFA. This site-level scan will generate insights on the current state of the food market, facilitate the creation of circular interventions, and support the development of the co-design labs and experimental prototypes taking place in the market.

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Paris

The Paris pilot is focused on timber flows across the French capital. It has a specific sectoral focus on the event industry in Paris and the temporary use of timber structures by this sector.

City-Level

A city-wide timber MFA will be carried out to develop an understanding of the most important timber flows going through the French capital. This initial mapping will identify the largest consumers of timber products by economic sectors, the types of timber products consumed, and how and where the timber waste generated yearly is managed in the city.

Site-Level

As the pilot team has a special focus on the event industry, an MFA will be carried out for a selected event to track its resource flows, with a core focus on timber products. The results of the MFA will highlight where circular interventions may have the greatest effect to reduce the amount of waste generated during the event. A second MFA will then be performed a year later to track progress driven by the new circular measures implemented by the event organizer.

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Vejle

The Vejle pilot team is focused on plastic flows from key sectors of the municipality. It places an emphasis on consumer plastics used in sectors such as the healthcare sector, the food retail sector, the public sector (e.g, schools), and private households.

City-Level

A city-wide plastic MFA will be developed to gain a better understanding of the plastics flows going through the city. This mapping and quantification process will provide insights into the largest consumers of plastics, as well as the most used plastic types. Lastly, it will characterize the flows of plastic waste through the city, and highlight their waste disposal.

Site-Level

As the pilot team has a special focus on key sites in the city, such as a nursing home, a school, social housing units, and several food retail locations, an MFA will be carried out on one of the selected sites to track its plastic flows. The results of the MFA will highlight where circular interventions may have the greatest effect to reduce the amount of plastic consumed, and how plastic waste can be recovered for productive purposes.

Berlin

The Berlin pilot team is focused on waste heat flows that are generated throughout Berlin. It aims to gain a better understanding of the availability of urban waste heat flows and investigate their potential to be captured and put to productive use.

City-Level

An energy flow analysis (EFA) will be carried out to map and quantify the amounts of waste heat available throughout the city. The EFA's goal is to identify the largest sources of waste heat and facilitate the prioritization of heat recovery strategies from the most promising sources.

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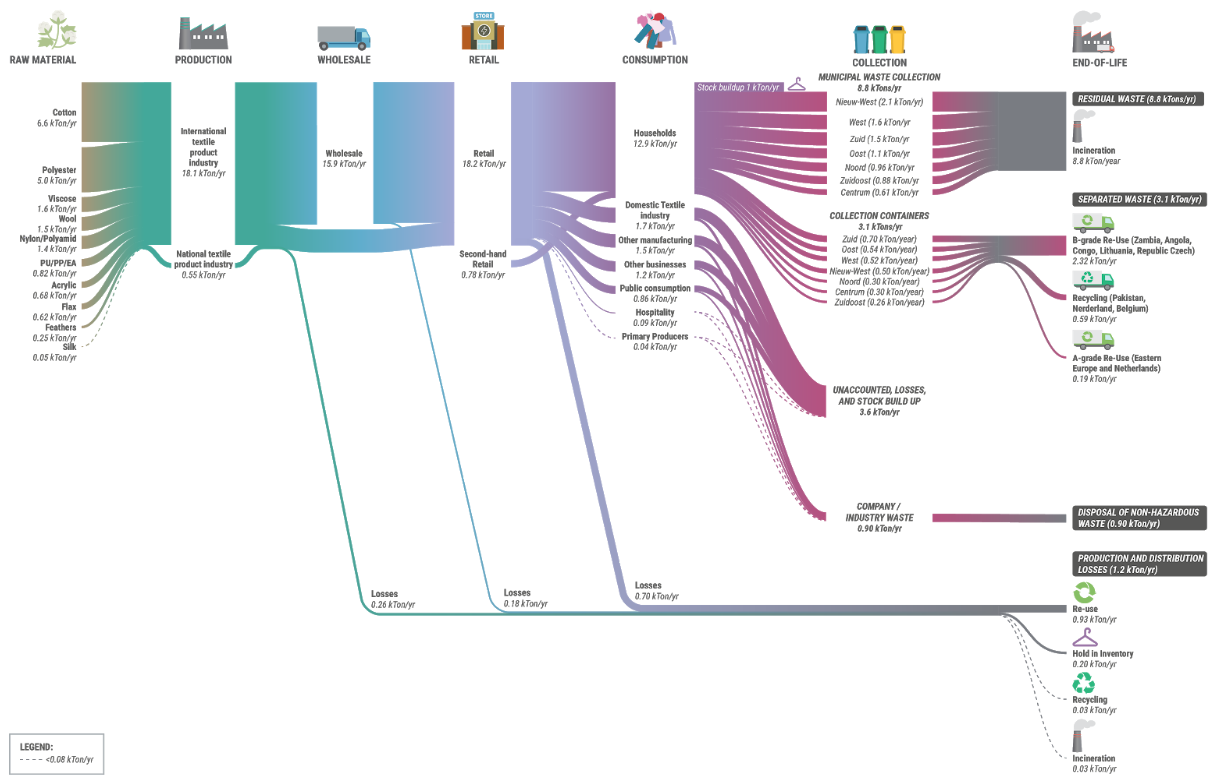
Cluj-Napoca

The Cluj-Napoca pilot is focused on the energy consumed by publicly managed buildings. It aims to gain a better understanding of the energy consumed by its public infrastructure, and track the progress in terms of energy efficiency gain potentially generated by the energy-saving measures and energy tracking tools used in its public buildings.

City-Level

An energy flow analysis (EFA) will be carried out to quantify the amounts of energy consumed through Cluj-Napoca's public infrastructure. The EFA's goal is to identify the largest consumers of energy to facilitate the prioritization of energy efficiency measures and to monitor the progress in energy consumption reduction due to the recent energy efficiency measures put in place.



Graphic 35: Textile MFA of Amsterdam (Metabolic, 2020).

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5. Conclusion

This document presents the process and outcomes of WP 3 Circular Engineering in year one of the REFLOW project. The first section shares the Circular Principles and Indicators, including: their scope and purpose, the method undertaken to derive them, an in-depth explanation of each of the 10 principles as well as a supplementary collection of case studies and key performance indicators. The second section details the process undertaken and results derived from the KPI refinement and environmental impact assessment process undertaken within WP 3 in close collaboration with the pilot cities. The third section introduces the urban metabolism methodology and the way in which this method is being applied within REFLOW as part of WP 3.

Key takeaways and insights have begun to emerge through these activities that help evidence the complexity of the REFLOW ambition and method, the differences and similarities between pilot cities, and how the various theoretical and technical building blocks of the REFLOW concept may be best aligned to support the project's objectives.

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Key takeaways

- **There remains a critical need to further define the REFLOW concept**, in particular the definition of the circular economy and the vision for regenerative cities held in common by consortium partners. The Circular Principles are one step in devising such a common vision and narrative, but greater work and coordination amongst partners and pilots will need to take place to this effect over year two of the project.
- **It is difficult to divide impacts within silos of environmental, social, and economic**. A holistic approach to impact assessment - that accommodates the interdependencies between the environmental, social, and economic spheres - is key to capture the natural complexity within sustainable transformation.
- **The circular use rate KPI was selected across all pilots**. Although originally used at the country-level, this KPI was calibrated to focus on the specific material stream defined by each pilot within their local context. This constitutes a novel use of this KPI, and within the context of REFLOW, we have the opportunity to experiment with it, across a wide variety of material and energy flows, in various contexts (events, building, food markets, and city-wide).
- **The iterative rounds of co-creation helped in facilitating discussions among the stakeholders of each pilot about the definitions and impacts of the KPIs**. This led to a common understanding of their goals and helped to establish clear definitions. Additionally, it provided a space to reflect on each pilot's activities and re-affirm the overall goals of each pilot.
- **The need to create and collect new data for REFLOW pilots is clear**. Some of the ambitious KPIs that were selected will necessitate the creation of new data and the development of new data collection tools. Creating a baseline for some of the KPIs will be an important step moving ahead.
- **The need for a multi-stakeholder approach to data collection and KPI monitoring is key**. Municipalities often have a central role in the data collection process and the KPI monitoring, however, our findings reflect that the monitoring of REFLOW KPIs will necessitate a multi-stakeholders approach.

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- **The circular urban metabolism approach is key to developing a thorough understanding of the current state of the REFLOW pilot cities**, and to identifying the most problematic environmental impacts associated with the resource flows monitored in this project. Combining the urban metabolism approach with the Circular Principles facilitates the development of a vision for a future circular urban metabolism for European cities.
- **The MFA approach will be a key tool for analyzing REFLOW resource streams**, whether at the city-level or at a site-level. The approach will also help pilot cities to prioritize the most impactful circular strategies.
- **REFLOW pilot cities possess their own unique context and ambitions**, that is represented in the diversity of approaches taken to analyze key parts of their urban metabolism. This diversity is also reflected in the interventions formulated by each of them to increase the circularity of their metabolism.

In the next phase of the project, WP 3 will focus on the further development of each pilot's urban metabolism as well as the expansion of the Circular Principles. The results of both tasks will be summarized in D3.2 Urban Metabolism: Initial Assessment (M12).

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Appendix 2: KPI long list

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Materials and Resources			
Circular Material Use Rate (CMU)	The circular material use rate (CMU rate) measures, in percentage, the share of material recovered and fed back into the economy - thus saving extraction of primary raw materials - in overall material use. The CMU rate is thus defined as the ratio of the circular use of materials (U) to the overall material use (M)	%	EUROSTAT manual; Metadata
Material import dependency	The ratio of imports (IMP) over direct material inputs (DMI) in percentage. The term 'material import dependency' shows the extent to which an economy relies upon imports in order to meet its material needs. Material import dependency cannot be negative or higher than 100%. Values equal to 100% indicate that there are no domestic extractions during the reference year.	%	EUROSTAT reference on Material Flow Accounts
End-of-life recycling input rates	The 'end-of-life recycling input rate' (EOL-RIR) measures how much of the total material input into the production system comes from recycling of "old scrap". It is important to note that the EOL-RIR only takes into account "old scrap", i.e. scrap from end-of-life products. It does not take into account scrap that originates from manufacturing processes ("new scrap"), which is sometimes used in closed-loop industrial symbiosis processes.	%	EU CE Monitoring Framework
Domestic Extraction of Materials (DE)	The amount of raw material (excluding water and air), in physical weight, extracted from the natural environment for use in the economy.	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
Import of Materials	Imports into the economy, in physical weight (at border)	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;

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Export of waste materials	Waste exports to other economies, in physical weight (at border)	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
Physical Trade Balance (PTB)	Imports minus exports	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
Domestic Material Consumption (DMC)	Domestic Extraction + Imports – Exports; The indicator is defined as the total amount of material directly used in an economy and equals direct material input (DMI) minus exports. DMI measures the direct input of materials for use in the economy. DMI equals domestic extraction (DE) plus imports.	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010; Resource efficiency dashboard;
Raw material consumption	Measures the total amount of raw materials required to produce the goods used by the economy (also called 'material footprint').	Weight	IRP, 2019; UNEP 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010;
Resource Productivity	The indicator is defined as the gross domestic product (GDP) divided by domestic material consumption (DMC). DMC measures the total amount of materials directly used by an economy. It is defined as the annual quantity of raw materials extracted from the domestic territory of the local economy, plus all physical imports minus all physical exports. It is important to note that the term 'consumption', as used in DMC, denotes apparent consumption and not final consumption. DMC does not include upstream flows related to imports and exports of raw materials and products originating outside of the local economy.	Euro/weight	EUROSTAT Europe 2020 RE indicators
Total Material Requirement (TMR)	Domestic extraction + Unused (domestic) extraction + Imports + Unused extraction in country of origin	Weight	Fischer-Kowalski, 2011
Total material consumption (TMC)	Total material requirement – Exports – Unused extraction of exports.	Weight	Fischer-Kowalski, 2011

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Material use per Euro of demand	TMC divided by the economic demand (euro)	weight/ Euro	Haas, 2015; Global material resource outlook to 2060 - economic drivers
Material footprint per capita and per GDP unit	RMC per capita per GDP unit	Weight / capita / Euro	World Bank, 2018; SDG12
Net addition to stocks	Net additions to stock (NAS) is a measure for the 'physical growth of the economy'. Materials in form of buildings, infrastructures, durable goods such as e.g. cars, industry machinery, or household appliances are added to the economy's material stock each year (gross additions), and old materials are removed from stock as buildings are demolished, and durable goods disposed of (removals). NAS is approximated using the following equation: NAS = DMC - DPO + BI (input-output).	Weight	EUROSTAT Europe 2020 RE indicators
Direct Material Input (DMI)	DMI indicates the direct input of material into the economy. DMI includes all materials which are of economic value and which are available for use in production and consumption activities and it is calculated as the sum of domestic extraction plus physical imports: DMI = DE + IMP;	Weight	EUROSTAT reference on Material Flow Accounts
Products promoting sustainability - green purchasing of local authority	The indicator investigates the number of organisations, including public administrations that purchase products promoting sustainability of consumption. "Sustainable products" - eco-labelled, organic, energy-efficient, certified timber or fair trade products - involve the adoption of environmentally and socially sound solutions in farming, forestry, food industries and in other production processes.	%	RFSC; European common indicators (ECI)
Self-sufficiency of raw materials for production in the EU	The share of a selection of key materials (including critical raw materials) used in the EU that are produced within the EU.	%	EU CE Monitoring Framework

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GDP	Gross Domestic Product	Weight	IRP, 2019; Global Material Flows and Resource Productivity 2016; Schaffartzik, 2014; Fischer-Kowalski, 2011; Steinberger, 2010; World Bank
Total solid waste generation per capita	This indicator measures the urban solid waste volume generated per inhabitant and per day. = Total urban solid amount of waste (in kg) / Number of inhabitants.	kg / year / capita	World Bank, 2018; EBRD; RFSC
Share of the population with weekly municipal solid waste collection	Number of people who have solid waste collected on a weekly basis	%	World Bank, IDB, EBRD
Proportion of municipal solid waste that is sorted and recycled	Formally and informally recycled materials are those that (following local government permits and regulations) are diverted from the waste stream, partially recovered, and sent for processing into new products. Municipal Waste recycling rate (%)= total amount of municipal waste recycled (year x)) * 100 / total amount of municipal waste generated in tonnes (year x)	%	World Bank, IDB, EBRD; RFSC; https://www.europarl.europa.eu/RegData/etudes/STUD/2017/581913/EPRS_STU(2017)581913_EN.pdf
Remaining life of current landfill(s).	This indicator measures the remaining useful life of the site of the sanitary or controlled landfill, based on the city's municipal solid waste generation projections (in years).	Years	World Bank, IDB, EBRD
Proportion of urban solid waste regularly collected and with adequate final discharge out of total urban solid waste generated, by cities	The numerator of this indicator is 'municipal solid waste regularly collected with adequate final treatment and disposal' and the denominator is 'total municipal solid waste generated by the city'.	%	SDG11.6.1
National recycling rate	Amount of material recycled in the economy	%	SDG 12.5.1

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Recycling rate of specific waste stream	Amount of specific material (Plastic/wood/biowaste/C&D etc) recycled in the economy/city	%	EU CE Monitoring Framework
Recycled Biowaste per capita	Kg of biowaste recycled per capita	kg/capita	EU CE Monitoring Framework
Recycling rate of specific packaging waste	The indicator is used to monitor progress towards the proposed 65% and 70% targets by 2025 and 2030 respectively. EU-wide target of 55% on recycling plastic packaging (by 2025); EU-wide 2030 target of 75% on preparation for reuse and recycling of wood packaging.	%	EU CE Monitoring Framework
Life time extension	The extent to which the project attempted to prolong the service lifetime of products	Likert Scale	Bosch et al, 2017
(a) Food loss index and	Index of the changes in the food losses percentages along the supply chain of key commodities over time (Current vs base year)		SDG 12.3.1(a)
(b) food waste index	The indicator aims to measure the total amount of food that is wasted in tonnes. It complements SDG 12.3.1(a) on Food Loss (which is under the custodianship of FAO). Both indicators look to divide the food value chain and measure the efficiency of the food system.	tonnes	SDG 12.3.1 (b)
Nitrogen use efficiency/Sustainable Nitrogen Management	Measures the Euclidean distance from an ideal point with optimal nitrogen use efficiency (NUE) and crop yield.	unitless	Zhang et al., unpublished; World Bank

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INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Energy			
Reduction in life cycle energy use	Reduction in life cycle energy use by a material/product achieved by the project (%)	%	ITU-T L.1410 (2014) Smiciklas, 2014; G. Rebitzer, 2004; Bosch et al, 2017
Circular Energy Use Rate (CEU)	The circular energy use rate measures, in percentage, the share of energy recovered and fed back into the economy - thus saving extraction of primary energy - in overall energy use. The rate is thus defined as the ratio of the circular use of energy to the overall energy use.	%	EUROSTAT manual; Metadata
Physical energy flow	PEFA records the flows of energy (in terajoules) from the environment to the economy (natural inputs),within the economy (products), and from the economy back to the environment (residuals)		EUROSTAT definition and metadata; EC Environmental statistics and account
Energy Consumption	Total final energy consumption, in GJ per capita per year and average annual growth	GJ / capita / year	WDI, World Bank, IDB
Energy Productivity	The indicator results from the division of the gross domestic product (GDP) by the gross available energy for a given calendar year. It measures the productivity of energy consumption and provides a picture of the degree of decoupling of energy use from growth in GDP. This can be calculated for a city and compared to its national average.		EUROSTAT Europe 2020 RE indicators
Energy dependence	The indicator shows the extent to which an economy relies upon imports in order to meet its energy needs. It is calculated as net imports divided by the gross available energy. Energy dependence = Net imports / Gross available energy.		EUROSTAT Europe 2020 RE indicators
Increase in local renewable energy production	Percentage increase in the share of local renewable energy due to the project	% in kWh	ISO/DIS 37120 (2013). Sustainable development and resilience of communities. Indicators for city services and quality of life. ICS 13.020.20; Eurbanlab; Eco-Districts, Concerto; LEED: CIVIS; IDEAS; Bosch et al, 2017

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Share of renewable energy in gross final energy consumption	Percentage of energy from a renewable source within the overall energy consumption	%	World Bank, SDG7.2, EBRD, CPI, EU Resource efficiency Scoreboard, RFSC
Proportion of population with primary reliance on clean fuels and technology	Percentage of population primarily using energy from clean fuels and technology	%	SDG7.1.2
Resilience of the electricity network to climatic extremes	Average share of population undergoing prolonged power outage in case of climatic extremes over the past five years (percentage)	%	EBRD, World Bank
Energy intensity measured in terms of primary energy and GDP	Energy intensity is defined as the energy supplied to the economy per unit value of economic output. Energy intensity is an indication of how much energy is used to produce one unit of economic output. It is a proxy of the efficiency with which an economy is able to use energy to produce economic output. A lower ratio indicates that less energy is used to produce one unit of output.	GJ/Euro	SDG7.3
Investments in energy efficiency as a proportion of GDP	The amount of direct investment in financial transfer for infrastructure and technology to sustainable development services. *usually when expanding infrastructure and upgrade technology for supplying modern and sustainable energy services	%	
Extraction of natural energy inputs	The flows of energy (in terajoules) from the environment to the economy (natural inputs); natural energy inputs: flows from the natural environment into the economy such as fossil energy carriers in solid, liquid and gaseous form, biomass, solar radiation, kinetic energy in form of hydro and wind, geothermal heat etc.;	TerraJoules	EUROSTAT Europe 2020 RE indicators; PEFA definition and metadata
Domestic production of energy products	Energy products: output flows from production processes as defined in national accounts (ESA); typically products produced by extractive industries, refineries, power plants etc.;	TerraJoules	EUROSTAT Europe 2020 RE indicators; PEFA definition and metadata

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Residual energy amounts	Energy residuals: mainly energy in form of dissipative heat arising from the end use of energy products, flowing from the economy into the natural environment.	TerraJoules	EUROSTAT Europe 2020 RE indicators; PEFA definition and metadata
Use of waste for energy purposes	Production of waste-to-energy plants	TerraJoules	EUROSTAT Europe 2020 RE indicators
Net use of domestic energy	Net use of energy produced locally	TerraJoules	EUROSTAT Europe 2020 RE indicators

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Carbon Footprint / Climate			
Greenhouse Gas emissions per capita	This indicator measures CO_2 emissions of the city, divided by city population. Estimates of CO_2 emissions must first be made within each sector (transport, electricity, etc.) and averaged.; Total national emissions of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the so-called F-gases (hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride (NF3) and sulphur hexafluoride (SF6)). Using each gas' individual global warming potential (GWP), they are being integrated into a single indicator expressed in units of CO_2 equivalents.		SDGs, IDB, EBRD, WDI, CPI, World Bank, EU resource efficiency scoreboard, RSFC
CO_2 Emission - total	Measures the intensity of CO_2 emissions from the entire economy	tCO_2	EPI; Hertwitch, 2009; RFSC; WRI-Climate Analysis Indicator Tool
CO_2 emissions by sector	electricity and heat production; manufacturing industries and construction; residential buildings and commercial and public services; transport; other sectors		WDI, World Bank
CO_2 Emission - Power	Measures the intensity of CO_2 emissions per kilowatt-hour of electricity and heat, as a blend of current-year intensity and a 10-year trend.	g CO_2/kWh	International Energy Agency
Methane Emissions	Measures the intensity of methane emissions from the entire economy, as a blend of current-year intensity and a 10-year trend.	Mt	EPI; WRI-Climate Analysis Indicator Tool

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Black Carbon Emissions	Black carbon (BC) is a component of fine particulate matter (PM ≤ 2.5 µm in aerodynamic diameter). It is formed through the incomplete combustion of fossil fuels, biofuel, and biomass, and is emitted in both anthropogenic and naturally occurring soot. BC causes human morbidity and premature mortality.	Mt	(Crippa, M., 2016); Emission Database for Global Atmospheric Research (EDGAR), release version 4.3.1, 2016.
Existence of a GHG emissions measurement system with a monitoring system	Does a measurement and monitoring system exist for GHG emissions in the country/city	y/n	World Bank, IDB
CO_2 emission per unit of value added	CO_2 emissions per unit value added is an indicator computed as the ratio between CO_2 emissions from fuel combustion and the value added of associated economic activities. The indicator can be computed for the whole economy (total CO_2 emissions/GDP) or for specific sectors, notably the manufacturing sector (CO_2 emissions from manufacturing industries per manufacturing value added (MVA).	kgCO_2 per USD (2010 value constant under SDGs)	SDG9.4.1
Ecological Footprint	It is a global indicator that represents the amount of land and sea needed to regenerate the resources human populations consume and to absorb the waste.	ha / an / capita	RFSC; Environmental Impacts of Natural resource flows

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Air Quality			
Air Pollution: Average exposure to fine particulate matter	Measures the average annual concentration of PM2.5 to which the typical citizen of each country is exposed.	µgm^−3	SDG11.6.2; Donkelaar et al., 2016
Air Pollution: fine particulate matter exceedance	Measures the weighted percentage of a country's population exposed to annual concentrations of PM2.5 that exceed WHO guidelines at four different levels: 10, 15, 25, and 35 µg/m3.	%	SDG3, 11, ISO37101-2016, RFSC;
	Number of times the limit of main air pollutants emissions defined by the European directives on air quality is exceeded (PM10, O3, NO_2)	µg/m³	Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

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SO_2 Emissions	Emissions from Transport	Mt	Crippa, M.,2016
NOx Emissions	Emissions from Transport	Mt	Crippa, M.,2016
Household solid fuels	Measures the actual outcomes from exposure to indoor air pollution from household use of solid fuels.	DALY rate	(Wendling, 2018); Forouzanfar, 2016

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Water [4]			
Circular Water Use Rate	The circular water use rate measures, in percentage, the share of water recovered and fed back into the economy - thus saving extraction of freshwater- in overall water use. The CWU rate is thus defined as the ratio of the circular use of water (U) to the overall water use (W)	%	EUROSTAT manual; Metadata
Water Stress	Level of water stress: Annual freshwater withdrawals, percentage of internal resources		World Bank, SDG6, WDI, WRI, EBRD
Water consumption per capita	Water consumption per capita (incl. ground water abstraction)	(L/person/day)	World Bank, GEF, IDB, EBRD; RFSC
Drinking water (access)	Percentage of population with access to drinking water facilities		EPI
Sanitation (access)	Percentage of population with access to sanitation facilities	%	EPI, SDG, World Bank, ISO 37120
Wastewater Treatment	Measures the percentage of wastewater treated, by the wastewater produced.	%	EPI

[4] Indicators for water were included for the Berlin PIlot

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Water Exploitation Index	i) the annual total fresh water abstraction in a country as a percentage of its long-term annual average (LTAA) available water from renewable fresh water resources; ii) the annual groundwater abstraction as a percentage of the country's long-term annual average groundwater available for abstraction; and iii) the annual surface water abstraction as a percentage of the country's long-term annual average surface water resources available for abstraction.		World Bank, SDGs, WRI, WDI, EBRD, EPI
Annual Freshwater Withdrawal	Annual freshwater withdrawals refer to total water withdrawals, not counting evaporation losses from storage basins. Withdrawals also include water from desalination plants in countries where they are a significant source. Withdrawals can exceed 100 % of total renewable resources where extraction from nonrenewable aquifers or desalination plants is considerable or where there is significant water reuse.	Million cubic meter	World bank; WRI
Water Productivity	Water productivity indicates how much economic output is produced per cubic meter of fresh water abstracted (in EUR per m3 or PPS per m3). It serves as a measure of the efficiency of water use.	Euro/m 3	EUROSTAT dataset
Non-revenue Water/ Water-loss	Percentage of water lost in the water distribution system. This is calculated as the percentage of water lost from the amount of treated water entering the distribution system that is accounted for by the water provider. This includes actual water losses (e.g., leaking pipes) and billing losses (e.g., broken water meters, absence of water meters, and illegal connections).	%	World Bank, SDG6, WRI, IDB, EBRD; RFSC
Lead exposure	Lead amounts found in water samples	DALY rate	Forouzanfar, M. H., Anderson, H. R., Burnett, R., & Dandona, L. , et alia (2016)

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INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Health and Well-being			
Encouraging a healthy lifestyle	Extent to which the project and associated activities serve to promote a healthy lifestyle among local residents (qualitative, unitless)	1 to 5 scale	Bosch et al, 2017 UNaLaB
Exposure to noise pollution	The per cent (%) reduction of noise level at night measured at the receiver, or the number of inhabitants exposed to noise >55 dB(A) at night, before and after NBS implementation		International Organization for Standardization (ISO). (2018). Sustainable cities and communities — Indicators for city services and quality of life (ISO 37120:2018); UNaLab

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Behaviour and Lifestyles			
Consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship (qualitative, unitless)	Linkert Scale	Bosch et al, 2017 Ng, J.A.I. (2015)

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Community Participation			
Number of stakeholders	Number of stakeholders involved in decision-making activities, and mechanisms to encourage community engagement		World Bank, 2018; EBRD;
Community involvement in planning phase	The extent to which citizens and other stakeholders have been involved in the planning phase of a given project (qualitative, unitless)	1 to 5 scale	Arnstein, S.R. (1969). Driessen, 2001; UNaLab
Community involvement in implementation phase	The extent to which citizens and other stakeholders have been involved in the implementation phase of a given project (qualitative, unitless)	1 to 5 scale	Arnstein, S.R. (1969); UNaLab

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Increased consciousness of citizenship	The extent to which the project has contributed in increasing consciousness of citizenship. the indicator provides a qualitative measure and is rated on a five-point Likert scale	Likert scale	ITU ,2014. Key performance indicators (KPIs) definitions for Smart Sustainable Cities. SSC-0162-rev3; Ng, J.A.I. (2015); Bosch, ET AL, 2017
People reached	Percentage of people in the target group that have been reached and/or are activated by the project	% of people	Bosch et al, 2017
Increased participation of vulnerable groups	The extent to which project has led to an increased participation of groups that are not well represented in the society	Likert Scale	Bosch et al, 2017
Quality and frequency of dialogue between and among domestic and external stakeholders.	The quality of dialogue is assessed based on aspects such as transparency, participatory, engagement, etc. on a linkert scale through a qualitative survey of participants.	Likert scale	UNDP Capacity Assessment Methodology User's Guide 2008; UNDP Practice Note on Capacity Development, Sep2006
Availability of public information in local dialects for dissemination to local users		Likert scale	UNDG Working Group on Capacity Development, March 2006; UNDP Capacity Assessment Methodology User's Guide, 2008
Presence of democratic structures	Presence of a structure that allows civil society to directly participate in urban planning and management and that operates regularly and democratically	y/n	World Bank, 2018; EBRD;

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INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Equity and Inclusivity			
Participation of vulnerable or traditionally under-represented groups	The extent to which the NBS project has led to the increased participation by groups of people who are typically not well represented in the society.	1 to 5 scale	Bosch et al, 2017
Vulnerable employment by gender (WDI)	Number of people classified as "vulnerable" employed, sorted by gender		World Bank, 2018; EBRD;
Urban/Rural income ratio	Average income ratio between urban population and neighboring rural population, and changes over time (GPSC)		World Bank, 2018; EBRD;
Hourly wage	Average hourly earnings of female and male employees, by occupation, age, and disability status (SDGs)		World Bank, 2018; EBRD;
Gini coefficient	Income Gini coefficient (SDGs, WDI, IDB, CPI). Measure of the deviation of the distribution of income among individuals or households within a country from a perfectly equal distribution. A value of 0 represents absolute equality, a value of 100 absolute inequality.		World Bank, 2018; EBRD;
Top consumption share	Share of consumption or income, highest 10 percent of population (WDI)		World Bank, 2018; EBRD;
Bottom consumption share	Share of consumption or income, lowest 10 percent of population (WDI)		World Bank, 2018; EBRD;
Service access	Ratio of access to services between 90th and 50th percentiles (GPSC)		World Bank, 2018; EBRD;
Availability and equitable distribution of blue-green space	The availability and distribution of space with respect to specific individual or household socioeconomic profiles and landscape design, measured using GIS and statistical analysis		Cohen, M., Baudoin, R., Palibrk, M., Persyn, N., & Rhein, C. (2012). Ibes, D.C. (2015). (Kabisch, 2014)

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INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Governance			
Green public procurement (as an indicator for financing aspects)	The share of major public procurements in the EU that include environmental requirements; Percentage of procurement using environmental criteria compared to total procurement of the city administration, on a one year period	%	RFSC; EU CE Monitoring Framework; SDG 16
Participatory governance	The proportion (%) of citizens involved in participatory governance		European Innovation Partnership on Smart Cities and Communities (EIP SCC). (2013.) Strategic Implementation Plan. Issues 14.10.2013. Brussels: EIP SCC; UNaLab
New forms of financing	The extent to which the project has contributed to, or inspired, the development of new forms of financing (qualitative, unitless)	1 to 5 scale	Bosch et al, 2017 Kabisch, 2016.
Policy learning concerning adapting policies and strategic plans	The extent to which the project has contributed to, or inspired, changes in municipal rules and regulations to support implementation and “mainstreaming” (qualitative, unitless).	1 to 5 scale	Bosch et al, 2017 Wamsler, 2014
Environmental protection expenditures	Environmental protection expenditure of private and public specialised producers, by type		EUROSTAT
Openness of participatory processes	The proportion of public participation processes in a given municipality per 100 000 residents per year	percent	UNaLab; Bosch et al., 2017
Citizens’ awareness regarding urban nature & ecosystem services	The extent to which a project has used opportunities to increase citizen’s awareness of urban nature and ecosystem services, and educate urban citizens about sustainability and the environment	1 to 5 scale	Bosch et al, 2017

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Existence of electronic systems for tracking the municipality's management	Are there effective systems in place to ensure accountability of city government in its management and use of public resources? What are the actions undertaken for developing an accountability/transparency framework that acknowledges the importance of (1) information (through an open data approach), (2) enforcement (focusing on the community and the need to meet customer satisfaction and legal compliance obligations), and (3) participation (based on a partnership approach with an engaged community)?	Yes/no	World Bank, 2018

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Policy			
Electronic systems for tracking the municipality's management	Existence of electronic systems for tracking the municipality's management	y/n	World Bank, 2018; EBRD;
Government accounts audited	Percentage of municipal government accounts audited	%	World Bank, 2018; EBRD;
Climate change strategy	Years since the city's climate change strategic plan was updated (CRI)	Numbe r	World Bank, 2018; EBRD;
Companies publishing sustainability reports	Number of companies publishing sustainability reports	Numbe r	UN SDG 12.6.1
Trust in institutions and public services	Average rating of trust by domain, sex, age and educational attainment level	Linkert scale	EUROSTAT Europe 2020 RE indicators

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INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Education and Training			
Level of education of labor force (GPSC)	Average level of education of labor force		World Bank, 2018; EBRD;
Mainstreaming of environmental education	Extent to which (i) global citizenship education and (ii) education for sustainable development (including climate change education) are mainstreamed in (a) national education policies; (b) curricula; (c) teacher education; and (d) student assessment		UN SDG
Adult education participation rate	Participation rate in education and training (project period) by sex, educational attainment level, age, and labour status		EUROSTAT
Allocation of expenditure of local authority for ongoing vocational training and exchange programmes	Ratio of training expenditure in the local authority on vocational training sessions and/or exchange programmes = (budget of local authority dedicated to vocational training sessions and/or exchange programmes)/(total budget of local authority)	%	SDG 4.7, RFSC

INDICATOR	DEFINITION	UNIT	CITATION(s)
IMPACT AREA: Employment			
Share of Jobs in Environmental Industries	The definition of environmental industries is given by OECD and Eurostat: Environmental industries are activities that produce goods and services capable of measuring, forecasting, mitigating or correcting environmental impacts as pollution, of water, of air, of soil, and problems linked with waste, noise and ecosystems	%	SDG 8, 9; RFSC; DATAR et CGDD, Indicateurs Territoriaux du Développement Durable, 2010; United Nations Environment Programme (UNEP), International Labour Organization (ILO), International Organisation of Employers (IOE), & International Trade Union Confederation (ITUC). (2008). Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World. Nairobi, Kenya: United Nations Publishing Services Section

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Establishment of new businesses	Number of new businesses established in the area surrounding implemented project		UNaLab
Proportion of manufacturing employment	Sectoral breakdown (GDP, employment) and evolution during the last two decades with disaggregation by gender (WDI)		World Bank, 2018; EBRD;
	Manufacturing employment as a proportion of total employment (SDGs)		World Bank, 2018; EBRD;
Youth unemployment	Youth unemployment rate (CPI)		World Bank, 2018; EBRD;
Unemployment rate	Unemployment rate (percentage), and change in rate over time (IDB, CPI, CRI)	%	World Bank, 2018; EBRD;
Proportion of small scale industry	Proportion of small-scale industries in total industry value added	%	UN SDG
Proportion of tech industry	Proportion of medium and high-tech industry value added in total value added	%	UN SDG
Job vacancies	Job vacancy statistics by activity and occupation	num	EUROSTAT Europe 2020 RE indicators
Value added by production in environmental sector	Value added by industry in the environmental goods and services sector		EUROSTAT Europe 2020 RE indicators
Employment in EU environmental economy	Employment in the EU environmental economy by environmental protection and resource management activities		EUROSTAT Europe 2020 RE indicators
Private investments, jobs and gross value added by investment in circular economy	Investment part of the EU's Investment Plan for Europe; Structural and Investment Funds; InnovFin; Circular Economy Finance Support Platform; Sustainable Finance Strategy; Green Employment Initiative; New Skills Agenda for Europe; Internal Market policy		EUROSTAT Europe 2020 RE indicators
Patents related to recycling and secondary raw materials as a proxy for innovation.	Number of patents related to waste management and recycling		EU CE Monitoring Framework

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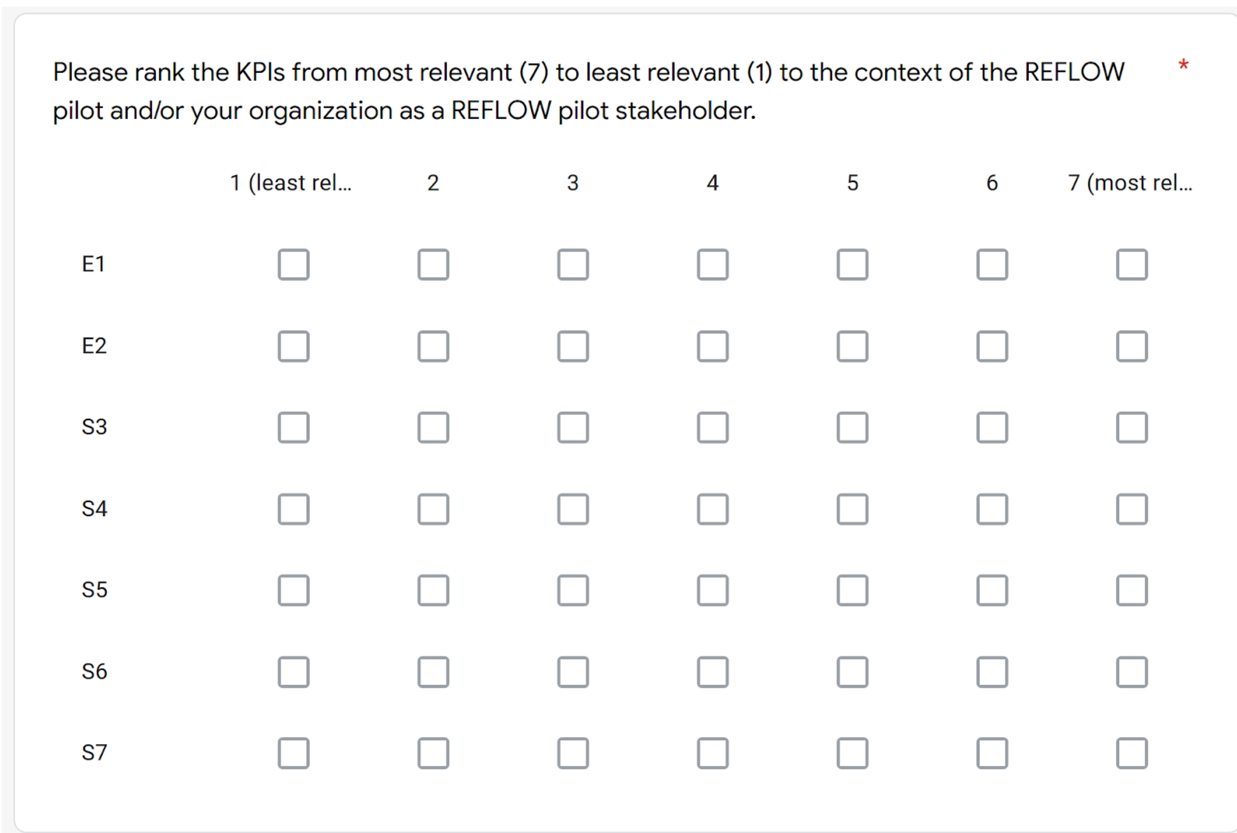
Appendix 3: KPI Ranking methodology

The Single Transfer Vote (STV) count method was used to arrive at the ranked list of shortlisted KPIs for all pilots following a ranking exercise done within the stakeholder survey. The methodology followed for the ranking has been explained below using an example:

Step 1: As part of the stakeholder survey, the pilots were asked to rank the shortlisted KPIs in relation to each other on a scale of least relevant (1) to most relevant (x=number of KPIs on the list), which in this example was 7. The format of the question is shown below:


Please rank the KPIs from most relevant (7) to least relevant (1) to the context of the REFLOW pilot and/or your organization as a REFLOW pilot stakeholder. *

	1 (least rel...	2	3	4	5	6	7 (most rel...
E1							
E2							
S3							
S4							
S5							
S6							
S7							

Graphic 36: Survey question on KPI ranking.

Step 2: Tabulating the responses to the ranking question. In the STV method, the order of ranking matters in deciding how the “transfer of votes” happen, therefore we require both the complete picture of the votes cast as well as the sequence of KPIs in order of preference.

Table 43: Responses to the ranking survey question .

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	E1	E2	S3	S4	S5	S6	S7
Responder 1	7	6	5	4	3	2	1
Responder 2	7	6	4	3	5	2	1
Responder 3	7	2	4	1	3	5	6
Responder 4	6	7	4	2	5	1	3
Responder 5	7	6	5	4	3	2	1

Vote sequence:

Table 44: Sequence of KPIs in order of preference by each responder.

	7	6	5	4	3	2	1
Responder 1	E1	E2	S3	S4	S5	S6	S7
Responder 2	E1	E2	S5	S3	S4	S6	S7
Responder 3	E1	S7	S6	S3	S5	E2	S4
Responder 4	E2	E1	S5	S3	S7	S4	S6
Responder 5	E1	E2	S3	S4	S5	S6	S7

Step 3: A vote distribution table was created. This step marks the number of votes each KPI got for each rank. This table is used as the base for all further rounds of selection.

Table 45: Vote distribution.

	E1	E2	S3	S4	S5	S6	S7
7 (highest rank)	4	1					
6	1	3					1
5			2		2	1	
4			3	2			
3				1	3		1
2		1		1		3	
1 (lowest rank)				1		1	3

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Step 4: Calculating the droop quota.The Droop quota acts as the minimum threshold a KPI needs to cross to be selected. It is an extension of requiring a 50% + 1 majority in single-winner elections. Here, it has been calculated as (Equation 1):

$$(Number\ of\ valid\ votes/number\ of\ KPIs) + 1$$

For the example, the droop quota was = (5/7)+1 = 1.7
It is acceptable for the number to be in a fraction and not rounded off when the number of votes are low, which is true in this example.

Step 5: Rounds of selection. Using the vote distribution table, the order of ranks by each responder and the droop quota, the following steps are followed starting from the top and moving towards the bottom of the vote distribution table (table xx):

1. A KPI which has reached or exceeded the quota is declared selected.
2. If any such selected KPI has more votes than the quota, surplus votes are transferred to other KPI proportionally based on their next indicated choice on all the votes that had been awarded to that KPI. The amount transferred to the second KPI is calculated using the following equation (equation 2):

$$Votes\ transferred\ to\ the\ next\ preferred\ KPI = \left(\frac{votes\ for\ next\ preference\ belonging\ to\ the\ original\ selected\ KPI}{Total\ votes\ for\ original\ selected\ KPI}\right) * Surplus$$

3. This process repeats until all KPIs have been ranked from first till last selection.

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Example

Round 1:

Table 46: Round 1 of STV count method.

		E1	E2	S3	S4	S5	S6	S7
Round 1	7	4	1					
	6	1	3					1
	5			2		2	1	
	4			3	2			
	3				1	3		1
	2		1		1		3	
	1				1		1	3

Since E1 has 4 votes as the highest preference, it crosses the droop quota of 1.7 with a surplus of 2.3 votes. These votes are now transferred to the KPIs which were the second preference according to table 44 . E2 and S7 are distributed the surplus according to equation 2.

Table 47: Vote transfer calculator from round 1 of STV count method.

Surplus	From	To	Amount
2.3	E1	E2	1.7
		S7	0.6

As we move down from the first round to the second, all votes remaining from round one of the unselected KPIs are carried over to the next round in addition to any surplus received from the first selected KPI.

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Round 2:

Table 48: Round 2 of STV count method.

		E1	E2	S3	S4	S5	S6	S7
	7	1.7						
Round 2	6	1	5.7					1.6
	5			2		2	1	
	4			3	2			
	3				1	3		1
	2		1		1		3	
	1				1		1	3

Here, E2 shows a total votes of 5.7 as a sum of (votes from first round + votes from second round + surplus received from E1) = (1 + 3 + 1.7). It surpasses the droop quota and is therefore selected in 2nd position in the ranked list. The surplus of 4 (total votes - droop quota) is transferred to the KPIs which have been given the next preference by all the responders.

S7 has a cumulative of 1.6 as a sum of (votes from first round + votes from second round + surplus received from E1) = (0 + 1 + 0.6). It does not reach the droop quota of 1.7, therefore does not get selected in this round.

Last Round:

In a similar fashion to round 1 and 2, the process is repeated till all KPIs are ranked, which in this case was a total of 6 rounds. At each stage, all KPIs that achieve the droop quota are selected, which may be 1, 2 or more. At a stage where multiple KPIs are selected, the rank is based on the number of votes they achieved till selection. The higher the number, the higher the KPI on the list.

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At the end of the process, we reach a table with all KPIs selected in this format:

Table 49: Final ranking round using STV count method.

		E1	E2	S3	S4	S5	S6	S7
	7	1st						
	6		2nd					
	5			3rd		4th		
	4				5th			
	3							6th
ROUND 6	2						7th	
	1							

Step 6: Comparing the final list to a cumulative vote count to check any major deviation(s).

The STV list is compared to the cumulative vote count, where the list is ranked by the total of the votes received in response to the survey ranking question as seen in table 43.

Table 50: Rank comparison between CVC method and STV method.

CVC ranked list	STVC ranked list
E1	E1
E2	E2
S3	S3
S5	S5
S4	S4
S6	S7
S7	S6

No major variation is seen between the two ranking schemes apart from the shuffle in position of S7, which in totality had a low vote count, but was marked as 2nd most relevant by one responder. The STV method takes that preference into account thus resulting in S7 achieving a slightly higher rank in the final list.

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