CIRCULAR AMSTERDAM
A vision and action agenda for the city and metropolitan area
Cities are the hotbed of innovation and circularity is now on the agenda; politically, socially and commercially. The ability to identify and implement circular solutions at the city level will lead to job creation, a cleaner environment, new or rejuvenated industries, and competitiveness in global markets. The circular economy provides solutions for many environmental, economic and geo-political challenges that cities worldwide are facing.

The first Circle City Scan was completed with the city of Amsterdam, which is a pioneer in the field of circular economy. This report identifies areas in which circular business models can be applied and highlights strategies to accomplish practical implementation of these sustainable solutions. The Circle City Scan addresses where and how to start with tangible projects, and what the impact is in terms of jobs, environment and added (economic) value.
EXECUTIVE SUMMARY

As a pillar of Amsterdam’s sustainability policy, creating a circular economy is high on the municipality’s agenda. Results from the study ‘Circular Amsterdam: A vision and roadmap for the city and region’ provide guidance to the municipality regarding potential steps towards increased circularity. The roadmap explicitly connects with and builds on the many initiatives that are already being implemented.

The City Circle Scan approach consists of four phases. In phase 1, the main material and energy flows as well as the employment levels in the economic sectors in the region were analysed, creating a solid base for phase 2. In phase 2, a comprehensive analysis of the value chains that connect multiple sectors within Amsterdam was conducted. Utilising macro-economic statistics, the study determined which chains can achieve the greatest impact from a circular perspective. The results were discussed during a round table discussion with representatives from the municipality and local stakeholders, resulting in the decision to perform a detailed analysis of the construction chain and the organic residual flow chain. Phase 3 explored the two chains in an ideal circular future. This future vision provides a view of how the chains (and their interactions with other chains) can be set up to be more effective. In phase 4, an action agenda and roadmap were drawn to kick-start relevant circular projects, and potential barriers were identified.

Results of the study show that Amsterdam has the potential to greatly reduce greenhouse gas emissions and material consumption while, at the same time, realising economic growth and stimulating employment opportunities. The economic activity of the Amsterdam metropolitan region amounts to 106 billion euro annually, of which 47 billion is accounted for by the city of Amsterdam (2013) (CBS, 2015). The following sections summarise the future vision and roadmap that have been developed for both chains and the impact that the implementation of these would have on the economy and the use of materials.

Construction chain
By organising the building chain in a circular way while fulfilling the growth ambition to realise 70 thousand new homes by 2040, the municipality can achieve a 3% productivity increase worth 85 million euro per year. This economic growth is realised in large part by value retention due to material reuse and efficiency improvements. However, this cannot be realised overnight.

Growth in productivity results in increased employment opportunities; over time, about 700 additional jobs can be created. 75 thousand people are currently employed in the Amsterdam building sector. For the most part, the additional jobs would be for low- to medium skilled personnel.

The outlined improvement of the reuse of materials leads to material savings of 500 thousand tonnes, which is significant when compared to the current annual import of 1.5 million tonnes of materials. Greenhouse gas emissions are estimated to decrease by half a million tonnes of CO₂ per year - equivalent to 2.5% of the current annual CO₂ emissions of the city of Amsterdam.

The above impacts are based on four strategies that improve the circularity of the construction sector: (1) Smart design: commit to smart design of buildings in order to make them more suitable for repurposing and for the reuse of materials. (2) Dismantling and separation: efficient dismantling and separation of waste streams enables high-value reuse. (3) High-value recycling: high value recovery and reuse of materials and components. (4) Marketplace and resource bank: exchanging commodities between market players. The roadmap and action agenda in the study present a large number of short and long term actions that can contribute to transforming the construction chain and, thus, to the realisation of the impacts. The table on the right presents a brief overview of the top 3 action points for this chain.
### Organic residual streams chain

High-value processing of organic residual streams for the city of Amsterdam can, over a period of five to seven years, lead to an added value of 150 million euro per year.

This future circular scenario is based on a variety of adopted measures, including source separation of organic waste in all 430 thousand households in Amsterdam. Separate collection makes it possible to direct the organic waste stream to new uses, such as the production of protein for animal feed, biogas and building blocks for the chemical sector, including the production of bio-plastics. In addition, organic waste streams from the food processing industry in the port area offer opportunities for higher quality processing, contributing to additional value creation.

In the long term, this scenario is estimated to create an additional 1200 jobs in Amsterdam, on top of the current total of 10 thousand jobs in the agriculture and food processing industry. Some of the jobs created will arise from the required adjustments to the waste infrastructure, including the installation of underground containers, pick up services for the separate waste streams and the more complex processing of waste flows. In addition to direct employment effects in the agricultural and food industry, there are chances for indirect increases in the number of jobs in areas such as engineering and logistics.

The material savings that can be achieved may add up to nearly 900 thousand tonnes per year, a significant amount compared to the current annual import of 3.9 million tonnes of biomass for the entire metropolitan region. The material savings consist mainly of materials that can be replaced by the higher-value processed waste flows. For example, the production of high-quality protein from organic waste can replace protein imports such as soy for animal feed, and the production of bio-plastics could replace oil-based plastic production. As a result, the expected reduction in greenhouse gas emissions is in the order of 600 thousand tonnes of CO₂, nearly 3% of the annual CO₂-emissions of the city of Amsterdam.

The above impacts are based on four strategies that can enable the higher-value recycling of organic residual streams: (1) Central hub for bio-refinery: a central hub for the valorisation of organic residue streams from household and industrial waste and waste streams from the industry. (2) Waste separation and return logistics: smart waste separation and return logistics to deploy the logistics hub of Amsterdam in a smart way and to increase the value of residual flows. (3) Cascading of organic flows: to deploy organic residual streams in the smartest way possible. (4) Retrieving nutrients: retrieving essential nutrients to close the nutrient cycle.

The roadmap and action agenda in the study present a large number of short and long term actions that can contribute to transforming the chain and, thus, to the realisation of the impacts. The table on the right presents a brief overview of the top 3 action points for improved processing of organic residual streams.

<table>
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<tr>
<th>1</th>
<th>VIRTUAL RESOURCE PLATFORM</th>
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<th>CIRCULAR FREE ZONE BIO-REFINERY</th>
<th>3</th>
<th>LAUNCHING CUSTOMER</th>
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<td><strong>INVESTMENTS</strong></td>
<td>The municipality can further develop and make publicly accessible digital (commercial) platforms for organic waste. Such a platform would offer a transparent overview of the supply, the demand and the use of organic residual streams in Amsterdam (and beyond). In addition, it can address the uncertainty in the market by improving the balance of supply and demand.</td>
<td>The municipality can initiate circular free zones. This could take away certain (legislative) barriers that currently hinder innovation, such as the ban on the use of digestate on agricultural land. This is currently blocking an important and essential part of the business case for anaerobic digestion as the current market value of digestate is low.</td>
<td>The municipality can introduce criteria in its purchasing policy to stimulate locally produced grass, wood (as in street furniture) and food (catering). The large buying power of the municipality itself can create an important and constant demand that allows local parties to further develop and professionalise.</td>
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<td><strong>STAKEHOLDERS</strong></td>
<td>AMS, Flowlv2, Dogstkaart, TNO, Municipality Wageningen UR</td>
<td>Orgaworld, SkyIRG, Schiphol Group, KLM, Port of Amsterdam and Sita</td>
<td>Municipality, Caterers and suppliers of facility management, Local producers, Exter, Kronkommers, Provalor, GRO, Holland, Taste Before You Waste, Instock, Food banks, Meerlanden and Fruityourworld</td>
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The urgency of the transition to a circular economy

Our linear way of producing and consuming is under pressure. The world’s population will grow to nine billion people by 2050, and, as the city of Amsterdam urbanises and grows by 10 thousand inhabitants per year, the demand on resources rises. This demand, combined with the finite supply of resources, will lead to scarcity and strong price fluctuations. More and more companies are, therefore, opting for the transition to a circular economy, which offers opportunities for innovation and export of new production techniques and business models, while reducing dependency on imports. For citizens, a more circular city will improve their quality of life, create new jobs and form new business models for entrepreneurs.

Amsterdam wants to be the front-runner in circularity, and the Amsterdam region is in a good starting position for transitioning to a circular economy. The region has many entrepreneurial and innovative businesses, citizens, start-ups, organisations and knowledge institutions that are already working within the framework of a circular economy.

The city of Amsterdam works according to the following seven principles of the circular economy:

1. All materials enter into an infinite technical or biological cycle.
2. All energy comes from renewable sources.
3. Resources are used to generate (financial or other) value.
4. Modular and flexible design of products and production chains increase adaptability of systems.
5. New business models for production, distribution and consumption enable the shift from possession of goods to (use of) services.
6. Logistics systems shift to a more region-oriented service with reverse-logistics capabilities.
7. Human activities positively contribute to ecosystems, ecosystem services and the reconstruction of “natural capital”.

Circular economy as a pillar for Amsterdam

The municipality of Amsterdam has committed to the circular economy as an important pillar of its sustainability policy, as apparent in its sustainability agenda (Amsterdam, 2014a), adopted on 11 March 2015. Within the existing policy, there is already space to accelerate the transition, through the development of circular free zones, for example. This is a good starting position, as confirmed in the national Green Deal, ‘The Netherlands as circular hotspot’.

Lately, the region has experimented with pilot programmes in the transition to a circular economy; however, the municipality wants to commit to a real transition in the coming period, and the efficient recovery of natural resources and materials, within the construction sector is an important area of focus. As the municipality would also like to stimulate economic activity, research and innovation, it is important to get a picture of the entire system, which is why Circle Economy, TNO and Fabric were hired to do a Circle Scan for the city.

The changing role of Governments

Circular business models are increasingly seen as promising by businesses (Accenture, 2014). As a result, the transition to a circular economy is mainly driven by companies at the moment. These front-runners still experience many barriers (regulation, for example), which slow down the speed of the transition. Governments play a crucial role in facilitating and guiding the transition to a circular economy (EMF, 2015a). Especially at the city and regional levels, the circular economy is taking shape and groups of citizens and businesses are starting all kinds of circular initiatives (RLI,
These developments show that a great deal of interest and commitment currently exists to capitalise on the opportunities offered by the circular economy. To scale up these initiatives support from the government is essential.

The government of the future does not direct, but brings parties together. To play that role, the government ought to remove barriers resulting from existing policy and actively encourage and challenge the market. One can think of, for example, the development of inspiring goals for a circular city, such as adjusting the private purchase and tender conditions, stimulating innovative research and start-ups that contribute to circular solutions, and implementing financial incentives. This last point, for example, can be fulfilled by differentiating tax rates and investing in good infrastructure to increase exchange of resources. A close cooperation between the government and the market offers a great opportunity to accelerate the transition to a circular economy.

Amsterdam Circle Scan: from vision to action
This document describes the results of the ‘Amsterdam Circle Scan’ and analyses the opportunities and challenges of creating a circular city. The results contribute to the further development of the municipal ambitions and agenda on the theme of a circular economy. The roadmap outlines steps towards stimulating the circular economy in the city. To create a circular economy, we must first understand what is not circular in our current economy. This document provides insight into the commodity flows in the city and metropolitan region. It shows where the processing of resources adds value to the local economy and how they can be reused in a smart way while highlighting where resources are being wasted. The report focuses on two value chains with a significant impact, their contribution to the regional economy and their potential to be more circular - Construction and Organic Residual Streams. For both value chains, we explored what a circular future may look like. To make the vision more concrete, four strategies were developed and translated into a specific roadmap for the city and region with concrete action points. The report concludes with recommendations and next steps. A key recommendation and follow-up step involves making circularity more measurable in order to monitor progress. The ‘circular indicators framework’ applied in this study offers a good starting point.

Jump start: build on momentum
The ambition to be a circular hotspot is widely supported in Amsterdam. Not only is the municipality progressive, but citizens and businesses are equally enthusiastic and energetic about the transition to a circular economy. The city is buzzing with circular initiatives, and this was once again made clear during conversations held in the region to gather input for the future visions and action points in this document. With the action points presented in this report, we want to contribute to and build on the growing momentum for the circular economy in this region. In the action agenda, we connected and built on, as much as possible, the many initiatives already underway. Internationally, Amsterdam is a pioneer and is being followed by other cities in Europe and beyond.
THE CITY CIRCLE SCAN METHOD

The City Circle Scan is a method that gives direction to cities through the development of a roadmap and action agenda for the practical implementation of the circular economy in their city and region. The method consists of four phases.

MAPPING OF MATERIAL FLOWS AND ADDED VALUE

To get a better picture of how circular Amsterdam currently is, the main material and energy flows as well as employment in the economic sectors in the region were analysed. The analysis employed data from (regional and national) statistics and sources, and was supplemented by interviews. It provides insights into material flows in and around the city. Simultaneously, activities and places in the region were assessed for their ecological impact. In addition, the analysis provides insights on where and how value can be created in the region and where there are opportunities for job growth and economic development.

EVALUATION AND SELECTION OF CHAINS

In phase 2, a comprehensive analysis was conducted of the value chains that connect multiple sectors within Amsterdam. The results of phase 1 were the starting point of this analysis. Based on macro-economic statistics, we established in which chains the greatest circular impact can be achieved. The result is a list of chains that have been prioritised on the basis of the following indicators: ecological impact, economic importance, value preservation and transition potential. These indicators were also used in the Dutch national government program, ‘Nederland Circulair’.

VISIONING

Then, in phase 3, we developed a future vision, exploring how the two chains can function in an ideal circular future. This future vision gives a view on how the chains (and their interactions with other chains) can be set up differently. For each of the two chains, we formulated four strategies for a circular economy. The future vision was tested in feedback sessions and in interviews with various experts and stakeholders in Amsterdam. The feedback was used to further refine the vision for the future.

PROJECT SELECTION AND FORMULATION OF ACTION POINTS

In phase 4, an action agenda with a planning and implementation strategy for starting relevant circular projects was drawn up. All are projects in which governments, research institutes, companies, entrepreneurs and citizens work together to make the two chains circular. Time paths for the actions and policy interventions were formulated, indicating which stakeholders are essential for a successful transition. The actions have also been assessed on four main effects: (1) value creation, (2) CO₂-reduction, (3) material savings and (4) job growth.
2. VISION OF A CIRCULAR CONSTRUCTION CHAIN IN AMSTERDAM

To get a picture of how the construction chain in Amsterdam can make better, higher-value and longer lasting use of material flows, we explored a potential future of the construction industry in Amsterdam. This vision of the future was partly based on interviews with experts and stakeholders. Their feedback was used to further refine the vision of the future. The starting point of this exploration was to retain the highest possible value in the construction chain by means of circular solutions. Therefore, this chapter describes four strategies that can be followed. These strategies are then placed in the context of the region (by linking with local initiatives and a selection of innovative market parties). Furthermore, a link is made with trading opportunities for the municipality, areas where the market is active and ways that the government can facilitate this. The roadmap describes concrete action points for the municipality, links this to timelines, and highlights which parties can play a role in the implementation. In addition, the impacts of implementing the strategies are calculated for: (1) value creation, (2) CO2-reduction, (3) material savings and (4) job growth.
In an ideal circular construction chain, the buildings are designed in such a way that materials will have the longest possible lifespan through reuse or repurposing. The introduction of a material passport is a concrete measure that can be of great help in stimulating reuse by increasing transparency to develop a business case and enabling reallocation of materials. Furthermore, chain cooperation and supply chain financing is especially important since it contributes to a longer term maintenance and use that does justice to the useful life of buildings. As a result, the economic, environmental and social performance improves.

Integrated planning is essential for the realisation of a circular future. Construction and demolition of buildings in Amsterdam should be coordinated so that the construction materials from demolished buildings may be used again in new construction projects and renovation projects. That way, the use of new materials in new construction projects will be reduced to a minimum. Bio-based construction materials can also play a role. Locally produced biomass, such as the production of elephant grass around Schiphol Airport or on wastelands of the port, can serve as part of this market. In addition, it is important that, next to local sources, national and international sources and production methods for sustainable bio-based materials are used. New production methods, including the use of 3D printers, can realise the local production of buildings. This can also increase the demand for bio-based plastic and, thus, stimulate the production of bio-composites.

Buildings can be constructed in a modular way. The flexibility of multifunctional buildings ensures that buildings have a longer life span despite the varying demands of residents and users. This underlines the role of architects and property developers in the design of buildings that are suitable for re-development. Modular construction can contribute to rapid and cost effective adaptation of different building functions, reducing vacancy and optimising unused building space.

In a circular Amsterdam, more focus will fall on smarter demolition. During the demolition of buildings, re-usable products and materials are separated, while maintaining their physical characteristics and economic value. During the separation, there is a special location (unused land close to construction sites, for example) for storing materials that will be used directly in the construction of new buildings and renovation of existing buildings. To support this, a materials database is required, which is linked to an online marketplace, where buyers can easily exchange these materials on the basis of quality and quantity.

The described vision is illustrated in a visual (see opposite and enlarged on the next page) that depicts the flows in the city. In the next section, this vision is translated into strategies and action items that use market, technical, technological and administrative instruments to realise these circular opportunities in the construction chain.
VISION OF A CIRCULAR CONSTRUCTION CHAIN

- Agriculture
- Biobased Industry
- Concrete Industry
- Infrastructure
- Materials registration platform
- Renovation
- Demolition & deconstruction
- High-value separation
- Local reusing
- Regional material bank
- DIY builders
- On-site 3D printing
- Materials added
- regional demand
- design
- regional supply
- local materials
- regional materials
- regained materials
- recycled
- reduce
- mixed materials
- abundant supply
- high-tech pavement
- concrete, metals
- wood
- plastics
- minerals
- City green maintenance
- Wastewater treatment
- existing stock
- cellulose
- biobased resources
- prefabrication
- recycling
- maintenance
- new construction
- DBFMO-D consortium
STRATEGIES FOR BUILDING A CIRCULAR CHAIN

From the vision described for the construction chain, we developed strategies and action items which enable the municipality to close the material cycles in the construction chain.

(1) Smart design
Smart design of buildings so that they are better equipped when their purpose changes and so that materials can be reused.

(2) Dismantling and separation
Efficient dismantling and separation of waste streams to enable high-value reuse.

(3) High-value recycling
The high-value recovery and reuse of materials and components.

(4) Marketplace and resource bank
The exchange of resources between market players to enable the reuse of materials in new buildings.

These circular strategies are explained on the basis of relevant existing activities that currently take place in Amsterdam. In addition, four strategies are displayed in a spatial view, similar to the spatial vision map. Even though the strategies are formulated separately, they are partially intertwined. Successful implementation of high-value reuse, for example, is dependent on efficient dismantling and separation techniques.

The following section lists the four strategies translated into a concrete roadmap and action agenda. The action agenda further explains where the municipality can be of influence, what other market parties can be involved and in what timeframe the transitions can take place. The roadmap and action agenda are formulated on the basis of the previously described research and analysis, as well as interviews with stakeholders and experts.

Explanation of the indicators
The effects of the circular strategies on the environment and the economy are calculated for the construction of 70 thousand homes in Amsterdam. Here, the impact will be realised over a period of five to seven years. Four indicators were used in determining impact: (1) net added value in millions of euro, (2) net job growth in FTE, (3) material savings calculated by value retention in domestic material consumption and (4) reduction in CO₂-emissions. These are further described below.

NET ADDED VALUE IN EURO
The circular strategies directly enable a number of sectors in Amsterdam to realise added value: more sales and more profit. “Net” means that any decreases in added value are calculated and that the indirect effects of all other sectors are taken into account.

NET JOBS GROWTH IN FTE
One of the social aspects of an increase in circularity is represented, among other things, by the realisation of jobs (FTE, Full Time Equivalent). Job growth is estimated on the basis of the increase of added value, of salaries in that sector and of the demand for low, medium and highly-skilled workforces. Net jobs growth refers to job growth that results in a direct reduction of unemployment.

MATERIAL SAVINGS
Use of materials is expressed in Domestic Material Consumption (DMC), which, in addition to the use of materials in an area, also looks at materials that are imported and exported. Apart from CO₂-missions (which already is explicitly included), DMC makes all environmental impact factors related to the circular projects quantifiable.

CO₂-REDUCTION
The most well-known impact of economic activities is CO₂-emissions. The impact of the strategies on emissions is expressed in Global Warming Potential (GWP), a globally adopted measure that expresses the avoided CO₂-emissions in the coming years, by an increase in circularity, over a period of 100 years. To make the impact comparable with the annual emissions in the region, the choice was made to convert the indicators to annual CO₂-emissions.

*Domestic Material Consumption, abbreviated as DMC, is a commonly used statistic that measures the total amount of materials that are used directly by an economy. It measures the annual amount of materials that are extracted in the geographical area, including all physical imports and minus all physical exports.
SMART DESIGN

Smart design of buildings is important in the transition to a regional construction circular chain (EMF, 2015a). Inhabitants move more frequently, so work areas should be regularly adapted to meet changing work patterns such as mobile working and flexible working hours. In addition, it has been found that companies tend to move to another building rather than renovating the current one. These factors lead to an increasing demand for flexible and customisable areas that meet the changing demands of tenants and owners. To illustrate the concept, we will focus on four categories of smart design, namely, modular and flexible design, 3D printing, bio-based materials and experimental construction areas.

Modular and flexible design One of the aspects of smart design is a modular and flexible approach, whereby buildings can be updated to new users and other applications without sacrificing the current safety guidelines (Schoenborn, 2012). These designs lead to real estate that is more functional and more durable, thus, offering a better revenue model during the utilisation period. Examples of integral modular designs are Solid in Amsterdam by housing association Het Oostent, TempoHousing student accommodation by Keetwonen in Amsterdam and Park 20 | 20 by Delta Development Group in Hoofddorp. Flexibly designed houses are often more attractive to users because they can adapt to changing lifestyles. For example, Hubbell in Amsterdam builds modular spaces for individuals. Companies also prefer flexible offices because they do not need to move as their business situation changes. Start-ups and other fast-growing companies in particular can benefit from such offices. Rent or purchase of flexible office space can even result in cost savings (Cushman & Wakefield, 2013).

3D-printing New technologies, such as 3D printing, can play a pioneering role in reducing cost and material use (EMF, 2015b). Such technologies lead to less waste and offer the possibility of new (e.g. bio-based) materials. The Amsterdam firm of architects, SO Architects, has, in collaboration with Hager and Henkel, started the project "3D Print Canal House" to investigate the possibilities of 3D printing for the construction industry. The research project looks at different building materials, such as recycled construction materials and stone waste (SO, 2015).

Bio-based materials New, sustainable building materials with a biological origin can contribute to designing smarter buildings. More than 3 million tonnes of biomass and organic residual streams are released from agricultural activities in the Amsterdam metropolitan area, from which significant amounts of bio-composite materials can be produced. This would, at least, be sufficient to supply the materials needed for the planned housing expansion of 70 thousand homes (CBS, 2014). An interesting example of sustainable building materials is the work of Waternet, who, together with stakeholders such as NPS and Cityblob, develop composite components. The municipality of Almere has already commenced projects involving bio-waste, which is used to generate bio-composite for the building sector. The 60 thousand m² of buildings planned for the 2022 Floriade can be built as circularly as possible through the use of biomaterials. Another interesting example is the trajectory of Waternet in which waste streams such as water plants are converted into (building) products.

Experimental construction areas Laws and regulations can be adjusted to make it possible to develop bio-based, modular buildings with flexible applications (Acceleratio, 2015). By modifying the building codes, developers get more room to experiment and more freedom to put their clever designs into practice. The success of Park 20 | 20 is partly due to the municipality of Haarlemmermeer, which created flexible rules for the area in which innovative building designs could be tested. In Ijburg, plans are already in place to create an experimental area for new developments. These free zones offer a great opportunity for start-ups that work on innovative concepts, contributing to the vision of Amsterdam as a start-up hub.
**DISMANTLING & SEPARATION**

By dismantling existing buildings in more efficient ways and by separating their waste streams, materials and components of old buildings can be better reused. An important but often ignored phase in the life cycle of a building is its end-of-life (Acceleratio, 2015). These days, a maintenance clause is sometimes included in contracts for real estate development; however, this almost never includes end-of-life costs. Therefore, destruction currently seems the cheapest option with a cost of only € 20 to € 30 per square metre (Circle Economy, 2015). By handling demolition of buildings in a smarter way, high-quality materials can be separated to avoid them from being contaminated by other resources. From a circular approach, it is necessary to take decommissioning into account early on in the design of buildings. Efficient separation of the waste streams can facilitate high-value recycling and reuse of these materials. This is especially the case in small-scale construction projects such as renovations where little attention is spent on this due to financial unviability. However, by dismantling smarter on a regional scale, and by separating materials and components in a better way, more mono-streams of materials are made available, which makes reuse worthwhile.

**Decommissioning** In the circular construction sector, the entire lifespan of a building is taken into account through close cooperation. The costs and benefits of a longer life span are divided in a fair way among the cooperating partners. The cost and time for each partner are monitored during all DBFMO-D (design, build, finance, maintain, operate and demolish) phases in which clauses for not only design, building, financing, maintenance and use of buildings are contained, but also demolition (Netherlands Court of Audit, 2013). Such contracts allow the components and materials in the building to be used again. These components and materials can then be sold to compensate for the demolition costs. In Amsterdam, there are companies already specialising in decommissioning- and demolition methods. Examples of these companies are VSM demolition works, Demolition Company Concurrant, Demolition Support Netherlands, Orange BV and Bentvelzen Jacobs.

**Waste separation** By separating construction and demolition waste, materials can be retrieved in a high-value manner without cross-contamination. Hybrid waste management systems, which combine individual and central sorting methods, can lead to better business cases. Companies like Icova and Waltec BV offer processes and technologies to separate construction and demolition waste. New technologies, such as the Smart breaker of SmartCrusher BV, make it possible to separate concrete in sand, gravel and cement. As a result, the value of the individual materials increases due to higher value recycling possibilities.

Visual representation of dismantling and separation: Buildings are separated in a smart and efficient way so that high-value resources are recovered and saved. In addition, components can be reused. The effects of circular strategies on the environment and the economy have been calculated for the construction of 30 thousand new homes in Amsterdam. It is expected to take five to seven years to achieve circular dismantling within the construction industry. Four indicators have been used to determine impact: (1) net added value in millions of euro, (2) net job growth in FTE, (3) material savings calculated by value retention in domestic material consumption and (4) reduction in CO₂ emission.
HIGH-VALUE RECYCLING AND REUSE

The construction chain is responsible for 40% of the total waste stream of Amsterdam (CBS, 2014). Although more than 90% is recycled, the vast majority of these materials are used as gravel for roads, a low-value application (Circle Economy, 2014) leaving a chance for higher-value reuse options. Office spaces also offer opportunities from a circular perspective. At the moment, about one-fifth of the office spaces in Amsterdam are vacant, which is inefficient when you look at the (financial) resources and raw materials used (DTZ, 2015). At the same time, the buildings present considerable financial potential. The challenge is to take advantage of the opportunities for high-value reuse of components and materials in buildings and the redevelopment of the buildings themselves in Amsterdam.

Better reuse Building- and waste materials can be reworked into new products. In Amsterdam, a special installation can be built that enables high-value recycling of building materials. This installation allows different companies to process and recycle varying streams of construction waste. A number of companies, such as Stonecycling, who work together with construction waste companies to recycle stone and ceramic waste to bricks, have already settled in Amsterdam.

Demo clean building materials Another example is AEB Amsterdam. They use the inert group-ash that is left behind when burning residual waste to produce building materials. Next year, a demo-scale pilot will start in which clean building materials will be created through a process in which CO₂ is permanently captured. Currently, this fraction is down cycled for use in road construction, but, in the future, that material can be recycled into building material. The pilot presents an opportunity to create a total of 300 thousand tonnes worth of building materials in which eight kilotons of CO₂ are permanently stored (AEB, 2015).

Retrieving materials from street furniture and paving materials The city of Amsterdam aims to retrieve more materials from street furniture by introducing certain procurement criteria (such as in the project “The Street of the Future” in Amsterdam). Struyk Verwo recycles old concrete pavements into new products that consist of 70% recycled or reused concrete (Struyk Verwo, 2015). Such technologies can bring companies together, enabling them to experiment and to extend their knowledge. Almere is working on the construction of a plant meant to recycle building materials in a high-value manner.

Repurposing existing buildings Excessive and vacant buildings in Amsterdam have a large share in the material and energy costs in the region. It is recommended that these buildings are optimised and are given a new purpose. Major renovation projects, such as ‘Stroomversnelling’, show that high-value renovation of existing housing can form a solid business case. Expansion and renovation projects lead to a significant energy consumption reduction during the remaining lifespan. Redevelopment projects in Amsterdam also are also attractive for the inhabitants due to an increase in housing possibilities.
MARKETPLACE AND RESOURCE BANK

Each building can be seen as a material bank full of valuable materials. A building could be seen as a modern take on traditional mines (United Nations University, 2014). However, after the dismantling, separation and recycling of building materials, a gap between the demand and supply of these resources remains. Demolition and decommissioning projects provide opportunities for processing and direct reuse of recovered materials in nearby construction projects. However, it is often unclear which materials are present in existing or decommissioned buildings and of what quality they are. High-value reuse is, therefore, a major challenge. There is a need for an advanced collection system and for intelligent logistics, which would make the exchange of building materials easier. Because many developing locations are located near waterways, the port of Amsterdam can be a central point in that logistical system. Shipping companies could play an important role in transport. Many logistics companies such as DHL and PostNL have considered offering reverse logistics for a wide range of material flows. In reverse logistics, an empty truck would be used for retrieving waste after it has delivered its products.

Commodity bank Currently, there are challenges in the temporary storage of construction waste at companies, mainly because this requires space and, thus, investment. A solution could be to arrange a centrally located physical storage for materials (commodity bank) - materials that are then traded in the online commodity marketplace. Vacant plots around Amsterdam, such as in the port and in Westpoort, Zaandam and Almere, are ideal locations for the temporary storage of construction waste before it is traded through the online marketplace. Designers and architects are invited to view a catalogue with materials to see if they can come up with new applications for these materials. Several companies, such as Brink Industrial, Repurpose, Turntoo and Icova, are working on their own resources banks.

Logistics for collection An online marketplace alone does not necessarily make the collection and transportation of construction- and demolition waste easier or cheaper as the material is very diverse and voluminous. Therefore, there is a need for an advanced collection system and for intelligent logistics, which would make the exchange of building materials easier. Because many developing locations are located near waterways, the port of Amsterdam can be a central point in that logistical system. Shipping companies could play an important role in transport. Many logistics companies such as DHL and PostNL have considered offering reverse logistics for a wide range of material flows. In reverse logistics, an empty truck would be used for retrieving waste after it has delivered its products.

Online Marketplace Via an online marketplace, supply and demand of building materials for local construction projects can be aligned (by means of GIS data) (Zhu, 2014). Besides information on the building, an information management system, building passports, and information on the quality and quantity of materials used in a specific building can be documented and made accessible. This provides opportunities for trading and the exchange of building materials between parties, and encourages reuse and high-value recycling. Enviromate has developed an online marketplace where construction companies can exchange and trade waste materials of construction projects in the United Kingdom. Such a system can also be used in Amsterdam. For new buildings in Park 2020, material passports are already being developed. These can also be applied for buildings in the rest of the region.
The spatial vision map indicates how circular strategies for the building chain in Amsterdam can be applied and how they are interlinked in a spatial context. The following strategies are described: (1) smart design, (2) dismantling and separation, (3) high-value reuse and (4) market place and commodity bank.
BARRIERS

Many of the ways to achieve a circular economy may already be profitable but often barriers present themselves when up-scaling a solution. Policy can play an important role in removing these barriers. We distinguish four types of barriers:

- **Laws and regulations** Existing policy often leads to unforeseen consequences of changing market conditions. An example of this is the Environmental Management Act (art. 1.1), which describes what is classified by law as waste and what is not (Government, 2015).

- **Culture** The circular economy requires close cooperation between sectors and chains. A lack of inter-sector networks and a conservative culture can be obstacles to quickly forming successful co-operations. Vested interests in sectors can add to this barrier.

- **Market** The existence of ‘split incentives’ is a barrier; the investments must be done by one stakeholder in the chain while the income is earned by another. Another market-related barrier is knowledge asymmetry, for example, knowledge with regards to the availability and quality of secondary resource flows. The lack of externality pricing, including that of CO₂, can also have a significant effect on the market. The last barrier that we want to mention in this category is the limited access to financing for circular initiatives.

- **Technology** Technological development has two important challenges: the up-scaling of a small pilot to commercial scale, and the interdependency and complexity of technologies that require simultaneous development.

These barriers have important implications for the extent to which some of the strategies can be implemented successfully, especially in the short term. In some instances, governments can overcome these barriers or the market may break down barriers; but, in many cases, the solution requires cooperation, experimentation and iteration. Below, an impact assessment per barrier is made for each of the four circular strategies. The assessment of the severity of the barrier comes from insights obtained from the interviews and is further based on estimates of the research team. For the top 3 proposed actions, the roadmap will address options to overcome these barriers.

<table>
<thead>
<tr>
<th>STRATEGY</th>
<th>TECHNOLOGY</th>
<th>MARKET</th>
<th>LAWS &amp; REGULATION</th>
<th>CULTURE</th>
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<tr>
<td>SMART DESIGN</td>
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<td>DISMANTLING &amp; SEPARATION</td>
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<td>HIGH-VALUE REUSE</td>
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<tr>
<td>MARKETPLACE &amp; RESOURCE BANK</td>
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This table indicates how high the barrier to a circular economy is for each of the strategies. (Source: Insights from interviews, literature (Acceleratio, 2015; EMF, 2015) and assessment of the research team.)

Overview of barriers in the construction sector, based on research, literature, interviews and insights from the research team.
ACTION POINTS

To create a circular construction chain, the following key interventions have been formulated for the municipality of Amsterdam. The actions stem from the vision and the underlying strategies and are linked to the previously described barriers.

SMART DESIGN
1: Assigning pilot projects in new areas New districts are ideally suited for testing new concepts such as smart design. The new developments in Centrumeiland in IJburg offer a chance to test alternative building codes. The municipality has already prepared an exploratory document entitled ‘Dromen over Centrumeiland’ (City of Amsterdam, 2014b). These include DIY plots (where residents have more control over the construction of their house) for which the new building codes are tested. In allocating land, the municipality may make requirements regarding the degree of circularity of the new building. A specific ceiling height could, for example, be recorded as a criterion, making repurposing easier.

2. Land allocation can be scored to the degree of circularity High-value recycled products, parts and materials hereby form an important selection criterion. Rebates on land prices can be given to projects that have a maximum score on circularity. This may include the use of bio-based insulation materials, 3D printers applied in construction, and modular and flexible design for foundations and construction elements.

3. Tender criteria for smart design principles in soil, road- and water construction Based on the results of pilot projects with smart design, in IJburg, for example, and based on feedback from local stakeholders, the municipality can define tender criteria, construction requirements and rules for future developments in Amsterdam. The goal here is to request the longest possible lifespan of buildings, and make the end-of-life value as large as possible through material and component recovery. It should take into account the lowest impact on the environment in the long term. An example of a similar set of instruments is the CO2-performance ladder (SKAO, 2015). The municipality can start with the circular procurement of new soils and road- and water construction projects.

4. Challenge startups to develop solutions for smart design The city of Amsterdam can build on the newly launched ‘Startup in residence’ programme where startups and companies seek solutions to local problems (SIR, 2015). Here, a possible solution could be to use local recycled or written off materials in the city through the use of smart design. Knowledge from AEB may be used in the waste processing and design implications.

DISMANTLING AND SEPARATION
1: Establishing procurement criteria of separation at demolition projects from the second half of 2015 to 2016, the Bijlmerbajes in Amsterdam has been tendered by the national government. The municipality can use this demolition project as a pilot for the separate collection, reuse and high-value recycling of construction waste. Selection criteria can be drawn up to encourage local use of construction and demolition waste. This way, dismantling is stimulated and more value is created from construction and demolition waste.

2. Initiate dialogue for better dismantling and waste separation in demolition projects The municipality can enter into dialogue with stakeholders on future demolition projects to discuss, for example, the removal of buildings in stages to maximise the recovery of materials and components.

3. Encourage local companies in the processing and the reverse logistics of waste The municipality can encourage local companies to be more self-steering with regards to waste collection so that retailers can take the initiative to use their waste streams. A materials map where local demand and supply for waste streams can be found could stimulate this further. This way, the municipality is also partially relieved of its own processing of waste.

HIGH-VALUE RECYCLING AND REUSE
1: Adjust zoning plans to allow for multifunctional buildings The municipality could assign areas like the ArenaPoort and Oosterdokseiland in Amsterdam with multiple permissions. This provides flexibility for buildings to be given a new destination at the end of their life cycle.

2. Innovation projects offer renovation and possible redevelopment projects for existing buildings The municipality can ask market participants to redesign existing buildings (in creative ways) through innovation projects. This could start with empty school buildings or other buildings that the city administers. To speed up this process, the municipality can create guidelines that encourage companies to renovate or find a new purpose for similar or new applications. For example, renovation is already being applied to buildings The municipality can ask market participants to redesign existing buildings (in creative ways) through innovation projects. This could start with empty school buildings or other buildings that the city administers. To speed up this process, the municipality can create guidelines that encourage companies to renovate or find a new purpose for similar or new applications. For example, renovation is already being applied to

4. Aim for high-value reuse in waste processing contracts Waste disposal contracts can specify the method of processing in order to stimulate high-value processing and to create market demand.

MARKET PLACE AND RESOURCE BANK
1: Initiating a ‘materials showroom’ for construction waste A large proportion of construction projects and initiatives for urban development are located near water, and the port of Amsterdam aims to become a hub for circularity. It is therefore conceivable that undeveloped areas of the port can be used for (temporary) storage of construction waste. The municipality could work together with stakeholders to make temporary storage of construction waste possible. The municipality can also stimulate innovation in the logistics and marketing of secondary materials by writing out innovation contests or projects such as “startup in residence”.

2. Facilitate the exchange and use of high-value building materials The municipality can facilitate the exchange of building materials between construction companies and waste companies by taking the initiative for setting up an online marketplace.

3. Encourage companies to use a material passport The municipality can encourage construction companies in future construction and development projects to register and report material volumes and types. This could be incentivised by providing discounts on plots once the stakeholder decides to adopt a material passport. Then, at the end of the useful life of a project, the information in the passport can be made available before demolition. This provides waste management companies with relevant information regarding which materials will be available.
Three action points, as shown in the table, have been selected from the interviews and discussions with stakeholders. In selecting these three action points, four major effects have been taken into account: (1) value creation, (2) CO2-reduction, (3) material savings and (4) job growth. The barriers that have been identified for the construction chain and the role that the municipality can fulfill has also been taken into account. The municipality can play an important role in directing the land allocation and the definition of locations for temporary storage of materials (action 1). The municipality can act as a launching customer via its purchasing policy, for example, when developing or renovating the municipal building portfolio (action 2). Lastly, the municipality can contribute to the development of a building passport and apply it to its own portfolio (action point 3).

<table>
<thead>
<tr>
<th>ACTION POINTS</th>
<th>TOP 3</th>
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<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>FACILITATING RESOURCE AND MATERIAL STORAGE</strong></td>
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<td>Matching demand to the supply of building materials and resources requires temporary storage, especially since the availability of large volumes of materials often does not synchronize with demand. A possible role for the government could be twofold. On the one hand, there is a need for physical storage facilities, for which the municipality can play a role in allocating locations. Given the expected volumes, locations near waterways are ideal for replacing road transport with water transport. On the other hand, the government can play a facilitating role in drawing up conditions that materials will need to meet in order to qualify for storage and reuse.</td>
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<td>Initiatives to establish physical resources banks have sprouted up throughout the country. Individual companies are now starting to set up their own resources banks in collaboration with up- and downstream companies. Amsterdam can facilitate innovation by creating a material repository that is backed by a wide range of stakeholders. This ambition’s logistical challenges align with the initiative to give the Westas an important logistical role in the circular economy. (ALB, 2015)</td>
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<td>A follow-up analysis is needed to study changes in the construction material flows in the city, both for large demolition projects and new construction. Complemented by city planning expertise, this analysis forms the input required for assigning locations for the (temporary) storage of resources. The actual operation and organization of these sites can be organized by both market participants and the municipality - or through public-private partnerships. Depending on the direction taken, the precise role of the municipality is to be determined.</td>
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<td><strong>2</strong></td>
<td><strong>STIMULATING HIGH-VALUE REUSE BY BEING A LAUNCHING CUSTOMER AND CONTRIBUTING TO THE DEVELOPMENT OF PROCUREMENT GUIDELINES.</strong></td>
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<td>In the early stages of development, high-value reuse of building materials can be encouraged by the government in two ways. The government can contribute to the development of procurement guidelines and building codes in which specific requirements have been formulated aimed at high-value reuse. Also, the government can play a role as launching customer for the use of recycled materials. Every year, 1.5 billion is tendered by the municipality for roads, waterways and construction. In addition to contributing to physical locations for the storage of resources, an online platform for the trading of building materials to match supply and demand is under development.</td>
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<td>The municipality’s material department plays an important role, and parties that innovate by reclaiming high-quality materials, such as Stonecycling, are also key players. Struyk, for example, uses end-of-life concrete pavement. The municipality can bring these like-minded parties together and encourage them to experiment in extending their technologies. Furthermore, this links to CO Green in Slotervaart, an ongoing project where 95% of high-quality material is reused locally after demolition. In addition, it is connected to Cirkel Stad Amsterdam where local projects in the field of circular construction, renovation and demolition are realized and, where possible, additional jobs are created (Cirkelstad, 2015).</td>
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<td>Developing criteria for building regulations and ensuring compliance calls for an increase in commitment. The municipality could possibly co-invest in new processing technologies via the AKEF or a circular development fund. A possible condition for this contribution could be that the activities are based in the city of Amsterdam so that any employment gains are realized in the city.</td>
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<td><strong>3</strong></td>
<td><strong>BOOSTING MATERIAL PASSPORTS AND CONTRIBUTING TO THE DEVELOPMENT OF GUIDELINES.</strong></td>
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<td>A materials passport for buildings captures information on materials used, processes and possibilities for reuse. The Government can make sure a (minimal version of a) material passport is recommended or made mandatory for new construction projects. Also, the municipality could implement material passports for its own property portfolio. Besides this, the municipality can contribute to the development of guidelines for passports. An example of this could be exploring how the use of passports can be made mandatory in real estate development and the issue of plots of land.</td>
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<td>Some construction companies in The Netherlands are currently experimenting with material passports. In the vicinity of Amsterdam, Park 20/20, realised by Delta Development, Reggeborgh and VolkerWessels, is a great example. In addition, these principles are most likely implemented in the Buiksloot area as well.</td>
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<td>Involvement from the municipality and city officials is required to determine how the materials passport for buildings can be embedded in policy. Services like those offered by the Kadaster are needed in registering passports. The introduction of the passport also requires investment into the expansion of registration systems.</td>
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<tr>
<td>The municipality, the Port of Amsterdam, the Cirkel Stad collaborative partnership, “start-up in residence”, Westas partners and AEB.</td>
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<tr>
<td>Construction, waste and ICT companies like BAM, Heijmans, AEB, Van Gansewinkel, Icova en Stonecycling, IBM and Delta Development Group.</td>
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CONSTRUCTION ROADMAP

1. FACILITATION RESOURCE AND MATERIALS STORAGE
2. STIMULATING HIGH-VALUE REUSE BY BEING A LAUNCHING CUSTOMER
3. STIMULATING MATERIAL PASSPORTS AND THE DEVELOPMENT OF PROCUREMENT GUIDELINES

ASSIGNING PILOT PROJECTS IN NEW AREAS

LAND ALLOCATION CAN BE SCORED TO THE DEGREE OF CIRCULARITY
TENDER CRITERIA FOR SMART DESIGN PRINCIPLES IN SOIL, ROAD- AND WATER CONSTRUCTION

CHALLENGE STARTUPS TO DEVELOP SOLUTIONS FOR SMART DESIGN

INITIATE DIALOGUE FOR BETTER DISMANTLING AND WASTE SEPARATION IN DEMOLITION PROJECTS
ENCOURAGE LOCAL COMPANIES IN THE PROCESSING AND THE REVERSE LOGISTICS OF WASTE

ESTABLISHING PROCUREMENT CRITERIA OF SEPARATION AT DEMOLITION PROJECTS

ADJUST ZONING PLANS TO ALLOW MULTIFUNCTIONAL BUILDINGS

INNOVATION PROJECTS OFFER RENOVATION AND POSSIBLE REDEVELOPMENT PROJECTS FOR EXISTING BUILDINGS

ESTABLISHING GUIDELINES AND GOALS FOR HIGH-VALUE RECYCLING OF CONSTRUCTION WASTE
AIM FOR HIGH-VALUE REUSE IN WASTE PROCESSING CONTRACTS

INITIATING A ‘MATERIALS SHOWROOM’ FOR CONSTRUCTION WASTE

FACILITATE THE EXCHANGE AND THE USE OF HIGH-VALUE BUILDING MATERIALS
ENCOURAGE COMPANIES TO USE A MATERIAL PASSPORT

The arrows indicate when a certain action can be applied and when impact is expected. This is dependent on many aspects such as speed of market implementation and market scalability.

BARRIERS
- Technology
- Market
- Regulations
- Culture

Gemeente Amsterdam
ECONOMIC AND ENVIRONMENTAL IMPACT OF A CIRCULAR CONSTRUCTION CHAIN COMPARED TO A LINEAR SCENARIO IN AMSTERDAM

The total economic activity of the Amsterdam metropolitan region amounts to 106 billion euro annually, of which 47 billion is accounted for by the city of Amsterdam (2013) (CBS, 2015)* and 1.7 billion euro by the construction industry per year. Amsterdam has plans to realise 70 thousand new homes by 2040 (Amsterdam, 2011). Part of this new construction is replacing existing homes that have been demolished and another part is accommodating the growth of the city. A macro-economic analysis has been carried out based on the circular strategies that can reshape Amsterdam’s construction activities. The results provide insight into the effects of implementing these strategies on economic growth, employment, material savings and reduction in greenhouse gas emissions.

This ‘circular scenario’ can be compared to linear growth paths in Amsterdam and takes both the direct and indirect effects of circular strategies into account. Efficiency gains from high-value reuse in cement production could, for example, lead to cost savings that, in turn, lead to an increase in spending on machines for which cement is an input. The net effect of the efficiency improvement can, therefore, be lower than the direct effect. In contrast to other sectors, productivity in Amsterdam’s construction industry declined 2.8% over the 2005 to 2012 period. A circular building chain can lead to a 3% increase in productivity growth, representing a value of 85 million euro per year for the city of Amsterdam. Compared to the 2.8% decline over 2005-2012, this is highly significant. This added value, however, cannot be realised overnight. Depending on the diligence with which companies adopt circular methods and depending on the speed with which stimulating policy is implemented, the economic decline could be redirected to a 3% growth per year over a period of five to seven years. This economic growth is realised for the most part by greater value retention due to material reuse and efficiency gains.

Productivity growth means increased employment opportunities; for example, increased demand for targeted demolition activities requires more manpower. On top of this, return logistics will become more complex. From a logistical standpoint, it is not the disposal of just a container of demolition waste but the transport of different waste fractions to various processing locations and then back to new construction after processing. A total of about 700 additional jobs can be realised in the city - a structural expansion of the number of jobs. For the most part, these are jobs for low- to medium skilled personnel. Set against the current 75 thousand jobs in the Amsterdam building sector, the approximately 1% gain would be a significant contribution, resulting in a 10% drop in unemployment in the construction sector (averaging 8.1% in Amsterdam).

Improving the reuse of materials leads to a saving of 500 thousand tonnes of materials required for the 70 thousand new houses to be built in Amsterdam alone. Set against the current annual import of 1.5 million tonnes of biomass for the entire metropolitan region, this can be characterised as significant. The expected reduction in greenhouse gas emissions rounds off to half a million tonnes of CO₂, equivalent to 2.5% of the annual CO₂-emissions of the city of Amsterdam.

In this study, the value creation of circular initiatives is compared to the total added value at basic prices, NOT to the Gross Regional Product. In this chapter, a TNO-analysis is applied, and the assumptions used stem from the following sources: (2014) Macro-level indicators to monitor the environmental impact of innovation. EMInInn (Environmental Macro-indicators of Innovation) THEME [ENV. 2011.3.1-9-3], FP7 project for the EU; D. Ivanova, M. Chahim, (2015) CBS.
The scalability map shows locations where opportunities exist to apply the four circular construction strategies for the construction chain. The strategies are dismantling and separation, high-value reuse, smart design, and the creation of a marketplace and resource depots. The red areas indicate future real estate projects. Blue represents areas where circular strategies on existing buildings can be applied. The white circles represent locations currently not in use, which can be considered as possible locations for the storage of materials or for developing new circular building projects.
3. VISION OF HIGH-VALUE RECYCLING OF ORGANIC RESIDUAL STREAMS IN AMSTERDAM

In order to achieve high-value recycling of organic residual streams in Amsterdam, we established a circular vision. The vision and roadmap were supplemented and refined based on conversations with experts and stakeholders. The starting point for the analysis was the realisation that there are many initiatives in the city and in the region that are focused on higher value processing of organic streams. At the same time, there is an opportunity to develop a strong cluster that focuses on further value retention and optimised cascading of organic residual streams in Amsterdam and the surrounding region. This chapter describes four strategies that are tailored to the region and link with local initiatives and innovative market parties. Furthermore, the chapter considers trading opportunities for the municipality, areas where the market is active and the role of the government is that of a facilitator. The roadmap describes concrete action points for the municipality to link to time lines, and highlights which parties can play a role in the implementation. The impacts of implementing the strategies are calculated for (1) value creation, (2) CO2-reduction, (3) material savings and (4) job growth.
In the ideal circular future of organic residual streams in Amsterdam, organic flows such as food and water of the highest quality are delivered to consumers. Organic residues are recovered in a high-value manner and reused in innovative applications. Core to this circular vision is integrated food production, food processing and biological processes, where nutrients and water flows are efficiently directed and residual flows are valorised. This leads to a more varied chain for organic residual streams that requires less energy, nutrients, water and resources and achieves significant economic, environmental and social benefits.

In a circular future, consumers have easy access to local food sources. Local, cooperative farms and breeders in the vicinity of cities will ensure the direct supply of fresh seasonal produce to consumers. The food chain will, therefore, be shorter, with more interaction between local growers and citizens resulting in a greater sense of community. By using underutilised city, roof and community spaces in a smart way for urban agriculture and city gardens, consumers get much easier and closer access to fresh food.

Innovative technologies for the distribution and storage of food also offer better opportunities for documentation and management of food products. Smart logistic solutions will continuously monitor food quality and ensure that food is transported within the correct time frame from producers to retailers and restaurants. At the same time, retailers and restaurants have smarter systems that provide information about the quality and shelf-life trajectories of their food supply, allowing them to optimise their sales before the expiry date of their food and before it needs to be discarded.

Food that can still be used but needs to be discarded due to its shape for marketing or other reasons can be offered on a virtual marketplace where food producers, retailers and restaurants can buy and sell 'food waste'. This enables a growth of innovative companies that can take advantage of this food waste stream.

In a circular future, Amsterdam becomes a bio-refinery hub, processing organic residual streams that can no longer be reused in a high-value manner. Separation and processing of mixed and homogeneous waste streams by producers, consumers and retailers offers opportunities to recover important nutrients that can be used in the agricultural sector. Processing these streams also provides opportunities for new packaging solutions, biochemicals, biofuels and biogas products, which can either be exported or used in Amsterdam.

The described vision is illustrated in a visual representation (see opposite and enlarged on the next page) that depicts the chain and stakeholders in the city. In the next section, the vision is translated into strategies and action items that use market, technical, technological and administrative instruments to realise circular opportunities in the chain.
From the described vision for high-value recycling of organic residual streams, we developed strategies and action items, such as land allocation and purchasing, to close material cycles in the organic residual streams chain. The strategies are:

1. Central bio-refinery hub
2. Waste separation and return logistics
3. Cascading of organic flows
4. Recovering nutrients

These circular strategies are explained on the basis of relevant existing activities that currently take place in the city and region. In addition, the four strategies are displayed in a spatial view, similar to the spatial vision map. Even though the strategies are described separately in order to distinguish action points that can accelerate the circular economy, they are partly intertwined with each other and should, therefore, be considered as a total package.

The following section lists the four strategies translated into a concrete roadmap and action agenda. The action agenda further explains where the municipality of Amsterdam can be of influence, what other market parties can become involved and in what timeframe the transitions can take place. The roadmap and action agenda are formulated on the basis of the previously described research and analysis, as well as interviews with stakeholders and experts.
Through cascading, the highest possible value can be extracted from organic residual streams (Bio-based Economy, 2015). These activities will be bundled into a central bio-refinery hub and a logistics hub where bulk products can be transported on a large scale, and where local small flows can come together. The port is an important node in the global trade of agricultural and energy products because of its strategic location and logistic connections. Processed materials from all over the world are traded here, and a processing cluster will enable the local marketing of organic residual streams. To realise a hub for the processing of organic waste and the optimal reuse of organic residual streams, a certain scale is required, which is possible for Amsterdam to achieve (Green Raw Materials, 2014). Such a hub will be able to produce a variety of bio-products, such as biomaterials, building blocks for the chemical industry, food, feed, biodiesel, biogas, lubricants, bio-based paint and oil, fertilisers, algae and bio-aromas.

Optimised cascading of organic residual streams To enable optimised cascading of organic residual streams, it is necessary to link and upscale existing initiatives so that the resulting volume is greater. Existing pioneering activities in the region include the Greenmills-cluster, an alliance between six companies (Noba Vetteredeling BV, Rotie BV, Biodiesel Amsterdam, Tank Storage Amsterdam BV, Chaincraft BV and Orgaworld BV) that is active in the further development of bio-refinery concepts and the optimal reuse of organic residual streams. On-site organic residual streams (including finished edible fat, animal fats and supermarket waste) are processed for the production of almost 300 million litres of biodiesel, 25 million cubic metres of biogas through anaerobic digestion (City of Amsterdam, 2015b) and 5000 tonnes of fertiliser. Chaincraft develops a technology on-site to distil components for the food and chemical industry from organic residual streams (Port of Amsterdam, 2014).

Close cooperation between AEB Amsterdam and Waternet has resulted in a joint industrial cluster in which AEB is burning 80 thousand tonnes of dry sewage sludge per year. The 11 million cubic metres of biogas that is produced from the fermentation of sewage sludge is burned in the CHP (combined heat and power) plants of AEB. Some of the energy and heat is delivered back to Waternet to use for their own processes and 10% is used by OrangeGas to produce green biogas (City of Amsterdam, 2015b). Plans are in place to increase production to around 22 million cubic metres. AEB has plans to extract fruit and vegetable fractions from waste - a first step towards further processing these waste streams to make products such as proteins, bio-oil and hydrogen. The production of sustainable steams and CO₂ by AEB will further improve the circularity.

Similar activities are planned for Schiphol Airport, such as an anaerobic digester plant. This facility, which, in the future, will be responsible for 6% of the energy supply of Schiphol (Coes, 2015), will make use of grass clippings from surrounding areas and from organic residues from the region, such as the nearby flower auction and Greenport Aalsmeer. Another project is Bioport Holland, a consortium between SkyNRG, the Dutch Government, KLM, Neste Oil, Schiphol Airport and the Port of Rotterdam that produces jet biofuels. With its direct airplane fuel pipeline (60% of the jet fuel consumption of Schiphol stems from the port of Amsterdam), the port area has the infrastructure, utilities and resources to produce jet bio-fuel.

Bio-based materials The use of bio-based building materials is an important opportunity to reduce the impact of scarce building materials (Ecorys, 2014; EMF, 2015). Locally sourced biomass can (partly) be used for the production of bio-based materials, reducing the impact of transport.

In Amsterdam, there are several companies active in this area. For example, Avantium is a pioneer in using conversion technologies for the production of renewable fuels and bio-based plastics (PEF) that can serve as an alternative to PET. At this time, Port of Amsterdam, Orgaworld and AEB are working together with TNO, Attero and the Association of Waste Companies on a project to replace petrochemical polymers and coatings with bio-chemical components (for example, bio-aromatics).
WASTE SEPARATION AND RETURN LOGISTICS

Good waste separation and smart reverse logistics are important in the optimal valorisation of organic residual streams (Consonni, 2015). At this time, the waste separation rate in Amsterdam is far below the Dutch average (CBS, 2015c) and organic waste in particular is rarely separated at the source. Finding solutions for the effective separation of domestic waste at the source in densely populated urban areas requires a complex technological approach, particularly for existing homes.

AEB is considering building a waste separation installation that can extract plastics, fruit and vegetable waste (organic waste) from the collected residual waste. The fruit and vegetable waste will initially be used for the production of green gas as a transportation fuel. At a later stage, waste will be used for the production of high-value processing. This enables superior processing of waste streams, increased information on the composition of the waste and improved logistics to match supply and demand. Where no underground waste containers are available, separate collection can be realised via alternate systems, such as the use of specific bags for the separation of different waste materials. A pilot for this is taking place in Reigersbos, where inhabitants receive colour-coded bags to separate and dispose of wastes in special containers (City of Amsterdam, 2015c).

Smart reverse logistics The market for meal boxes such as the BeeBox is growing fast, and other large retailers like Albert Heijn have recently entered this market. It is expected that the market for meal boxes will grow significantly over the next few years (Keuning, 2015). The meal box trend, in combination with the growing interest in reverse logistics among logistics service providers such as PostNL, offers opportunities for the development of solutions for the reverse logistics of organic waste. Once food boxes are delivered, the same carriers can be used to collect organic waste, and organic residual streams can then be transported to the bio-refinery hub for high-value processing.

Street smart containers A possible solution for existing buildings is to place waste separators in existing underground waste collection systems to enable separation of organic and mixed waste. The underground containers can be equipped with smart sensors for the measurement of waste streams. This enables superior processing of waste streams, increased information on the composition of the waste and improved logistics to match supply and demand. Where no underground waste containers are available, separate collection can be realised via alternate systems, such as the use of specific bags for the separation of different waste materials. A pilot for this is taking place in Reigersbos, where inhabitants receive colour-coded bags to separate and dispose of wastes in special containers (City of Amsterdam, 2015c).
CASCADING OF ORGANIC FLOWS

Although there are a variety of options for the recovery and reuse of organic waste for other purposes, 97% of the household organic waste in Amsterdam is burned for energy recovery and only 3% is reused or recycled for other purposes (Circle Economy, 2014). Incineration currently provides valuable energy and heat, but several new technologies and business models can now be applied to these waste streams to create more value (Bio-based Economy, 2015).

The recovery of foods in the Amsterdam metropolitan area, new restaurant and catering concepts aim to preserve edible food scraps from warehouses and shops. Many of these companies, such as InStock, are well set up with permanent shops and a neat shop front. There are also bottom-up community initiatives, such as Guerilla Kitchen, and companies like Kromkommer process edible but deformed or damaged foods, which are not suitable for retail, to make soups and other food products, giving them a second life that is in line with their original purpose.

Cascading of organic residual streams Organic residual streams that cannot be directly reused can be cascaded to high-value applications (Wahab, 2015). Companies like Exter can extract additives for the food processing industry; an example of this is the extraction of bio-aromatics and reactive flavours from vegetable proteins as a replacement for chemical flavourings. Waste water and organic waste from a variety of municipal, industrial and agricultural sources can be treated in large-scale algae growth projects (Lofius, 2013). GRO Holland uses discarded coffee grounds from cafes and restaurants in which to grow oyster mushrooms, which are then immediately sold or used as ingredients for food.

Production of high-quality protein The emergence of insects as a source for both animal feed and human consumption has led to the growth of insect farming using organic residues, as seen in companies like Amsterdam-based Protix Biosystems, which uses food waste to grow insects. In addition, algae grown from organic wastes are rich in high-quality protein and can be processed into a wide range of products such as animal feed, fertilisers, fuels, chemicals and pharmaceuticals. Algae can be used to improve plant production, reduce sensitivity to diseases and act as a natural pesticide.

Biomass in public spaces Public areas and unused spaces, such as port areas or the berms of highways, can be used in a smart way for the production of biomass. Different grass types are suitable for the production of fibre and protein and can be used locally as raw material for the production of cardboard or as an alternative to soy. Organisations such as Meerlanden have experimented with alternative uses of public green areas. Initiatives such as Fruityourworld show that it is possible to share public spaces with others and to grow fruit there for and by local residents.
RECOVERING NUTRIENTS

Across the whole food chain – from field to fork – only 5% of the nutrients placed in the soil are actually used to provide us with nutritional value (Circle Economy, 2014a). The remaining 95% of the nutrients are lost somewhere in the cycle. For example: crops absorb only 30 to 50% of the applied fertiliser and use almost 25% of that for the growth of non-edible parts, which, in the current model, are disposed of as waste; in Amsterdam, large quantities of nutrients, such as minerals, fertilisers, foodstuffs or animal food that, at some point, end up in the environment, are imported; and the sewer drainage system is a valuable resource for nutrient retrieval. Mankind produces, on average, 500 litres of urine and faeces in a year. Because the human body does not absorb all the nutrients from the food we consume, this waste is full of nutrients. An important opportunity to improve the nutrient cycle in Amsterdam is in the application of decentralised, local processes to recover these nutrients.

Fertiliser manufacturing Globalisation of the food production system has led to the concentration of many large-scale food processors in the Amsterdam port area, such as soy processing companies like Cargill, and Ahold, Coffee Company, Starbucks, Olam International and ADM Netherlands, where coffee and cocoa are being processed. Residues from these companies can be used in the production of fertilisers through a process in which phosphates can be recycled. An example of a company in the Amsterdam port area that recycles nutrients from waste streams of Cargill is ICL Fertilizers Europe, which uses residual flows with a high phosphate content. ICL Fertilizers strives to replace 15% of the phosphate ore in 2015 and 100% in 2025 (Langefeld, 2015). The first tests show promising results for the use of ‘secondary’ phosphates, but additional research is needed to further extend this approach.

Decentralised processing The municipality could develop local pilots in order to recover nutrients from the food system through anaerobic digestion plants and develop techniques to convert urine into valuable nutrients such as nitrogen and phosphate. A disadvantage of these techniques is that they are often not financially profitable (AEB, 2015). Decentralised management of waste water can be beneficial in areas linked to excessive water through-flow, such as densely populated urban areas. Further investment in the cascading of waste water and process technologies could lead to improvements in the recovery of energy, heat and nutrients.

Visual display of recovery of nutrients: Organic residual streams are processed through decentralised, local processes to recover nutrients. The effects of circular strategies on the environment and the economy are calculated for the organic residual streams in Amsterdam. It is assumed that it will take five to seven years to achieve a circular arrangement of the processing of organic residual streams coming from all 430,000 Amsterdam households in the long term. Four indicators have been used in determining impact: (1) net added value in millions of euro, (2) net job growth in FTE, (3) material savings calculated by value retention in domestic material consumption and (4) reduction in CO2 emissions.
The spatial vision map indicates how circular strategies for the organic residual streams in Amsterdam can be applied and how they are interwoven in a spatial context. The following strategies are described: (1) central bio-refinery hub, (2) waste separation and return logistics, (3) cascading of organic flows and (4) recovering nutrients.
Many of the ways to achieve a circular economy may already be profitable but, when up-scaling a solution, barriers often emerge. Policy can play an important role in removing these barriers. We distinguish four types of barriers:

1. **Laws and regulations**
   - Existing policy often leads to unforeseen consequences in changing market conditions. An example is the Environmental Management Act (art. 1.1), which describes what is legally classified as waste and what is not (Government, 2015).

2. **Technology**
   - Technological development has two important challenges. Up-scaling a small pilot to a commercial scale is often challenging, and the interdependency and complexity of technologies that must be developed together can also be a barrier. These barriers have important implications for the extent to which some of the strategies can be implemented successfully - especially in the short term. In some cases, governments can overcome these barriers, and the market may break down barriers in others, but, in many cases, the solution requires cooperation, experimentation and iteration. For each of the four circular strategies, an impact assessment per barrier is made below. The assessment of the severity of the barrier comes from insights obtained from the interviews and is further based on estimates of the research team. For the top three actions, the roadmap will address options to overcome these barriers.

3. **Culture**
   - The circular economy requires close cooperation between sectors and chains. A lack of inter-sector networks, a conservative culture and vested interests in sectors can be obstacles to the efficient formation of successful cooperation.

4. **Market**
   - The existence of ‘split incentives’ is a barrier; the investments must be done by one stakeholder in the chain while the income is earned by another. Another market-related barrier is knowledge asymmetry, such as knowledge with regard to the availability of secondary resource flows and its quality. The lack of externality pricing, including that of CO₂, can also impact the market. The last barrier that we want to mention in this category is the limited access to financing for circular initiatives.

### BARRIERS

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This table indicates how high the barrier to a circular economy is for each of the strategies. (Source: Insights from interviews, literature and assessment of the research team.)

The above table is a summary of the most relevant and significant barriers that apply to this chain in achieving a transition towards a circular economy. This is based on research, literature, interviews and insights from the research team.)

- The flow of organic residual streams is highly varied, both geographically and across time (impacted, among other things, by seasonal variations in green waste such as roadside grass), which forms an obstacle when trying to complete the business case.
- High-value bio-refinery technologies are in the early stages of development. For up-scaling and commercial viability, significant investment into additional research and development (R&D) is required. A lack of funding for this can make both the speed of and the chances for success uncertain.
- Market demand for end products of bio-refining is currently low due to factors such as ignorance of market players, a limited ability to realise significant supply and a lack of clear quality criteria.
- The production of high-quality protein by growing insects (larvae) on organic residual streams is required to comply with the current laws and regulations regarding slaughter of live animals, which raises practical and, thus, financial barriers.
- Policies that aim to increase the share of green gas into the natural gas network give too little consideration to the interests of importers and more to the interests of (traditional) network operators.
- Recovered nutrients, such as phosphates (by processing of struvite, for example) from waste water may, under current laws and regulations, not be applied as fertiliser on agricultural land and can, therefore, not be capitalised on, which makes the business case more difficult. A recently signed green deal provides an adjustment in the classification of waste under VANG and REACH (Sloover, 2014).
- According to current legislation, digestate from anaerobic digestion cannot be used as fertiliser on agricultural land (to replace artificial fertilisers), which complicates the profitability of digester plants.
- For waste substances, a waiver on the legislation is required per waste substance and per installation. This is an intensive and lengthy process that has been undertaken for struvite in Amsterdam.
- European regulations concerning the ‘expiry date’ and food hygiene create uncertainty for the high-value reuse of food.
- Various technological possibilities to enable greater source separation rates of organic residual streams are being examined. The technological complexity of these solutions (such as the link between technological installations in households and the necessary infrastructure) raises challenges that require both further technological development and the planning of underground installations and infrastructures.
CENTRAL BIO-REFINERY HUB

1. Expanding and designating new ‘free zones’ and ‘circular field labs’ In a number of industrial clusters, such as the harbour area, policies can be temporarily eased to support the development of bio-refining activities. Legislation that currently stands in the way of the development of bio-refinery concepts includes the ban on the use of digestate, which is rich in nutrients (especially phosphate), on agricultural land. This is currently blocking an important and essential part of the phosphate cycle. The establishment of clear criteria can give clarity to this underdeveloped market.

2. Further developing of a sustainability fund specified for the circular economy A circularity fund should be financed by public and private parties with the aim of financially supporting innovative projects before the market provides starting capital, private equity and bank financing. The circularity fund can build on the experiences of the ‘Amsterdam climate & energy fund’ (AKEF). The fund should, however, lead to changes in the classification of recovered substances under VANG and REACH (Sloover, 2014).

3. Establishing criteria for ‘new bio-based products’ Currently, the market is being hampered by uncertainty around quality specifications for bio-based products. The lack of clear criteria is currently a problem for two projects involving the breeding of insects using organic waste with the aim to produce proteins that can be used as fodder in, for example, aquaculture. Growing insects now falls under the complex regulations of the Slaughter Act. Better criteria can give clarity to this underdeveloped market.

WASTE SEPARATION AND RETURN LOGISTICS

1. Renovating underground waste containers The renovation of waste containers, in Amsterdam-West, for example, can lead to an improvement in the share of source separated waste. The suggestion is to equip existing and new containers with the ability to separate fruit and vegetable waste in addition to the current separation of paper and glass. A container replacement campaign is being rolled out in Amsterdam West over the next three years. This modernisation could act as an incentive for local SMEs and for metal- and installation companies in particular. New requirements for separate waste collection can also be included in procurement criteria for the municipal waste infrastructure.

2. Rebuilding waste hubs into centres for the circular economy Current waste hubs can be transformed into recycling activity hives similar to the municipal recycling platforms in Almere. This optimises reverse logistics and the share of separated waste collection at source (Amsterdam Connecting Trade, 2014). This can lead to a decrease in the amount of transport needed. By connecting information about the composition of waste, the residual flows may be worth more. A stimulus package and match-making services to entice companies to locate in the region.

3. Creating variable tax rates for different waste categories (in the so-called Diftar system) In very densely populated residential areas of urban regions, it is more difficult to separate household waste. By taxing grey household waste more heavily through a differentiated tax system (Diftar), source separation of domestic waste will be (financially) stimulated.

CASCADING ORGANIC RESIDUAL STREAMS

1. Creating ‘breeding grounds’ to promote urban agriculture This increases local food production and biomass production. In addition, empty buildings can be used to produce food. Examples of and initiatives in urban agriculture are expanding rapidly. An example in Almere is ‘Agromere’, which aims to put a process in motion that should eventually lead to a new residential area in which agriculture is fully integrated (Jansma, 2015).

2. Stimulating locally produced products, biomass and nutrition through purchasing policy Local production of biomass and food reduces the need for transport, benefiting the environment (PBL, 2014). One of the sources for wood is green areas of the city (City of Amsterdam, 2014). To increase the production of biomass at the municipal green facilities, a more holistic approach to the management of municipal green and waste is required. Public green spaces can be used for the growing of special species of plants (e.g. shrubs) (Urgenda, 2015) that are specially bred to grow quickly, produce more biomass, take in more CO₂, save more rain water and absorb more particulates.

RECOVERING NUTRIENTS

1. Realising an integrated phosphate strategy The municipality can help realise a closed phosphate cycle. The municipality ought to encourage industrial symbiosis and technological innovation in order to achieve this. Residual streams containing phosphate should be matched up with parties with a demand for phosphate. First steps in this direction have already been taken in projects that involve AEB, ICL and Waternet, among others.

2. Promoting decentralised waste-water management systems This enables the local recovery of heat, energy and resources. Research done in Buiksloot has shown how the urban environment can be set up at a neighbourhood level to allow decentralised reception of waste and water (Amsterdam Smart City, 2015). It should include, for instance, the separation of waste water types (grey, yellow and black water) and the local valorisation these streams. The municipality can build on this research.
Three action points, as shown in the table, have been selected from the interviews and discussions with stakeholders. In selecting these, four major effects have been taken into account: (1) value creation, (2) CO2-reduction, (3) material savings and (4) job growth. These measures have also taken into account the barriers that have been identified for the construction chain, and the role that the municipality can fulfil.

**1. Virtual Resource Platform to Further Develop and Make Publicly Accessible Specific Geo-data with regard to Demand and Supply of Organic Residual Streams in the City and Region**

The municipality can further develop and make publicly accessible a digital (commercial) platform for organic waste. Such a platform can offer a transparent overview of the supply, demand and use of organic residual streams in Amsterdam (and beyond). In addition, it can address the uncertainty in the market by improving the matching of supply and demand. This may be a response to the current uncertainty in market participants about supply and demand of flows. The lack of understanding has been mentioned as an obstacle to planning by many of the regional stakeholders, which, in turn, affects the financing due to supply risks. The platform would provide insight into fluctuations in supply and demand on the basis of, for example, seasonal variations in the availability of green waste. The municipality can also stimulate innovation concepts, linking small and large businesses.

**2. Circular Bio-refinery Free Zone to Identify Specific Locations Intended as Circular Free Zones and Draw Up Rules for Further Development**

The municipality can initiate circular free zones. This could take away certain (legislative) barriers that currently hinder innovation, such as the ban on the use of nutrient-rich digestate (especially phosphate) on agricultural land. This is currently blocking an important and essential part of the business case for anaerobic digester plants because the current market value of digestate is low.

**3. Launching Customer to Develop Purchase Criteria for the Use of Locally Produced Grass, Wood and Food**

The municipality can introduce criteria in its purchasing policy to stimulate locally produced grass, wood (as in street furniture) and food (catering). The large buying power of the municipality itself can create an important and constant demand that allows local parties to further develop and professionalise. With the local production of biomass and food, the need for transport and its associated environmental impact is reduced (PBL, 2013). The local production of wood can take place in the municipal green facilities of the city (Municipality of Amsterdam, 2014a). To increase the production of biomass in the municipal green facilities, a more holistic approach to the management of municipal green and waste materials is required. Public green spaces can be used for the planting of special species of plants (e.g. shrubs) (Urgenda, 2015) that are specially bred to grow rapidly, deliver more biomass, take in more CO2 and absorb particulates.

**Stakeholders**

AMS, Floow2, Oogstkaart, TNO, The municipality and Wageningen UR

**Connection to projects**

The AMS-run program ‘Urban Pulse’ has initiated planned activities around the mapping of resource streams such as organic residual streams into spatial maps. There are also activities within the municipality around providing insight into waste streams associated with geo-data. In addition to this, the municipality can engage with organisations that use big data and have great potential for the circular economy (Lacy, 2015), such as Wageningen UR and AMS, who conduct research into the use of big data (Top, 2015).

**Investments and results**

The investment required to set up a platform is largely for the development of the IT-infrastructure and for the conceptual development of the platform. Although there are many market participants, including large IT parties, that deal with the development of such platforms, the municipality can play the role of initiator. The ‘out-of-pocket’ development costs for a platform can be financed by private and public parties. The effects and impact on the actual volume of processing organic flows through the deployment of the platform will probably take several years before it is of significant size. This is because the development, buy-in and critical mass required by market parties will take time.

**Virtual Resource Platform with regard to Demand and Supply of Organic Residual Streams in the City and Region**

In selecting these, four major effects have been taken into account: (1) value creation, (2) CO2-reduction, (3) material savings and (4) job growth. These measures have also taken into account the stakeholders. The measures to be taken fall completely within the terms of the Municipality Act. The designation of circular free zones could be an effective way to neutralise the barriers described in the local barrier overview. It is a measure that requires investment, especially in organisation, supervision and enforcement. The measures to be taken fall completely within the terms of the Municipality Act.

**CIRCULAR BIO-REFINERY FREE ZONE**

By making (open) data available, the municipality can stimulate innovation in the city (action point 1), play an important role in setting the high barriers around laws and regulations and for bio-refining technology (action point 2), and can increase the demand for circular products by altering its own purchasing policy (action line 3).

**LAUNCHING CUSTOMER TO DEVELOP PURCHASE CRITERIA FOR THE USE OF LOCALLY PRODUCED GRASS, WOOD AND FOOD**

The municipality can introduce criteria in its purchasing policy to stimulate locally produced grass, wood (as in street furniture) and food (catering). The large buying power of the municipality itself can create an important and constant demand that allows local parties to further develop and professionalise. With the local production of biomass and food, the need for transport and its associated environmental impact is reduced (PBL, 2013). The local production of wood can take place in the municipal green facilities of the city (Municipality of Amsterdam, 2014a). To increase the production of biomass in the municipal green facilities, a more holistic approach to the management of municipal green and waste materials is required. Public green spaces can be used for the planting of special species of plants (e.g. shrubs) (Urgenda, 2015) that are specially bred to grow rapidly, deliver more biomass, take in more CO2 and absorb particulates.

**PURCHASE CRITERIA FOR THE USE OF LOCALLY PRODUCED GRASS, WOOD AND FOOD**

The effects of these measures may soon be visible since there is a direct market demand for local products.

**Launch Customer to Develop Purchase Criteria for the Use of Locally Produced Grass, Wood and Food**

Municipality, caterers and suppliers of facility management, local producers, Exter, Kromkommers, Provalor, GRO, Holland, Taste Before You Waste, Instock, Food banks, Meerlanden and Fruityourworld

**Specific Geo-data with regard to Demand and Supply of Organic Residual Streams**

Food banks, Meerlanden and Fruityourworld.
ROADMAP ORGANIC RESIDUAL STREAMS

SHORT TERM (1 YEAR)

1. FURTHER DEVELOPMENT AND ENSURING PUBLIC ACCESS TO GEODATA FOR SUPPLY AND DEMAND OF ORGANIC WASTE IN THE CITY
2. TO IDENTIFY SPECIFIC LOCATIONS INTENDED AS CIRCULAR FREE ZONES AND DRAWING UP RULES FOR FURTHER DEVELOPMENT
3. TO DEVELOP PURCHASE CRITERIA FOR THE USE OF LOCALLY PRODUCED GRASS, WOOD AND FOOD

TOP 3

- EXPANDING AND DESIGNATING NEW ‘FREE ZONES’ AND ‘CIRCULAR FIELD LABS’
- FURTHER DEVELOPING OF A SUSTAINABILITY FUND SPECIFIED FOR THE CIRCULAR ECONOMY
- ESTABLISHING CRITERIA FOR ‘NEW BIO-BASED PRODUCTS’

- DIFFERENTIATING AMSTERDAM AS AN ‘(INNOVATIVE) HUB FOR BIO-REFINERY’
- RENOVATING UNDERGROUND WASTE CONTAINERS
- REBUILDING WASTE HUBS INTO CENTRES FOR THE CIRCULAR ECONOMY
- EQUIPPING STREET CONTAINERS AND WASTE INFRASTRUCTURE WITH SMART IT SYSTEMS
- CREATING VARIABLE TAX RATES FOR DIFFERENT WASTE CATEGORIES

- REALISING AN INTEGRATED PHOSPHATE STRATEGY
- PROMOTING DECENTRALISED WASTE-WATER MANAGEMENT SYSTEMS

ARROWS

The arrows indicate when a certain action can be applied and when impact is expected. This is dependent on many aspects such as speed of market implementation and market scalability.

BARRIERS

- Technology
- Market
- Regulations
- Culture
ECONOMIC AND ENVIRONMENTAL IMPACT OF A CIRCULAR ORGANIC RESIDUAL STREAMS COMPARED TO A LINEAR SCENARIO

The total economic activity of the Amsterdam metropolitan region amounts to 106 billion euro annually, of which 47 billion is accounted for by the city of Amsterdam (2013) (CBS, 2015)*. The contribution of the agricultural sector to the city of Amsterdam amounts to 248 million euro and the contribution of the food sector amounts to 593 million euro. The current recycling of organic residual streams in Amsterdam provides a lot of room for optimisation. The city of Amsterdam has ambitions to increase the source separation of the organic fraction over time in all 430 thousand households in Amsterdam. In 2015, every inhabitant of Amsterdam generated an average of 92 kilograms of vegetable-, fruit- and garden waste (Amsterdam, 2015d). This separate collection makes it possible to use the organic fraction for new uses such as the production of protein for animal feed, biogas and building blocks for the chemical industry. A fully circular organic residual stream chain can result in an increase in productivity of 14% for the agricultural sector and 7% for the food sector in the city of Amsterdam over a period of five to seven years. This is on top of the linear growth scenario. The resulting added value to the economy could amount to 150 million euro per year.

In this study, value creation of circular initiatives is compared to the total added value at basic prices, NOT to the Gross Regional Product. In this chapter, a TNO-analysis is applied, and the assumptions used are from the following sources: Chiewa, et al. (2014) ‘Environmental impact of recycling digested food waste as a fertilizer in agriculture—A case study: Resources, Conservation and Recycling; Vandermeersch, et al. (2012) Environmental sustainability assessment or food waste valorisation option’, Département of Sustainable Organic Chemistry and Technology; Leceta, et al. (2015) ‘Bio-based films prepared with by-products and wastes: environmental assessment’, Journal of Cleaner Production.

The material savings consists mainly of materials that can be replaced by higher-value processed flows. An example of this is the production of high-value protein to replace imported protein such as soy for animal feed. The production of bio-based building blocks for the chemical industry enables the production of bio-plastics to replace oil-based products. The material savings that can be achieved may add up to 900 thousand tonnes of CO₂ emissions of the city of Amsterdam.

In addition, this transition could create 1200 local jobs in the long term, nearly 8% of the current 10 thousand jobs in the agriculture and food industry. Jobs created would include employment for the adjustment of waste infrastructure such as underground containers due to an increased need for pick up services for the separate waste streams, as well as for the more complex processing of these flows. There is a greater labour requirement for a facility such as Greenmills, which has various bio-refinery factories with private operators, compared to a facility where all large-scale and unsorted waste is processed. In addition to the direct employment effects in the agricultural and food industries, there is the potential for the creation of additional jobs in the supply industry in activities such as engineering and logistics.

The contribution of the agricultural sector to the city of Amsterdam (2013) (CBS, 2015)*. The metropolitan region amounts to 106 billion euro annually, of which 47 billion is accounted for by the city of Amsterdam (2013) (CBS, 2015)*. The potential economic and environmental impact of a circular construction chain in Amsterdam compared to a linear scenario is calculated for Amsterdam. Here, the impact will be realised over a period of five to seven years. Four indicators have been used in determining impact: (1) net added value in millions of euro, (2) net job growth in FTE, (3) material savings calculated by value retention in domestic material consumption and (4) reduction in CO₂ emissions. The values for the four indicators are shown in the four circles. The distribution in added value is shown in the bar chart.
The scalability map shows the organic residual streams chain where opportunities lie for four circular strategies: (1) waste separation and return logistics, (2) cascading of organic flows, (3) recovery of nutrients and (4) bio-refinery hub. Green markings show places where household waste is released and, thus, where the potential lies for separation and return logistics. Green and yellow points indicate supermarkets and street markets and reflect the potential for cascading in retail and industry. In addition, large multinationals and food processors are displayed on the map to indicate opportunities for the industry.
4. CURRENT STATE

To create a circular economy, we must first understand what is not circular in our current economy. This chapter provides insight into how resources move through the city, where they will be processed to add value to the local economy and where resources are wasted or cascade back into the system to be reused. To reach this understanding, the region was looked at in terms of material flows, energy consumption and employment. The various streams were then examined in order to identify which areas of circularity, quality of life and economic vitality can be improved in the city. For example, where is waste created? And where are the short and long term opportunities to convert these into opportunities for the city and the region? To get a more detailed picture of the ‘non-circular’ situation at present, we conducted an analysis based on regional and national statistics supplemented with specific organisational data.
CIRCULARITY MEASURED

One of the challenges in determining a strategy to create a circular economy is measuring circularity and gaining a good understanding of the status quo. For measuring the circularity of the city, region and sectors, the ‘circular indicators framework’ was developed by Circle Economy and TNO. The framework describes four main indicators that provide insight into the essential aspects of circularity. The first three indicators were evaluated using quantitative data provided by CBS and TNO. The indicator for transition potential was investigated by means of interviews and qualitative reviews of specific companies, organisations and other stakeholders within their respective chains. This framework was also used by Circle Economy and TNO for establishing the priority chains for a national project with the Ministry of Infrastructure and the Environment. The four key indicators, with each specific sub-indicator, are represented on the right.

In the figure opposite is an overview of the results of the framework applied to the thirty sectors that CBS differentiates in the macro-economic statistics of the region. Per sector, the figure indicates how big the ‘economic added value’ is to the regional economy (y-axis), what the ‘ecological impact’ is (x-axis) and how big the potential is for value retention (size of the bubble).

The above figure shows how the 30 sectors in the Amsterdam metropolitan area score on ‘economy’, ‘ecology’ and ‘value retention’, the three main indicators in the ‘circular indicators framework’. (Source: based on CBS-data with analysis of TNO and Circle Economy team)
The material flows for Amsterdam are analysed and visualised in the following diagram. This figure provides insight into how resources move through the metropolitan region and city, where they will be processed to add value to the local economy and where resources are wasted, or, ideally, cascaded back into the system to be reused. From this review, three important aspects - which are largely linear but which have the potential to create a circular economy in the region - appear to determine the current status.
ECONOMIC PERSPECTIVE
The import, processing and transport of materials and goods is an important economic activity in the metropolitan region. The Amsterdam metropolitan area has the largest seaport and airport in Europe. Through these two ports combined, more than 100 million tonnes of goods are imported and 30 million tonnes are exported annually (Port of Amsterdam, 2013). The gross added value of the seaport amounted to 3.5 billion euros in 2012, which was derived mainly from business and industry, including the metal industry, and the transport and logistics sector. For Schiphol Airport, the gross added value in 2012 amounted to 5 billion euros (Ministry of I and M, 2015). The total direct employment of the Amsterdam seaport is 34 thousand jobs; for Schiphol it is 65 thousand (Port of Amsterdam, 2013).

The food and construction sectors have a relatively low use of circular services. Circular services are sectors that are focused on product design, rental, repair and recycling. The average use of circular services in the Amsterdam metropolitan area is 14%. The construction- and food chain is slightly below the average, making use of only 12% and 13% of circular services respectively.

LOGISTICS HUB
The metropolitan region is highly dependent on imports of resources. In the metropolitan region, 10 million tonnes of material are consumed annually, of which 60% is imported from abroad, see Figure 4.1 and 4.2 for further details (CBS, 2015b). More than 50% of the import consists of fossil fuels, used mainly in the petroleum industry for the production of plastic.

The supply of materials is vulnerable to strong price fluctuations and distortions in the geopolitical context. The high trading volume in the MRA offers economic opportunities but, at the same time, exposes the MRA to disruptions in supply. In addition, the import of biomass from abroad has significant negative consequences for the environment, due to non-sustainable land use and agriculture in South America and other regions.

Use of materials and processing of by-products
Use of materials in the making and processing industry is dominated by biomass and minerals. In the metropolitan area, more than 10 megatonnes of materials - of which 40% is biomass and 40% is fossil fuels - are consumed annually (CBS, 2015b). Biomass is used mainly by industry (70%) and the agricultural and food sector (20%). A large part of the biomass use is allocated to the extensive food and beverage industry. Minerals such as coal are mainly used in the utility sector (74%) and industry (17%) (CBS, 2015b). Metals are mainly used in industry (90%).

Large flows of organic and mineral waste originate from industrial waste. Of the waste that is produced in the MRA, only a small part is collected through the municipal system as household waste - see Figure 4.3 for further details (CBS, 2015b). One-sixth of the 6 million tonnes per year is municipal solid waste, consisting mainly of minerals and organic waste (in Amsterdam 14% is household waste and 86% is industrial waste). Non-municipal waste amounts to about 5 million tonnes a year and consists mostly of organic waste. This offers opportunities for bio-refinery applications for high-value use of both municipal and non-municipal residual streams.

Waste in Amsterdam is, to a large extent, processed in a relatively low grade. One third of the total waste is incinerated to generate electricity and heat. This creates less value compared to recycling or reuse. For domestic waste, the rate for ‘useful reuse’ as defined by the CBS is 85%. This includes activities such as the use of granulated demolition and construction waste for road foundations, which, in a circular economy, can be regarded as a low-value application of recycling. Through high-value reuse, recycling and composting, more value can be extracted from these waste streams.
To understand the extent to which various chains contribute to the economic and ecological impact in Amsterdam, a chain analysis has been conducted. This chain analysis provides insight into the connections between sectors in an economy, such as the connection between the materials (physical flows) and economic value (monetary flows). An example of this can be seen in the production of oil, which is linked to the production of plastic from this oil, which is then linked to the use of plastic packaging material in the food chain, and later linked to the waste treatment of plastic packaging. Exploring which of the chains between sectors result in large impacts is a starting point for prioritising possible interventions. The four indicators used to measure impacts from the ‘circular indicators framework’ have been explained in the beginning of this chapter. For the economical and ecological impact and value retention, a comprehensive analysis was conducted, linking hundreds of value chains and sectors together. The ten chains with the highest impact or the greatest potential were selected. Stakeholder interviews were used to assess the transition potential. The ten value chains are shown in the table below, with shades of blue indicating the potential impact. Of the ten chains, six are included in the final analysis.

After consultation with the municipality and local stakeholders, the decision was made to focus on the construction chain and organic residual streams, as these have the highest economic and ecological impact, as well as the highest value retention and transition potential.

The analysis of the value chains serves not only to achieve a transparent selection of important chains at which circular initiatives should be focused, but also provides an overview of economic sectors and actors that are associated with that particular chain. These actors can be a source of inspiration in the development of concrete projects in the Amsterdam metropolitan area.

Opposite is a representation of a non-exhaustive and select group of actors for the construction chain and organic residual streams chain.
INDICATORS CIRCULAR ECONOMY

This page represents how the city of Amsterdam, the metropolitan region and The Netherlands score on three indicators: value retention, economic impact and ecological impact. Together, these three indicators give an initial idea of how, on a city-level, circularity could be measured. The three indicators were developed in the context of RACE (Realisation or Acceleration towards a Circular Economy), a program initiated by the Ministry of Infrastructure and the Environment. A summary of the indicators is presented later. Previously, TNO and Circle Economy calculated these indicators at the national level. The value retention is estimated according to resource efficiency: the amount of waste that is produced to generate an added value of 1000 euro. The economic impact is measured in added value per person and the percentage of circular services in the economy: the proportion of the added value in an economy that is generated by services focused on product design, rental, repair and recycling. The ecological impact is measured by environmental costs and CO₂-emissions.

<table>
<thead>
<tr>
<th>VALUE PRESERVATION</th>
<th>RAW MATERIAL EFFICIENCY</th>
<th>Raw material efficiency indicates possible waste reduction in production of goods, measured in kilograms of waste per €1,000 output</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
<td>NEDERLAND</td>
</tr>
<tr>
<td>N/A</td>
<td>39 kg</td>
<td>N/A</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>USE OF RENEWABLE RESOURCES</th>
<th>The use of renewable resources is the percentage of imports (net and domestic) consisting of biomass compared to total imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
</tr>
<tr>
<td>N/A</td>
<td>66%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECONOMIC IMPACT</th>
<th>GROSS VALUE ADDED</th>
<th>Gross Value Added per person is the economic value in € per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
<td>NEDERLAND</td>
</tr>
<tr>
<td>€61295</td>
<td>€33616</td>
<td>€31256</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CIRCULAR SERVICES</th>
<th>Circular Services is the percentage of services - related to the circular economy - compared with the Gross Value Added</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
</tr>
<tr>
<td>N/A</td>
<td>14%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ECOLOGICAL IMPACT</th>
<th>ENVIRONMENTAL</th>
<th>Environmental costs are the costs of exhaustion, water pollution, CO₂-emissions, toxicity and land use in € per kilogram</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
<td>NEDERLAND</td>
</tr>
<tr>
<td>N/A</td>
<td>52 €/kg</td>
<td>63 €/kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO₂ EMISSIONS</th>
<th>CO₂ emission is the amount of carbon dioxide which is released into the atmosphere in kilograms of CO₂ per person</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSTERDAM</td>
<td>MRA</td>
</tr>
<tr>
<td>5345 kg CO₂</td>
<td>8575 kg CO₂</td>
</tr>
</tbody>
</table>
5. RECOMMENDATIONS AND NEXT STEPS

The roadmap and action agenda presented in this Quick Scan offer a starting point, giving concrete direction to the ambition, vision and agenda on the theme of a circular economy for two specific value chains – construction and organic residual streams. The municipality can focus on expanding the details of these plans as a next step. Stakeholders, both within the government and in the market, will need to be engaged to actually take action on the proposed directions. Listed below are some next steps advised for the municipality.

Further development and selection of indicators that provide insight into the level of circularity in the city of Amsterdam can be undertaken. This basic set of indicators can be used, among other things, to measure progress. The applied ‘circular indicators framework’ in this study (Chapter 4) can give direction to the next steps.

The indicators can be applied in an interactive circularity dashboard that displays the progress of the most important indicators. The dashboard can be used internally, but can also involve inhabitants of the city more actively on the subject of a circular economy. In addition, Amsterdam can (in the future) benchmark against other cities on their circular performance.

To come to a detailed feasibility of the proposed actions, more analysis is needed. This analysis can include, for example, a detailed (social) cost-benefit assessment for the various parties needed for implementation. Next steps in the investigation of opportunities for the city and region are part of the program ‘Urban Pulse’, which is led by Amsterdam Metropolitan Solutions (AMS) and Circulaire Stad.

The need for greater transparency and a better understanding of the demand of (secondary) resource flows in the region and beyond is mentioned by many stakeholders as a condition for a circular economy, particularly for an optimal exchange and high-value processing of streams. Further development of (geographically explicit) digital material platforms would be crucial to connecting the supply and demand of residual streams and materials.

Related to the previous point, there is also a need for active coordination to match supply and demand. The municipality could potentially explore the appointment of chain directors who would be responsible for active matchmaking.
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FABRIC
Eric Frijters, Co-founder
Olv Klijn, Co-founder
Bas Driessen, Co-founder

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Kees van der Lught, Strategic advisor & innovation manager, Waternet
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Ad van Vught, Strategic Purchasing Manager, Exter
Bart de Wit, Manager SME’s, Companies, Rabobank Zaanstreek

Circle Economy is a cooperative whose mission is to globally accelerate the practical implementation of a circular economy. To accelerate the worldwide transition towards a circular economy, we use two main levers:
1) Practical action, aimed at developing practical solutions;
2) Campaigns, communication and engagement, aimed at spreading our message. We focus on projects and activities that are both practical and scalable.

TNO is a non-profit organisation that applies thorough scientific principles to a wide range of disciplines. TNO is active within five key sustainability themes: industry, healthy living, energy, the environment and defence and security.
TNO is one of the most internationally oriented research and technology organisations in Europe and has an unparalleled knowledgebase full of information about innovation, sustainability and policy making. Maintaining and improving this knowledgebase is a high priority as we continue to develop within international knowledge networks.

FABRIC is a knowledge-intensive design studio led by Eric Frijters and Olv Klijn. The involvement of the two founders in architecture, urban planning and research led to the creation of FABRICations. Our motto is: “Think while you do.” The motto expresses the thorough approach that characterises FABRIC. Our innovative solutions are rooted in a huge technical, historical and cultural knowledge. With each project, we invest in research to further increase the available knowledge and to further improve the quality of our proposals. We want to be the best knowledge provider and the most innovative solution creator. That is why we often form partnerships with other similar knowledge-intensive companies.
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*The photographs used in this report were obtained via Shutterstock.