
# Circularity by design

Toolbox for design choices in the urban environment

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# Reading Guide

## Introduction

Within the Flagship Project Circularity by Design (CbD) (2019-2022), we have applied (re)design principles to develop a sustainable agrifood system within the Amsterdam Metropolitan Region. The critical question is how to increase the circular use of bio-organic streams of food, feed, biomaterials and waste within the urban environment. How to prevent inefficiencies and to valorise and upcycle surpluses and wastes? Taking an integrated approach, we have developed a number of tools to support assessment, selection and decision making and the stakeholder governance process. These have been co-created in the living labs, or CbD 'challenges' in the city of Amsterdam, with support of AMS Institute. By design means intentionally taking the circularity principles of "Safeguard-Avoid-Prioritise-Recycle-Enthropy" as lead criteria for developing and implementing initiatives. We need to changing together to bring the transition towards a circular bioeconomy on challenge and city level within reach.

This interactive pdf has been developed in such a way that it may be of use for other cities' stakeholders across the globe to start designing their own circularity approach. This brochure presents various tools, and acts as a guide, or simply to inform yourself and your colleagues/peers.

## Summary

Both the world and urban population are on the rise. Expectations indicated that approximately 75% of the world's inhabitants will live in urban areas by 2050. This burdens the current agri-food system and we need to start taking a circular approach to be able to feed the ever-expanding cities.

The Circularity by Design Toolbox presents guidance and examples for the urban environment. It describes 4 tools on the Governance for Circularity (Governance Roadmap), Circular Animal Feed (Classification Tool), Circular Biomaterials (Circularity Dashboard) and Circular Sanitation (Application of black & grey water), as well the overall Circularity by Design Principles.

## Colophon

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# Governance for circularity

Governance is about developing a match between the contextual systemic aspects of power relations, the broader economy and environment, and the intended results of more circularity based on trust, social equity and respect. This match is sought through the translation into ambition and the intends, the inclusion of various groups and the co-creation, the rules and organisation, the incentives and opportunities.

Identifying the issue, the relevant systemic features and matching governance means that there is a view to who the participants and stakeholders are. And by that, the process of identifying the deeper values involved is started. For stimulating a transition process, the question is how to develop links between a strategic, a tactical and an operational level. The strategic level represents the societal values, like public safety, environmental quality, welfare and care for future generations. The tactical level covers social safety, cohesion, opportunities to express one's identity, respect. The operational level embraces the interpersonal values of motivation, enthusiasm, skills etc.

The governance challenges are related to the ability to achieve a co-creation of circular solutions where both the scale of the operation and social aspects are included in the process. It is about working at multiple levels, from local to (inter)national. It is also about enhancing and employing the social structures involved, using the powers of social relations and shared values and other cognitive aspects. For every issue it is of great importance to identify and engage problem owners and convince them about their role and responsibilities. The aim is to arrive at a co-creation of coherent circular solutions based on trust. But the road to co-creation calls for a range of interactions, from informing, consulting to collaborating with the stakeholders.

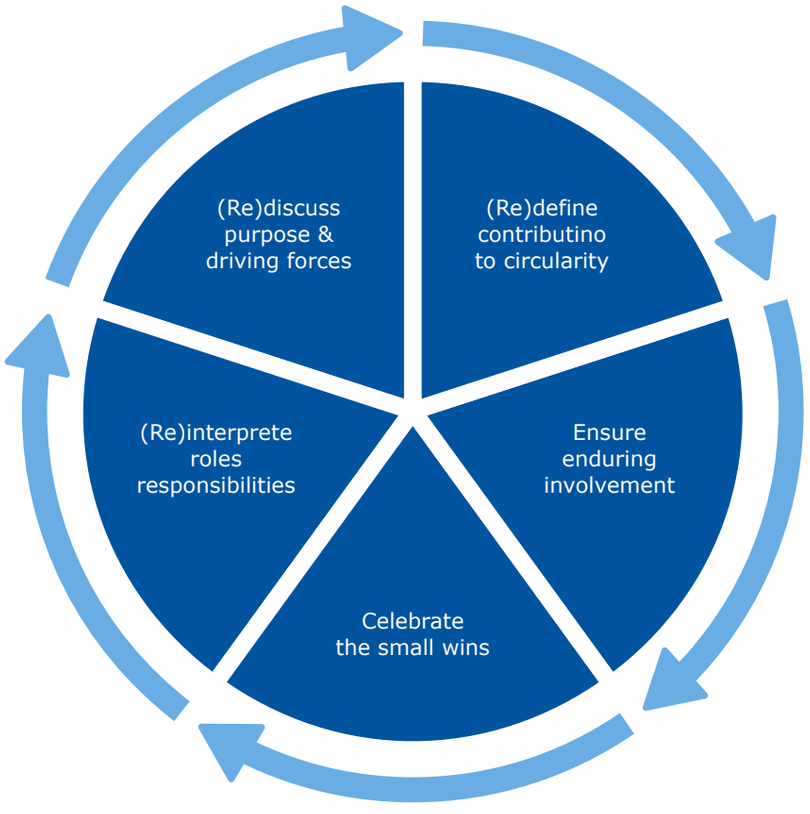


# Governance Roadmap

In the interactions with stakeholders we came up with some of the essential aspects needed for defining the steps forward. The crucial distinction made is the one between the technical and the social/societal side of the process or project in question. It is this distinction that creates the ability to define and (continuously) redefine the values, ambitions and priorities involved, and allow solid efforts to remove barriers and create or enhance the incentives involved.

**Governance**

- Values & ambitions
- Inclusion & co-creation
- Rules & organisation
- Incentives & opportunities
- Ownership & responsibilities




**Emerging results**

- Enhanced self-organisation
- Enthusiasm & trust
- Adds to social equity & respect
- Inclusive social networks
- Achievements acknowledged

## Steps in the process

**Step 1: Demarcation of project's social system**
A joint search for and definition of the aim, scope and boundaries of the system influenced by the project. For this a description is needed of what to achieve in concrete terms, spell out why this contributes to the circularity ambitions and link the description to the relevant context. As the process of implementation evolve, this exercise should be repeated in order to sharpen the focus.

**Step 2: Define the involvement of stakeholders**
Identify the relevant and needed persons, groups, organisations and networks that shape the social capital in the system. This could be for the project team, with connections to for instance the local government, neighborhood commissions or other community-based groups. It is also about finding ways to become and stay involved; decide the level of participation needed, with the direct or indirect involvement. Here we see a need for plan for the participation and the communication. This step is about both the type of concrete involvement and about the type of involvement needed to make things work.

**Step 3: Specify the tasks, responsibilities and costs for the social process**
Step three goes further than step 2. The social process of any project or programme is easily underestimated. It is often a time-consuming, uncertain, volatile and costly process. It is vital to take the changeable and uncertain character of the process into scrutiny. It is important to define the roles and responsibilities of the tasks involved. And by that also define who is paying for the social process. Often the hard decision points are revealed when the bill is presented. This might be challenging in a complex process of project commissioners, team, contractors and sub-contractors.

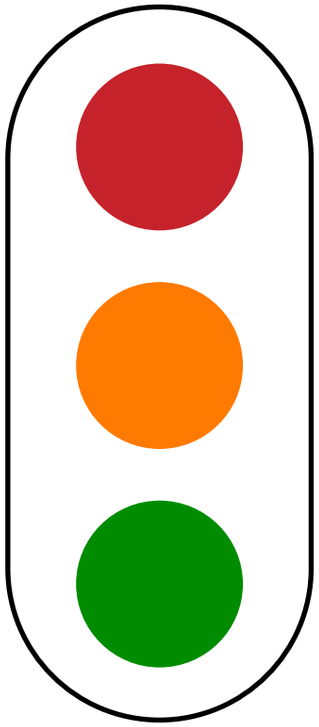
**Step 4: Conduct a recurring discussion of the intentions and driving forces behind the involvement of everyone**
Circularity is not necessarily the driving force behind everybody's action. The task is then to conduct a frequent or at least recurring discussion of the intentions and how these link up to how the intentions can bring the AMS goals to impact. This offers opportunities to discuss changes and possibilities to mitigate negative impacts.

**Step 5: Celebrate small wins**
We propose to include a process of celebrating small wins (Weick, 2001; 2009). Despite a deep engagement in circularity, the interest in any given issue soon diminishes without results, and people wander off bored (Weick 2001: 440). A sound transition scheme, therefore, must be aware of the small wins (Selnes and Termeer, 2011). Celebrating small wins refer to the identification and display of minor successes on the long road to circularity. The challenge is to orchestrate a process whereby taking distance from the original problem definition is central. Lessons that are complex but more recently learned usually have a better chance of producing lasting changes in perceptions (Weick 2001). Small wins might even engineer great success. By itself, one small win may seem unimportant. Much of the artfulness in working with small wins lies in identifying, gathering, and labelling small changes that are present but unnoticed (Weick, 1984). But small failures must also be scrutinised (Weick 2009). For this, much needed motivated critical voices are to be added. There is no substitute for success at the end of the day. And sharing experiences is a good way of working.

# Guidance

The Social Readiness Level (SRL) is here being developed to clear out how mature the process of interaction is, within a project. The SRL is inspired by the TRL, the technical readiness level. The SRL can also be used to stimulate discussions on how to move to a more mature level of development. To simply ‘find out what works and do more of the same’ does not take into account the complex and diverse biophysical, social, and economic contexts that shape circularity. Focus on technological innovations is then vital but should not obscure the behavioural, organisational, and institutional changes that are needed. The usage of SRL could also serve to stimulate critical reflection of bottle-necks and reveal new opportunities for a product, project or programme.

## Stoplight Social Readliness level



| | **Description** | **Indicators** |
|---|---|---|
| | Goals and social process initiated, sign of a fit wit the context, some means allocated bur envisioned applications limited. Mainly innovators at worl.<br>**SRL-1-3** | • Initial plan with goals for public safety and justice, health quality of the environment, respectfor/access to knowledge<br>• Local involvement announced<br>• Project group at work<br>• Budget: < 50k<br>• Number of contacts: <50 |
| | Project and process acknowledged, reliability, participation and trust increases and broadens.<br>**SRL-4-7** | • Plan acknowledged by a government, with priorities for public safety and justice, health, quality of the environment<br>• Project group integrated into multi level decision making<br>• Prototype circular solution in practice<br>• Local involvement planned<br>• Number of contacts: >50 |
| | Project and proces proven and operational, acess to means and decision making. High level of co-creation and trust. Ready for upscaling/spreading.<br>**SRL-8-9** | • Implementation plan approved by government with actual implementation for public safety and justice, health, quality of the environment<br>• Active local involvement (number of events & participation)<br>• Support citizens/NGOs<br>• Project group integrated into multi level decision making<br>• Agreement with municipality on social justice, inclusiveness<br>• Number of contacts: >150 |

| SRL | Description | Description |
|---|---|---|
| 1 | **A project with a goal clearly initiated** | A social project process is initiated, observations of goal directed social interaction are reported. A description of the project is made, containing an initial narrative, objectives, how to deal with participation, with process-steps. Trust inside the community is emerging but limited to a few convinced participants. |
| 2 | **Social process approach formulated** | At this level there is some proof of goal-directed interaction based on a description of the process, with a division of tasks and responsibilities. But envisioned applications are still speculative at this stage. |
| 3 | **Experimental proof of concept** | Collaboration and process development are now clearly initiated. A project group or organisation is established, with some action based on the process set-up; described in a document. A shared community language is emerging. |
| 4 | **The project is supported by local government** | The project (with its social process) is acknowledged by a governmental authority, offering some kind of an official status, an acknowledgement of the narrative, objectives and general operation. There is some evidence that the project might be attainable. Trust spreads out, also outside the project, there is access to means. |
| 5 | **The project is validated in a relevant environment** | The reliability of the (social process of the) project significantly increases. There is a clear and visible broadening of the participation in a process fitting the context, but still in a somewhat simulated environment. First signs of access to decision making. |
| 6 | **The project is demonstrated in a relevant environment** | The social process of the project is verified as functional in the intended system. The social process is matching the (physical) product prototype in a system and demonstrated in a simulated environment. A deeper sense of shared identity and responsibilities is evolving. |
| 7 | **The social process of the project is demonstrated in an operational environment** | A major step for the maturity. A verified social and technical prototype is emerging in an operational environment based on deep involvement in a co-creation. |
| 8 | **The social process of the project is working well and qualified** | The social process and physical product are integrated into an actual functioning system. Widespread trust and substantial access to means and decision making. High level of co-creation. Often this SRL represents the end of development. |
| 9 | **The actual social process of the project is, together with the technical solution, proven in an operational environment** | The system is proven and ready for full public or commercial deployment. Successful deployment by end users. High levels of participation and institutionalisation, based on coherence and trust. High level of recognition to the contribution of a circular society. |

# Circular Animal Feed

Animals have the ability to make food systems more circular. Livestock animals and insects can upcycle food leftover streams from the food system that are inedible for humans into valuable animal proteins, manure and other ecosystem services. Furthermore, it reduces the environmental footprint of pet animals when food leftover streams replace specific primary products in their diet. The Amsterdam Metropolitan Area (AMA) produces a variety of streams that can be used in feed of producing and non-producing animals. However, not all food leftovers are suitable for use in feed. Products have to compile with legislation, be safe, palatable, and nutritious. Here we describe the principles of a systematic for classification and assessing suitability of food leftover streams as potential feedstuff in animal diets.

The systematic has resulted in a tool to practically assess food leftover streams as potential feedstuff in animal diets. The developed systematic was based on a previous screening tool that evaluated food leftover streams' aspects on origin; supply and availability; technical properties; nutritional properties; environmental, social, and corporate governance; economy; food safety and legislation; and upcycling. The systematic developed further includes additional items on food safety and legislation and nutritional properties. Since feeding of food waste streams to animals is not without risks, their safety needs to be assessed. Streams should therefore be assessed for their presence of animal proteins, because of the risk for transmissible spongiform encephalopathy agents, and the risks due to microbial, chemical, and physical hazards.



# Classification Tool

Assessment of the microbial, chemical, and physical hazards (classified as negligible, low, moderate, and high) of six selected food (waste) products when being used as animal feed according to different legislation/risk scenarios.

| Product | Volume in AMA (in ktons)* | Scenario | Microbial TSEs | Microbial other pathogens | Chemical | Physical |
|---|---|---|---|---|---|---|
| **Brewers grain** | 3 | Currently allowed in feed | Negligible[1] | Negligible[1] | Low[5] | Low[8] |
| **Cookies** | 6 | Currently allowed in feed | Negligible[1] | Negligible[1] | Low[5] | Moderate[9] |
| **Candies** | 0.2 | Currently allowed in feed | Negligible[1] | Negligible[1] | Low[5] | Moderate[9] |
| **Processed animal proteins (PAP**) slaughter residues of non-ruminants animal species** | N/A | Feed ban, no feeding of PAP | Negligible | Negligible | Negligible | Negligible |
| | | Restricted feed ban***, allowed but with sterilisation and no cannibalism | Negligible[2] | Negligible[4] | Low[5] | Low[8] |
| | | No feed ban, allowed after sterilisation | Negligible[2] | Negligible[4] | Low[5] | Low[8] |
| | | No feed ban, allowed with no sterilisation | Low[2] | High | Low[5] | Low[8] |
| **Meat and bone meal (MBM**) of non-ruminants animal species** | N/A | Feed ban, no feeding of MBM | Negligible | Negligible | Negligible | Negligible |
| | | Restricted feed ban, still no feeding of MBM | Negligible | Negligible | Negligible | Negligible |
| | | No feed ban, allowed after sterilisation | Negligible[2] | Negligible[4] | High[6] | Low[8] |
| | | No feed ban, allowed with no sterilisation | Low[1] | High | High[6] | Low[8] |
| **Kitchen and household waste** | N/A | Feed ban, no feeding of swill | Negligible | Negligible | Negligible | Negligible |
| | | No feed ban, allowed after sterilisation | Negligible[3] | Negligible[4] | Moderate to high[7] | Moderate[9] |
| | | No feed ban, allowed with no sterilisation | Negligible[3] | Moderate | Moderate to high[7] | Moderate[9] |

* Estimations derived from challenge owners in the CbD project.
** PAPs are category 3 animal by-products; MBM are category 1 and 2 animal by-products.
*** Restricted feed ban: avian animal by-products are fed to pigs, and vice-versa, porcine animal by-products are fed to poultry. Ruminant animal by-products will not be re-used in animal feed.

## Explanation of hazard assessment values

1 Hazards are considered negligible because products do not contain animal proteins.
2 Hazards are considered negligible because it was assumed that the feeding of ruminant animal protein remained prohibited. Hazards were considered slightly higher when products are not sterilised because of accidental contamination with ruminant animal proteins (EFSA Panel on Biological Hazards (BIOHAZ) 2018).
3 Hazards are considered negligible because it was assumed that category 1 and 2 animal by-products (which are considered specific risk material for TSEs) will not be used in food (and therefore do not end up in kitchen and household waste). Moreover, it was assumed that category 1 and 2 animal by-products from ruminants will not be used in feed either.
4 Hazards are considered negligible because sterilisation is assumed to kill pathogens rapidly (Dame-Korevaar et al. 2021).
5 Although hazards may be present, they are considered low because products originate from the food industry with high manufacturing standards. Furthermore, most mycotoxins are metabolised by animals and will therefore not accumulate in the system (Focker et al. 2022).
6 The Dioxin contaminated products fall under category 1 animal by-products and dioxins are only degraded at high temperatures (>850°C). The hazard is therefore considered high.
7 Kitchen and household waste may contain heavy metals and dioxins up to or exceeding EU limits (Dou, Toth, and Westendorf 2018). Hazards are therefore considered moderate to high.
8 Although hazards may be present, they are considered low because products originate from the food industry with high manufacturing standards.
9 Products are assumed to become mostly free of physical hazards, such as packaging material, contamination (kitchen knives), due to several removal procedures (sieving, magnetic attraction, eddy current separation or density methods) but small amounts may still be present (Pinotti et al. 2019).

# Guidance

Any product that is considered as a feedstuff should be first described in terms of the following aspects

1 **Origin;** includes required information on the name of the product, process/industry where the product originates, production process, supplier, region, and tracking-and-tracing. Though not addressed in the screening tool, the genetic origin(s) of the product are valuable for the classification (see Table 1 in Appendix 1) and should be documented.

2 **Supply and availability;** includes required information on available volume per year, frequency of availability, storage stability, and the strategic interest of the supplier to have an alternative sales channel on the long term. Though not addressed in the screening tool, the degree of temporal variability in quality is relevant to know.

3 **Technical properties;** includes required information on capacity of the feed producer/farm to effectively store and process the product, and any required on-site separation of the product (e.g. in relation to processed-animal-proteins, nGMO). Though not addressed in the screening tool, physical properties (consistency as in from dry solid to liquid and particle size as in from large structures to fine (ground) particles) is relevant to know.

4 **Nutritional properties;** includes required information on similar products with known nutritional properties, class of feedstuffs the product belongs to (see Table 3 in Appendix 1), potential target animal category, and shadow price (range; used in linear programming for formulating recipes of animal diets) for specific target animal category. Additional considerations regarding nutritional properties to include in the tool are outlined below.

5 **Environmental, social, and corporate governance (ESG);** includes required information on certificates relevant to ESG, if the product originates from an ESG-critical region, strategies of the supplier to mitigate ESG-related risks, degree of supplanting cropland for human-edible food products, whether the product is a co-product or side stream and if so from what, contribution to the value of the ESG-criteria, and whether the environmental impact is quantified (PEFCR-compliant) and available in reputable databases (e.g. GFLI, FeedPrint).

6 **Economy;** includes required information on the product price and its pricing, and to which commodities the price is linked.

7 **Food safety and legislation;** includes required information on GMP+ certification (or equivalent) of the product, presence of SecureFeed certification, and, in case deemed required, whether the product adheres to additional requirements (e.g. SKAL, GMO-free, soy-free) and presence of relevant certificates. Additional considerations regarding food safety and legislation to include in the tool are outlined below.

8 **Upcycling;** includes required information on potential better valorisation as a feedstuff and what is needed to improve opportunities to upcycle the product.



# Circular Biomaterials

How to make a choice what technology or innovation to valorise biomaterials? During the design phase of any initiative or development within the city, the 'challenge owners' will be facing some difficult choices: a multitude of different biomaterials need to be included in the design. After taking inventory of materials, wastes and potential valorisation options, how do you know what is the best choice for your challenge? The circularity Dashboard helps to make that choice. We illustrate the use of this tool by the example of the Green Tower in the *Bijlmer Bajes Kwartier* as one of the CbD project Challenges. The 1200 households and 70 business that are projected for the Green Tower will be generating approximately 200 tonnes of organic wastes annually, including mainly kitchen wastes. Within the challenge, the following seven options for valorising these biomaterials were identified:

1 Conversion into compost
2 Conversion into biogas, the residue is converted into compost
3 Chemistry (production of caproic acid by the Amsterdam company ChainCraft)
4 Production of bioplastics (PHA: poly-hydroxy-alkanoate)
5 Use feed for pigs
6 Use as feed for insects
7 Conversion into insect chitin

Choosing between various options for residue valorisation is common practice in the biobased economy. Traditionally, mostly economic considerations and technological feasibility prevail in the selection process. However, selection based on the degree of circularity is becoming a necessity and will require the inclusion of additional indicators. Within the Circularity Dashboard, the following selection indicators were included:

1 Product value
2 Mass conversion factor
3 Maintaining functionality
4 Regional utilisation
5 Matching volumes
6 Legal aspects
7 Public opinion
8 Government policy
9 Challenge owner opinion/preferences
10 Cost/benefit
11 Technological Readiness Level (TRL)
12 GHG emission reduction



# Circularity Dashboard

The circularity dashboard: indicators of circularity, prerequisites and stimulating factors for seven valorisation options for kitchen waste in the Green Tower. Where no numerical value was possible, a 3-level color coding can be applied: green is favorable, orange is medium and red is unfavorable. The results will then allow the stakeholders for improved decision making, as it informs them on the various indicators choice across the valorisation options.

| | Compost | Biogas | Chemicals | Bioplastics | Pig feed | Insect feed | Chitin |
|---|---|---|---|---|---|---|---|
| **Product value** (€/ton) | 15 | 1540 $CH_4$ | 3500 caproic | 3500 PHA | 40 | 40 | 4444 |
| **Mass conversion factor** (kg product/ton GF+E) | 150 | 64 $CH_4$<br>150 compost | 100 caproic<br>150 compost | 22 PHA<br>150 compost | 1000 | 1000 | 1 chitin<br>185 compost |
| **Maintaining functionality** | ▲ | ▲ | ■ | ■ | ● | ● | ● |
| **Regional utilisation** | ● | ● | ■ | ■ | ● | ● | ● |
| **Matching volumes** | ● | ● | ● | ● | ● | ● | ● |
| **Legal aspects** | ● | ● | ● | ● | ▲ | ▲ | ● |
| **Public opinion** | ● | ● | ● | ● | ● | ● | ● |
| **Government policy** | ■ | ● | ● | ● | ▲ | ● | ● |
| **Challenge owner opinion** | ■ | ● | ● | ● | ● | ● | ● |
| **Cost/benefit** | ■ | ■ | ● | ■ | ● | ● | ● |
| **TRL-level** | 9 | 9 | 8 | 7 | 9 | 9 | 9 |
| **GHG emission reduction** (kg $CO_2$-eq./ton GF+E) | Low | 176 | 63 | 78 | 92 | 92 | 1.5 |

● High score
■ Medium score
▲ Low score



# Guidance

The Circularity Dashboard is a useful tool to select various valorisation options for biomaterials, exemplified by organic kitchen waste. It summarises all information in one table.

The dashboard used in the study is just an example, more indicators can be added. The scoring of the non-numerical values is subjective and depends on the interpretation and standards of the users (mostly a team of experts and decision makers). The information can be used to select the most favorable valorisation routes but it also shows promising options with only a few bottle necks that may be solved by research and development or by change of policy.

Learning experiences:

- Dare to estimate when exact data are not readily available
- The composition of the biomaterials (here: organic kitchen waste) covered is dynamic: amounts can potentially
  change dramatically after the dashboard has been made
- List of criteria and their weight depends on priorities of the users
- Compare valorisation/recycle options for your biomaterials
- Compare your current choice or preference with alternative routes
- The Circularity Dashboard can also be used the other way round by starting with the desired outcome of the upcycling/valorisation route: what do the end-users need? And which alternative biomaterals and valorisation routes can be appliedd to achieve those desired outcomes?

# Circular Sanitation

In the food system, an important residual stream in terms of nutrients is wastewater, in cities especially coming from household sources. At the moment, the conventional system from soil to food to sewage is organised in a linear way, without nutrient recovery. These valuable nutrients are lost for use within the agri-food system. Circular sanitation can enable better recycling of nutrients. It can deliver nutrients and fertiliser products to replace unsustainable (imported) synthetic fertilisers. By enabling the reuse of nutrients locally, it decreases the need for transport as well. Circular sanitation provides a potential to minimise existing costs or bring additional financial and environmental value for companies and society.

The term ‘circular sanitation’(CS, sometimes called ‘new sanitation’ as well) is used for sanitation that deals differently with wastewater than conventionally done, with the aim to process wastewater effectively and sustainably. Wastewater is not seen, named or classified as waste, but as a raw material from which energy and nutrients can be recovered.

Circular sanitation is used to indicate one or a combination of the following options:

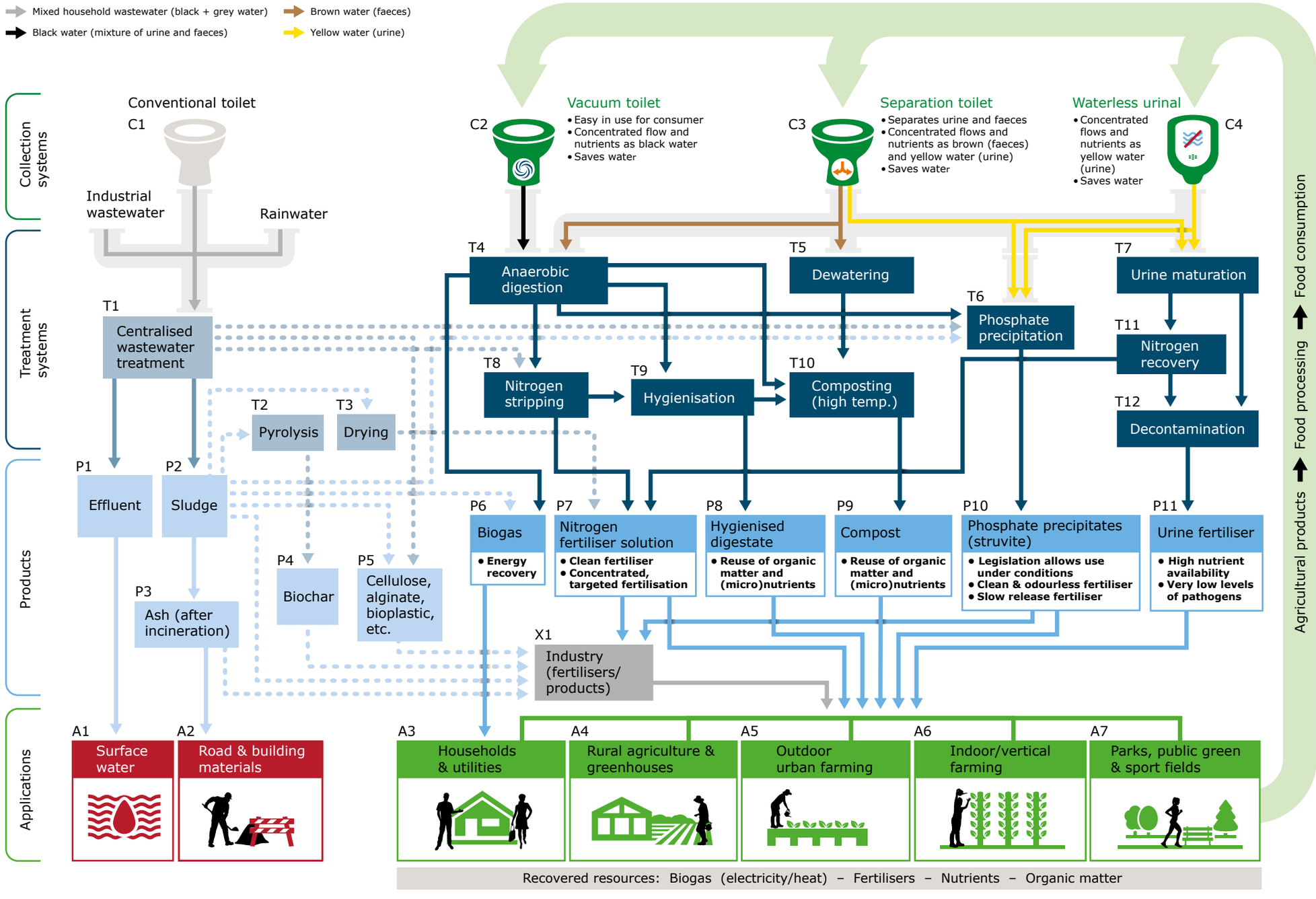
1 Source-separated sanitation: sanitation systems in which urine and/or faeces are separated from other wastewater streams (e.g., from the shower)
2 Decentralised sanitation: small-scale sanitation systems that have a wastewater treatment system separate from the centralised communal wastewater treatment.

Separating urine and faeces enables better reuse of nutrients (i.e. use as fertilisers) because the flow and nutrients are more concentrated and less contaminated. In this way risks can be reduced. For example because:

- Urine can be kept separate and is not contaminated with e.g., pathogens from faeces
- Sanitation streams are not mixed with other household wastewater or wastewater from industry.



# Application of black & grey water




Overview of (present, cetralised) conventional wastewater treatment system (left, lighter colors) and (right, darker colors), and most important/relevant existing and potential routes for recycling of nutrients and other resources (circularity), including collection, treatment, products and applications.

# Guidance

Potential routes for circularity in sanitation systems are shown in the infographic in Figure 24. Four levels in the routes are shown in the infographic:

1 **Collection systems** (top layer ●)
These are the toilet systems. The toilet systems mainly differ in water usage (dilution of nutrients) and separation at source of waste streams. A conventional toilet (C1 in infographic) leads to a mixture of urine, faeces, flush water and grey water (water from other household systems, e.g. bathroom and kitchen), here visualised with a grey arrow. Vacuum toilets (C2) use very little water and keep the sanitation stream separate from grey water, resulting in a so-called black water stream. Separation toilets (C3) can keep urine and faeces (source) separate, creating both a yellow water and a brown water flow. Waterless urinals (C4) only collect urine and therefore lead to a concentrated nutrient solution in the form of yellow water.

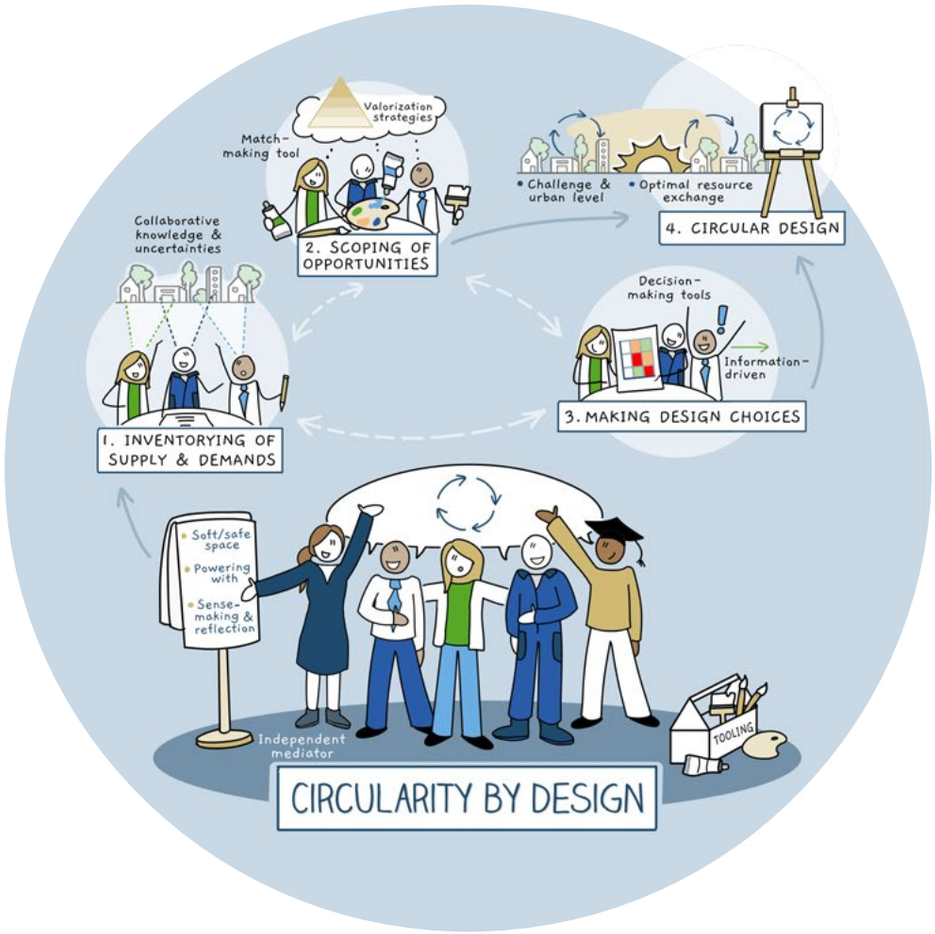
2 **Treatment systems** (second layer ●)
These are systems that treat wastewater streams e.g. to reduce mass by removing water and make sludge, to up concentrate flows, make streams safer for use by eliminating pathogens, and/or recover nutrients as fertilisers, biogas and other resources ready for (re)use. Treatment can be low-tech or high-tech and can be at different spatial scales (centralised versus decentralised).

3 **Products** (third layer ●)
These are materials and resources resulting from treatment of sanitation streams. Many products can be used in some way to recycle nutrients or organic matter as fertilisers (P7-P11), or fibres (P5) or energy (P6). Products can be solid or liquid or gaseous. Some products could/must be further treated in the industry (X1, grey box), for nutrient rich products in the mineral fertiliser industry to make clean and safe (mineral) fertilisers, e.g. for ashes (P3). Or there can be a need to up concentrate products or mix products with other nutrient-rich streams to get a higher quality liquid and/or organic fertiliser with better nutrient composition, for example for struvite (P10) and ammonium sulphate (nutrient rich solutions, P7).

4 **Applications** (bottom layer ●)
These are the type of use and locations in which products resulting from treatment of circular sanitation streams could be used effectively (A3-A7). Most of these applications are related to (urban) agriculture for food production (A4-A6), but products from circular sanitation can also be used for fertilisation of non-food plants in households and utilities such as flowers and plants (A3), and parks, public green and sport (grass) fields (A7). Streams which have more risks in terms of contaminants like pathogens, heavy metals and organic pollutants can preferably be used for non-food plant fertilisation, whereas streams with less risks (e.g. urine, struvite and ammonium sulphate) could be more relevant in food crop production.



# Circularity by Design Principles




## The importance of a Circular Design perspective for the urban environment

Relatively simple questions guided the research: What does circularity mean within the city context, for example, what happens if you try to close the loop of food and biomass resources, and how can you connect producers, services and consumers in the urban environment? To answer these questions, one needs to look into the meaning of design and urban in relation to the circular bio-economy.

Design indicates that something is ***intentional***, from the onset and throughout. Design does not happen spontaneously, and it cannot be left to its own devises. To support the design process, you need an ***independent mediator*** who stimulates interaction between all actors involved. The interaction needs to have a co-creative process, which itself needs a soft and safe space for 'designers' to work in. Those involved are committed to ***sense-making and reflection***, which is not necessarily easy or in step with any leading consensus. Designers are working with – not over – each other. Design also presumes the stage ***before implementation***. However, a design typically does not start with a blank sheet: There are likely existing preconditions and even physical elements to take into account (e.g., buildings, infrastructure, organisations' preferences).

Circularity within the urban environment raises important questions about ***feasibility***: How circular can a city become? With an ever-growing urban population, the city itself will never produce enough food for its inhabitants. On the other hand, what citizens eat and use influences the demand for resources heavily and shapes supply chains and the regions where food and bio-materials are produced. We are left with additional questions: What is the optimal balance where inputs and outputs operate in an ***optimal exchange of resources***, fitting the societal context and needs of citizens? Increasingly, cities are recognised for the role they play in the food system. Ambitions and strategies are being developed to become climate neutral, sustainable, healthy, etc. Circularity by design helps to turn that dream off in the distance into applicable practice. It also ***connects grassroots-level challenges with urban-level achievements***.

# CbD Concept

## A circularity-by-design approach

It is aimed to arrive at better designs than the current linear practice. Working with AMS Institute and Challenge Owners from the Amsterdam Metropolitan Area (AMA), we constructed tools to support cities, municipalities and regions in their transition towards a circular bio-economy. Our results inform and encourage stakeholders at the urban and regional levels across the globe to take this circularity-by-design approach. The approach consists of four steps:

**Step 1: Taking inventory of supply and demand**
The scope of what one person sees is limited, and it bears pointing out that a person does not know what he or she does not know: Combining insights into collaborative knowledge brings insights to the table and creates a common knowledge base. While you are gaining a clearer picture about the demands and supplies regarding resources needs and functions, you will also learn about uncertainties, gaps and disagreements. Only when these wrinkles are front and centre will you be able to work with and around them. To support this inventory step, we have created a circular bio-economy database for by-products within AMA as an example. It is not easy to collect data with sufficient quality, but improvements can be made: The data are meant to help establish ambition levels and also to be able to determine what consequences opportunities or design choices have.

**Step 2: Assessing the scope of opportunities**
You also need options: what techniques, concepts or solutions can help to create your circular design? What is readily available, and what would be interesting to pursue? A resource-oriented question such as ‘What can you do with elephant manure?’ can be a good starting point, but also good starting points might be the creation of a circular communal living site or the redevelopment of a whole high-rise neighbourhood. Cities are neither built in a day or built for only a day – the expectation is that they last a lifetime, or even centuries! Options do not necessarily need to be fancy or high-tech: they need to point towards what will become the new normal on how to circulate agri-food resources within the city.

**Step 3: Making design choices**
Resources can be allocated for very different uses, such as for food, feed, bio-materials or improving soil in neighbouring farms. Matching demands with options requires answering questions such as ‘What will be the best choice for the specific challenge?’ and ‘How can I compare different options?’ Each option will have a different ‘scorecard’ with regards to socio-economic and environmental indicators, allowing to prioritise options. We have delivered a set of tools that provide users with a ‘one-glance’ overview of different valorisation strategies and help for making choices that fit the context and ambitions of stakeholders involved.

**Step 4: Circular design**
The previous three steps do not necessarily follow a chronological order: circumstances and people involved can change during the design process, in which case it is beneficial to retrace your steps and adjust where needed. The example challenges from the ‘Circularity by Design’ project function as inspiration and demonstrate that it can be done. They vary in terms of both magnitude and ambition. This is inherent to the design process: priorities vary, and that is fine with us. Besides, we would like to continue exploring!

# Guidance

**Aim at circular designs: be ambitious!**
Circularity invokes new and radical ideas to be brought to the table because it drives discussion, sense-making and involvement. It requires people to ***look at the full picture***. Circular designs are ambitious, robust solutions that transcend individual issues. It is not a patchwork or 'self-serve buffet' of so-called environmentally-friendly technologies. It ***avoids fragmentation*** when applied from the start onwards.

The circularity-by-design approach follows the five circularity principles, delivers an optimal resource exchange, develops a shared language and provides a better understanding among people involved; finally, it allows the selection of solutions that fit the needs of the city.

**Set yourself up for success: include the scientific community**
Scientists are ***joining forces with*** stakeholders from the city. Quick-win actions can be undertaken on one's one and do not need an elaborate approach. However, those actions which really contribute to circularity will benefit from taking a wider perspective, utilising the comparison of options and stressing the importance of making choices jointly. A ***scientific foundation*** is beneficial to achieve balanced choices, to prioritise efforts and to help mitigate 'intuitive' choices towards transformative choices. Circular design creation requires ***knowledge about the alternatives***. Scientific organisations are a treasure trove of expertise, sources and understanding of the matter; these organisations can more easily digest information and make it accessible to the municipality. However, as academics, we are not mere ivory tower know-it-alls lacking empathy for what is happening in the city. We are curious people, and we like to solve puzzles together.

**Stimulate parametrisation and data availability**
It is crucial to collect data, facts and opinions that should be used to make design choices, thereby turning data into information and making it accessible. Not surprisingly, the research team immediately encountered a lack of data on available resources in the City of Amsterdam. This lack of sufficient data is very likely to be the same for other cities and regions, even across the globe. Knowledge about the resources helps to better understand local phenomena and, therefore, will lead to better design choices. ***Dynamic data platforms*** can be used to track and monitor circularity performance over time and ***feed match-making and decision-making tools***. Supporting tools from the research include, e.g., the 'Circularity Dashboard' to select optimal allocation of resources for challenge owners and in circularity hotspots at city level. The platforms are dynamic as they will need continuous data updates as circumstances change over time.

**Connections lead to better choices**
Collaboration is key, as also seen in the 'accelerating' flagship project. It is people who drive change – not technology. Circularity can be designed, but only by different stakeholders, at the same time and at the same table. The design team should be ***'multi'***: multi-actor, multi-stakeholder and multi-disciplinary. It takes time to understand the needs and desires of challenge owners and stakeholders, for all to speak the same design language. But doing so will pay off with better designs. Cooperation might also lead to related solutions in other fields (e.g., water, other materials, climate), since in cooperating you can get to know each other('s issues) better. Circularity by Design increases social capital. All actors have a role to play in connecting for circularity.

**Become an owner yourself**
High ambitions attract **frontrunners** like bees to honey. These 'challenge **owners**' who are not afraid to move forward, even when not all solutions are available yet – these people develop as they go. They do not use low Technology Readiness Levels (TRLs) as a delay tactic, but rather as an advantage. Challenge owners assume ownership and feel responsible for finding solutions. It might look hopeless from the outse – multi-problems, nightmarish legislation, unwilling parties – but it is important to find ways to engage more people, keeping thresholds low and easy for people to join in.

As an urban stakeholder, we invite each of you to also become a frontrunner, to **lead by example**, to become a launching customer and to be demanding of circular designs related to any biomass flows in your city. **Personal commitment** is important. If this commitment is a mask for (political) gains, it will lead to wavering support. In addition, we call out to avoid fragmented voices, i.e. we speak with one voice across departments.