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Circular food chains and cascading of biomass in metropolitan regions

Vision on metropolitan biorefinery concepts in relation to resource-efficient cities

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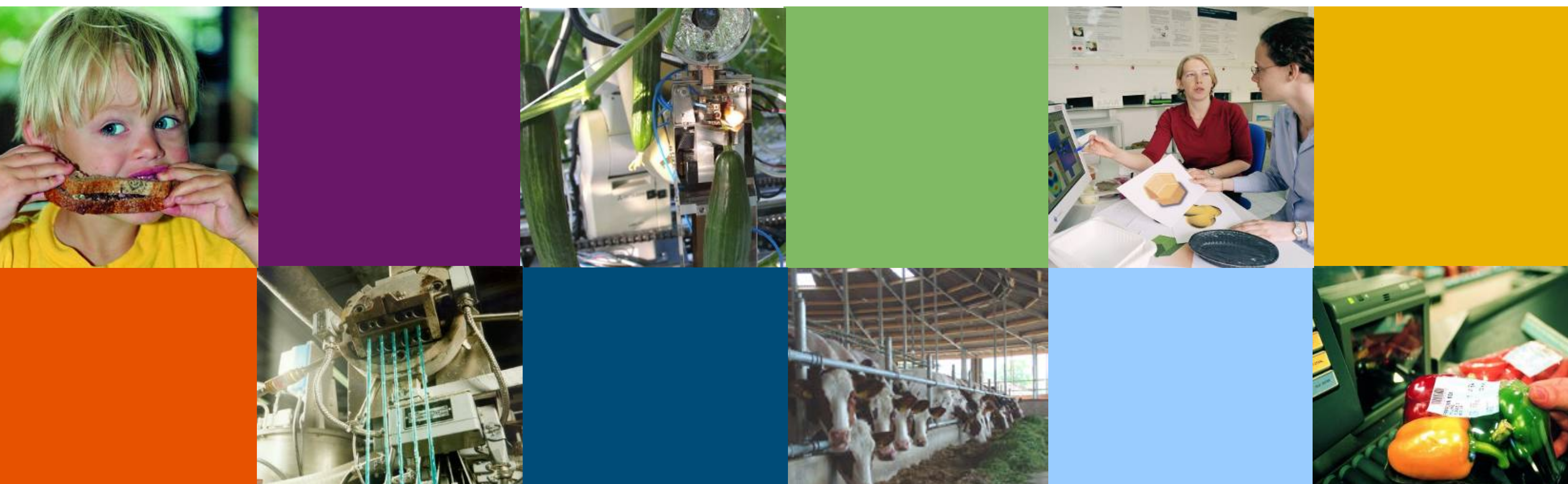
Report 1790



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Abstract

Expectations are that 80 percent of the global population will reside in urban areas by the year 2050. As urbanisation levels increase so do ecological footprint sizes in these areas, as it is in the cities that income levels are higher, and where higher levels of disposable incomes exist. Whereas the circular economy is gaining ground as a concept for increasing sustainability by the efficient use of available materials and resources, urban areas are often recognised as attractive starting points for making the transition towards a circular economy. The paper "Circular food chains and cascading of biomass in metropolitan regions" contains the description of a vision on how biorefinery concepts in current and future metropoles may contribute to the increased efficiency in the use of resources for biomass production. As such this vision forms the interpretation of the principles of the circular economy within the context of biomass value chains and within the geographic boundaries of a metropolitan region. This is also referred to as the circular metropolitan system. With this paper researchers from Wageningen Food & Biobased Research intend to contribute to a scientific basis for increasing resource use efficiency in metropolitan regions through developing appropriate and sustainable biorefinery concepts.

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Content

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1 Metropolitan context and the pressure on resources

'*All cities, big and small, can and must help build the sustainable, resilient food systems of the future*'. This statement by FAO's Director José Graziano da Silva at a summit in 2016 of mayors from all over the world, stresses the necessity of involving the cities in the solution for increasing global nutrition security within the boundaries of resource use efficiency. 'Rapid urbanisation puts pressure on food systems and natural resources', according to the FAO Director (Graziano da Silva, 2016). After all, cities form the habitat for an increasing number of people that all consume food products and produce waste.

In 2014, there were 28 mega-cities worldwide, home to 453 million people or about 12 percent of the world's urban population (Figure 1). Of today's 28 mega-cities, sixteen are located in Asia, four in Latin America, three each in Africa and Europe, and two in Northern America. By 2030, the world is projected to have 41 mega-cities with 10 million inhabitants or more. Projections for 2030 indicate that more people will live in smaller urban areas than in megacities in the medium-term future. Overall, nearly half of the world's 3.9 billion urban population resides in relatively small settlements with fewer than 500,000 inhabitants (United Nations, 2014). Expectations are that by 2050 80% of the global population will live in urban areas (De Wilde, 2015). The largest growth of urban areas can be found in African and Asian regions although even a European city like Amsterdam has grown 12% the last decade (CBS, 2016).

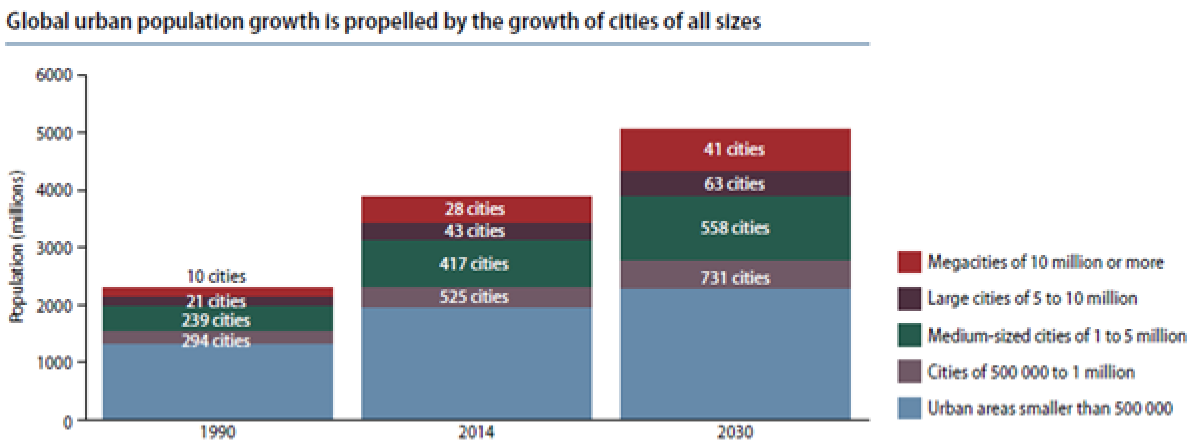

Figure 1 Global urbanization 1990-2030 **(**Source: United Nations, 2014**).**

As urbanisation levels increase so do ecological footprint sizes, as it is in the cities that income levels are higher, and where higher levels of disposable incomes exists. Cities can consume up to 80% of the global material and energy supply and produce 75% of global carbon. Therefore bringing about global change in levels of consumption and waste output requires a specific focus on city regions (UNEP, 2012).

This paper contains the description of the context and solution approaches for future 'resource efficient cities'. The paper was formulated by researchers from Wageningen Food & Biobased Research (WFBR) as part of the assignment to contribute to a scientific basis for increasing

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resource use efficiency in metropolitan regions through developing appropriate and sustainable biorefinery concepts. The paper contains the interpretation of the principles of the circular economy within the context of biomass value chains and within the geographic boundaries of a metropolitan region (hereinafter referred to as the 'circular metropolitan system').

A circular economy is an industrial system that is restorative or regenerative by design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models' (see also Figure 2, Ellen MacArthur Foundation, 2012 & 2015).

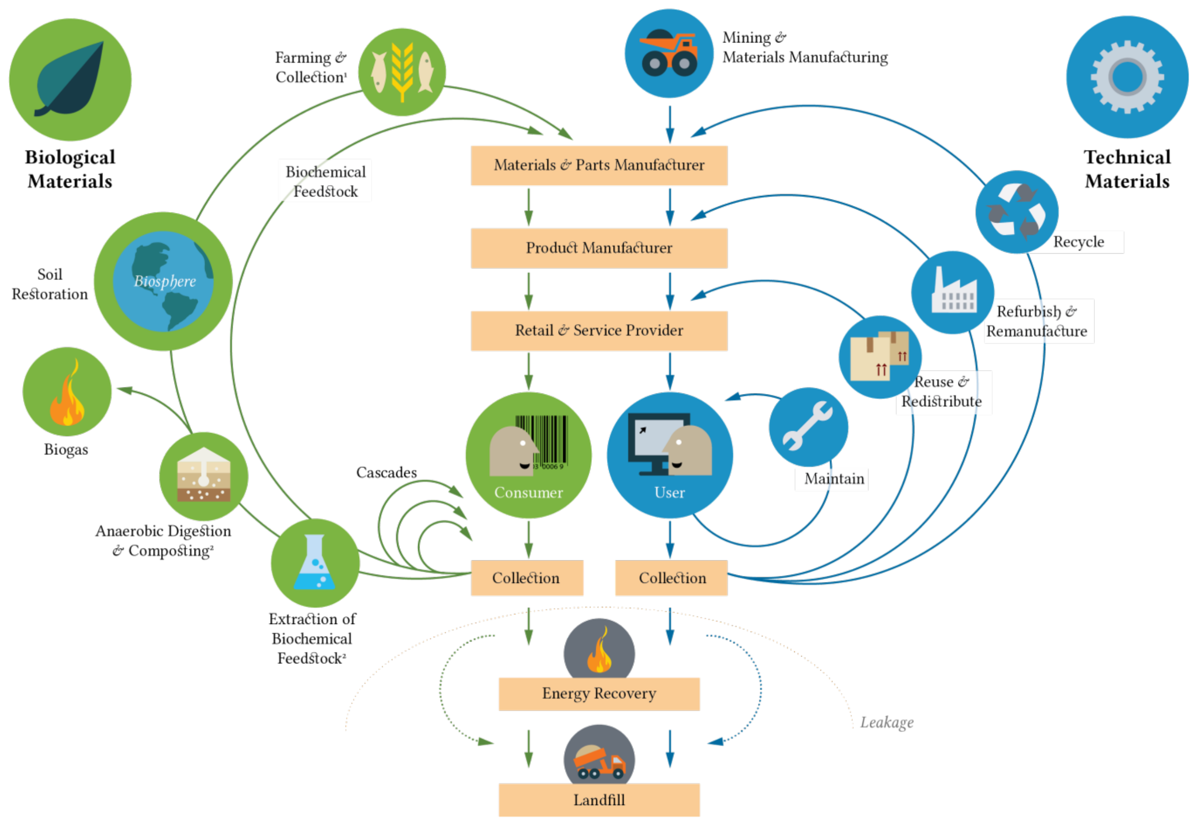

Figure 2 Outline of a circular economy (Source: Ellen MacArthur Foundation, 2012).

The concept of 'resource efficient cities' forms one of the four pillars in the Wageningen University & Research agenda for Metropolitan Solutions that contribute to urban ecosystems' health and productivity. With the metropolitan scope, Wageningen University & Research targets intense urbanized regions, existing of a patchwork of urban, suburban and peri-urban areas, which include built and green-blue structures.

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As starting point for the research on metropolitan issues by WFBR this paper focuses on exploring concepts and solutions for enabling these ‘resource efficient cities’. This paper on circular metropolitan systems is linked to the recently developed ‘Vision on how to achieve resource use efficiency in integrated food and biobased value chains’ (Annevelink et al., 2017). That particular vision looks broader than only metropolitan systems, viz. at a circular economy, so for example also at agricultural production.

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2 Why do we need a transition to circular metropolitan systems?

Cities are attractive starting points for making the transition to a circular economy[1]. They are defined places where products are produced, consumed and discarded in large quantities. Their high population density and industrial productivity mean that waste streams can be cost-effectively collected, transported and recycled (Cramer, 2014). The high concentration of consumers means also a high concentration of citizens and other stakeholders important for the acceptance and understanding of the concept of circular economy.

A range of driving factors gives input to the need for encouraging circularity within the metropolitan region:

Climate change / global warming:

- Reducing negative environmental effects from transport, (energy) consumption, waste treatment, etc. to increase the quality of life in the metropolitan region.
- Necessity of safeguarding and improving the quality of life in urban areas by lowering GHG-emissions and particulate matter emissions.
- In general, the necessity of decreasing the impact from urban areas on climate change.

Natural resources (efficiency):

- Avoiding the depletion of natural resources that are necessary for our human existence.
- Guaranteeing sustainable and efficient use of natural resources for the supply of sufficient food and non-food products to the metropole.
- Creating more value from natural resources at lower costs, e.g. for the transport of goods, for waste treatment, etc.

(Food) Market:

- Growing and changing food demand of the urban consumer.
- A growing number of consumers will no longer visit a supermarket for their daily grocery shopping. Instead they will order their food products online by tablet or smartphone and have their order delivered on their doorstep or collect their package from an agreed pick-up-point.
- Growing demand of convenience products (cut vegetables, ready to eat meals)
- Growing volume of home-delivery food concepts.
- Growing consumer awareness of the environmental impact from food production.

[1] Metropolitan area as urban agglomeration with a city as core of the metropolitan area.

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- Consumers' growing demand for food products from local growers and food producers in the region.
- Increasing availability of local food produced from urban and peri-urban agriculture, as well as from other food production concepts that are initiated by local communities.

Logistics:

- Food logistics - altering concepts of food supply in the city will put pressure on the cities' logistical infrastructure (e-tail, home-delivery).
- Waste logistics - separation of residual streams at the source, frequency of waste collection, central/decentral processing of residual streams.
- Processing allocation - central- vs. decentral processing / cascading of residual streams.

Transport:

- Increasing traffic congestion in cities will require countermeasures to curb road transport movements and enable a shift to other modalities (electric, bicycle, waterways).
- Innovative concepts for the transportation of goods and people (e.g. groupage / city distribution, uber-concept).

Technology:

- (Clean) transport technology (electric, PV), home-delivery concepts (hubs / collection points), ICT, smart technology / internet-of-things, sensor technology (RFID)
- Utilisation of residual heat in adjoining production facilities
- Production: LED cultivation / urban agriculture, aqua-culture
- Bio-refinery technology enabler for processing / cascading of organic residual streams

Policy:

- City ambition to develop a climate-neutral city.
- Zero-waste cities with cost–efficiency through valorisation of waste streams. In the expanding metropoles the demands for sufficient food and for resource efficiency converge into concepts that address the cities' zero-waste ambition.
- Encourage resource use efficiency in all processes and businesses within the city boundaries.
- Create a more resilient metropolitan (eco) system. Here transition towards a bio-economy is connected with the decrease of the sensitivity for disturbances in the supply of food to the urban society.

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3 What are the characteristics of a circular metropolitan system?

Chapter 2 showed that metropolitan systems have to switch from a linear to a circular economy. The concept of the circular economy is based on the idea that interconnections should be developed between value chains for different material and energy flows in order to reduce waste and increase efficiency. This requires changes throughout all value chains that are located in the metropolitan system and a shift to new business models. Circular chains are created through co-operation between companies working in consortia and through involvement of users and local government authorities. Evaluation of investments in circular value chains will be measured by their impact on the resilience of the ecosystem.

Biorefinery concepts can contribute to achieve a transition to circular metropolitan systems. Renewable resources can be used in a biorefinery to produce a mix of products (e.g. biobased materials, biochemicals, biofuels and bioenergy) in order to achieve a sustainable, low carbon, resource efficient metropolitan economy. First of all a biorefinery can produce energy from secondary and tertiary biomass waste streams in order to reduce the need for "external" energy. Furthermore it can produce durable products from food production side streams in order to minimize the need for "external" materials. This of course does assume that food production takes place within the metropolitan system. Finally a biorefinery can also be used to improve the resource efficiency of agro-production in order to valorise more of the feedstock. This would be outside the metropolitan system and produce feedstock which enters the metropolitan system.

Many of the required resources (e.g. food and biobased products) will still enter from outside the metropolitan system. Some resources will be largely consumed immediately like food and energy. Others will only be partially transformed during their use like paper, textiles and building materials. Understanding the scale (size) and quality of these different types of feedstock flows and their residues is the key for designing a sensible circular metropolitan system. The aim of such a circular system should to be to re-use the remaining resources for the metropole as long as possible, flowing around in many cascading circles (preferably as small as possible). Of course a circular approach will only happen if this offers the best value for resources and a minimum impact on the system (GHG, use of land, nutrients & water).

Residues will be avoided as much as possible throughout the whole value chain by using the following circular strategies: i) smarter use & production (refuse, rethink, reduce) , ii) prolonging life time of products & parts (re-use, refurbish, remanufacture, repurpose) and iii) useful application of materials (recycle and recover) (PBL, 2016). These strategies do not completely avoid residues, but they do diminish the need for new virgin feedstock. The waste that finally leaves the metropolitan system should still be used at the highest possible value and will possibly re-enter the metropolitan system again later on.

In a circular metropolitan system there will be an integration of food and non-food value chains by exchanging resources and capacities (e.g. in transport, warehousing, production/processing facilities, etc.). Centralized integrated logistical centres that combine food and noon-food value

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chains will enable to solve issues like (rapidly decreasing) quality, availability and costs of these new feedstocks. So the flow of food and biobased products into the city and waste flows out of the city should not be considered separately, but in conjunction with each other and other flows of goods that will have the same transport problems to reach the consumer. Of course they may differ in transport conditions such as processing, packing and/or transport conditions related to quality and therefore finding optimal ways of combining these different streams is essential.

Example of projects on circular metropolitan systems are:

- Circular Buiksloterham in Amsterdam (www.buiksloterham.nl) - 'Buiksloterham, a neighbourhood in the north of Amsterdam, is in a unique position to serve as both a living test bed and catalyst for Amsterdam's broader transition to becoming a circular, smart, and biobased city' (Metabolic, 2014).
- TO2-Adaptive Circular Cities (ACC) project (www.adaptivecircularcities.com) - This project was about finding waste-to-resource options for biogenic residues in an adaptive circular city. The focus was on waste from households and from retail, restaurants etc. that are related to a municipal area (see Figure 3). Industrial food processing waste was not considered yet. Both traditional and alternative technology options for the valorisation of biogenic waste streams were identified. Furthermore a confrontation matrix has been developed to find a match between biogenic municipal residues and the available technology options. Although there also is a strong link with industries and logistics (including harbours) in the circulation and mutual use of resources, this was not taken into account in this specific project.

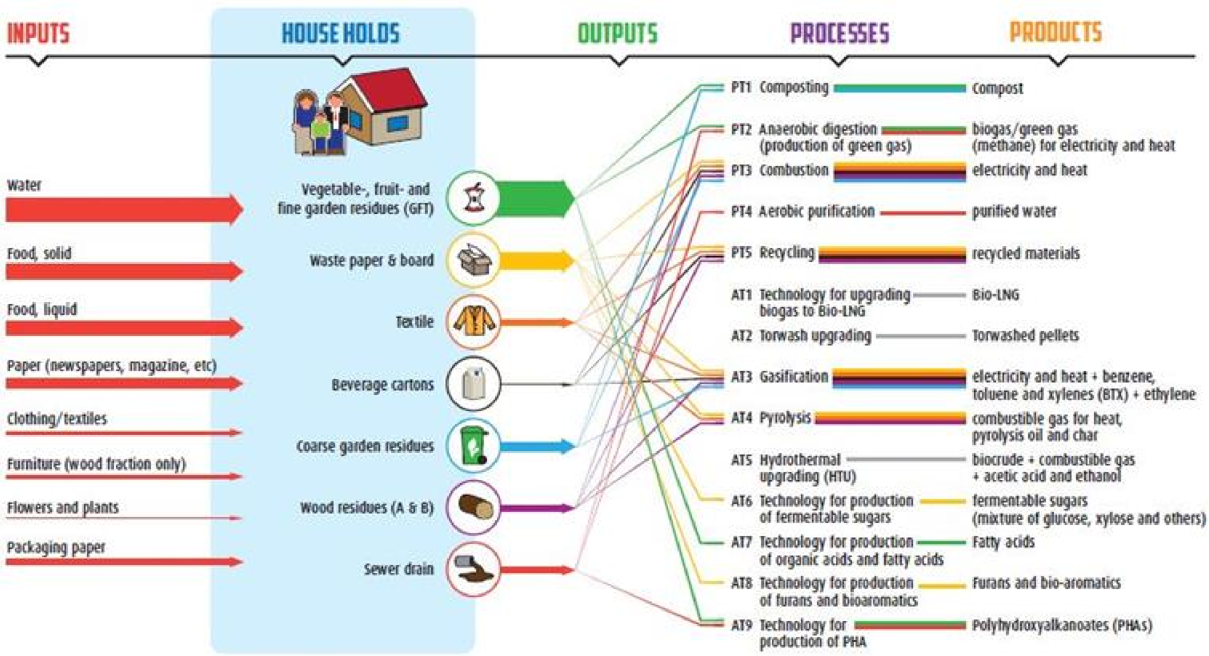

Figure 3 Confrontation matrix between residues and processes (Annevelink et al., 2016).

- Circular Amsterdam - The City of Amsterdam has commissioned a report into the potential for transitioning to a circular economy in Amsterdam and the Amsterdam Metropolitan Area. Worldwide, this is the first such research on this scale. The report has shown that a circular economy offers many opportunities for the city and its business community (Amsterdam, 2016).

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4 What are relevant factors for a circular metropolitan systems?

The following factors will influence the transition towards a circular metropolitan system:

Design	•	Product design: circular design to improve material selection to improve life span and repair options, functionality during the product use-phase design, and efficiency in the reuse /recycling of materials in the product's end-of-life phase.
Chain integration	•	Circular metropolitan systems are more than a focus on improved recycling of food waste, organic biomass residual streams and nutrients. It is more than a changed perspective on biogenic waste management towards sustainable resource management.
	•	In our view a circular city embodies the integration between food and biobased value chains. It is needed to identify and develop local value chain networks within the metropolitan (urban) region to close loops and to cascade residual streams. Biorefinery technology can be used to achieve synergy in these networks.
Resource management	•	Technology for local biorefinery concepts for both processing resources and valorisation of residues.
	•	Waste separation concepts and technologies: creating the opportunity to link material specifications with processing – and product requirements.
	•	For many products that can be made from waste, such as bioplastics, there are a number of conversion steps, which takes you far away from the original feedstock. So quality specifications from the final product need to be translated to quality specifications of the original feedstock using several steps with intermediate products.
Logistics	•	The city forms an organisational logistic system for communication, use and distribution, in which borders mostly have to be removed.
	•	New waste collection systems that deliver separated residue streams in order to retain the possibility for processing cascading according to the highest output value.
	•	Intelligent logistical systems (transport, storage, pre-treatment, etc.), e.g. organised city distribution systems (type of public transport for goods).
Business models	•	New business models that deal with new ways of communication within and organisation of the value chains. An example are 'secure networks' that use blockchain technology (a data structure originally developed for bitcoins) for exchanging information.

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Regulation	• Food is a multi-attribute product, which means that general principles from industrial ecology may not apply to food when it is produced with inputs that is classified as waste in previous links of the chain. There are important sanitary and legal issues here, but also issues of culture and taste[2]. These issues will also apply to biobased materials for food packaging.
Consumer / social innovation	• Local stakeholder involvement (e.g. ideas of citizens for local production and residue treatment). • Three levels of innovations: technical, process and systems.

[2] Schmid, 2015.

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5 What research is needed to integrate biorefinery concepts in a circular metropolitan system?

- Collect data about the various resource and residue streams in a metropolitan region.
- Collect logistical data e.g. about congestion, city distribution, etc.
- Assess the composition and quality of these resources and residues.
- Collect data on the demand on a feedstock level (volume, required quality, etc.) for food and non-food products in a metropolitan region (e.g. by prioritising for the most important chemical processes).
- Describe the current system.
- Choose the most appropriate/suitable biorefinery value chain concepts for various resources and residues to produce new high value resources.
- Describe possible biorefinery value chains within the context of the metropolitan area.
- Include other aspects in the design, like distribution systems and communication systems.
- Calculate the effects of a design to assess its value on some key performance indicators (technical, economic, environmental, social, etc.).
- Assess the effects of the new designs in comparison with a base case.
- Design new business cases that can be implemented in the circular metropolitan system.

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6 Possible solutions for future resource efficient cities

The inventory of resources and residue streams within the metropolitan boundaries will create a perspective on routes for biomass valorisation. In combination with the technological potential for biorefinery processing and logistics, new value chains may arise when the restrictions for technical, operational and economic feasibility are met.

In anticipation of this inventory the following possible solutions can be considered:

- **Possible solution #1:** The most important way of tackling the problem of waste streams is prevention. Waste streams still present can be valorised, i.e. the biorefinery of residual waste streams into nutrients, chemicals, and energy (biogas) for local use (i.e. within the metropolitan area).
- **Possible solution #2:** Shift from global and international trade to more regional chains will reduce the need for energy inputs for transport, as well as will lead to reduced nutrient imbalances, and a diminished need or eliminated need for artificial fertilizers. The highest environmental impact on food systems is often at the production. The shift in production location can mean an increase in environmental impact higher than the savings in other part of the chain.
- **Possible solution #3:** Cross-sectoral collaboration and integration - collaboration with biorefineries, other business and utilities to exchange and cascade resources that were previously regarded as waste. Residual organic streams are upgraded in biorefinery processes.
- **Possible solution #4:** Packaging innovation - examples are tomato leaves for biobased packaging; use of biobased / biodegradable plastics in food packaging.

(inspired by: Rabobank 2014 – circle scan: current state and future vision Agri & Food Sector. Rabobank / Circle Economy)

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