METABOLIC CIRCLE ECONOMY BLUE CITY spring associates

CIRCULAR ROTTERDAM

Opportunities for new jobs in a zero waste economy

METABOLIC CIRCLE ECONOMY

Phase 1:

THE CURRENT STATE OF THE CIRCULAR ECONOMY IN ROTTERDAM

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CIRCULAR ROTTERDAM: EXECUTIVE SUMMARY

The Netherlands is seen as a 'circular hotspot' in Europe – a center for knowledge and innovation in the field of the circular economy. Dutch cities have taken the lead in the transition to a circular economic model in the way of innovation, tendering, urban design, and materials management. Rotterdam is one of these frontrunners, and has the most ambitious objectives of all. By 2030 the city wants circularity to become common practice, aiming to reduce primary resource use by 50%. In achieving this, Rotterdam seeks to create 3,500 to 7,000 jobs that contribute directly to the circular economy.

THE CIRCULAR ECONOMY

The circular economy is a new economic model that keeps human activities within the safe capacity of the planet, while simultaneously achieving a thriving and resilient society. This happens primarily through designing smart and closed material cycles which ensure that we get much more value out of our materials than is now possible. These cycles deliver many economic benefits, such as lower costs through reduced waste, compared to our current linear model. Eventually, however, a circular economy is about more than just financial benefits in the short term. There is a widely supported realization that we need to devise a sustainable and resilient economy to prevent us from having large-scale material shortages or crossing irreversible tipping points in the natural systems of the planet. The importance and the urgency of this transition is underscored by new European and Dutch legislation that targets a higher degree of circularity.

TIME FOR ACTION

There have been a great deal of published analyses and theories that describe the potential of the circular economy. It is time to act. In line with its entrepreneurial character, Rotterdam is well-placed to roll up its sleeves and make the investments necessary to initiate a large-scale transition to a circular economy. To understand where the focus should be, at the end of 2017 Rotterdam initiated a project to map the next steps needed to inspire the circular transition within the city. By mapping the current state and showing the opportunities for the city, this report offers a basis from which government and the business community in the city can join forces. This project consists of three consecutive phases:

Phase 1: The current state of the circular economy in Rotterdam and possible Interventions

It is essential to first review the current state of the circular economy in Rotterdam, so that after that we can see where the focus should be placed in the transition to a circular city. Where is the most value lost in the material flows through the city? Which of these are accompanied by the largest direct and indirect impacts? And where are the greatest opportunities for new, circular employment opportunities?

This report tries to answer these questions. The research focuses on four key sectors that are definitive for a circular Rotterdam: construction, consumer goods, agri-food and green flows, and healthcare. The primary outcome of this phase of the project is to create a long list of possible interventions that can contribute to the zero-waste ambitions of Rotterdam and generate circular employment.

The interventions described in this document are not intended as a definitive or comprehensive set of possibilities. Our analysis clearly indicates where the most important priorities are in terms of waste and impact reduction. The mentioned interventions are possible ways to address how these impacts occur, and how to reduce them. The main objective of these interventions, however, is to serve as input for the stakeholder discussions in Phase 2 of the project.

Additionally, the current-state analysis of circular employment described in this report is primarily intended as a discussion point and a first indication. The methodology for circular economics assessments is still under development, and definitions of what can be considered a circular job will probably change. In the future, more sophisticated methods will be developed to to define more representative estimates.

Phase 2: Stakeholder workshops

In the second phase of the project we invited the key stakeholders in and around the city to three stakeholder workshops. This phase is to better understand the interests, motivations and needs of different stakeholders for the transition to a circular economy, and to identify possible ways for cooperation or to discover ways in which the City of Rotterdam can provide support.

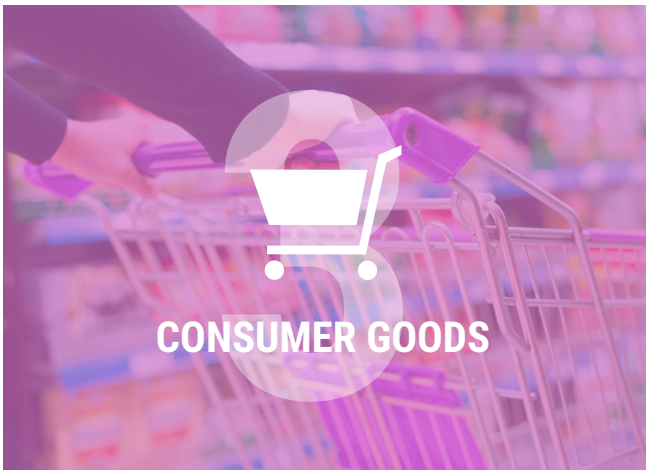
The focal point of this phase is the hub and workshop of the circular economy in Rotterdam, BlueCity, which will also function as a central point for circular development when this project is over. The output of this phase is an identification of the interventions that the stakeholders see as the most promising, and which they are committed to implementing.

Phase 3: Cost-benefit analysis

The final phase of the project is to choose which interventions identified in the second phase are the most promising for Rotterdam, and to take them to the level of practical implementation. We carried out a cost-benefit analysis for the interventions, gaining insight into the required investments, policy adjustments that may be required, and collaborations that must be set up for successful implementation. We also calculated in more detail the circular economy and employment benefits of these interventions. In this phase we have produced a roadmap with practical steps that can be taken, explaining our recommendations for the various stakeholders about what they can do to contribute to the realization of the circular vision of Rotterdam.

Four key sectors of the city

The research focuses on four key sectors that determine a circular Rotterdam: construction, consumer goods, agri-food and green flows, and healthcare. Construction is important because this sector in the Netherlands is responsible for 66% of all waste (OECD, 2015). Consumer goods, such as electronics, paper, clothing, plastics, are now often processed at low value, but they are potential treasures full of valuable materials. Agri-food is an important sector in the circular economy because its environmental impacts in the form of climate change and water consumption are enormous. Finally, healthcare - with a focus on hospitals - has been included as a key sector for Rotterdam. The city is a globally emerging frontrunner in the healthcare and medical industry and individual hospitals are already showing far-reaching ambitions to reduce their impact.



PHASE 1: KEY FINDINGS

Circular performance of Rotterdam

Though Rotterdam is doing well on resource management if we compare it to similar-sized European cities, it still has a long way to go before it can be considered fully circular. Currently, only about 22% of the solid waste generated in the city is recycled (though on a positive note, almost no waste is sent to landfills).

But achieving fully circular status goes far beyond simply getting to 'zero waste.' As is the case with other cities, many of the resources consumed in Rotterdam lead towards significant impacts throughout their supply chains – destroying biodiversity in some of the world's most ecologically sensitive regions, circulating toxic materials throughout our environment, and contributing to greenhouse gas emissions, among many other impacts. Until these effects are brought within a range that our planet can handle, Rotterdam's economy cannot be considered genuinely circular. Some of the primary impacts of the city's resource footprint are related to the city's demand for food (in particular meat and dairy) as well as the consumption of electricity and fuels.

In the coming sections, we describe some of the more important findings from our research for each of the sectors and for the overall metabolism of the city. However, there are some overarching conclusions that we would like to bring forward before delving into the details.

Prerequisites for transitioning to a circular city

For all sectors there are a number of shared activities for the transition to a circular city. Many of these are already being used to a certain extent in Rotterdam, but should be given more emphasis:

- Waste elimination measures offer some of the greatest potential for impact reduction. Instead of handling wastes once they have been created, which requires their transport and processing, wastes should be avoided through improved management of products and services. For example, every Rotterdammer wastes an average of 62 kg of food per year. The value of mixed organic waste is around 60 times lower than the value of the food it once was. It will benefit the city as well as the financial health of its residents to take more active strides in preventing unnecessary waste.
- Without more effective separate waste collection, many of the higher value circular opportunities for waste reprocessing will remain inaccessible. Pure and uncontaminated resource streams need to be consistently available to provide a consistent basis for investment in new reprocessing technologies. Though Rotterdam is already taking steps to increase its separate waste collection rates, these efforts should be doubled if the city is serious about achieving a circular economy. An entire ecosystem of new companies can develop around the manufacturing of new products from 'wastes,' but only if these are consistently made available at high quality.
- Only limited progress towards circularity is possible without investing in circular design and sectoral transformation. Ultimately, many sectors cannot become fully circular until genuinely circular products are designed – and become the dominant resource flow throughout the economy. Depending on the specific circumstance, products need to be designed for durability, repair, modularity, disassembly, ease of tracking, and safe dissolution into the environment. Governments must stimulate design innovation and then incentivize the purchase of only circular products. Rotterdam has a unique opportunity to tap into the talent at neighboring TUDelft's industrial design program to stimulate the development of new companies focused on circular design. These can further build the local economy by becoming branded export products.
- Investment and long-term policy support are critical factors for a successful transition. Entrepreneurs and civic actors alike will need consistent and long-term support in order to successfully make the transition to a circular model. Rotating investment funds, circular innovation grants, and circular procurement incentives are just some of the tools that could be used in supporting the transition. Equally importantly, the city should provide structural support for organizations wishing to invest and innovate in a circular direction. This could take the form of developing a local platform or program that provides knowledge resources or legal support to stakeholders working jointly on moving towards the circular economy.
- Most of the interventions we looked at lead to job creation rather than job loss. One of the promising conclusions we can draw from our evaluation of circular interventions is that the majority of them have either a neutral or positive effect on employment. At the outset of this study, this was not a safe assumption to make, since many circular activities potentially require greater automation for reasons of efficiency and precision. Indeed, there are some interventions that are likely to lead to some job losses, but on balance, the outlook is that a transition to circularity will create more local employment. In some cases, this may be due to 're-shoring' effects, where jobs that are now currently sent overseas are redefined and reintegrated into the local context.

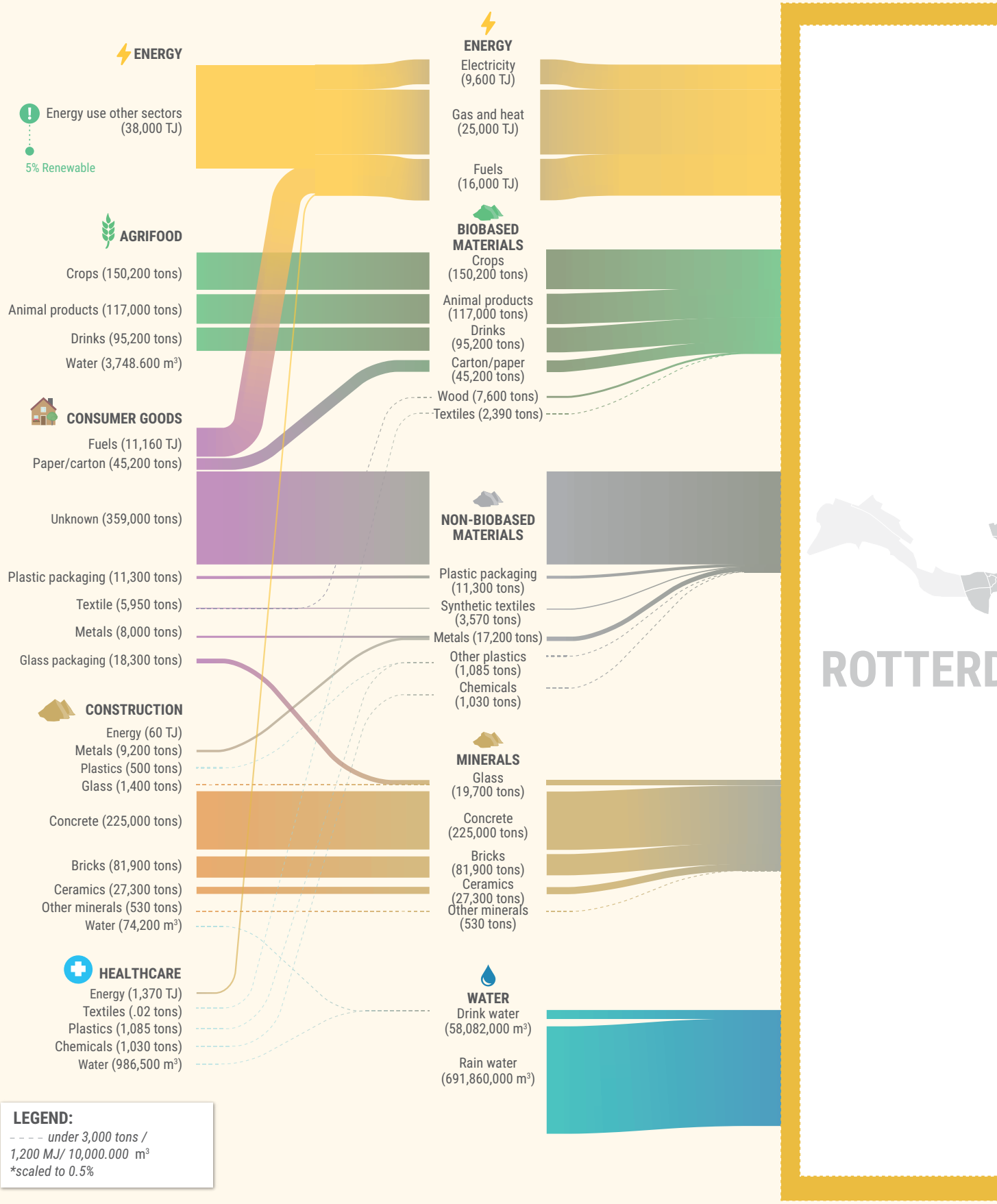
CIRCULAR JOBS

For Rotterdam, a first baseline assessment has been carried out to measure the number of circular jobs in the various sectors of Rotterdam. It appears that 10% (31,000 jobs) of the total number of jobs are circular, above the Dutch average (8.1%). In the center of Rotterdam, strong representation of supporting circular jobs can be seen, such as design for the future and digital technology. Direct circular jobs such as repair activities are strongly represented around the city edges. Furthermore, digital technology in particular is very much integrated into Rotterdam.

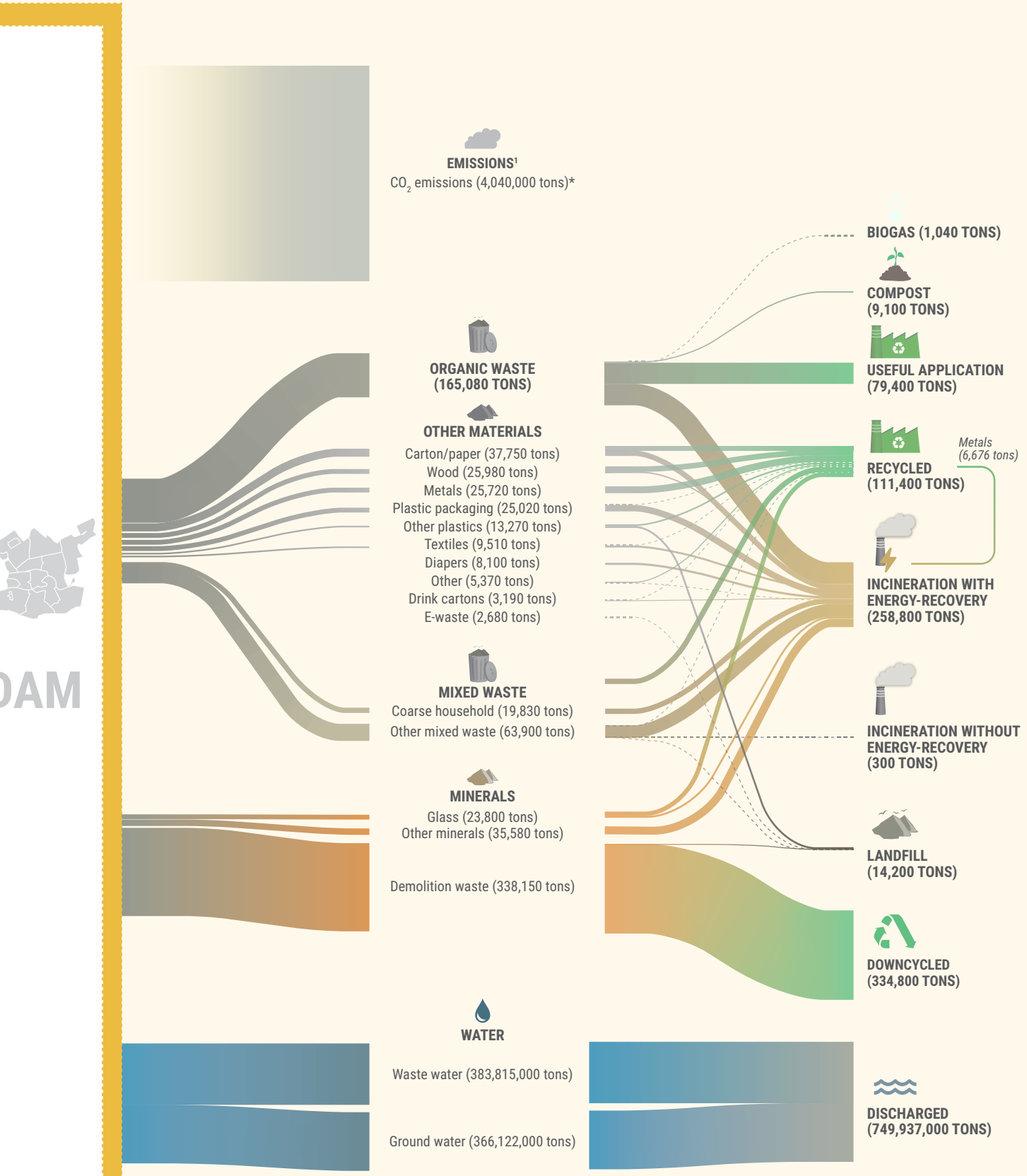
The job potential for Rotterdam lies, on the one hand, in the use of digital technologies in the facilitation towards a circular economy. And on the other hand, the re-use, repair and circular design of products. It can be expected here that job losses may arise in regard to production of new products and materials, but also job creation in reuse and recycling of materials. This shift in jobs towards the end of the chain will - certainly combined with robotisation - create a necessary shift in the type of jobs and the skills required for this.

Other ways to reduce the environmental pressure of hospitals is to install filters that contain harmful substances, and get medicines out of wastewater. In addition, many hospitals can reduce drinking water demand and also reduce environmental impact by using eco-friendly products for part of the cleaning work. Many of the initiatives mentioned are already being applied in one or more hospitals in Rotterdam. Mutual cooperation and exchange of experiences can make the healthcare sector, as a whole, more circular.

OVERVIEW OF ROTTERDAM MATERIAL FLOWS 2015



METABOLIC CIRCLE ECONOMY



[1]Excluding industrial and professional shipping

KEY OUTCOMES BY SECTOR:

AGRI-FOOD AND GREEN FLOWS

About 14% of the food entering the city is wasted. That is slightly above the national average of 12%. Most organic waste is not disposed of separately and therefore ends up in the incinerator as residual waste. But a small portion is collected as organic waste and is processed at high value by making biogas and compost.

The analysis for the agri-food sector in Rotterdam shows that there are several solutions to the leakages of the current linear system in the various streams of the agri-food sector. The proposed measures aimed at reducing food waste can collectively reduce up to 50% of the current volumes of food waste. All kinds of high quality products can be made from organic waste such as compost, biogas, chemicals and even imitation leather. The separate collection of organic waste is an important measure.

In addition, benefits can be realized for the health of the population and the environment by making vegetable products more attractive and popular as an alternative to meat. Production of meat and dairy has a huge impact on the environment. Increasing local sustainable food production can also help to significantly reduce impacts while stimulating new local economic clusters. These strategies can build on existing momentum already achieved by Rotterdam entrepreneurs and further improve the image of the city.

CONSTRUCTION

Rotterdam construction is still far from circular at this point in time. A lot is being built in the city, but more is being demolished. For every 100 homes that were added in 2015, 110 were demolished. This causes large flows of building waste in greater quantities than in other parts of the country. In other large cities and in the province of South Holland, demolition rates are many times lower. For a truly circular building sector, the material choices and the final deconstruction must already be taken into account in the design of new buildings. By building smartly, homes can eventually be dismantled and parts can be reused.

In the building industry, it is particularly important that the large annual quantities of construction and demolition waste be reduced by extending the life of buildings and issuing fewer demolition permits, as long as safety, quality of life, and development of the housing market are not compromised. For existing buildings not designed for dismantling, it is important to give renovation priority over demolition. According to our analysis, it is possible for Rotterdam to bring about a reduction of up to 350,000 tons of construction waste by implementing a set of interventions. The choice of materials is also important because this has a great effect on the total environmental impact of building. In the field of energy, a lot of profit can be achieved by installing solar panels and also in not connecting homes to gas. In addition, a central construction hub on the outskirts of the city, in combination with clean transport to and from the construction site, would reduce the inconvenience for the environment, cut down air pollution, enable more efficient construction, and lower construction costs. Ultimately, smart and clean building logistics can prevent more than 12% of total emissions from the Rotterdam construction sector.

CONSUMER GOODS

The consumer goods that enter Rotterdam every year are a veritable treasure chest for valuable raw materials and materials. The total value of the metals in consumer goods consumed annually is almost the same as the material inputs of the entire construction sector. The consumer goods sector is the most complex of the sectors we have studied, for the most part because there is insufficient data available on the consumption habits of people. We recommend that Rotterdam takes steps to collect more data to better understand this topic.

Despite the data limitations, it seems almost 50% of the metals and a majority of the scarce materials are in this material stream. Because many consumer goods also consume a lot of energy, there is significant overlap between objectives for material management and material recovery (for example, extending product life cycles through sub-platforms) and ensuring products are replaced when it is needed.

Packaging materials account for 35% of all current waste streams in this sector, mostly being burned for energy production. The total amount of packaging can be reduced to 40% through changes such as waste-free food stores implemented as the norm in the city, which would see a total reduction of 30,000 tons of materials per year. The packaging that remains ideally would be designed to be biodegradable, or for optimal recycling.

Although this involves a systemic change, and adjustments to distribution chains would be necessary beyond the borders of Rotterdam, the city can still stimulate local innovation and new business around this design challenge. Pay-As-You-Throw levies and door-to-door collection could see a reduction in mixed waste flows of 87,000 tons per year.

Specialized technologies for recycling specific product streams such as diapers, textiles, drinks cartons and car tires now make it possible to recover these materials at a high level, although implementation requires investment. More systemic interventions in the consumer goods sector are encouraging redesign of products according to circular design principles (eg design for repair or disassembly), reducing the total impact of products by switching to alternatives using fewer materials, or setting up an Upcycle Mall in the region with specialized recycling facilities for different types of waste.

HEALTHCARE

Rotterdam is an emerging global leader in the healthcare sector. A number of Rotterdam hospitals are already leading in the area of sustainability and innovation. Compared to the city as a whole, the hospitals are only responsible for a small portion of the waste and materials. But relatively speaking, these are waste streams that have a lot of impact. For example, hospital waste water contains a concentrated and substantial flow of medicine residues, endocrine-disrupting residues and cleaning products.

Hospitals are perhaps the last places where you want to save on materials, especially if this puts the quality of care at risk. The interventions that come out of our analysis therefore focus primarily on reducing the need for hospital visits. After all, fewer patients means a lower material requirement. That is why it is important that preventive care becomes the norm. If people live more healthily, the number of sick patients also decreases. The average health of Rotterdammers is below the national average, and below the average for other large cities in the Netherlands. This indirectly results in more hospital visits, and therefore in greater material requirements and environmental impacts. In addition, an attempt can be made to keep the average time that patients spend in a hospital as low as possible, for example by improving food in hospitals, and by creating a healthy, restful, natural and pleasant environment in the hospital. In addition to the benefits for the environment, the economic benefits of a healthy population are even more evident.

PHASE 2: STAKEHOLDERS

We organized two workshops for companies and other stakeholders to exchange knowledge and to examine which interventions they were most enthusiastic about and wanted to contribute towards. A total of 56 participants joined the workshops, representing a wide variety of companies across the four different focus sectors. The first stakeholder session focused on completing and prioritizing the sets of interventions/projects per sector and mapping the barriers to be overcome. On the basis of this session, fifteen interventions were selected and we continued to work on this during the second session. Ultimately, based on the input from the stakeholders, seven interventions were selected that have a significant impact and where the participants also want to be actively involved. For these seven interventions, cost-benefit analyses are made in the next phase:

- **Household waste is fermented**
- **Valorize uniform organic flows**
- **Stimulate circular building**
- **Establish marketplace for building materials**
- **Separate plastic better**
- **Start upcycle mall**
- **Install Pharmafilter**

PHASE 3: COST-EFFECTIVENESS ANALYSIS AND ROADMAP

The cost-benefit analysis shows that most of the interventions investigated yield net benefits. However, investments are required in the right installations and infrastructure. Circular demolition seems to be able to significantly reduce material consumption and also yields the most benefits, creating an estimated 280 jobs. The fermentation of organic waste is the only intervention that does not generate any net benefits, but costs extra. In addition to calculating the business cases, roadmaps have been drawn up for each sector, with policy interventions. In doing so, measures have been highlighted to accelerate the circular economy in the city and to be introduced in the short, medium and long term. For the interventions, we looked at best practices, stakeholders and knowledge partners for each.

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INTRODUCTION

A growing world population and rising consumption levels are impacting on our environment in more and more ways. The expansion of industrial activity is leading to unprecedented levels of raw material consumption and pollution, with the carrying capacity of our planet at a breaking point. It is not just about environmental issues either. Shortages of critical raw materials such as water or biomass can cause both economic shocks and humanitarian crises. It is important to be aware that we have to switch quickly to a strong, resilient, circular economy. A circular economy is a new economic model for addressing human needs and fairly distributing resources without undermining the functioning of the biosphere or crossing any planetary boundaries.

The benefits that a circular economy can offer in helping regions to create new industries, transform existing sectors, and develop new production chains can be significant. However, this transition has major consequences for business operations, and requires significant breakthroughs in finance and technology.

CITIES TAKE THE LEAD IN THE CIRCULAR ECONOMY

Cities are the beating heart of human civilization. They are the global drivers economic activity, thriving centers of creativity, and home to the majority of the world's population. Cities are an accelerator of innovation and productivity, but also of consumption. Inhabitants of cities have a higher average income and more per capita consumption than their counterparts in rural areas. Urban areas cover only 3% of the total global land area, but house more than half of all people on earth, consume more than 75% of all available raw materials and emit 60-80% of all greenhouse gases. The expectation is that these percentages will increase further and by 2025 no less than 60% of all people on earth will live in cities. This increase in urbanization stimulates expansion of the city limits, an increase in demand for – and development of – infrastructure, and a growing need for products and services within cities.

The Netherlands is already one of the most urbanized countries in the world: over 90% of the population lives in the city. This offers both the possibility and the responsibility for cities and regions to take a leading role in the transition to a sustainable economy.

Cities currently function as global resource drains rather than as self-sufficient producers. They import food, energy and materials from outside their borders. Despite growing recycling rates, most resources flows still end up as waste or downcycled materials, contributing to the 'linear' structure of our economy.

Within cities, the increase in personal vehicles has led to traffic jams and poor air quality. The huge expanses of concrete, steel and asphalt in our urban infrastructure create a heat island effect, causing temperatures in urban areas to be on average higher than in surrounding rural areas. The fact that cities have fairly low water permeability and fragmented ecological habitats causes many environmental problems. Cities can also have many social problems, with urban areas evoking associations of pollution, crime and social segregation.

CIRCULAR ROTTERDAM RESEARCH

Rotterdam has the ambition to be a leader in the circular economy field, aiming to create at least 3,500 to 7,000 jobs by 2030 and building towards becoming a zero-waste city. The city already has taken big steps, with progressive research involving circular frontrunners like BlueCity, Waste2Chemicals, and Better Future Factory. That was necessary, because after the economic crisis of 2008, in which Rotterdam and others were hit hard in the construction industry, political discourse on employment is driving interest in the circular economy more than ever before. By realizing the transition to a circular economy, Rotterdam can create jobs on a regional scale and at the same time contribute to a healthier environment. The city wants to to bundle and utilize the acquired knowledge to create concrete circular jobs and circular industry and businesses. The purpose of this project is to create the right conditions to transition to a circular economy. Therefore the focus lies on materials and jobs in the circular economy.

This will happen in three phases:

- **Phase 1:** Performing baseline analysis
  - a. Raw materials analysis
  - b. Employment opportunities analysis
  - c. Developing metabolism vision and circularity KPI's
  - d. Developing vision for jobs and circularity KPI's
  - e. Setting up a database
- **Phase 2:** Dialogue with relevant stakeholders of the city
  - a. Workshop 1: vision creation and goals + results
  - b. Workshop 2: strategy and how to implement it
- **Phase 3:** Recommendations and impact analysis
  - a. Developing costs and benefits
  - b. Roadmap and policy recommendations
  - c. Workshop 3: getting started with players and resources

RESEARCH SCOPE AND METHODOLOGY

The most important objective in Phase 1 is to get a clear picture of the metabolism of Rotterdam, the raw materials flowing through the city, and the various impacts that go with these. The biological term metabolism refers to the sum of the processes and resources that together balance the materials and energy of an organism to make life possible. It is often applied to cities or organizations that have a comparable pattern of raw material consumption to support operational activities. To achieve this, we carry out a so-called material flow analysis (MFA) of Rotterdam to quantify the flows of materials, energy and water in the city for the reference year 2015.

In this study, we exclude the industry located in the port. The transition of industry in the port has already been investigated, for example by the Wuppertal Institute (2017). Although much attention is usually paid to the economic activities and material flows in the port area, it is important to examine the city separately in this report. The economic interaction between the city and the port area is limited: the port area supplies goods and services worth €2.2 billion to the city, which is only 3.3% of the total production. At the same time, the city provides €3.6 billion worth of economic value to the port area, or 5% of the total economic output of the urban economy (Kuipers et al., 2015).

If we mention something as within Rotterdam, we specifically mean the area within the boundaries of the municipality and not the activities that fall outside of it. These borders cover an area of 319 km^2 (of which 206.44km^2 is land area), with a population of 634,660 inhabitants (Statline, 2017c). There are a number of limitations that arise from the use of a single reference year (2015) for the scope of the analysis. The assumption here is that the previous years are relatively similar to 2015. However, a large portion of the material flows depend on the economic activities that take place in a city, such as in construction, which can vary greatly over the years. So, although the reference year can roughly be considered as representative, some variation must be taken into account if we generalize on the basis of this dataset.

In addition, we will come to a baseline analysis that forms the basis for the development of long-term substantiated measures. These measures can be both business initiatives and government interventions, and can vary from building an advanced textile processing center to creating an interactive raw materials atlas. In addition to examining the mass of all raw materials, we also look at the contextual factors such as impact, costs, risk and systemic effects that are associated with this.

Some of these factors are marked as hotspots in the MFA, while others will be dealt with in more detail in separate sections of the report. With the collected data, we can answer a number of important questions about where Rotterdam needs to focus on fulfilling its circular ambitions:

- What is the current level of resource use and material efficiency?
- Where do the largest losses in terms of materials and value currently occur within Rotterdam's material flows?
- Which of these are associated with the largest upstream and downstream impacts?
- What effect will adjustments on the current material management policy of the city have on the current state of affairs, for example by generating new financial possibilities?
- Which intervention areas have the highest priority to achieve a circular model?

STRUCTURE OF THE REPORT

This report consists of the following chapters:

- **Chapter 1:** describes Rotterdam in the context of the surrounding ecosystem.
- **Chapter 2:** explains our definition of the circular economy.
- **Chapter 3:** outlines a brief picture of what a circular Rotterdam could look like.
- **Chapter 4:** provides an overview of the metabolism at city level, an impact analysis of the most important materials and the most important critical performance indicators (KPIs) for a circular economy.
- **Chapter 5-8:** presents the results of the metabolism and circular jobs analysis, with the emphasis on agri-food and green flows, construction, consumer goods and healthcare sectors. In addition, interventions per sector are described.
- **Chapter 9:** offers conclusions and takes a look ahead at future steps.


DEN HAAG
DELFT
Schiedam
Spijkenisse
Hellevoetsluis
Hoogvliet
Oud-Beijerland
Goudswaard
Maasdam
Haringvliet
A15
A29
N59

CHAPTER 01

ROTTERDAM'S CONTEXT

ROTTERDAM'S CONTEXT

Figure 1: Centre of the city with the Erasmus Bridge on the right (West 8, Benthem Crouwel Architects and MVSA Meyer and van Schooten Architects, 2013; Oceandiva, 2016)

HISTORY

Around the year 1270 in what is now called the Hoogstraat, a dam was built in the river Rotte as a measure against the regular flooding, and residents created a small fishing village. In 1340 the town achieved city status. For a long time the Rotterdam economy was mainly based on fishing of herring, and trade in freight on the rivers Rotte and Schie (Couvreur, n.d.). From 1568 Rotterdam took to trade with England, France, America and Spain in a period of economic growth and prosperity.

In the 18th century the inner city was filled with houses, industry, and department stores, and the city was particularly densely populated within its walls. There were also a few developing industries (sugar, coffee, tobacco, and gin), but the French occupation (1795-1813) brought on a period of recession.

However, after the occupation, between 1866 and 1872, the construction of the canal Nieuwe Waterweg made Rotterdam accessible from the shore and this made the city the international hub it is now. The city was cleaned up, the capacity of the port was extended, and the urban area expanded beyond the city walls. A recession followed after the First World War that lasted until 1926. During the Second World War, the historic city center was completely destroyed and had to be redeveloped after the war (Rotterdam Partners, 2013).

The port grew towards the west in the direction of the sea. Larger and deeper ports were constructed closer to the coast, and petrochemical industries became more and more important. A number of large oil refineries were established in the city and much of the freight from the port consisted of crude oil and petrochemical products (Catarinella, 2017).

THE CHARACTER OF THE CITY

In the reconstruction of the city after the Second World War, Rotterdam opted for spacious urban design and to embrace modern architecture (Rotterdam Partners, 2013), but a rigid separation of functions and strictly functionalist architecture resulted in a somewhat cold and business-minded city (Couvreur, n.d.). The approach of the spatial planner for this reconstruction made Rotterdam the only Dutch city with a pronounced cityscape similar to major American cities (Frijhoff et al., 2004). However, the architectural metamorphosis became appreciated Europe-wide: in 2015 Rotterdam was appointed European City of the Year by the Academy of Urbanism (Carmona et al., 2017).

Rotterdam is currently working on transforming once again: this time from a world-famous port city into a metropolis with a recognizable skyline on the water and modern architecture.

Examples of modern architectural projects are Rotterdam Central Station, the cube houses designed by Piet Blom in 1984, and the Erasmus Bridge that the inner city connects with Kop van Zuid (see below). There is a lot of open space and entrepreneurs get the freedom to experiment with new and innovative concepts.

Contemporary Rotterdam is known as a city of opportunities and possibilities, a city of innovation, and a city where a no-nonsense mentality of hard work and entrepreneurship is paramount.

POPULATION AND DEMOGRAPHY

Rotterdammers are proud of their openness, and the city is home to many minorities. The fast economic growth between 1965 and 1973 led to a great demand for labor, which caused large immigration waves of workers from the Mediterranean and later from Suriname. Recent economic growth in the 1990s led to further immigration. Today about 40% of the Rotterdam population is of foreign origin. This has led to a cosmopolitan atmosphere, with a great diversity in cultural, culinary and religious respects (Couvreur, n.d.).

The demographic profile of different areas of Rotterdam varies significantly. According to a recent area analysis, the city center is 70% singles between 20 and 40 years old, significantly more than in other urban areas. Living in this district are relatively large numbers of highly educated residents with higher income, with more than half (51%) of the population coming from a migrant background. The majority (80%) of the housing is for rent. A majority of the stores (70%) are owned by residents with a migrant background (City of Rotterdam, 2009).

The open and enterprising nature of the city and its population seems to be paying off. In recent years, the makeup of the workforce has leaned more towards the creative sector. When the recession started in 2008 Rotterdam had a relatively low-educated labor force, but this has been rectified in recent years, partly due to a strong influx of highly educated immigrants, with the result that in 2016 the productivity of the workforce in Rotterdam was 12% higher than the Netherlands average (Euromonitor International, 2017). Today, 33.8% of the workforce is highly educated (compared to 33.3% average in the Netherlands), although the share with medium-high training is slightly lower than average and the proportion that has low education levels is higher than average. (EVR2017, n.d.).

Figure 2: The new Central Station (top left), cube houses designed by Piet Blom (right) and the Erasmus bridge (bottom left) (West 8, Benthem Crouwel Architects and MVSA Meyer and Van Schooten Architects, 2013; Urban Pixels, 2016)

TRENDS AND DEVELOPMENTS

Rotterdam, the largest port in Europe and the tenth largest globally, has always been a center for the transit industry, with a market share of 30% in container transport. Over the years several important companies made Rotterdam their home base. These range from Unilever to Eneco, to Shell Chemicals, and more producers in the chemical industry, wholesalers, pharmaceutical companies, logistics, electrical, and architectural sectors. In 2016 the amount of foreign investment in Rotterdam increased significantly, mainly in the maritime and offshore sectors, industry, agri-food, and the smart Industry and IT sector. These investments were mainly from Asia, North America and Europe (Rotterdam Partners, 2016).

Rotterdam is well known by its port as a connected hub in the Netherlands and Europe, and has historically had a strong industrial profile. Nowadays however, the city is busy changing that profile to a hub for the creative sector, leading the way in technology, services and a highly educated workforce. The success of this transformation will depend on the extent to which the city can develop in the area of housing stock, infrastructure and public spaces, and how its competitive position develops within the Randstad and Europe.

Nevertheless, the deep relationship with the port remains crucial for the city, and remains one of the main sources of added value (15.5 billion in 2012). The port is one of the smartest ports in the world and a strong incentive for innovation and development. The city and port have combined for a joint initiative called the Rotterdam Innovation District, where, with flexible regulation, a breeding ground was created for innovative start-ups and other organizations.

ECONOMIC OVERVIEW AND TRENDS

For Rotterdam, we have selected a number of core sectors, based on data from an OECD 2009 study on employment in Rotterdam (City of Rotterdam Regional Steering Committee, 2009) and a few other sources. The Rotterdam economy is characterized by a high level of activity in the field of commercial services. This one sector alone accounts for 20.3% of all jobs in the city (City of Rotterdam Regional Steering Committee, 2009). In addition to the service that focuses on specific industries, there are also more than 8,050 companies active in legal services, marketing, market research, and research & development.

The creative sector has plenty of potential for creation of around 12,500 jobs. About 625 companies are active in the culture, sports and recreation sector, including art, libraries, museums, and zoos.

The development of the creative sector also leads to all kinds of applications and innovations for the other sectors, but also the creation of an increasing number of companies in the creative sector itself. This is particularly the case for design-related work including architecture, technical and graphic design, audiovisual and new media. There is sometimes designated land and buildings for these enterprises and startups. In the material flow analysis in this report we largely avoid assessing the creative sector given its relatively negligible material output.

The transport sector is another important sector for the Rotterdam economy, where 1,495 companies are active. In addition, more than 1,900 companies are active in information and communication, a large majority of which are IT-related services, and a small part in telecommunication, publishing, and TV and music production works (Statline, 2012). Transport and communication accounts for 9.7% of all jobs in Rotterdam (City of Rotterdam Regional Steering Committee, 2009).

FOCUS SECTORS

We have identified 4,000 companies related to production, processing, trading and sale of food (Statline, 2012). Agriculture alone accounts for 1.8% of all jobs in Rotterdam (City of Rotterdam Regional Steering Committee, 2009), and this does not even count the companies that trade or sell food products. There is 28.3 m^2 of green space per inhabitant (Morar et al., 2014). Together agricultural products and green spaces represent a single major material flow.

In the building sector, which is traditionally associated with high amounts of material, 4,955 companies are active in Rotterdam, including companies active in the development and construction of buildings, civil engineering and a large number of other specialist building activities (Statline, 2012). The construction sector provides 7.1% of all jobs in Rotterdam (City of Rotterdam Regional Steering Committee, 2009).

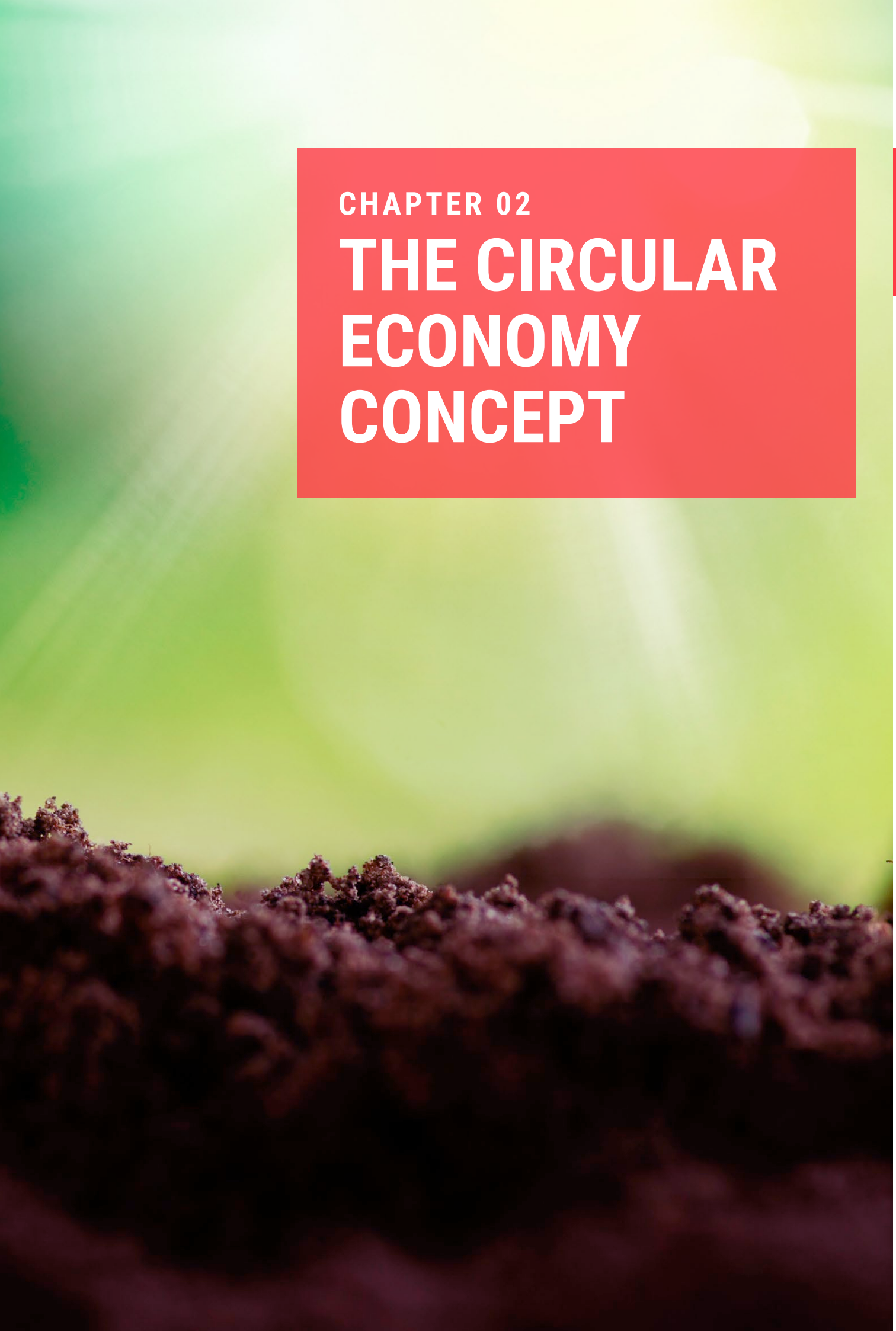
In terms of numbers of companies in the city, companies active in retail or wholesale trade are the clear leader, with 10,950 companies in the sector, including all forms of consumer goods and B2B goods and services (Statline, 2012). In our material flow analysis, however, we focus on consumer goods with tangible material value.

The healthcare sector has 2,290 companies in Rotterdam city, including companies around various health activities, household care and welfare, and social help without accommodation (Statline, 2012). The medical sector is mainly clustered around the Erasmus Medical Center (MC), the most important hospital in Rotterdam. The combination of leading research, care and education employs about 12,000 people. The Erasmus MC is important for the economic development of the city, especially in maintaining connections with other regional healthcare institutions, governments and the business community.

In our material flow analysis we will be focusing on the four sectors of agri-food, construction, consumer goods, and hospitals.

Sector	Activity	Indication of importance
AGRI-FOOD	Production, distribution and consumption of food and other agricultural products	More than 4,000 companies; production alone accounts for 1.8% employment in Rotterdam. 178 kton of waste
CONSTRUCTION	Construction and development of construction projects, civil engineering, and specialist construction activities	More than 4,955 companies; 7.1% employment. 395 kton of waste
HEALTHCARE	Hospitals, doctors, care centers, homes and research	2,290 companies; about 12,000 jobs (12.5% employment); special attention in economic policy Rotterdam. 11 kton of waste and specific waste streams
CONSUMER GOODS	Sales and wholesale of consumer goods	10,950 companies in distribution; 15,5% employment. 229 kton of waste

Figure 3: Sectors that are focused on in this report



CHAPTER 02

THE CIRCULAR ECONOMY CONCEPT

THE CIRCULAR ECONOMY CONCEPT

The term 'circular economy' has sharply increased in usage in policy and business after being promoted in a 2011 joint report by the Ellen MacArthur Foundation (EMF) and McKinsey & Company (Ellen MacArthur Foundation, 2012).

We currently live in a so-called linear economy, in which biotic (e.g., plants and animals) and abiotic (e.g., minerals or metals) raw materials are extracted, consumed, and finally sent to landfill or disposed of in such a way in that they are no longer reusable - for example by incineration, application of chemicals, or through the use of products such as paint that have not been designed for recovery. Less than 10% of the materials flowing through our economy are recycled annually (Haas, Krausmann, Wiederhofer & Heinz, 2015).

The EMF-McKinsey report presented the opportunities that can be harnessed by to switch to a 'circular economy', which is broadly understood as an economy that is regenerative and waste-free by design. It is growing in popularity in business mainly due to the significant potential revenue gains that could be earned through reuse of primary raw materials currently lost in the 'take-make-dispose' model, and by extending the value-generating life cycles of products.

In a study of twelve primary sectors, McKinsey concluded that "the circular economy represents a net material cost saving between $340-380 billion per year in the EU 'transition scenario', and $520-630 billion per year in a 'progressive scenario' ". The research also considered the value of alternative revenue models and consumption patterns based on structural recovery of materials, such as lease-based construction, and a progressive approach to the responsibility of producers.

IMPLEMENTATION OF THE CIRCULAR ECONOMY

The circular economy requires the design of an economic model that results in closed cycles of high-quality raw materials, in the same way as happens in natural systems. The basic principles of designing an economic system based on this model initially seem straightforward, and include:

- Design all products for easy repair, disassembly, and full recyclability.
- Create the necessary business structures and incentives to get these materials back into the economy at their highest possible value (preferably as whole products or components).
- Strive to use only responsibly-sourced renewable resources for both energy and material provision.
- Avoid the use of toxic substances that may continue to circulate in our environment.

In practice, however, there are many complex and difficult questions to resolve in implementing these principles, especially since we are now in the middle of a transition from an economic system that does not revolve around circular concepts. The result is that we have encountered some challenges, including:

- What if the recycling of materials consumes a huge amount of energy? Is recycling in these cases still the most 'circular' solution? In other words, what is more important - reducing CO_2 emissions or the preservation of materials?
- What if products or buildings are completely recycled, but many scarce materials are locked into the construction cycle? How do we take the different lifetimes of different materials into consideration when we design circular products and infrastructure?
- Is it more 'circular' to use bio-based materials even if this leads to excessive land use, water shortages, or loss of biodiversity in comparison with the use of materials based on fossil fuels? How do we prioritize the trade-offs between impacts on the entire chain?

These are just a few of the challenges that surface when you go deeper into the practical implementation of a circular system. Underpinning these considerations are two fundamental concepts that must be taken into account: shifting burdens and safe operating spaces. By understanding these concepts properly we can design a framework that achieves a regenerative and fair circular economy operating within safe planetary boundaries.

BURDEN SHIFTING

Burden shifting happens when we aim for one goal, such as recovering material value through recycling, but at the same time cause new problems, such as increasing CO_2 emissions or releasing toxic substances into the environment.

To avoid this problem, we have to recognize that improvements in material management can sometimes lead to other negative impacts on people or the environment. Sometimes we have to evaluate our behavior on the basis of a whole spectrum of parameters.

With a holistic set of performance indicators, it is possible to track circular activities so they deliver a broad range range of positive impacts, rather than just optimizing for high impact on material recovery at the expense of other performance areas.

In addition, we need a set of guidelines to make better choices between different impacts. We need a broad shared insight, based on science and ethics, relating to what impacts society, and at what cost.

This is where the idea of safe operating space can be applied, because it gives us a better understanding of the limits of the biophysical and socio-economic systems we are part of and about the impacts which we must avoid to leave these systems to function and flourish.

"SAFE OPERATING SPACE"

Our planet does not have infinite capacity to absorb changes. The concept of the Planetary Boundaries (Planetary Limits), introduced in 2009 by the Stockholm Resilience Center (2010), describes nine core systems of the earth that must remain within a certain range, to reduce the risk of destabilization. These nine boundaries define a 'ceiling' of total impacts that we can cause without leading to catastrophic disruption.

Kate Raworth has built on this concept in her recent book Donut Economics, in which she describes that there is at the same time a minimal 'floor' of material consumption necessary to meet the needs of people and business. Here we are talking about basic needs such as food and clothing, as well the resources needed to provide higher human needs such as culture and personal development. The concept of a 'floor' of required raw materials explicitly recognizes the reality that extracting raw materials goes hand-in-hand with cost for the environment, but is required for the fulfillment of human needs. Between this 'floor' and 'ceiling' we have a safe operating space to work within. This means that our economic system inherently has limits and that it must comply with the best practices and guidelines on the use of raw materials within a circular economy.

In addition, this safe operating space must be taken into account to keep up with the economic reality. For example, in the first issue mentioned above, the question is whether it is desirable to have a more complex material cycle if this is accompanied by higher greenhouse emissions. However, we know that energy can also be generated in a renewable way. So we would probably have to recycle everything with renewable energy, no matter how high the energy needs for this.

However, renewable energy generation requires equipment built with non-renewable raw materials, which are becoming increasingly scarce and also needed for other important applications such as in medical equipment. Research has shown that without careful management of these raw materials large shortages will affect the generation of sustainable energy (Heller et al., 2013). Energy efficiency is therefore still very important - we must not waste our energy supply on activities that can be done more efficiently or better, even if the energy comes from renewable sources. The only way this restriction can be avoided is to eliminate the material limitations that stand in the way of the production of renewable energy. Energy efficiency therefore remains one systematic priority.

THE SEVEN PILLARS OF THE CIRCULAR ECONOMY

Over the past five years, Metabolic has developed a framework to address these issues. Our thinking is grounded in the idea that besides cycling raw materials at high quality, a circular economy also needs to operate within the carrying capacity of our planet and in respect to the rights and needs of people. In addition, solutions to some problems should not create even bigger problems.

Taking all of these emerging insights together, we have formulated our own working definition of the circular economy:

The circular economy is a new economic model for addressing human needs and fairly distributing resources without undermining the functioning of the biosphere or crossing any planetary boundaries.

Figure 4 illustrates Metabolic's 'seven pillars' framework for evaluating circularity. Each of these seven pillars are performance indicators. We need to evaluate all of our actions not just on one parameter, but on a complete spectrum. To achieve real progress towards a circular economy, it is clear that we need new incentive structures, new business models, and new ways of evaluating our economy to assess whether it is functioning within the safe limits of Earth's carrying capacity. Ultimately, a circular economy must provide realistic alternatives to our current economic model. It must provide for human needs and result in a fair distribution of resources while operating within planetary boundaries. Within our framework we can formulate a vision for the future, identify problem areas, and identify solutions that improve performance in all aspects of the circular economy.

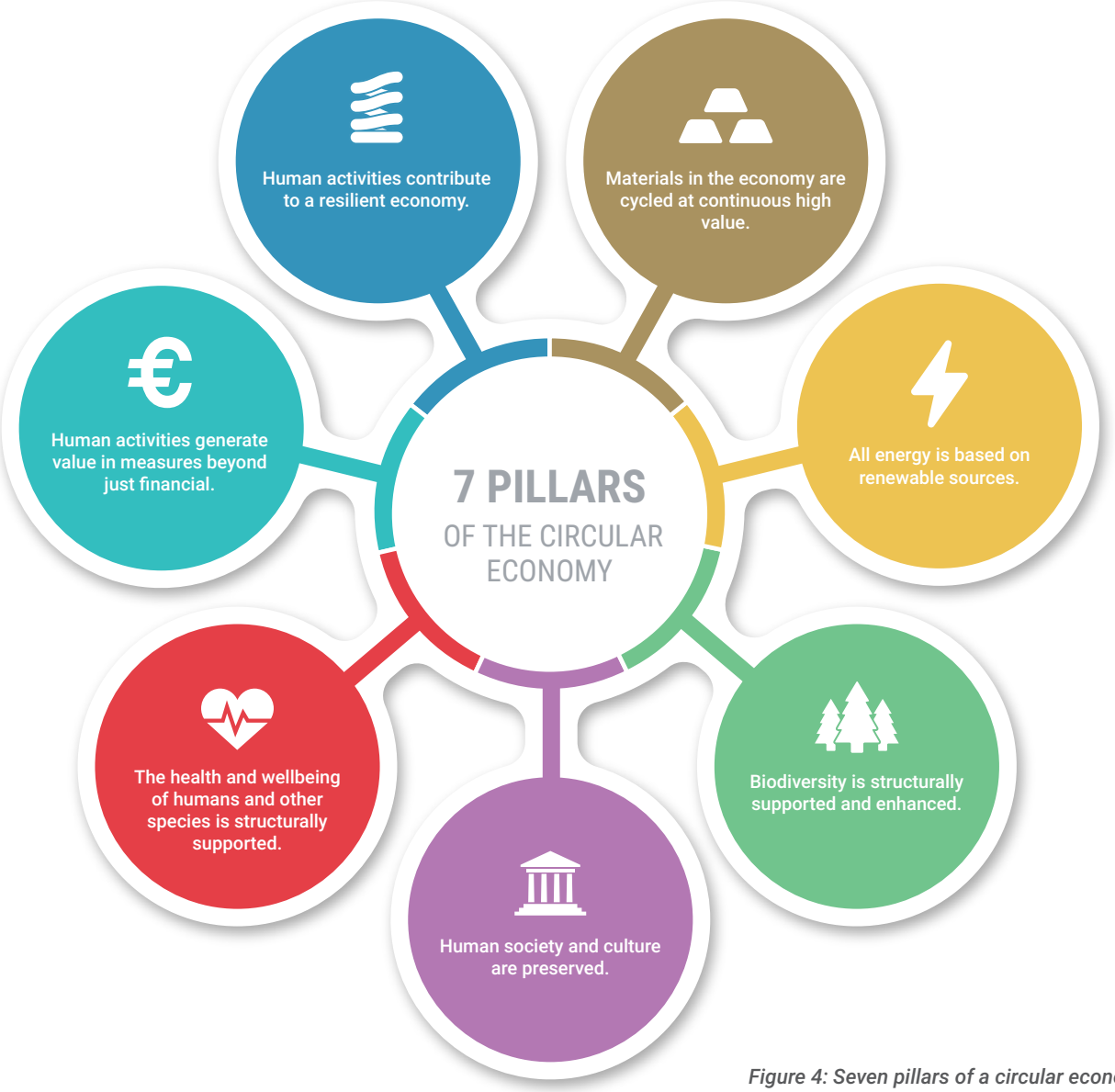


Figure 4: Seven pillars of a circular economy

EMPLOYMENT AND THE CIRCULAR ECONOMY

The circular economy is a way in which we make effective use of the resources that we already have. It provides a holistic solution to the world's emerging resource problem that has resulted from the linear take-make-waste economy. In a circular economy, resources are not consumed, but recovered in a system that is continuous and long-lasting, with the goal of keeping them functioning at their highest potential. Instead of destroying value after the use phase, value is retained through cycles of reusing, repairing, remanufacturing or recycling (see figure below). For this, we need new business models and innovative product design that makes use of non-toxic materials that can be endlessly cycled. As such, it reduces our unhealthy and harmful dependency on scarce natural resources and provides economic, ecological and social benefits.

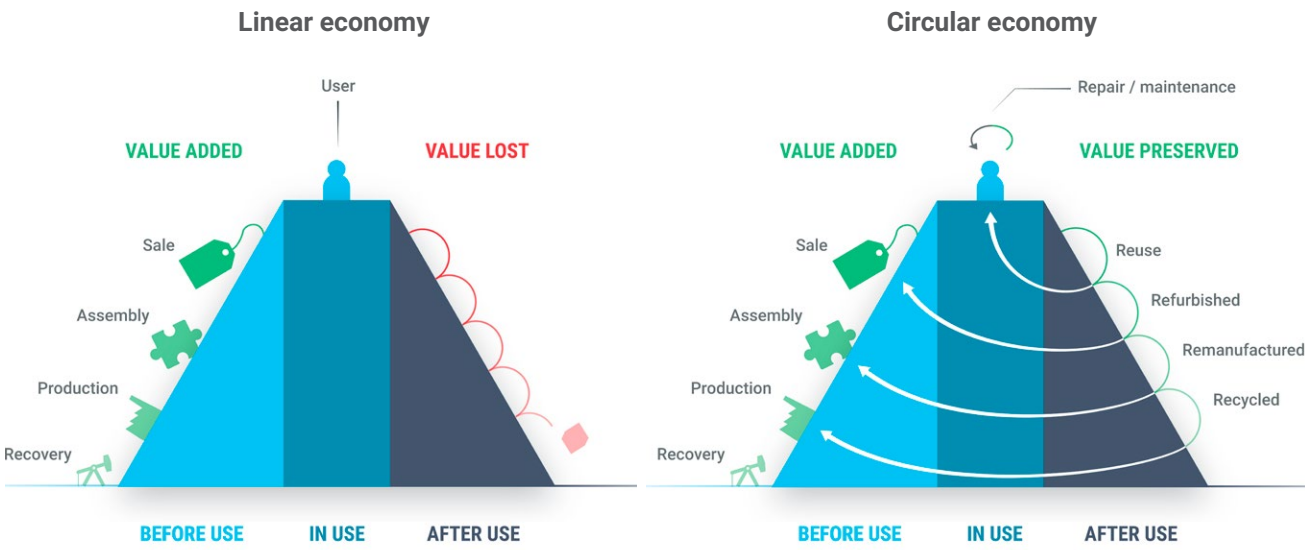


Figure 5: The Value Hill model proposes a categorization based on the life cycles of a product, and thus clarifies the systematic differences between the current linear economy and the circular economy we are working towards (Achterberg, Hinfelaar, & Bocken, 2016).

By applying circular strategies and principles, companies can achieve the highest possible economic and social value, and at the same time reduce their negative impact on the environment. Circle Economy has composed seven basic principles, shown in Figure 6, which show which strategies organizations and companies can apply in order to implement the circular economy.

On the basis of this model, the circular economy consists of both (A) primary circular strategies and (B) supporting circular strategies. Primary circular strategies include prioritizing renewable sources, prolonging the lifespan of products, using waste as a raw materials, and considering new business models. Supporting circular strategies include working together for value creation, designing for the future, and the integration of digital technology.

A. PRIMARY CIRCULAR STRATEGIES	
Prioritise regenerative resources	Ensure effective use of renewable, reusable, non-toxic resources as base material and energy sources.
Preserve and extend what's already made	While resources are in-use, maintain, repair and upgrade them to maximize their lifetime and give them a second life through take-back strategies when applicable.
Use waste as a resource	Utilize waste streams as a source of secondary resources and recover waste for reuse and recycling.
Rethink the business model	Consider opportunities to create greater value and align incentives through business models that build on the interaction between products and services.
B. SUPPORTING CIRCULAR JOBS	
Collaborate to create value	Work together throughout the supply chain, internally within organizations and with the public sector to increase transparency and create joint value.
Design for the future	Account for the systems perspective during the design process, to use the right materials, to design for appropriate lifetime and to design for extended future use.
Incorporate digital technology	Track and optimize resource use and strengthen connections between supply chain actors through digital, online platforms and technologies that provide insights.

Figure 6: Basic principles of circular employment

WHAT ARE CIRCULAR EMPLOYMENT OPPORTUNITIES?

Circular employment is jobs within the circular economy - in short, circular jobs. The categorization of basic circular principles in the previous section can also be used to analyze circular employment. In alignment with this, we therefore distinguish (A) primary from (B) supporting circular jobs. Together they form the direct circular employment opportunities. On top of that (C) indirect circular jobs where jobs themselves are not circular, yet facilitate the circular economy.

The method that was applied to calculate the number of circular jobs in Rotterdam was developed by Circle Economy and Rotterdam's Erasmus University. It is based on a subdivision of the economy starting from sectors. On the basis of the seven basic principles of the circular economy, more than 1,400 sectors are distinguished and classified according to primary, supportive, and indirectly circular jobs. All jobs in circular sectors are considered circular. However, this is not the case for the supporting and indirect circular jobs, as not every activity in those sectors is circular. The method to distinguish these jobs is discussed at the end of this report.

Definition of circular jobs

Circular jobs are all full- or part-time jobs that are related to one of the seven basic principles of circular employment.

***Direct** circular jobs are jobs that follow **primary and supporting** circular strategies.*

***Indirect** circular jobs are jobs that facilitate direct circular jobs.*

A. PRIMARY CIRCULAR JOBS	
Solar panel installer	The solar panel installer works within the energy sector to promote the use of solar as a renewable energy source. The job contributes to the circular economy by 'prioritising regenerative resources', the first strategy of the circular economy.
Appliance technician	The appliance technician contributes to the circular economy by extending the lifetime of products. By embodying one of the strategies of the circular economy, 'to preserve and extend what's already made', all repair and maintenance jobs are considered circular.
Recycling operative	The recycling operative's job consists of sorting through recyclable waste and separating materials to be recovered. This sorting and separating constitutes an essential element in the recycling process, which involves the 'use waste as a resource' strategy, and thus presents itself a circular job. Day to day activities of the recycling operative include physical labor and machine handling such as forklift driving.
Leasing process manager	The leasing process manager is responsible for the coordination of the external service partners distributed across market segments. By contributing to the workings of a product as a service model, the leasing process manager contributes to the circular economy through the 'rethinking the business model' strategy.
B. SUPPORTING CIRCULAR JOBS	
Director of a trade association	The director of a trade organization manages an organization with members representing different companies across sectors and value chains, and thus facilitates cooperation for multi-faceted value creation..
Architect	The architect designs buildings and is therefore responsible for the extent to which the materials used can be recovered after the use phase, and can therefore design for the future.
Data analyst	The data analysis processes data that, for example, can match the supply and demand of secondary raw materials and can thus support circular activities through the integration of digital technology..
C. INDIRECT CIRCULAR JOBS	
The courier's job does not directly contribute to the circular economy, however, they can play a role in enabling reverse logistics schemes for circular businesses. When the number of circular activities increases, the demand for logistics services will grow.	

Figure 7: Examples of jobs in the circular economy

CIRCULAR EMPLOYMENT IN ROTTERDAM

The graphs on the next page show the circular share of jobs in the Netherlands and Rotterdam, distributed as: (A) direct primary, (B) direct supportive, and (C) indirect circular employment. Circular jobs represent 31,000 of the more than 310,000 jobs in Rotterdam - 10% of the total. Of the more than 43,000 companies registered in the city, more than 5,700 contribute directly to the circular economy. All other companies contribute only indirectly to the circular economy.

This is how Rotterdam scores better than the Dutch average. The circular economy represents 8.1% of total employment nationally. That Rotterdam does better than the rest of the Netherlands is mainly due to the relatively large amount of direct supportive circular employment; that share is almost as large as the proportion of primary circular jobs in the city.

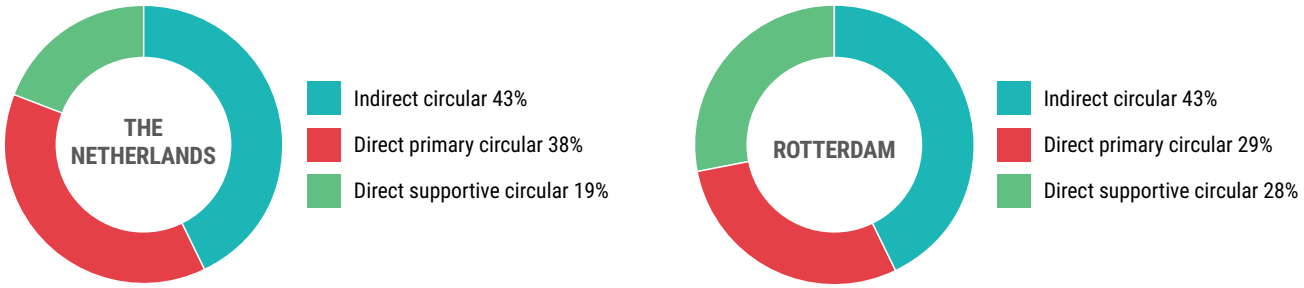


Figure 8: Circular share of jobs in the Netherlands and Rotterdam

The chart below shows the direct circular employment (A and B), and how it is divided across the seven basic principles of the circular economy in Rotterdam and the Netherlands. As far as employment is concerned, 'Integrate digital technology' is the most important circular strategy for Rotterdam. More than 33% of the direct circular employment derives from activities that the support circular economy through software development, information technology services, telecommunications, and web portals. Rotterdam has over 40% more circular employment in digital technology than the rest of the Netherlands.

With a fifth of direct circular employment in activities around 'extend the life of products' Rotterdam has also built up expertise in this area. However, this is still a lot lower than the Dutch average, and the city is lacking unique skills and expertise in this area. The same applies to jobs in activities related to 'design' for the future 'and' using waste as a resource'; they are well represented in Rotterdam, but form no unique approach compared to the rest of the country.

'Prioritize renewable sources', on the other hand, delivers fewer jobs than the above strategies, but is significantly more important for Rotterdam than the rest of the Netherlands. This is down to the use of renewable energy through wind energy. This often takes place outside the urban area and the port of Rotterdam is designated by the national government as one of the areas where large-scale wind power will be produced.

From the above results, Rotterdam sets itself apart in the knowledge-intensive part of the circular economy. For activities in 'integrate digital technology ' the proportion of jobs that require higher education is greater than for the rest of the economy, and for primary circular activities. Cognitive and interactive skills are therefore more important for circular activity in Rotterdam than manual skills (Burger et al., 2017).

The City of Rotterdam aims to create 7,500 jobs by 2030. The 'direct circular jobs' in the methodology used amount to 21,280. This means that the intended growth is 35% relative to the current number of circular jobs.

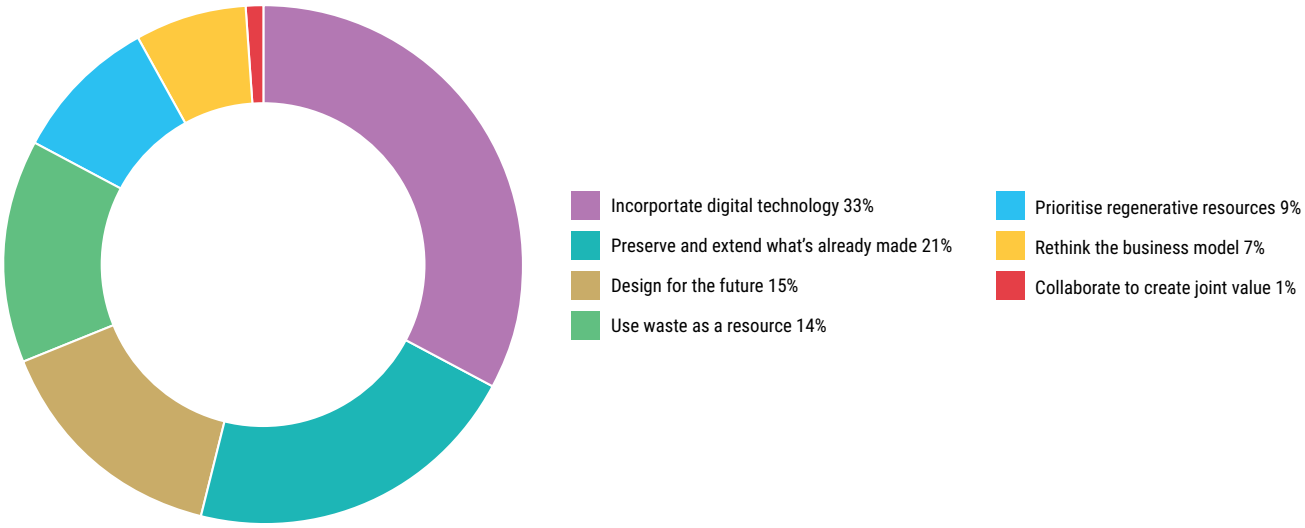


Figure 9: Circular jobs in Rotterdam

CHAPTER 03

VISION FOR A CIRCULAR ROTTERDAM

VISION FOR A CIRCULAR ROTTERDAM

If we apply the principles of a circular economy to the city, then we face the challenge of translating abstract and strategic goals into specific objectives that take into account scale, time and space. Not every geographical unit can or must meet all the characteristics of a circular economy. The key question is: how can cities contribute to these higher (circular) goals and at the same time fit within the broader economy?

Most costly is the moving of material, water or energy (in connection with transport losses and the costs of transport itself) and however much is available in close proximity (for example, sun and rain), the more important it is to close the loops locally. That is why energy and water are the streams that must first be closed on a local scale. This is not possible in a very densely populated city center, but in the areas just outside, such as the port and industrial areas in Rotterdam. In addition to energy and water, the closure of the local material cycle is important, in particular the short cycle of food waste and other organic waste. The more complex the materials and the longer they remain bound in a product (such as the case with electronics, household goods and building materials), the lower the priority will be when closing this cycle at local level. However, this requires a local repair or collection infrastructure that makes it possible to keep the materials in the cycle for as long as possible.

The result is a bio-cultural region that is self-sufficient for certain raw materials, but actively trades with other regions in scarce areas or geographically specific products. The impacts of the products and raw materials consumed in Rotterdam are kept to a minimum by smart production processes, the sharing of raw materials and maximum reuse, high-quality logistics and recycling systems, and the emergence of new economic sectors built on the industries of the past.

After a fifteenfold reduction in the use of raw materials and emissions, the per capita impact of the inhabitants of Rotterdam remains within both the regional and planetary boundaries.

A LOOK TO THE FUTURE

In the following sections we offer a look at the future as it would look within the vision of a waste-free and circular Rotterdam.

ZERO WASTE

In its circular future, Rotterdam can proudly call itself a zero waste city. Back in 2015, when Rotterdam set off on its transition path, just around 22% of its solid waste was recycled – and quite a large portion of the methods used back then would not qualify as recycling today. The majority of the city's solid resources were put into low-value applications, like cement used as road-filler, or incinerated for energy production.

Today, 98% of all residual materials are separately collected, and only 5% of waste that is too low quality or hazardous is incinerated for energy recovery. The amounts of hazardous waste are still decreasing each year as old stocks of products and buildings are slowly replaced. Each household is equipped with smart sorting containers that simplify the process of separating different materials. The containers' built-in sensors tell users if they've sorted something incorrectly. But the incentive to properly sort resources is already very high: for every kilogram of correctly sorted waste, residents get Rotterdam Coins paid directly into their digital wallets. They can use their earnings for the purchase of local goods, many of which have been remanufactured or regrown from those same residual streams. If they have Rotterdam Coins left over, they can also use them to pay for their – fully renewable – energy bill, or even pay their taxes.

In construction, design is now approached in an entirely new way. Architects first of all look at how buildings can be renovated in a sustainable way and consult closely with specialized companies that will be able to carefully dismantle the building. In the development of new buildings, the architects devise sustainable concepts based on the latest innovations that ensure buildings can easily be adapted and even disassembled in the future. A real-time raw material monitoring platform, the Rotterdam Circularity Dashboard, continuously monitors the availability of different material flows, from citrus peels to old shoes. These raw materials are automatically transported to the various processing facilities in the city, which are run by both small and large entrepreneurs. This dashboard also keeps track of orders of different materials.

A FLOURISHING ECONOMY

With these innovations, which resulted in the supply of previously-unavailable high-quality and pure resource streams, a whole new cluster of industries began to develop throughout Rotterdam. New product innovation exploded in the early 2020s. At first, the major focus of R&D activities was on processing bio-wastes into new materials – like clothing, furnishings, and biodegradable packaging. Later, it became clear that complex consumer goods like household appliances could also generate more value in this new economy.

Product manufacturers discovered that they could actually claim financial benefits for every kilogram of materials that was successfully harvested from their products – provided that they included an RFID tag that could by scanned at the automatic sorting and disassembly unit. Innovation in this field prompted TUDelft to transform its prestigious Industrial Design program, and led to a whole new generation of product designers living in and around the Rotterdam area.

But before anything is ever disposed of in Rotterdam, it gets the royal treatment of repair and refurbishment, maximizing its usable lifespan. The Upcycle Mall is one of the busiest places in the city, with cafes serving food from the building's greenhouses, and with many different stores and workshops. The Mall has led to a completely different social dynamic than existed in the earlier 2000s, when the main options available for spending time with friends involved eating or drinking at a café or bar. People come to the mall to learn new skills, but also to socialize while repairing their own clothes or trading their old bike in for something else.

These new, local industries have transformed the local Rotterdam economy, creating thousands of new jobs, boosting the city's resilience, and serving as an example for other cities around the world.

A PICTURE OF HEALTH

Not everything in Rotterdam was reinvented in the transition towards the circular economy. Where the city was already strong, it became even more so. Rotterdam has been long-known for its highly developed healthcare sector, servicing not just the city, but also the broader region. Local hospitals and health providers also adopted circular practices, resulting in profound effects on the health and wellbeing of the city's residents. One of the early realizations in the transition to circularity was that each patient treated represented a cost to society: stress for family members, less time to work or volunteer, and more resources consumed at hospitals. That's why the medical sector in Rotterdam pioneered a more holistic approach to circular care by focusing on boosting the health of the city's whole population – starting from diet and habits. Once patients do make it into the care system, the impact of their care is dramatically reduced through the sector's commitment to 100% renewable energy, leased and disassembled medical equipment, and advanced cleaning and waste-treatment technologies.

It also has to be said that the overall health of the city's population increased dramatically as a result of large-scale change in dietary habits. In an effort to meet its Paris accord commitments, Rotterdam began an active campaign to move towards healthier and lower-impact diets. Because there are many quality alternatives on the market at alternative prices, 70% of the population only consumes animal products once or twice a week, which has led to an enormous decrease in the city's greenhouse gas emissions, and a broad range of health benefits. Some residents also attribute their increased consumption of local produce, grown in Rotterdam's landmark floating vertical farms, as one of the factors in their greater well-being.

GREEN HAVEN

Circular Rotterdam no longer looks like the concrete metropolis it once was. Its rough edges slowly softened as nature became an increasingly central element in the design of buildings and public places. The most dramatic change only happened recently, in 2027, when the city finally did away with all personal vehicle transport in the inner city. All the asphalt roads were converted into green boulevards, with walkways meandering among trees and flowers. At the center of each boulevard are rail-lines for the public transport vehicles, which can be ordered on command from any part of the city. They are driverless and each have several seating compartments, allowing people to be picked up and delivered efficiently to their final destination.

A BLUEPRINT FOR CIRCULARITY

Though Rotterdam has made great strides, and most people around the world consider it a model of circular progress, it is not in the city's nature to stop innovating and exploring. Its society continues to be dynamic and creative, continuously seeking for new social or technological innovations that can help it evolve to the next level.

PERFORMANCE ASPECTS OF A CIRCULAR ROTTERDAM:

MATERIALS:

All materials that enter the city are recycled at high quality. Products made in the city are designed to be easily reused, refurbished, or recycled. Because of this, 100% of waste materials are collected, with almost all of them processed for reuse. Materials are only incinerated if they are completely discarded or constitute an environmental hazard and have no further handling possibilities. Materials also include nutrients such as nitrogen and phosphorus contained in liquid waste streams.

ENERGY:

All energy consumed in the city - whether for heating, lighting, cooking or transport - comes from renewable sources. The city is much more energy-efficient and consumes only a quarter of the total energy compared to 2015.

BIODIVERSITY:

The city is integrated with the hinterland by means of nature reserves and green connections. Flora and fauna have the space to thrive in the circular city, with its many specially designated living areas and the limited hard surfaces. In many ways, the city feels more like a natural area that is integrated with buildings than a concrete landscape with a number of parks.

SOCIETY AND CULTURE:

Communities are tight-knit, with residents supported by friends and family. There are social and cultural activities in abundance. Diversity is celebrated and communication between different social groups is frictionless. People get satisfaction from their daily activities and everyone shares in activities that they consider important and that at the same time meet the needs of the wider community.

HEALTH:

The air quality in the circular city - both inside and outside - is as pure as now can only be found in untouched nature reserves. Almost all sources of pollution have been eliminated. Streets and neighborhoods are designed for hikers and motorless transport. An abundance of green areas leads to better mental health and productivity, as well as strong social support networks. Healthy food is easy to obtain.

VALUE GENERATION:

The city has a robust economy built on a small fraction of the physical resources that cities of similar scale consume today. The city uses less than 10% of the imported primary raw materials compared to now. The economic productivity of raw materials has increased dramatically. Other forms of value, such as aesthetic quality, disease-free days, biological diversity and innovation, are proactively monitored in combination with added value as benchmarks for economic progress.

RESILIENCE:

Irrespective of the challenges - from extreme weather to global economic volatility - the city recovers easily and quickly. The population is well-informed and friendly, willing to work together in times of crisis, and able to organize themselves through the many networks and communities that the average resident is part of. Rotterdam is self-sufficient in a number of essential raw materials such as water and energy. Because the city has a well-developed recycling industry and close relationships with surrounding (urban) farmers, it is able to meet a large portion of the food requirements and other facilities. The urban population has a diverse range of knowledge and skills that support a complex set of economic activities. Buildings and infrastructure are designed for flexibility, growth, and resilience against possible environmental calamities.

CURRENT CIRCULAR EMPLOYMENT OPPORTUNITIES AND KEY SECTORS

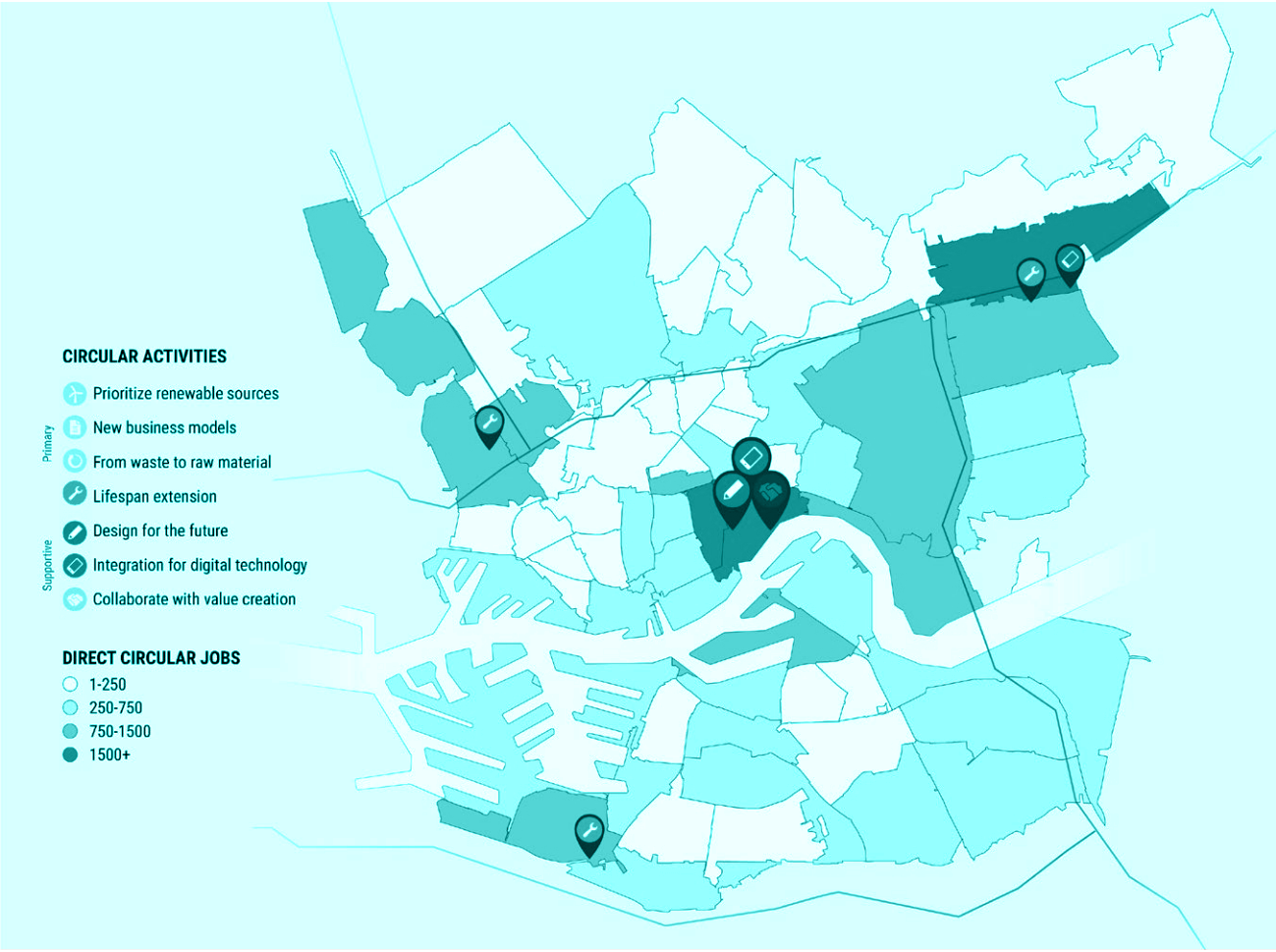


Figure 10: Direct circular employment opportunities at the district level in Rotterdam

The map shows direct circular employment by postcode in Rotterdam. One neighborhood can offer as many as 3,000 circular jobs. In addition, indicators with circular activities - divided into the seven categories - are displayed.

The urban economy of Rotterdam relies heavily on service-oriented industry that is characterized by a high degree of supporting and indirect circular jobs. This is in line with the national trend: supportive and indirectly circular jobs tend to concentrate in the urban centers, where primary circular jobs are located in industrial areas (Circle Economy & EHERO, n.d.), and this trend is already visible within the city.

The largest concentration of circular jobs is concentrated in the city center, but circular jobs are also found in the north-east, west and south peripheries. Circular employment in the center is dominated by supporting circular jobs, but beyond this, primary circular jobs are gaining in importance. In the northeast there is a concentration of circular jobs, especially in the field of digital technology. In the west, the Spanish Polder, an industrial estate with more than 600 companies, houses a clustering of 'core' jobs focused on life extension. There is also a strong concentration of circular jobs throughout the southern periphery.

In addition to circular employment, the map also shows hotspots for the four Rotterdam key sectors: environmental parks process the waste generated by the consumer goods sector; two hubs of local food production represent the ambitions for short urban food chains of the agri-food sector; the Erasmus Medical Center is a symbol for the healthcare sector; and for the construction sector, the Feyenoord neighborhood has the largest construction assignment for 2018.

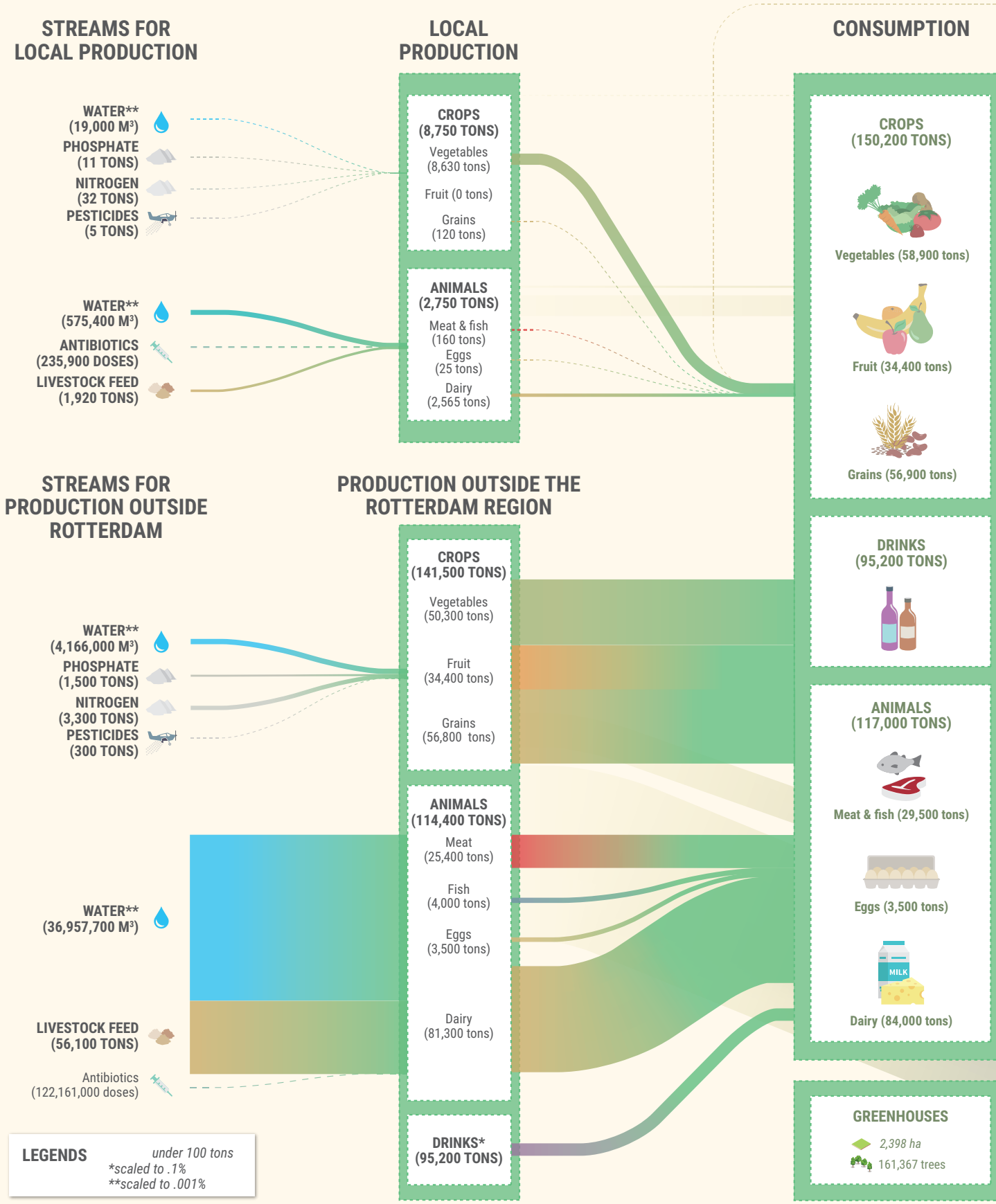
In the next section of the report we will make a baseline analysis of both material flows and circular jobs of these four strategic sectors, which form the basis for the search for circular opportunities throughout the economy and the city.


van LUDEN
GUILLEMOUSSE

CHAPTER 04

OVERVIEW OF ROTTERDAM MATERIAL FLOWS

OVERVIEW OF ROTTERDAM MATERIAL FLOWS 2015



METABOLIC CIRCLE ECONOMY

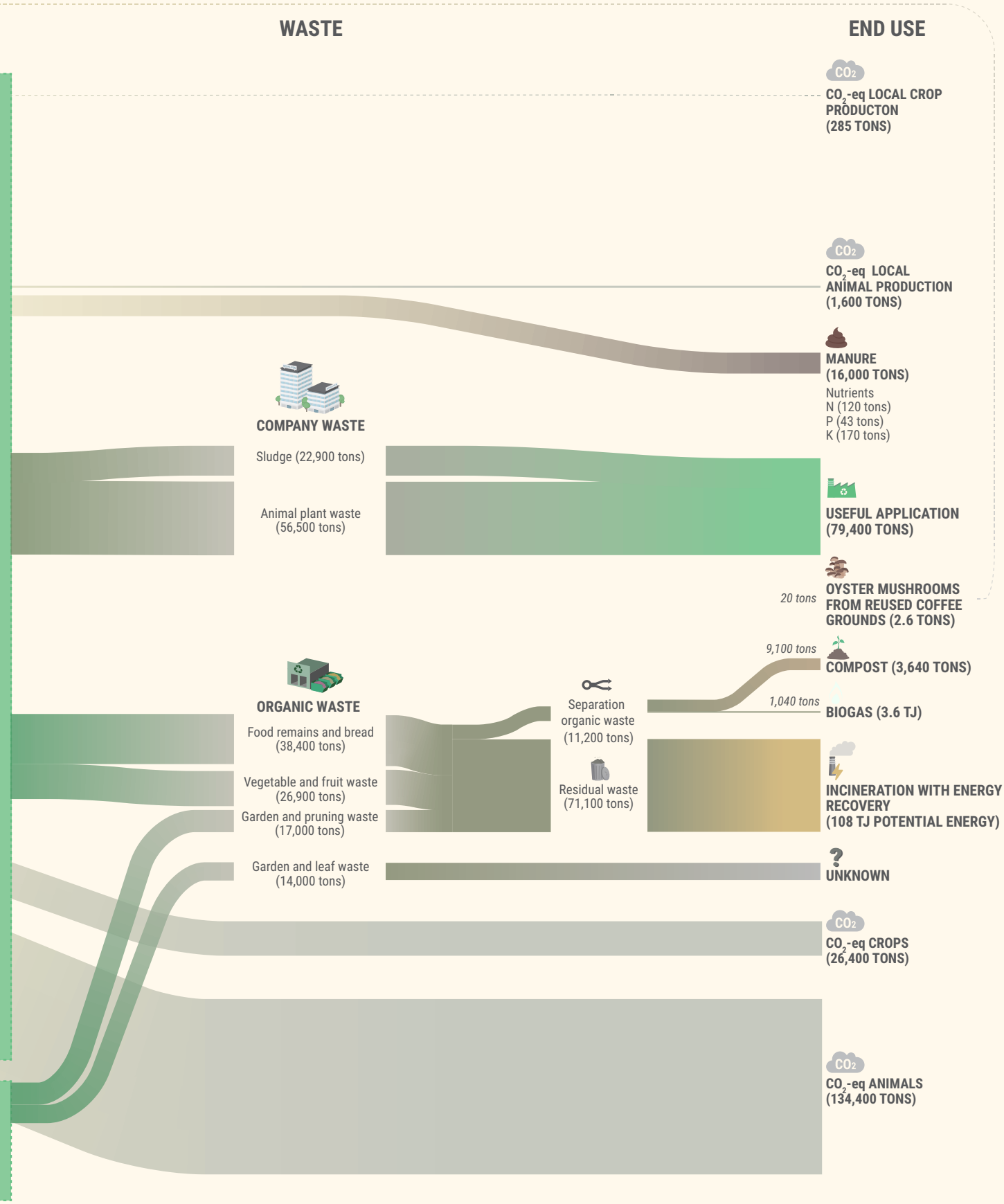


Figure 11: Overview of material flows through Rotterdam 2015

The graphic on the previous page schematically represents the energy, material, and water flows passing through Rotterdam in 2015. Each of the lines represents a different resource category.

- The lines are scaled so that their thickness corresponds with the total material mass of that category, with material inputs entering on the left and waste streams exiting on the right.
- In this overview, we have also represented all of Rotterdam's energy demands in the estimated mass of materials (mainly fuels) that is needed to generate the amount of energy consumed.
- All of the data are based on actual figures collected from the City of Rotterdam, the Nutrition Center, and Statistics Netherlands, with the exception of material inputs for the agrifood, healthcare and consumer goods sectors, which are estimated based on available information from online databases and sector reports. More detailed information on the methodology and assumptions can be found in the Appendix.

ROTTERDAM'S METABOLISM

Because our study excludes the industrial activities of the port, our general overview of Rotterdam's material flows shows a similar pattern to that seen in many Dutch cities. This pattern is defined, to a large degree, by the resources needed to fulfill people's basic needs: food, water, shelter, energy, and consumer products. However, the exact quantity of the resources consumed and the wastes generated is dependent on the specific economic profile of the city, the habits and interests of the city's residents, and the type of technologies used for activities like construction, logistics, and waste processing.

By mass, Rotterdam's largest resource inputs in 2015 were dominated by water, fuels, food and drinks, and construction minerals:

Drinking water	58 million tons
Fuels	609,000 tons
Construction Minerals	463,000 tons
Food and Drink	362,200 tons
Consumer Goods*	434,500 tons

**(excluding 12.780 tons of personal vehicles)*

As a subset of the categories listed above, Rotterdam's total material input in 2015 was 1,260,000 tons (excluding fuels and water). On the output side, we see that 384 million tonnes of wastewater, 4 million tonnes of CO_2, and 680,000 tonnes of solid material were generated as wastes in 2015. A very small percentage of the solid waste – only 0.4%, was sent to landfill, which already indicates good performance on an important circular economy metric. However, at the same time, only 29% (201,240 tons) of solid waste was reused, recycled, or composted. The remaining quantity of solid waste was incinerated or downcycled, although over 99% of incineration also resulted in the generation of power.

Though Rotterdam's handling of waste streams is already among the best for European cities, there is clearly a great deal left to gain if the city wants to realize its circular ambitions. As we discuss in the interventions section of this report, Rotterdam can make use of many opportunities to maximize the value extracted from its various waste streams, while reducing both the upstream and downstream impact of its resource footprint.

LOCAL CHARACTERISTICS

Despite the fact that Rotterdam's metabolism follows the basic pattern of Dutch cities, there are many local variations that result from Rotterdam's specific context. The world wars of the last century have formed the physical environment of the city. The innovative character of the city and the openness to change and innovation is the result of this recent past. The diversity of the cultural background of the inhabitants is also characteristic of the city and also appears to have an effect on the metabolism, where products come from come and the typical habits of the inhabitants. More detailed research is needed to further flesh this out.

At first glance, we see that Rotterdam's ratio of solid waste disposal to solid material demand is relatively high, at almost 0.8. This means that the amount of solid waste Rotterdam generates is 80% by mass of what it consumes in solid inputs each year. This ratio is higher than in typical urban contexts. In most other cities, a larger percentage of the solid materials consumed end up in the material stock of the city (in the form of buildings, infrastructure, or products), or consumed as food and later discharged into wastewater (as human waste). To understand this, and other unique characteristics of the material flows in Rotterdam, we take a quick look at some of the macro-level trends that are behind them.

BUILDING AND CONSTRUCTION: A CITY IN TRANSFORMATION

Rotterdam is in the process of physically reinventing itself – and its building stock. Despite the scarring effects of bombings during World War II, 31,4% of Rotterdam's housing stock was constructed before 1945, which is significantly higher than the 19% of housing built before 1945 across the Netherlands as a whole. Almost 70% of the housing currently standing in Rotterdam was put up in the 72 years since the end of the war. A large part of this housing stock is now considered low-quality. For this reason, among others, the Woonvisie Rotterdam lays out a plan to replace inexpensive rental housing with more expensive family homes.

In 2015 for every 100 new homes in Rotterdam, 110 will be demolished (727 in total). In the other three big cities there is a completely different picture. There are between two and twelve homes demolished for every 100 new homes. The same trend exists in non-residential construction. Rotterdam is demolishing more buildings than elsewhere, and the demolition activities are not projected to decrease in the coming years. Permission was recently granted to purchase 20,000 homes to demolish in the coming years (RTV Rijnmond, 2017).

Because of this, Rotterdam actually produces more construction minerals as waste material than it consumes in the construction of new buildings. This puts the city in a unique position of experimenting with new demolition and material re-use techniques in order to close the resource cycle in the construction sector.

FOOD AND AGRICULTURE: DEPENDENT ON OTHERS

Another aspect visible in the graphic is the relatively high amount of organic waste produced in the city relative to the consumption of food - 82,300 tonnes of food waste relative to 267,000 tonnes of food consumed. About 38,400 tons of this waste is avoidable bread and food waste that is produced by households. This means that an equivalent of 55.6% of the mass of food products consumed is disposed of as waste. The total food waste would be enough to feed more than a hundred thousand people for a year.

According to a recent survey by WasteWatchers, restaurants in the Netherlands waste on average 12% of food products (Sanoma Digital, 2015). Rotterdam consumers however wasted 14% on average. The waste of hotels, restaurants and cafes is equal to the consumption of ten thousand people.

There are 320 food product producers and processors in Rotterdam (Statline, 2012), including 215 companies working with baked goods. The largest amount of organic waste comes from these activities and local food production, including local animal production, resulting in approximately 107,200 tonnes of additional local organic waste per year, of which 56,500 tons of 'animal plant waste' (organic production waste) and 16,000 tons of manure.

WASTE MANAGEMENT: LOSS OF VALUABLE MATERIALS

Most of the waste in the city is downcycled or burned for energy recovery. Only a small part of the waste is of high enough quality to be reused in, for example, making compost from organic waste residues. In the field of waste management the city lags behind the rest of the Netherlands. An important reason that Rotterdam is lagging behind other Dutch cities in the field of high-quality recycling waste is that most waste is not separated before it is returned. Moreover, there is also more household waste per person in Rotterdam than in other big cities. Separated glass, plastic, and paper is particularly low compared to the other four major cities. In terms of collecting organic waste, Rotterdam does much better than Amsterdam, but in The Hague and Utrecht up to seven times more is collected per person.

The lower recycling percentages may be partly linked to the relatively high poverty level in Rotterdam compared to other Dutch cities (IDEM Rotterdam, 2016). On average, 18% of Rotterdam residents live below the poverty line, and in some neighborhoods an even higher percentage. In Agniesebuurt and Oude Noorden the percentage is 24% and 28% respectively, and there has been an upward trend in recent years (Hoogstad, 2016). Poverty disproportionately affects certain demographic subgroups: 60% of the poor are women, and non-Western immigrants are also overrepresented in the statistics (Moors and Graa, 2013). Some studies show that when there is a lack of financial incentive for recycling, such as pay-as-you-throw charges or deposits, people with low income are less likely to recycle because they have different priorities. Other studies show that one of the main drivers of recycling uptake is if people believe that recycling is important, and know what they do, it can be handled differently.

There is a clear positive trend in the area of separate collection if you look to 2016 compared to 2015. In 2016, the city stimluated the separate collection of waste by allowing 18,000 additional households separate collection of organic waste, and other methods. This lowers the threshold for separate collection considerably.

ENERGY: RUNNING HOT

Although energy is often seen as a separate issue from material management, the two are inseparable. The carbon emissions that we discharge into the environment is one of the biggest material 'leakages' in our current linear system and leads to a significant loss of raw material complexity. The 62,900 TJ that Rotterdam used in 2015 equals 1.7 million tons of fossil resources. That is many times the quantity of building materials the city uses.

Even excluding the enormous energy consumption of the Port, Rotterdam is a more energy-intensive city than most in the Netherlands, at almost 100 GJ per inhabitant. The energy consumption in the built environment is 45 GJ per inhabitant, although this does not differ greatly from Amsterdam where the average is 42 GJ per person (Climate Monitor, 2017). The CBS statistics also show that the average energy consumption per home in Rotterdam is slightly lower than average. Commercial

services consumed 11,100 TJ of energy in 2015, about 17.5 GJ per inhabitant. However, the fuel consumption for road traffic per inhabitant is higher than in Amsterdam, for example. This is not necessarily connected to the residents themselves, because many commuters go to and from the city to work every day by car.

In the field of renewable energy, within the boundaries of the municipality there are many windmills, especially in the port. The national government has chosen the Port of Rotterdam as a location for large-scale generation of wind energy. The city aims to increase capacity in the port by 80% to 350 MW by 2025.

The share of solar energy that is generated locally is, however, a lot smaller compared to the rest of The Netherlands. Only one in a hundred households has solar panels on the roof in the city, delivering 41 MJ per inhabitant. The Dutch average is 239 MJ per inhabitant. In neighboring cities such as Dordrecht, Delft and The Hague, the generation of solar energy per inhabitant is to two times higher. Some energy is generated by waste incineration, but this is not a circular form of waste management.

IMPACT ASSESSMENT

It is natural to focus on mass and volume as indicators of significance when first delving into an analysis of material flows for a city like Rotterdam. Indeed, the sheer quantity of a certain material can often point to its importance in terms of the amount of impact it causes, but that is not always the case.

The impact is not only based on the quantity of materials, but also the energy intensity and type of resources that are needed to make the products. The so-called embedded impacts are very different per product. Producing a kilogram of meat requires much more energy, land and water than a kilogram of grain. To get a quick understanding of how some of the material and energy flows through Rotterdam rank on different kinds of impacts, we evaluated the major flow categories on three important indicators: land use, water use, and CO_2 emissions (in CO_2-equivalents).

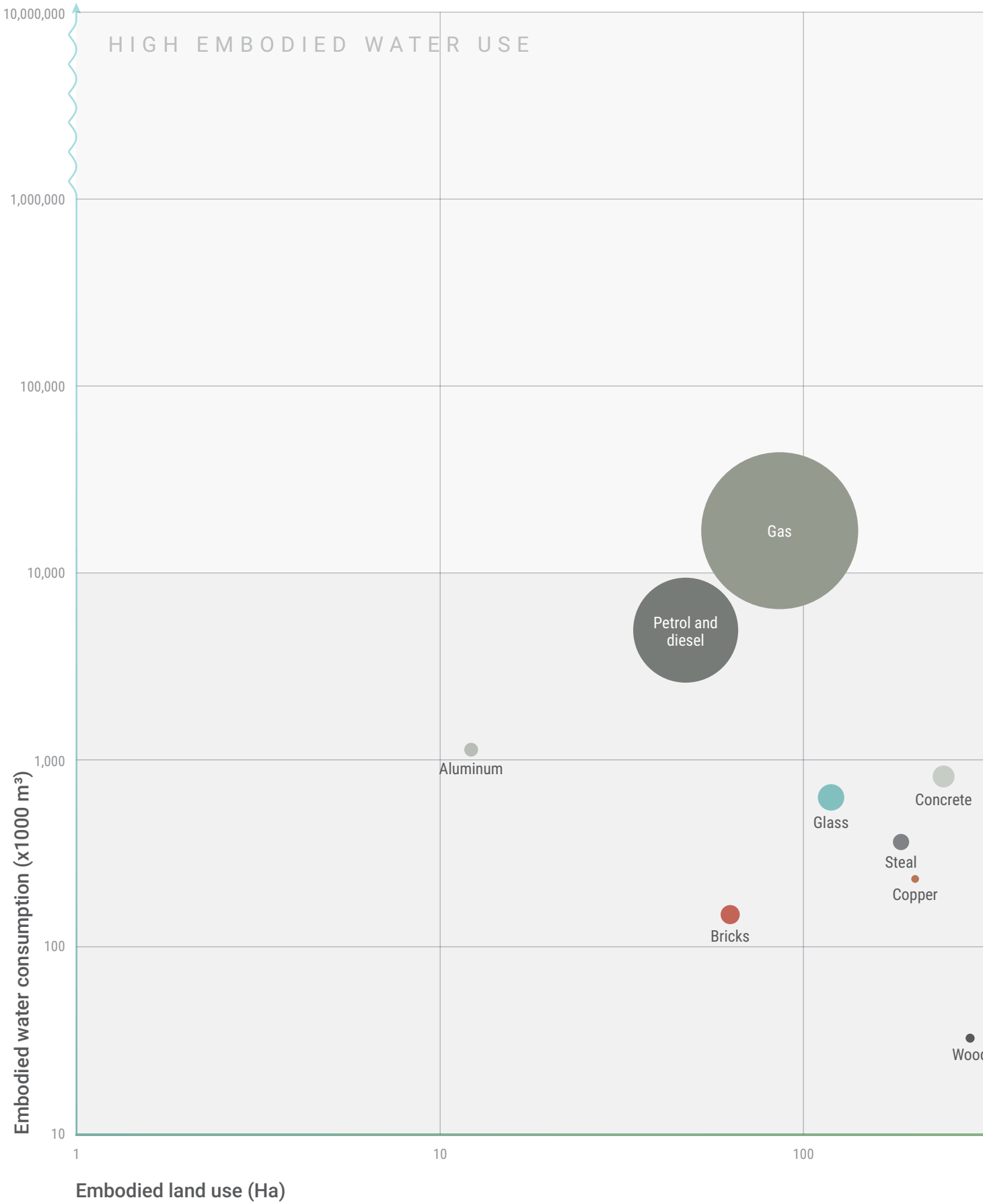
Figure 12 shows the results of this analysis. The y-axis of the graph represents the amount of 'embodied water' per category of resource used, while the x-axis shows the amount of 'embodied land.' The size of each of the bubbles represents the total amount of CO_2 emitted per category. Though there are some clear correlations between the mass of each resource flow and its impact, one of the main takeaways is that mass is not the main determinant.

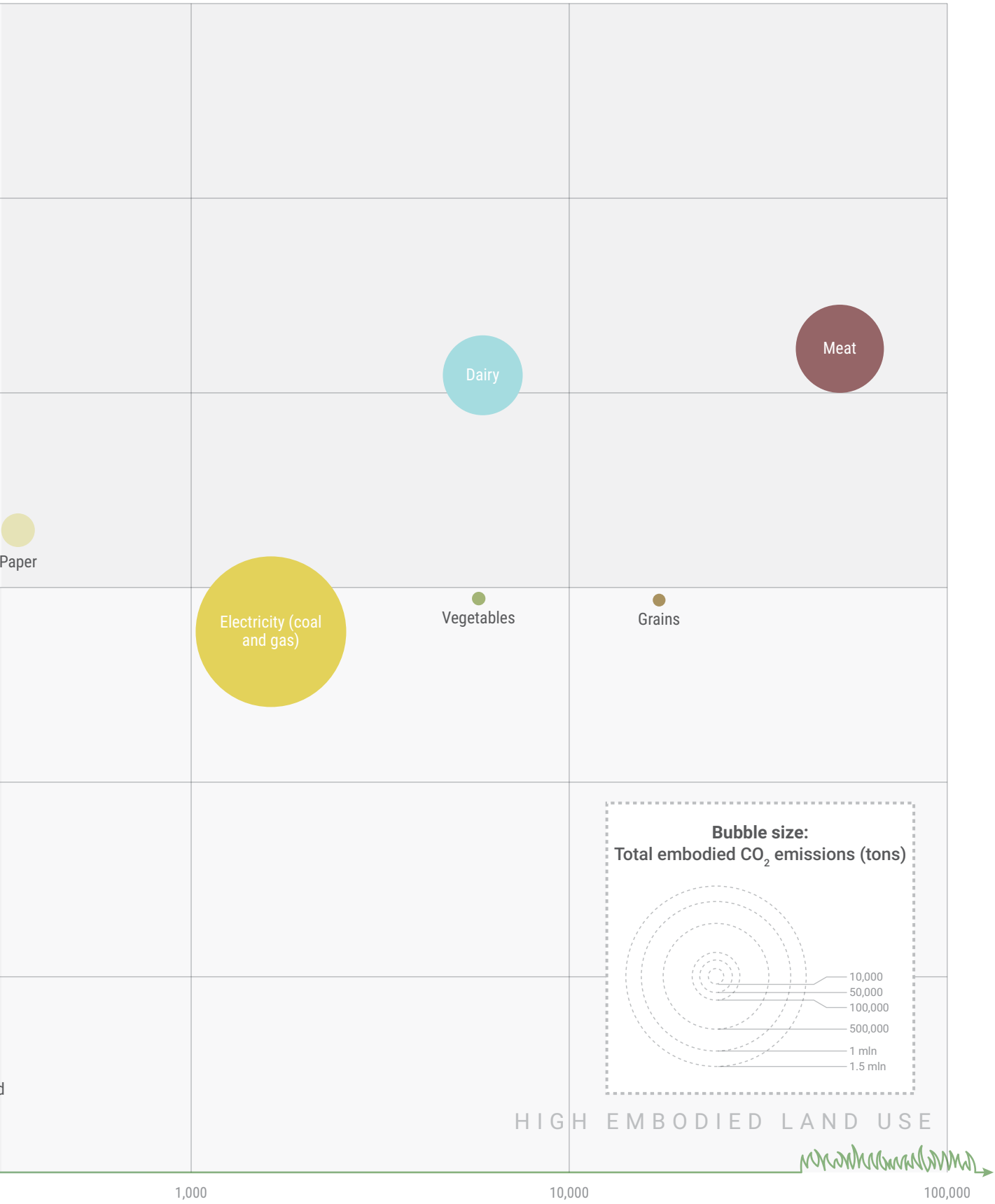
In the upper right quadrant (indicating the highest water and land consumption) are the animal products. The consumption of meat is by far responsible for the highest land and water consumption of all materials. For each inhabitant there is more than 900 m^2 per year land and 465,000 liters of water needed to produce all the dairy and meat consumed. The production of animal products also produces a lot of CO_2 emissions. Although the mass of crops such as grain and vegetables that are consumed is larger than meat and dairy, water use and emissions from production is much lower.

If you look at embedded CO_2 emissions (represented by the size of the bubbles), you see the different energy carriers stand out clearly. Gas has lower CO_2 emissions per energy unit than electricity and petrol but because gas is used so much, gas is still the largest source of CO_2 emissions. Furthermore, the share of renewable electricity is still limited.

Building materials such as concrete, aluminum, bricks, steel, copper, and wood are more prominent in this impact analysis of different materials compared to simple representations of their mass. This comes because there are major differences in the intensity of different production processes. The making of a kilogram of aluminum, for example, requires 76 times more CO_2 emissions than a kilogram of concrete. The production of metals is much more energy-intensive than minerals, and the value of metal relative to weight is therefore also higher than from bricks or concrete.

IMPACT ANALYSIS





Figuur 12: Impact analysis

ROTTERDAM CIRCULARITY SCORECARD (KPIS)

With an understanding of Rotterdam's resource flows and the impacts connected to these, we can assess the city's current performance on a range of key indicators. Regularly monitoring these Key Performance Indicators (KPIs) is essential to see whether policy changes and private sector efforts are actually resulting in Rotterdam's progress towards a circular economy.

Indicators can never tell the whole story of what is going on in a city, but they can point to important trends and raise flags if certain unexpected results occur. It is essential to pick a broad range of metrics that cover all aspects of concern related to circularity – looking beyond just material management to include impacts like carbon emissions and social parameters like job creation. As a starting point, we have taken Metabolic's seven pillars definition of the circular economy (see Figure 4). Achieving a waste-free economy is an important, but limited part of the bigger picture. Overall, we aim to evaluate how well Rotterdam's economy is currently:

- Preserving natural capital, (such as biodiversity) and stable planetary systems (such as climate)
- Optimally using raw materials and minimizing the overall demand for virgin resources
- Recovering raw materials in an effective and sustainable way
- Minimizing risks to health during production and consumption cycles
- Generating a broad range of value, including sustainable sources of employment
- The development of a robust and resilient society

Not all the data that we would ideally use for calculating these indicators is readily available. We have calculated detailed scores where possible, made estimates for some, and suggested additional data collection in the future for those areas where information is currently not available.

We recommend recalculating these metrics on an annual basis. Ultimately, the city should devise methods for connecting performance on these indicators with the activities in the economy that determine that performance. For example, companies and citizens alike should be given clear insight into how their behavior and selection of technologies influences the city's circularity as a whole.

RESOURCE USAGE:

INDICATORS	ROTTERDAM 2015 SCORE	COMMENTS
Total Raw Material Productivity *(GDP / tonne direct material Input)*	€24.940	
Primary Raw Material Productivity *(GDP / tonne of primary material input)*	€24.940	*We currently have no indication of the raw material inputs from recycled sources that enter Rotterdam. In this case, this indicator is the same as the above.*
Raw material demand per capita *(ton / capita)*	3,9	*Including energy*
Primary raw material demand per capita *(ton / capita)*	3,9	*This would ideally be smaller than the total raw material demand*
% Renewable Material Used *(%)*	16,56%	*It is assumed that food, paper and half of all textiles are renewable*
% Recycled Material Used *(%)*	-	*No data on recycled material consumption*
Waste Generated / Capita *(€ / ton of waste)*	€ 79.417	
Waste Generated per capita *(ton / capita)*	1,23	*Excluding CO_2 emissions*
% Solid Material Applied to High-Value Re-Use *(%)*	22,45%	
% Solid Material Applied to Low-Value Re-Use *(%)*	67,31%	*Most of the waste is incinerated or downcycled in 2015*
% Solid Waste to Landfill and Incineration without energy recovery *(%)*	2,31%	*Excluding energy recovery*
% Scarce Materials Recovered at High Value *(%)*	-	*Further research is needed to calculate this indicator*
% High Impact Materials Recovered at High Value *(%)*	-	*Further research is needed to calculate this indicator*
Potentially toxic material flows *(%)*	0,16%	*This stream contains small chemical waste and hazardous waste from hospitals*
Energy requirement per capita *(GJ / per person per year)*	101	*The energy requirement consists of electricity, fuel and heat*
GDP per Energy requirement *(€ / GJ)*	967	
Supply Renewable Energy *(%)*	5,10%	*According to the climate monitor*

Figure 13: Indicators for the use of raw materials

ENVIRONMENTAL IMPACT:

INDICATORS	ROTTERDAM 2015 SCORE	COMMENTS
CO_2 Intensity *(ton / capita)*	6.37	
Embedded water use *(ton / capita)*	-	Further research is needed to calculate this indicator
Embedded Land use *(ton / capita)*	-	Further research is needed to calculate this indicator
Embedded Energy use *(ton / capita)*	-	Further research is needed to calculate this indicator
Embedded CO_2 emissions *(ton / capita)*	-	Further research is needed to calculate this indicator
Raw Materials with High Risk for Impact on Biodiversity *(%)*	-	Further research is needed to calculate this indicator

Figure 14: Indicators of environmental impact

SOCIETY, HEALTH AND CULTURE:

INDICATORS	ROTTERDAM 2015 SCORE	COMMENTS
Social Cohesion *(Participate objectively)*	102	The district profiles are measured every other year by the City of Rotterdam
Health Good / Very Good *(%)*	68,5%	Percentage of the population that describes their own health as good or very good
Population with middle or high education *(%)*	0,76%	Graduates with a completed HBO or WO degree
Annual average air quality Particulate matter *($PM_{2.5}$ $\mu g/m^3$)*	15	
Percentage of Population Dying from Diseases of the Respiratory System *(%)*	0,075%	Diseases of the respiratory system can be an air quality indicator, but also of habits such as smoking

Figure 15: Indicators of society, health and culture

ECONOMIC PERFORMANCE:

INDICATORS	ROTTERDAM 2015 SCORE	COMMENTS
Unemployment *(%)*	**8,2%**	
Average household income *(€)*	**€31.000**	
Change in GDP through Circular Activities *(%)*	**-**	This indicator can be tracked from now on
Share of Circular Jobs *(%)*	**10%**	
Change in Circular Jobs *(%)*	**-**	This indicator can be tracked from now on
Population below Poverty line *(%)*	**18%**	

Figure 16: Indicators of economic performance

CONCLUSIONS

These indicators are meant on the one hand to explain the current situation so that future progress can be measured. On the other hand, this is also a good impression of how the city currently rates compared to other municipalities. The Gross Domestic Product (GDP) in euros per ton of direct material input is almost € 25,000. This number is an underestimation because not all flows are included, but focused on that of the researched sectors. Nevertheless, it seems to be a good score for a city. Almost 4 tons of materials (including energy) have entered the city per person in 2015. Of this, 16.6% was from renewable sources such as food, paper, and cotton. In the end this led to 1.23 tons of solid waste per person. The annual amount of household waste per person (444 kg) is higher than in Amsterdam and Utrecht, but lower than in The Hague. Looking at the waste processing, most waste is now being recycled or incinerated with energy recovery. Only 2.31% is now deposited or burned without energy recovery.

The energy requirement excluding industry is 100 GJ. This is quite high compared to, for example, Amsterdam, where the demand comes to about 71 GJ per person. There are many embodied effects for the environmental impacts that require further research to identify and calculate. The embodied indicators show the implications of the city's metabolism outside the municipal boundaries. The direct CO_2 intensity comes to 6.37 tons per person. Because a circular economy from the previously defined definition is an overall vision on various aspects of sustainability, health characteristics, and social aspects, these indicators give a detailed picture of the city and are important for culture, resilience, and of course the economy. The percentage of Rotterdammers that describe their own health as well or very well is 68.5% in 2015. That is lower than the average in South Holland (74.2%) and the national average (75.6%). In Amsterdam and Utrecht. this percentage is higher.

Another aspect that is measured is the average concentration of PM2.5 in the air. Rotterdam scores in this area better than Amsterdam, but worse than, for example, London.

In the area of economic performance, the city is below many other cities in terms of unemployment and family income. There are also a relatively high number of people below the poverty line. The percentage of jobs that is already circular is 10%. This is relatively high compared to other cities.

CIRCULAR INTERVENTIONS PER KEY SECTOR

The overview of Rotterdam's metabolism shown in Figures 13 to 16 gives us some high-level insights on the city's current level of performance on circular economy metrics. To really understand the reasons why certain resources are currently used sub-optimally, we take a more detailed look at the four key sectors that have been selected for this analysis: agrifood, building and construction, consumer goods, and healthcare.

We examine each of these sectors in more detail and describe the kinds of actions that can be taken in Rotterdam for the city to move towards a fully circular economy, while also creating new employment opportunities. In each of the four sections that follow, we first look at the current situation and resource performance within that sector, then provide an overview of possible interventions that can be taken to achieve circular goals. These are listed in a table along with a ranking of their individual feasibility, positive impact potential, and likely effect on job creation. The most promising interventions for Rotterdam are discussed in more detail later, and form the inputs for the stakeholder sessions, which we host in the following phases of the project.

DEFINING CIRCULAR INTERVENTIONS

We identified circular interventions by looking at the greatest current impacts and resource losses within the system, and selecting measures that can be taken by local stakeholders (government, companies, civil society) in order to prevent or reverse them. With the most important measures, it is not only about prevention of loss of value, but also creating circular jobs. For a circular, zero-waste Rotterdam, the measures must be ranked, based on the potential to reduce environmental impacts, or the potential to eliminate waste at the source. After these types of interventions have been implemented, it will be time to look at end-of-pipe solutions that generate value from existing waste streams. To realize a fully circular city, we employ a circular decision-making hierarchy to make decisions on the most effective circular interventions.

REDUCTION

The easiest way to prevent the impact of raw material extraction and production, is reducing our production. It is important to design a system where low energy and materials demand is central. The goal should not be to increase the demand for raw materials or reduce quality of life.

SYNERGY

As soon as the demand for raw materials and the related effects have been reduced as much as possible, then it is time to look at the prospect of exchanging residual flows. If, for example, residual heat is produced in a building, it would be ideal to absorb this heat and reuse it on the spot. In particular, locally available resources (such as rainwater or heat from local water sources) and raw materials known to be released during the demolition of buildings are important to consider in this design step.

PRODUCTION AND PURCHASING

As soon as the opportunities for synergies become exhausted, it is time to see how the remaining demand can be met from clean, renewable or otherwise environmentally favorable sources. Resources that are in local production are preferable because the impact is usually lower and the efficiency higher, because no transport or major infrastructure investments are needed. In the long run however, the choice for local resources must be guided by impact and efficiency.

MANAGEMENT

It is important to get feedback on how the system works to keep it optimal. This includes, among other things, the provision of transparent data and a single information network to enable an efficient and well-functioning system. This form of feedback makes behavioral change and technological adjustments possible.

EVALUATION OF THE INTERVENTIONS

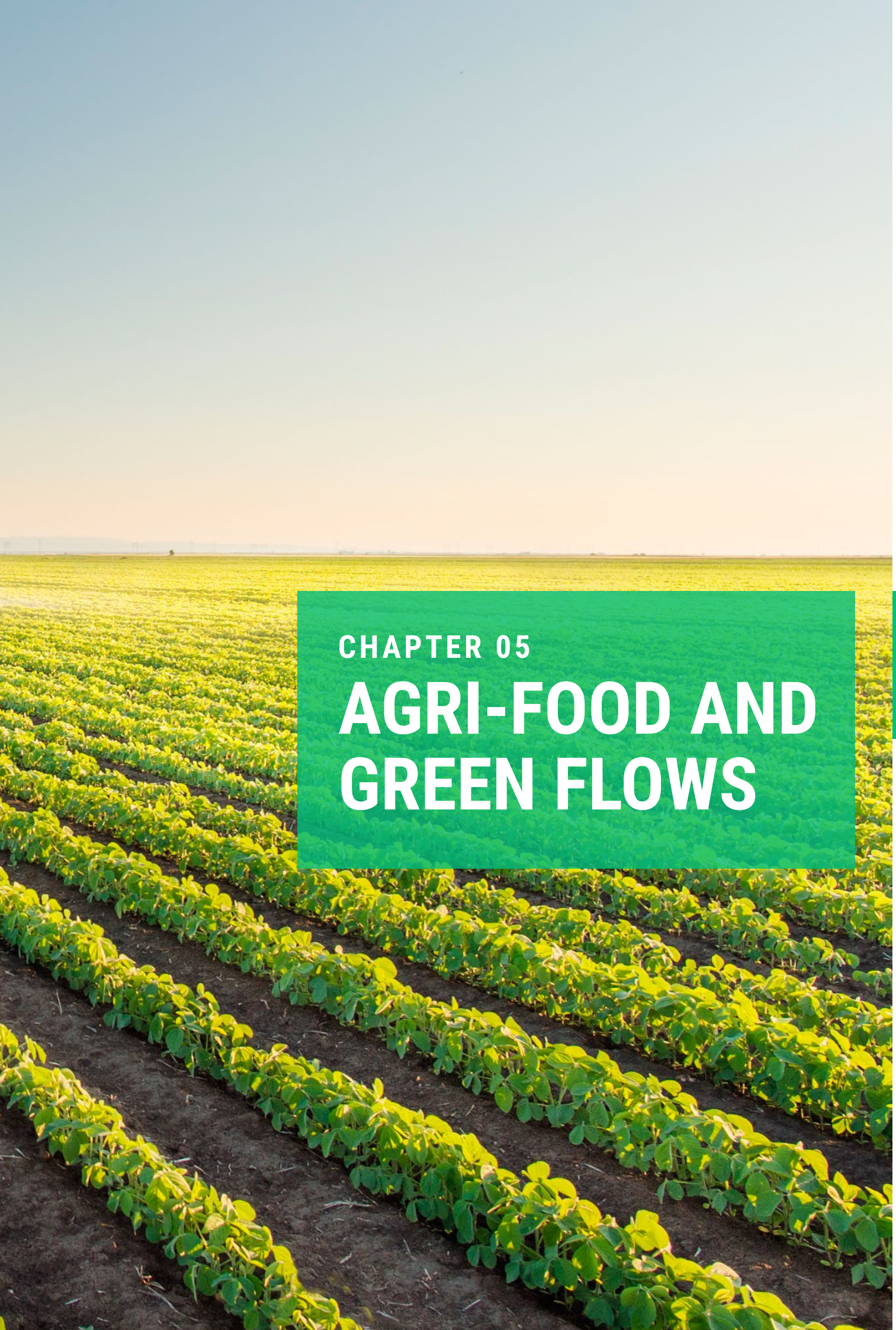
Using the hierarchy we mentioned above, we have developed a long list of circular measures for each sector. To identify the most promising options we have assessed every intervention for feasibility and potential positive impact. To make an evaluation of feasibility we ask the question: How difficult will it be to successfully implement the intervention, given various barriers to success?"

We consider five aspects of feasibility, described briefly in the next text box. We ranked each of the interventions for each aspect of feasibility on a scale of 1 (very unfeasible) to 3 (very feasible) and took the average as the final value for feasibility.

- **Social feasibility:** Social feasibility considers how many peoples' minds need to be changed and how resistant they are to change.
- **Economic feasibility:** Economic feasibility involves the amount of resources that would be necessary to implement an intervention versus the perceived direct or indirect benefits.
- **Practical feasibility:** Practical feasibility includes the number of people that would need to be mobilized, distance that would need to be traveled, and any other physical limitations which exist.
- **Political feasibility:** Political feasibility includes the legal and legislative barriers or incentives which may hinder or promote implementation.
- **Technical feasibility:** Technical feasibility involves the available technologies or knowledge which can enable the implementation of an intervention.

For effectiveness, we consider what the effect would be if the intervention were successfully implemented, and we ask ourselves: "what share of the impact would be mitigated if this is successful?"

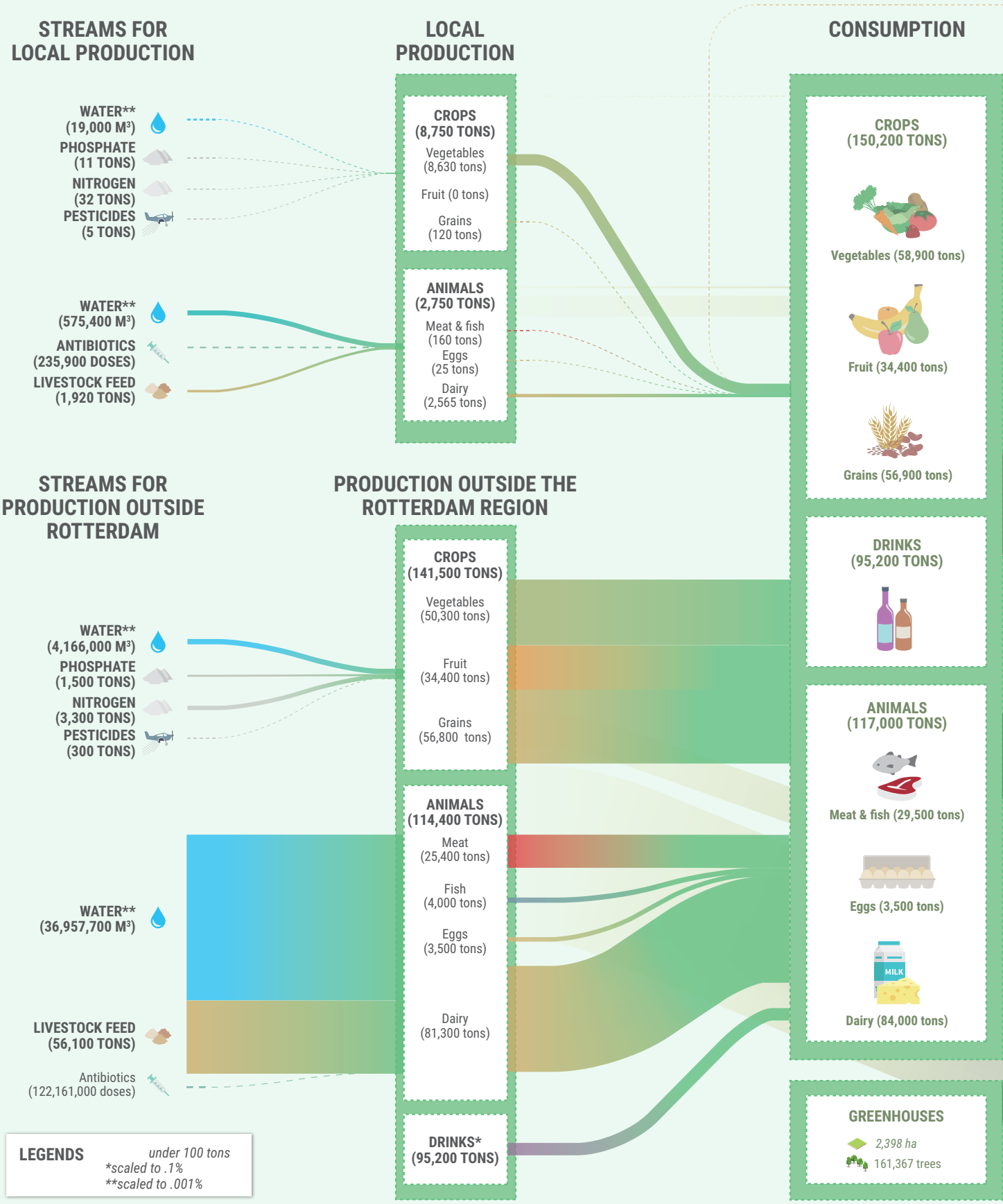
Even a very feasible intervention may be less of a priority if it has a negligible effect. To measure effectiveness and rank the interventions from one to three, we estimated the share of the impact mitigated against the goals.



CHAPTER 05

AGRI-FOOD AND GREEN FLOWS

AGRI-FOOD AND GREEN FLOWS IN ROTTERDAM IN ROTTERDAM 2015



METABOLIC CIRCLE ECONOMY

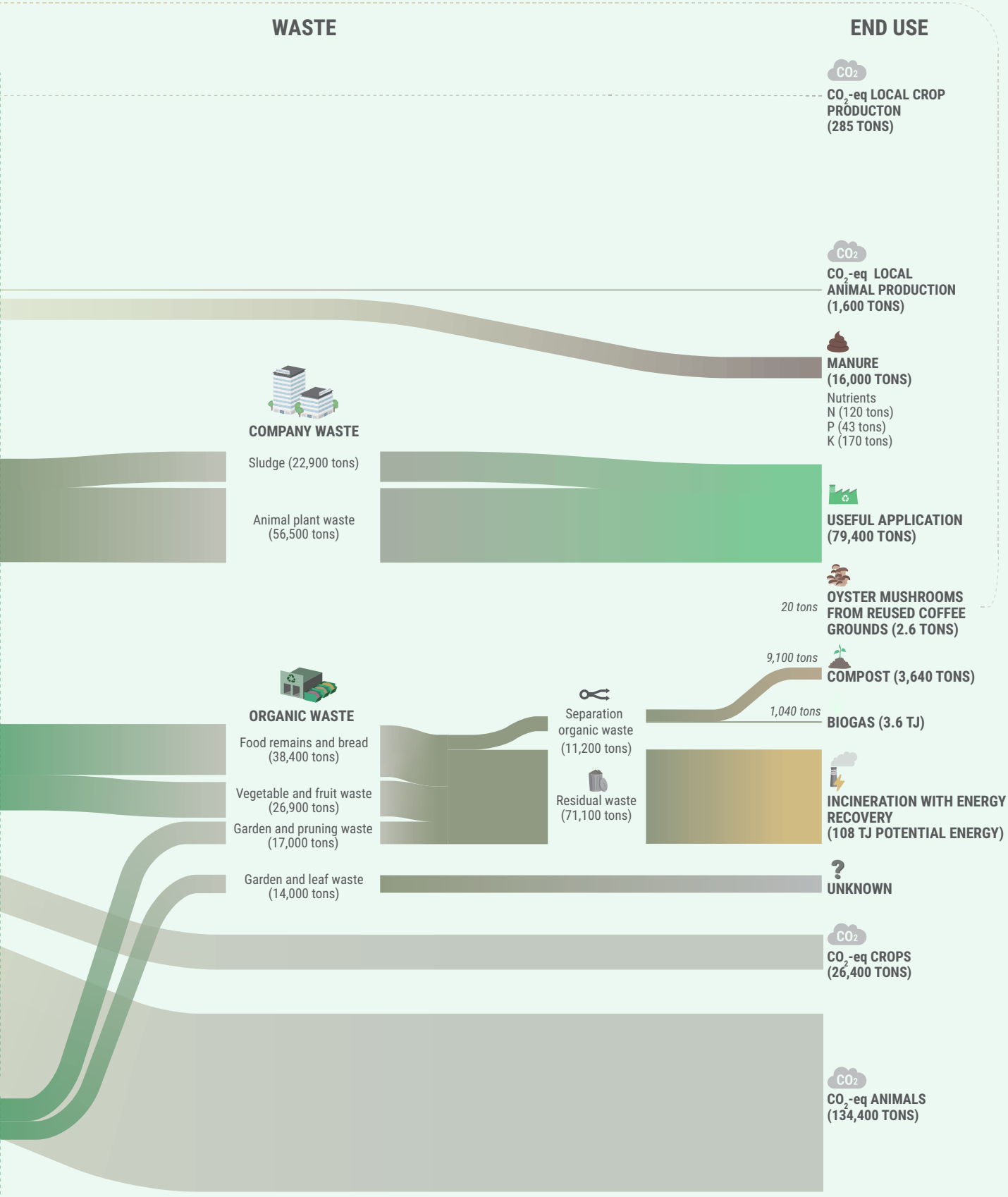


Figure 17: Material flows: Agrifood and Green Flows Rotterdam 2015

AGRI-FOOD AND GREEN FLOWS IN ROTTERDAM

The material flow analysis of 'agri-food and green streams' comprises the following flows: organic residual flows from households, food production and residual flows in the region, wholesale (including import) and retail food, waste processing, organic waste flows, green waste and pruning.

FOOD FOR THE CITY

The agricultural sector is a core sector in the Dutch economy. The country is in fact the second biggest exporter of food in the world, based on economic value (Viviano, 2017). Although the region around Rotterdam produces food and there are many greenhouses, the city focuses more on agricultural services and logistics than on production. The city is renowned as a transit port for fruit, vegetables, juices, soya beans, maize, vegetable oils, grain and seeds (Rotterdam Partners, 2015).

Annual livestock production is limited to meat (160 tons), dairy (2,565 tons) and eggs (25 tons), while agriculture focuses on vegetables (8,630 tons) and grains (120 tons). The city has no production of other fibers, fruit and nuts, and crops for beverages. Similarly to other Dutch cities, Rotterdam's food and drink production does not meet its local demand: 96% of food and drink must be imported from outside the municipal area: an important characteristic of the agri-food system in Rotterdam is its high dependence on food produced outside the city.

Rotterdam and its surrounding municipalities have a particularly low level of self-sufficiency and depend on products that are produced outside the region, certainly when compared with cities such as Milan, London, or Berlin (Zasada, Schmutz et al., 2017). A low percentage of food production within a city is common and not necessarily problematic, but it does lead to major shifts in impacts: the majority of the inputs for food production for Rotterdam such as water (41,123,000 m3), cattle feed (56,100 tonnes), and antibiotics (122 million doses), and outputs such as emissions (160,400 tons) and manure (587,000 tons) take place outside the city (Van Odijk et al., 2016).

ETNICITY	HOUSEHOLDS %
Surinamese	8,7
Antilleans	4,0
Cape Verdeans	2,5
Turks	5,7
Moroccans	4,7
Other Non-Westerners	8,2
Native	53,3
Other EU	8,0
Other Western	5,0

Figure 18: Households (%) according to ethnicity of the head of the household

LOCAL DIETS

Rotterdam has a very diverse population, with about 49% of residents with a migrant background (Statline, 2017c), and about 33.8% non-Western immigrants, as can be seen in Figure 18. Culture and nationality have an influence on food consumption, resulting in more diverse eating patterns in Rotterdam compared to less diverse Dutch cities (Foodlog, 2015). For example, Dutch people with a Surinamese background usually follow a Surinamese diet, with more grain products (in the form of rice or noodle dishes), and about twice as many fish as native Dutch. People of Turkish origin have a diet of many vegetables, grain (Turkish bread), meat, fruit and soup. The average consumption of alcoholic beverages is also low among Surinamese, Turkish and Moroccan (RIVM, 2016).

GREEN SPACES AND GREEN WASTE

Within the city, the built environment comprises mainly residential homes, work areas and infrastructure. There are also parks and green areas (Frantzeskaki et al., 2014), although only 6.6% of the city is dedicated to green space (ARCADIS, 2017), which is relatively little compared to other cities. For example, Amsterdam has 13% green space, and Stockholm 40% (World Cities Culture Forum, 2015). Green waste that is collected during the maintenance of public green spaces and households, amounts to almost 14,000 tons per year. In addition, almost 17,000 tons of plants and flowers contribute to this waste stream.

ORGANIC WASTE

Rotterdam produces 82,300 tons of household organic waste per year. Of this, 26,900 tons is food remains (peels, eggshells, remains) and 38,400 tons is food waste that could have been avoided. Apart from the high economic value of this type of waste, this quantity of food waste is enough to feed more than a hundred thousand people a year. Only 6% of domestic household waste is collected separately; 94% of organic waste

ends up with the other waste in the waste bin. This lack of separation makes it impossible to use organic waste for high-value applications. Separate organic waste collection is a condition for the transition to a circular economy in Rotterdam.

From the organic waste that is collected separately, 20% is used for biogas and the remaining 80% is transformed into compost. A small portion of the organic waste is used directly for food production. For example, 21 tons of coffee grounds is used as a substrate for growing of oyster mushrooms in BlueCity. All other organic waste that ends up in the residual waste stream is incinerated with energy recovery. Although this is certainly better than combustion or landfill, it leads to the destruction of large volumes of chemical value and nutrients.

Other significant organic waste streams in the city stem from business activities. Food processing companies produce almost 23,000 tons of organic sludge and 56,500 tons of mixed animal and vegetable waste. According to available statistics, this material is all reused or put towards useful applications. However, much improvement is still possible for these streams. Finally, agricultural activities within Rotterdam result in the production of 16,000 tons of manure. It is unclear how this material flow is currently being used, but it is to be assumed that it is used as a fertilizer for agriculture.

The agri-food sector supplies more than 24,500 jobs in Rotterdam, of which more than 1,700 are circular. When it comes to circular activities, the agri-food sector processes organic residual streams into animal feed and uses it for heat and energy generation. Over and above the circular processing of residual streams, the circular potential of the agri-food sector of Rotterdam lies at the beginning of the value chain, resting on the transition to green energy and circular food production. Rotterdam is already strongly committed to local, urban and sustainable food production, from which a number of iconic projects have developed, such as Dakakker.

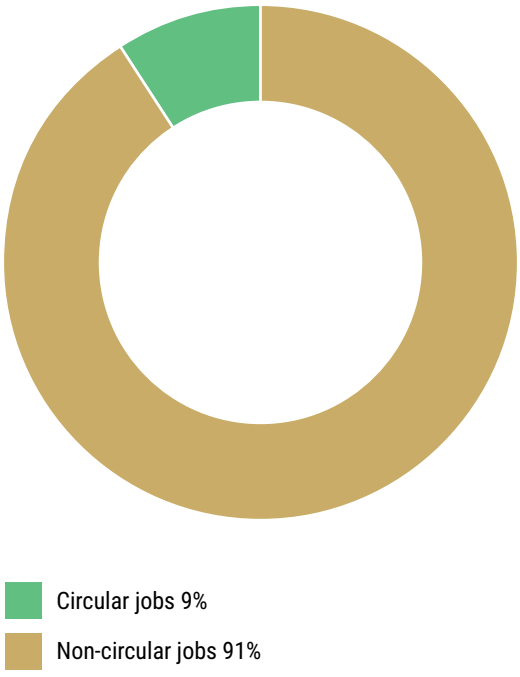


Figure 19: Jobs in the Agri-Food Sector

ENVIRONMENTAL IMPACT OF THE DIET OF ROTTERDAMMERS

One of the biggest impacts people have on the planet is caused by discarding food that is not eaten. According to a study commissioned by the European Union that looks at the average European household, transport, and food and drink is responsible for about 70-80% of the ecological impact within a broad range of impact categories. Food, drinks, and tobacco contribute 20-30% in most impact categories (European Commission, 2006). Agriculture currently accounts for about half of the impacts for all needs relating to plants and animals, including people, habitable land (38% of all the land), accounts for 69% of fresh water consumption, and is responsible for about 25% of global greenhouse gas emissions (Gladek et al., 2016). It is also the biggest human cause of biodiversity loss.

In addition to greenhouse emissions, food consumption in Rotterdam accounts for approximately 130 million m3 water, almost 123 million doses of antibiotics, and about 5,000 tons of agricultural chemicals (fertilizers and pesticides) (Van Odijk et al., 2016). It is also likely that a large portion of the nearly 400,000 tons of animal feed needed to feed the livestock consumed in the city, has led to deforestation and destruction of living environments in some of the world's most biodiverse regions. At the end of last year, 66% of the Dutch soy imports from unsustainable sources contributed deforestation of the Amazon rainforest (Hombergh, 2016). Soy is used in many products, but three-quarters of the world's soy production is used for animal feed (World Wide Fund for Nature, 2016), which contributes to the long list of impacts related to animal products.

Since 96% of the food consumed in Rotterdam is produced outside the city, most of Rotterdam's food-related impacts originate outside the city. If we extrapolate the volumes, the total estimated greenhouse gas emissions from food production alone amounts to 166,500 tons. That is the same as the emissions produced by 130,737 passenger cars at average use in a year. This does not include transport, processing and packaging. Approximately 84% of all carbon emissions in the Rotterdammer's diet comes from animal products (meat, milk, eggs and fish).

INTERVENTIONS FOR A CIRCULAR FOOD SYSTEM

There are two key objectives for the transition to a fully circular agri-food system in Rotterdam:

- Ensure that all raw materials are continuously recycled at high quality.
- The ecological and health impacts of all products and activities of the value chain are minimized.

Looking at the current raw material flows and the footprint of the Rotterdam agri-food sector, we can translate the above aims towards a number specific goals:

- Minimize the total amount of waste from food waste and food processing waste.
- Ensure that all other waste (domestic organic waste, industrial waste, slurry and sludge) is put to high-value use, and the current applications are improved where possible.
- Reduce the total impact footprint of consumed food in the city by switching to consumption and production patterns with a lower impact.

In Figure 20 we present a range of possible interventions that can be implemented to achieve these goals. We have organized the interventions according to the flow or impact that they can potentially mitigate and have made estimates for the total amount of impact that can be reduced. The most promising interventions are described in more detail.

NR.	IMPACT FOCUS	INTERVENTION	TYPE	FEASI-BILITY	POTEN-TIAL FOR IMPACT REDUC-TION	POTEN-TIAL FOR JOB CRE-ATION	POTEN-TIAL FOR JOB LOSS	LINK TO VISION
A1	Water, land use, emissions	Stimulating sustainable agriculture	Production & purchasing	Medium	Medium	High	Neutral	Materials, energy, biodiversity, health, value
A2	Organic waste	Collect organic waste at front door	Synergy	Medium	Medium	High	Neutral	Materials
A3	Organic waste	Pay-As-You-Throw policy	Synergy	High	High	Low	Neutral	Materials
A4	Organic waste	Manufacturing chemicals from waste	Synergy	Medium	High	High	Low	Materials
A5	Food waste	Subsidies for projects that stop food waste	Reduce	High	Low	Medium	Neutral	Materials, energy, biodiversity, health, value
A6	Sludge (companies)	Manufacturing chemicals from waste	Synergy	Medium	High	Medium	Low	Materials
A7	Manure	Vermi-composting	Synergy	Low	High	Medium	Neutral	Materials, biodiversity
A8	Manure	Bio-fermentation	Synergy	Low	High	Medium	Neutral	Materials, biodiversity
A9	Animal & vegetable waste (companies)	Manufacturing chemicals from waste	Synergy	Medium	High	High	Medium	Materials
A10	Food waste (consumers)	Education campaign Highlighting cooking, storing and choices	Reduce	High	Low	Low	Neutral	Materials, energy, biodiversity, health, value
A11	Emissions from animal products	Public purchasing food with a small one footprint	Production & purchasing	High	Low	Low	Neutral	Biodiversity, health, energy
A12	Organic waste	R & D investment in bioprocessing tech	Synergy	Medium	High	High	Neutral	Materials, energy, biodiversity, value
A13	Food waste (retail)	Use of apps such as FoodCloud	Reduce	Medium	Low	Low	Neutral	Materials, energy, biodiversity, health, value
A14	Food waste (catering industry)	Use of apps such as Winnow, TooGoodToGo	Reduce	High	Low	Neutral	Neutral	Materials, energy, biodiversity, health, value
A15	Food waste (retail)	Ban on retail food waste	Reduce	Low	Low	Medium	Neutral	Materials, energy, biodiversity, health, value
A16	Food waste (retail)	Part platforms such as NoFoodWasted	Reduce	High	Low	Neutral	Neutral	Materials, energy, biodiversity, health, value
A17	Food waste (catering industry)	Doggy bag policy	Reduce	High	Low	Neutral	Neutral	Materials, energy, biodiversity, health, value
A18	Organic waste incentives	Organic waste collection in offices	Synergy	High	Low	Neutral	Neutral	Materials
A19	Manure	Bio-refining	Synergy	Low	Medium	Medium	Neutral	Materials, biodiversity
A20	Emissions from animal products	Campaign for sustainable and healthy food	Reduce	High	Low	Neutral	Neutral	Biodiversity, health, energy
A21	Emissions from animal products	Incentives for meat substitutes	Production & purchasing	Medium	Low	Low	Neutral	Biodiversity, health, energy
A22	Food waste (consumers)	More precise labelling methods	Reduce	Medium	Low	Neutral	Neutral	Materials, energy, biodiversity, health, value
A23	Mixed organic waste	Collecting pure organic waste flows	Synergy	Low	Low	High	Neutral	Materials, value
A24	Organic waste	Monitoring organic waste production	Management	Low	Medium	Low	Neutral	Materials

Figure 20: Possible agri-food interventions

REDUCE

Many residual waste streams are inevitable; as long we eat eggs, there will be egg shells. There is little that we can do to to prevent these material streams. Instead, we have to focus on value-retaining and efficient methods to keep these materials in continuous cycles. However, some waste categories are exactly that: waste. Within the Rotterdam agri-food cycle, food waste is the best example. Every kilogram of food that is wasted represents a loss of embodied value and impact. Based on science that says about a third of all edible food is wasted worldwide, there is a movement to prevent food waste at the source, which has led to dozens of initiatives across the globe.

In Europe, the Netherlands is the second largest producer of food waste, with more than 9 million tons per year (after Great Britain and Germany) (Sedghi, 2015). According to data from Eurostat, 42% of all food waste takes place at the household level, followed by 39% during the production phase, 14% in the hospitality industry, and only 5% on retail / wholesale level. Consumers must therefore be the main, but certainly not the only, targets for interventions that minimize food waste. The first set of interventions that we take a closer look at are therefore the interventions that ensure that food is consumed instead of wasted.

Food waste by consumers: 28,200 tons

More than half of food waste by Dutch households happens because food is not eaten before the 'Best before' date (Nutrition Center, 2014). A significant percentage of this food spoils faster than necessary because people are not aware of the best way to preserve food. However, at the same time a large portion of wasted food is edible, yet thrown away because consumers think that it is unhealthy to eat it after the 'Best before' date. Confusion about the health of food after the 'Best before' date on the label accounts for more than 20% of household food waste (Williams, 2016). Another 47% of food waste occurs because people are cooking more than they can eat (Voedingscentrum, 2014). Preventing household food waste is difficult, but there are a number of promising developments which we will discuss further below.

INTERVENTION A10.

CONSUMER EDUCATION CAMPAIGN ON MESSAGES DO, COOK AND STORE

- **What:** The British Foundation, WRAP, launched the Love Food Hate Waste consumer campaign in 2007 (Love Food Hate Waste, n.d.). WRAP does research into the most effective strategies for changing consumer behavior around food. The City of Rotterdam could start or support a local campaign around the prevention of food waste, mainly focused on the needs and interests of the residents of Rotterdam. This campaign could also include information about how common foods should best be treated and preserved, or about local food sharing initiatives.
- **Impact**: WRAP's tools, information booklets, recipes and marketing have helped British consumers prevent 13 billion pounds of food waste in the past decade (Wrap, n.d.), wich amounts to a reduction of about 10% in total food waste for the region (Smithers, 2017c). WRAP's findings have been converted to tools for reducing food waste in processing phase, retail and catering. The potential impact of such campaigns could in principle be larger than the 10% success had by WRAP, if they specifically targeted the needs of the Rotterdam consumer. If the same success rate were achieved in Rotterdam, 2,820 tons of food waste could be prevented per year.
- **Feasibility:** Setting up such a campaign is very feasible. The City can choose to initiate and finance, or support, such a program. The only potentially significant barrier would be financing and capacity, but this kind of project is likely eligible for EU subsidies for (partial) support.
- **Employment:** The impact of this initiative on employment would be minimal, although for a long-term campaign such as Love Food Hate Waste, there would ideally be a permanent team of 2 to 5 people full-time working on it.
- **Relevance to Rotterdam's context:** There is already a lot going on in the area of food waste in Rotterdam, though most projects are not focused on domestic waste. The campaign and accompanying website can form a central point for connecting food waste initiatives in Rotterdam (such as citizens' initiative Zero Food Waste Rotterdam) under one collective umbrella, increasing their sphere of influence (CityLab010, 2017). This platform can also become a link to the EU-wide "Platform on Food Losses and Food Waste" (Gore-Langton, 2016).

INTERVENTION A22.

BETTER LABELS ON FOOD

- **What:** There are a range of different projects that can improve the communication on food packaging. In Great Britain, standards for food labelling have been made simpler and labels have new logos that advise which products should be stored in the refrigerator, cupboard, or freezer to preserve them optimally (Smithers, 2017a). There are also more high-tech ways of labeling: the Sainsbury's supermarkets have recently had one smart label that changes color and

indicates how long a pack of ham remains good after opening (Smithers, 2017b).

- **Impact:** If, as research shows, indeed 20% of food is thrown away by confusion about labels, then better labelling strategies will address a large part of this impact. In addition, better information about the correct storage of food can also help mitigate other causes of waste. Better labels could also improve the redistribution of food that can no longer be on the shelves at supermarkets. Better labeling standards could potentially counteract 30% of household food waste, which amounts to 8,460 tons per year.
- **Feasibility:** A possible barrier for implementing this initiative is that it requires cooperation between multiple brands and retailers, and should potentially happen at national rather than local level. The process may also include changes in legislation, which can take a long time.
- **Employment:** Initiatives for smart labels can create new jobs, involving research for the development and monitoring of these, and in development of labeling technologies such as labels that change color.
- **Relevance to Rotterdam's context:** As far as we know, there are currently no projects in Rotterdam that focus on improving labels. Projects or initiatives like this could focus on reusing food whose 'Best before' date has passed, and for example, donating to causes (such as the FoodSharing initiative) (Open Rotterdam, 2017).

Catering industry food waste: 7,520 tons

Food waste in restaurants consists of several sub-fractions: ingredients that are not used (due to over-purchasing), individual components of recipes (such as sauces that remain untouched) and uncleaned plates from customers (The Daily Meal, 2014). Although pretty common in America, it is not common in Europe to take home leftovers, and even in some countries stigmatized (Sorrel, 2016). To counter this, recently, a marketing campaign was launched in Italy to transform 'doggy bags' into 'family bags', so to speak, to make take-home leftovers normal. This commitment from restaurants to provide their customers with the option can be a simple way to stimulate people. A few other initiatives are trying to counteract this aspect of food waste in restaurants already.

INTERVENTION A14.

ADOPTION OF DISCOUNT AND EFFICIENCY APPS

- **What:** One of the up-and-coming ways to prevent the wastage from too many cooked meals in restaurants is through a number of smart apps. The Too Good to Go app offers discounted meals to restaurants and other vendors before they close for the evening. Apps like Winnow and Wise Up from Unilever help commercial kitchens monitor and analyze their food, with the aim of improving purchasing and processing. The City of Rotterdam can make an effort to help spread awareness of these kinds of an apps via an informative campaign or by implementing direct incentives. In addition, the city could organize a challenge for the development of local apps that have similar functions to the ones listed above.
- **Impact:** The Winnow app claims that kitchens using their app save 3 to 8% on their purchasing costs (and therefore have the same waste percentage) (Wong, 2017). The Too Good To Go app has already been downloaded more than 1 million times and claims to have saved 10,000 meals in the first 16 months of their existence. Different apps will have different impacts, but the results can be impressive with little effort. Our conservative estimate is that at least 260 tons per year can be saved.
- **Feasibility:** The biggest obstacle for implementing this strategy is the broad adoption of the apps, and determining which are really the most effective. However, this is a no-regrets intervention since there can only be benefits from the effort.
- **Relevance to Rotterdam's context:** Restoranto, a Rotterdam app for selling leftover meals, has made progress on picking up local restaurants and generating a user base, but it seems to be on hold right now for further development (RTV Rijnmond, 2016).

Retail food waste: 2,660 tons

Retailers are generally quite efficient in the planning for and supplying of food, and have the lowest waste rates in the entire food supply chain (5%). Nevertheless, opportunities that can prevent food waste should be taken. As is the case in the restaurant sector, a number of apps have been developed that prevent food waste in the retail sector.

NoFoodWasted, an app developed in the Netherlands, alerts customers when products on their shopping list are available in local supermarket, close to their expiration date, which helps to promote near-decay products (intervention A16). FoodCloud, an app that is now only available in Great Britain and Ireland, uses a similar strategy to alert charities to food surpluses in supermarkets for donation (intervention A13). However, one of the first barriers to overcome is convincing supermarkets to donate these products instead of throwing them away.

INTERVENTION A15.

BAN ON RETAIL FOOD WASTE

- **What:** Last year the French government introduced a law that prohibits supermarkets from throwing away unsold food, which is common practice for many retailers. The new law orders supermarkets to donate food to charities, with a fine of 75,000 euros if they do not (Chrisafis, 2016). Similar legislation is now being discussed in other EU countries. Rotterdam could implement its own version of the rule, tailor-made for the local context.
- **Impact:** A year after the introduction of the new French law, it appears to have had mixed success. Only 24% of the food overflow went to charities, partly due to logistical complications (GoreLangton, 2017). But also due to digital technology that helps to communicate about availability of food and more simple labels that help to understand risks, the policy has ensured that a large part of waste has been prevented. If 30% of the savings generated by this approach could be realized, this would result in a saving of 340 tons per year.
- **Feasibility:** Several challenges stand in the way of implementing this intervention at the local level instead of the national level. This approach can contrast with national policy and create complexity in supply chains that operate nationally. In addition, smaller retailers can have more difficulty implementing it than larger ones. Companies may complain that this rule undermines their business model because they need to offer their products for free.
- **Employment:** Such a law can form an emerging market of organizations which focus on saving and reusing of food, potentially allowing hundreds of jobs to be created.
- **Relevance to Rotterdam's context:** A ban on supermarkets throwing away food can be simplified through the work of Rotterdam organization FoodShare. It could also help the relatively high share of the population living below the poverty line in some districts with a cheap or free supply of food.

SYNERGY

When unavoidable waste has been reduced as much as possible, the next challenge is to gather the remaining material flows in as pure a form as possible so that they can be processed into new high-quality products. The interventions in this category take both the challenges around the high value collection of separate material flows and the adoption of new methods and technologies for processing these materials into new products.

COLLECTION

European cities have in recent decades emerged as world leaders in the field of separated waste collection. Recent research that analyzed waste collection in the EU revealed that there are some key factors contributing to the success of these initiatives (Rotterzwam, 2017). One of the most important among these is the implementation of a Pay-As-You-Throw schedule, in which levies are imposed on residents per kilogram of mixed waste that they throw away, creating a strong incentive for separating recyclable waste (intervention A3). This charge is used to finance the separate collection of waste streams. Successful municipalities have done this in combination with producer responsibility initiatives and free market mechanisms for collecting recyclable waste. Another factor that played a role was clear communication about what can and can not be recycled, and what can be thrown in every waste bin, allowing high-quality waste streams to emerge. Research has further shown that bio waste is the most difficult waste stream to collect separately. Cities that do this well have usually included it in collection requirements once they have successfully managed to separately collect paper, glass, and metal first. To further support this, cities could have stricter requirements for offices to separate organic waste (intervention A18).

We can even go even further than just collecting mixed organic waste by collecting specific types of organic waste separately as mono-stream fractions (intervention A23). Mixed organic waste has variable properties and can be difficult to consistently convert to a high-quality product, while separate fractions can be at the base of completely new industries. Mono flows of organic waste types that have upcycling potential include:

- Coffee grounds to grow oyster mushrooms
- Fruit and vegetable peels to make fake leather
- Potato peel for fire resistant insulation material and as a silencer
- Seeds, stems and leaves for decorative finishing for walls and furniture and flexible acoustic panels
- Grain residues for envelopes and interior walls and acoustic insulation (a ton of grain residue can be used for about 1,000 m^2 thin skin covering (Carra, 2017)

Multiple attempts to make organic mono material flows into new products are already going on in Rotterdam, given the creativity and energy of the entrepreneurial sector. Examples include the production of oyster mushrooms on coffee grounds by Rotterzwam (Rotterzwam, 2017) and Fruitleather Rotterdam (Fruitleather Rotterdam, n.d.), a company that makes imitation leather from fruit waste. It is possible that these initiatives can independently ignite the demand for organic mono-flows, but it is more likely that structural support from the City would support this undertaking.

PROCESSING

When organic waste fractions are collected separately, they can be used for the production of a number of different high-quality products. Some of the well-known and most advanced in this respect are composting (intervention A7), bio-fermentation (intervention A8), and the production of soil cover for landscaping. There are already good applications of organic waste fractions such as manure, garden waste and organic waste, but there are also a number of other possibilities for converting waste into high-quality products. The choice for a certain mix of technologies must be based on local conditions, so that valuable nutrients such as phosphorus can ultimately be regained for agriculture. In general, energy production from biomass is a low-value application of chemically complex material. Although this is useful for very low-grade flows of organic waste, biomass has a higher circular value in combination with nutrient recovery.

Organic waste: 76,840 tons

As already stated, 94% of organic waste in Rotterdam ends up in mixed waste streams, allowing recyclable waste to become polluted, and impossible to recover. The city is already working on separate organic waste collection, but statistics show that there is still room for improvement. Below we describe a specific way that the city can improve performance in this area (City of Rotterdam, 2016a).

INTERVENTION A1.

DOOR-TO-DOOR COLLECTION OF BIO WASTE

- **What:** Door-to-door collection systems have the highest recycling percentages and the best quality recyclable waste. This usually happens through households using colored trash cans or other containers and weekly or biweekly having their waste collected at home.
- **Impact:** With door-to-door systems, cities have collected between 20 and 73 kg per capita of bio-waste (i.e. 7% of total waste collection) (Seyring et al., 2015). In Rotterdam, such a success rate would result in 64,000 tons of organic waste being saved from combustion.
- **Feasibility:** There are many challenges when it comes to implementing separate waste collection in inner cities, where apartments are often too small for storage of waste indoors and collection on the sidewalk is difficult due to the high traffic pressure. But because this intervention is a condition for high-quality processing of organic waste, it is nevertheless important to invest in this. In the parts of the city where it is possible, curbside collection is recommended. Where this is is not possible, additional public containers can be introduced along with biodegradable garbage bags for the collection of organic waste. For the development of an appropriate strategy, a contest could be developed, where entrepreneurs are invited to come up with ideas to successfully solve this challenge. The most important factor for a successful system is good publicity and information, which helps the public and relevant organizations participate from an early stage stage, and acceptance and participation is then high from the start. Although the municipality does not have control over waste separation within households, they can build public housing so that there is enough room in the kitchen to collect waste separately. This can also become a criterion for circular tender.
- **Employment:** Jobs are created in several ways by the development and implementation of a separate waste collection system: waste collection jobs and multiple jobs in the bioprocessing sector.
- **Relevance to Rotterdam's context:** New flows of useful bio-waste can deliver valuable materials in existing and new business initiatives within the city - from small initiatives like Fruitleather Rotterdam to new activities that can take place in the port.

INTERVENTION A4.

WASTE FOR CHEMICAL PROCESSING

- **What:** Mixed organic waste can be used as an input for different chemical production technologies. The most valuable resource that can be gained from mixed and relatively inconsistent flows are complex carbon molecules. Organic waste can be used for pyrolysis, gasification, oxidation and fermentation until the principles of acetic acid such as methanol, by the production of syngas by means of gasification, or ethanol by means of fermentation.
- **Impact:** Almost all fractions of the collected organic waste can be used as inputs for chemical processes, which can yield up to 76,000 tons upcycled material per year.

- **Feasibility:** Significant investments and R & D are required to realize projects that rely on mixed organic waste as input for chemical production, though several companies are already at advanced stages of development. Co-investments in circular chemical facilities by government and industry should be considered to support the feasibility of this type of project. The profit of these installations can then partly finance the costs of separate collection systems for organic waste.
- **Employment:** These activities can potentially create new jobs in both the city and the port, although they also have the potential to eliminate jobs in current bio-processing activities such as composting and biogas. Job loss can be mitigated when the organic waste is split between different uses, although a certain minimum volume must be achieved to make the business case of a facility on this scale realistic.
- **Relevance to Rotterdam's context:** Rotterdam is already the likely location for a waste-to-chemicals factory that will convert syngas from residual waste to methanol. This project is a partnership between various parties, including AkzoNobel, Van Gansewinkel, Air Liquide, AVR, Enerkem, Port of Rotterdam, the City of Rotterdam, the Province of South Holland, and Innovation Quarter (Port of Rotterdam, 2016). Although this project is a big step, there is continuous investment and evaluation required. Ideally it will serve as the first pilot for the development of a new waste-based chemical program in Rotterdam.

PRODUCTION AND PURCHASE

The interventions investigated in this section look at ways to reduce the overall impact of the food consumed in Rotterdam, mainly due to changes in diet, purchasing and production. We also look at how Rotterdam can generate extra value and circular activities by developing its urban farming activities.

Food-related impacts: water, greenhouse emissions, agri-chemicals, parts per million of antibiotics

As mentioned earlier, the choices we make regarding our diet is one of the most significant ways we have a negative impact. The main way to solve this is via the source and type of food that enters the city. The municipality can set a good example by introducing new guidelines for the circular procurement of food that is served in government buildings and at public events (intervention A11). This is already happening within the Dutch government, but the spectrum of impacts included in these guidelines can be broadened. The municipality can also play a leading role in promoting more sustainable and healthier diets (intervention A20). Aside from a more detailed and controlled set of activities on sustainable procurement of food, the city can also create incentives for the development and consumption of vegetable meat substitutes (intervention A21). Vegetable protein substitutes are a fast-growing segment. Supporting local entrepreneurs who are focused on this topic, and linking them to existing food processing knowledge and skills can lead to long-term growth and stimulation for the sector. Finally, the city can take further action to support local urban agriculture.

INTERVENTION A1.

INCENTIVES FOR LOW-IMPACT URBAN AGRICULTURE

- **What:** Certain types of urban agriculture projects can have a very high productivity per square meter and thus help to avoid a wide range of food-related impacts. Vertical agriculture systems, in particular, have the potential to bring about significant impact reductions, though these technologies are still under development.
- **Impact:** Impact reductions through urban agriculture strongly depend on the type of agriculture chosen. Switching from traditional agriculture to hydroponics for the production of vegetables can save up to 90% of water consumption, for example, but can also lead to higher energy requirements. The exact profile of Rotterdam's urban agriculture projects must be carefully evaluated on a broad set of environmental impact and economic criteria.
- **Feasibility:** The feasibility of urban agriculture depends on the specific situation. It's important to consider the value of land, as well as the demand for energy in the proposed technology. Not all places in a city are suitable for urban farming. The peri-urban areas are often the most suitable. The city can stimulate the transition by identifying suitable zones and writing tenders for the use of the land or building. Projects should be evaluated according to an integrated assessment framework that avoids impacts and prioritizes the potential for job creation.
- **Employment:** A 2009 study looked at the development of urban agriculture and local food processing in Detroit and found that 4,700 local jobs were created by the transition [39]. The exact number of jobs that resulted from this economic transition is again dependent on specific initiatives, but there is clear potential for economic development.

- **Relevance to Rotterdam's context:** Rotterdam already has an active community of agricultural producers and iconic urban farming projects, such as Uit Je Eigen Stad, Rotterzwam and DakAkker. These initiatives can be supported by a wider network for urban food production, and can potentially join hands in selling their products through initiatives such as local food cooperatives.

MANAGEMENT

When collection and processing systems are implemented, it is important for the city to continue collecting accurate and up-to-date information about the performance of these systems. Placing sensors in the various organic waste collection bins (intervention A22) can be a smart way to measure when and where organic waste is deposited. This can also be used to improve the efficiency of collection. On a domestic level, smart devices such as refrigerators can tell people when their food spoils and apps can improve the efficiency of purchasing habits (intervention A14). This can all help to gather more information about the functioning of a circular agri-food sector in Rotterdam. We will not describe any of the interventions here, because their usefulness will only become clear once the interventions out of the previous three steps have been implemented.

CHAPTER 06

CONSTRUCTION

THE CONSTRUCTION SECTOR IN ROTTERDAM 2015

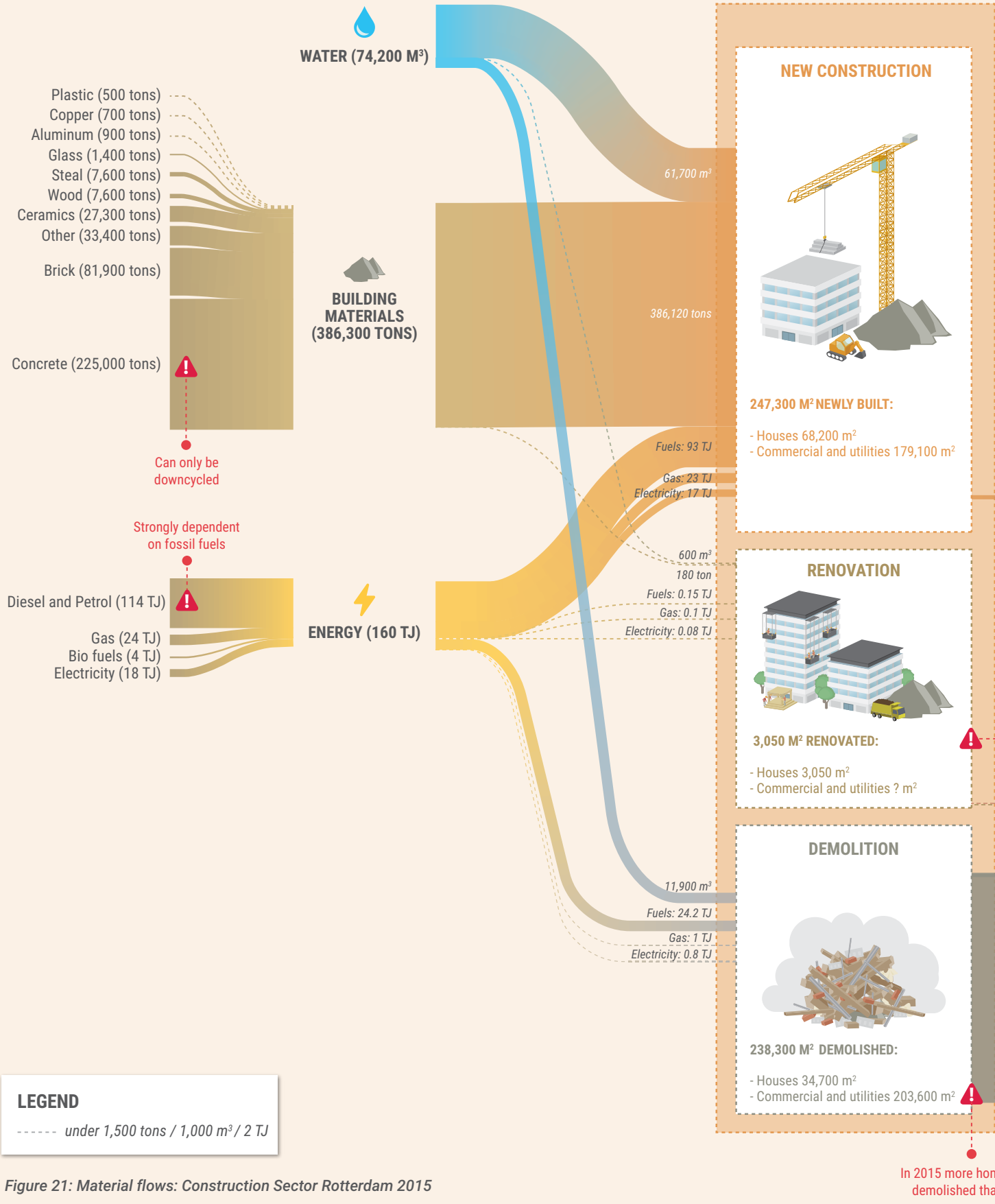
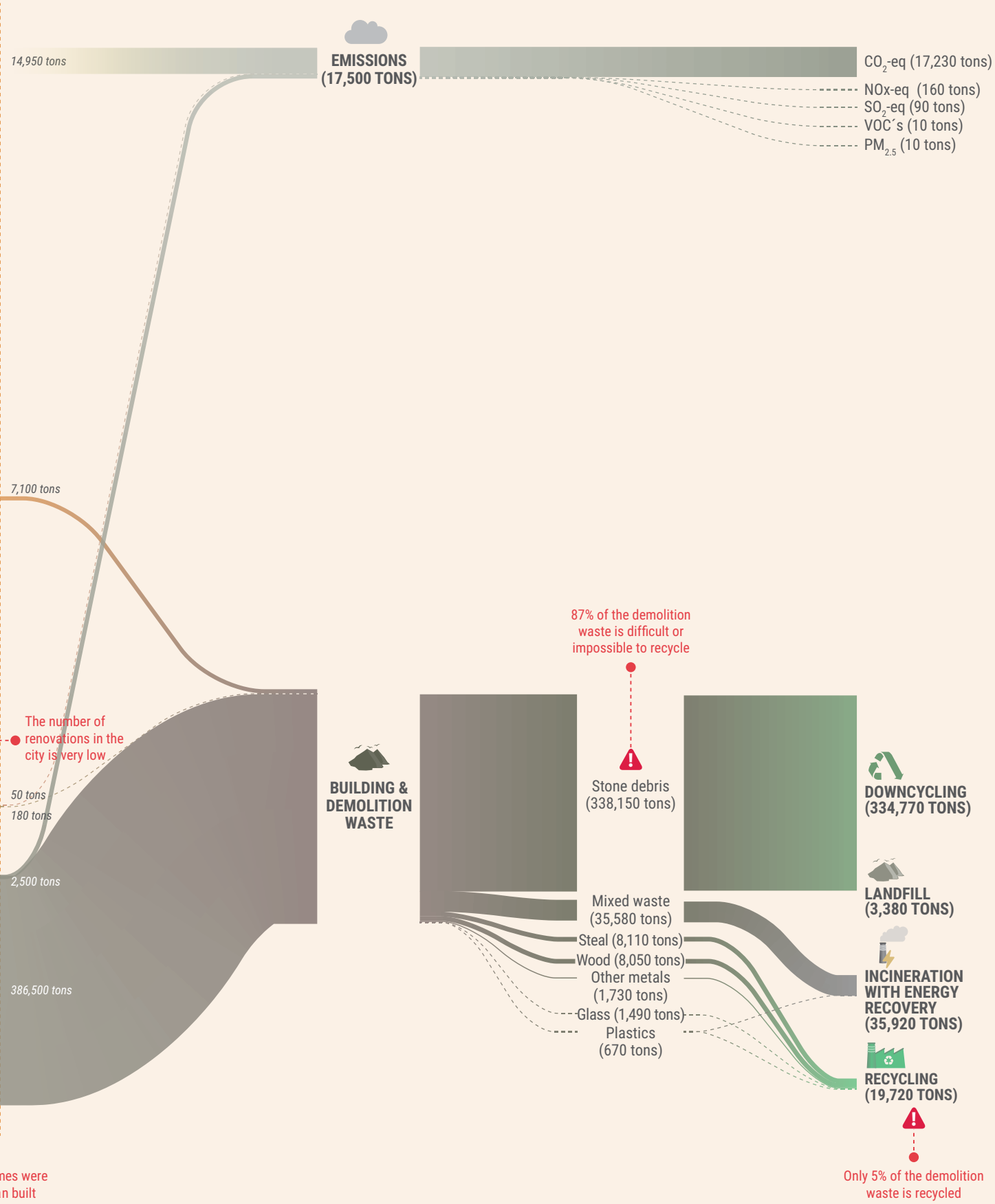


Figure 21: Material flows: Construction Sector Rotterdam 2015

METABOLIC CIRCLE ECONOMY


14,950 tons
EMISSIONS (17,500 TONS)
CO_2-eq (17,230 tons)
NOx-eq (160 tons)
SO_2-eq (90 tons)
VOC´s (10 tons)
$PM_{2.5}$ (10 tons)
7,100 tons
87% of the demolition waste is difficult or impossible to recycle
The number of renovations in the city is very low
50 tons
180 tons
2,500 tons
386,500 tons
BUILDING & DEMOLITION WASTE
Stone debris (338,150 tons)
Mixed waste (35,580 tons)
Steal (8,110 tons)
Wood (8,050 tons)
Other metals (1,730 tons)
Glass (1,490 tons)
Plastics (670 tons)
DOWNCYCLING (334,770 TONS)
LANDFILL (3,380 TONS)
INCINERATION WITH ENERGY RECOVERY (35,920 TONS)
RECYCLING (19,720 TONS)
Only 5% of the demolition waste is recycled

THE CONSTRUCTION SECTOR IN ROTTERDAM

The analysis of the most important material flows in the Rotterdam construction sector is based on three different types of activities within the city: new construction, demolition and renovations. A first look at the material flow analysis (MFA) of the construction sector in Rotterdam immediately shows the now-linear nature of the activities in the sector. Nearly 386,000 tons of materials come into the industry as inputs in the form of building materials, and almost the same amount (393,780 tons) is released in the form of demolition waste. Although part of this is being recycled, the majority is downcycled into lower value materials, burned, or sent to landfill.

It is going to be a great task for the city to make the transition to a zero-waste construction sector in the next 10 years. The construction sector is one of the least efficient sectors within Europe (Ellen MacArthur Foundation, 2015), and Rotterdam is no different, with its emphasis on architecture and large construction projects. To make Rotterdam's construction sector zero waste in 2030, a complete review of current building materials, methods and processes, the use phase of a building, as well as maintenance, repurposing, and disassembly is needed. A more detailed analysis of the data and activities in the construction sector brings a number of issues to light, such as a relative high demolition percentage, an underutilisation of Rotterdam's urban mine and the dependence of the construction sector of fossil fuels.

RELATIVELY HIGH AMOUNTS OF DEMOLITION COMPARED TO RENOVATION AND NEW CONSTRUCTION

The linear profile of the current model comes to the fore when looking at the relative prevalence of demolition in the sector. In 2015, 247,300 m^2 new constructions were built while 238,300 m^2 current buildings were demolished. This indicates that for 96% of the construction activities, demolition was required beforehand, thus leading to a double impact on the environment: with both costs and impacts from the processing of residual waste flows as well as from the production of new materials. The large amounts of material released from demolitions is not incidental: in the coming years 20,000 homes will be demolished. This is part of implementing the plans set out in the Rotterdam Housing vision. This vision is aimed at building new, more spacious houses for Rotterdammers with a higher income, in time stimulating throughput within the housing market, so that cheaper but more modern homes become available for lower income groups (RTV Rijnmond, 2017). The total proportion of the area that has been renovated is 75% smaller than the area that has been demolished.

If, in theory, all demolition materials can be completely reused for new buildings, that would naturally provide a large flow of secondary building materials. This would drastically reduce the impact of new construction and would require no new building materials to be produced. Unfortunately, this is not currently a realistic assumption, though there are, as we go into later in this section, indeed possibilities to realize a large part of this potential. After circular demolition and disassembly of old buildings, however, reconciling demolition and new construction is also an essential part of a sustainable consruction sector for Rotterdam.

STONY RUBBLE AND CONCRETE

Concrete forms more than 50% of the total volume of the largest incoming material flow in Rotterdam construction. Add to that the 22% of the volume of the incoming material flows that bricks are responsible for, and it is no surprise that the vast majority of the materials released during demolition and renovation material flows consist of stony rubble: about 80% of the total. This is not only problematic because of the financial loss of value (or the underutilized financial potential) but also because of the enormous environmental impact associated with the production of new concrete (CE Delft, 2013). What currently lies ahead of these residual flows is hardly high-quality future applications: almost the entire stream of stony debris is broken and downcycled to foundations in ground, roads and hydraulic engineering. This market is, however, almost saturated and so ecological and economic incentives exist to find a better application for these residual flows (Schut et al., 2015).

MIXED WASTE FLOWS IN CONSTRUCTION

Proportionally, other residual flows, such as mixed waste, are small: about 10% of all construction and demolition waste falls into this category. In this case, virtually the total residual waste is burned, meaning the potential for high-quality reuse is completely lost. Better sorting and processing of these waste streams, or collecting these materials separately, therefore forms an important step in the transition towards a circular, waste-free construction sector. Materials such as wood, metal

and plastics can in theory be recycled, provided they are kept in pure and easily recyclable form, which currently applies to only 5% of the total volume of construction and demolition waste.

METALS AND THE VALUE OF THE URBAN MINE

Although metals such as copper, steel and aluminium are an even smaller fraction of the total mass of the construction and demolition waste (9,840 tonnes or 2%), these are the materials with the highest energy demand and environmental impacts in the extraction and production process. In addition, these valuable materials are 'secured' in the built environment for a long time and the sector has therefore built up the largest stock of metals from all economic sectors. Because of their value and the preservation of their functional properties, metals are attractive new raw materials for the recycling industry. Of the 5% of the total flow applied to high-grade BSA, half consists of metals (furthermore, 40% is made up of plastics and smaller fractions of glass, plastics and paint).

DEPENDENT ON FOSSIL FUELS

Only 4% of the energy used in the Rotterdam construction sector currently comes from from renewable sources. For liquid and gas fuels, which together account for a majority of the energy consumption, only 2% is bio-based, and electricity consumption comes from only 12% renewable sources. Two thirds of the energy consumption results from diesel and petrol for vehicles and generators. For Rotterdam's construction sector to transition to renewable energy sources, one of the biggest challenges is finding a practical alternative to the current dependence on diesel and petrol.

The construction sector in Rotterdam provides almost 12,000 jobs, of which more than 700 are linked to the circular economy. The construction sector is not directly circular, but through its annual usage of almost 400,000 tons of building materials, there is great potential for circular employment through the re-use and reprocessing of construction materials. This is indeed in line with the current share of circular jobs in construction, which is mainly realized in demolition.

The current emphasis on circular development in construction in Rotterdam is on the reuse and revaluation of the existing building stock in the city centre. Through building transformation, innovation and sustainability the city is already working towards circularity in the construction sector, and circular employment goes hand in hand with this.

At the same time, the construction sector also provides an indirect boost to Rotterdam's circular employment. The sector is closely interwoven with design activities among architects and engineers, who through 'design for the future' link directly to the circular economy.

IMPACT OF THE ROTTERDAM CONSTRUCTION SECTOR

The direct impacts of the construction sector are significant, but it is precisely the indirect impacts of the sector that ultimately have the greatest impacts in terms of energy consumption and CO_2 emissions. The way in which the construction chain designs the built environment largely determines the energy performance of buildings, and thus the energy demand of the built environment. In Rotterdam the built environment is responsible for an annual energy consumption of more than 12,500 Terajoule (Climate Monitor, 2017). In comparison, that is almost 80 times more than the construction sector needs for demolition, renovation and construction work. In addition, the built environment in Rotterdam is annually responsible for 2.3 million tons of CO_2 emissions (Climate monitor, 2016), more than 130 times more than what the construction sector directly emits during demolition, new construction and renovation work. This means that with regard to CO_2 emissions, the use phase (heating, use of appliances, etc.) has a much greater impact than the construction and demolition phase.

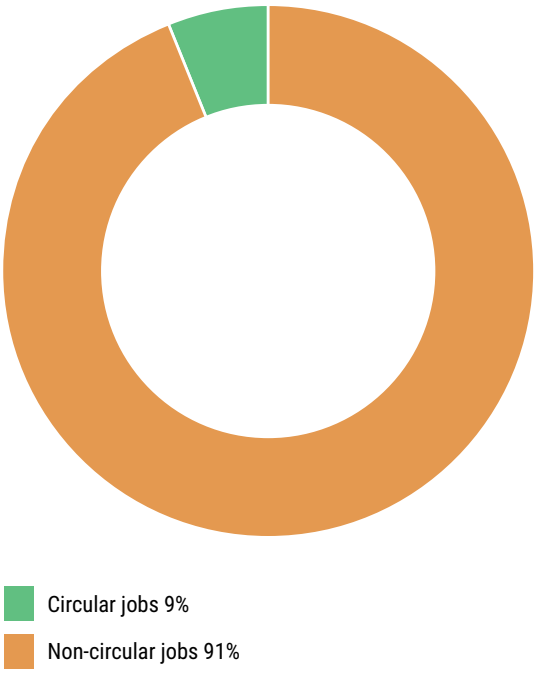


Figure 22: Jobs in the Construction Sector

EMBODIED ENERGY AND EMISSIONS

In addition to the indirect impacts from the use phase of buildings, production of building materials also brings a large number of impacts with it: the embodied impacts arising from mining of raw materials and the production of building materials further up the chain. These include energy consumption, CO_2, emissions, land use and water consumption.

The production of building materials -- concrete, steel and aluminium in particular -- results in significant energy consumption. In Rotterdam this comes down to an embodied energy consumption of 1,097 TJ per year, of which 292 TJ via concrete (55.9% of the material input), 210,520 GJ via steel and 197,100 GJ via aluminium. In Rotterdam this embodied energy demand is almost seven times higher than direct energy consumption in construction activities. The customer's design and specifications thus play a crucial role in the preservation of the built environment.

With energy consumption comes CO_2 emissions, seeing that most of our energy worldwide is still produced from fossil fuels. The production of the building materials needed for residential and non-residential construction in Rotterdam results in a CO_2 output of approximately 89,270 tons per year, of which 22,195 tons via brick, 21,375 tons via concrete and 14,440 tons via steel. This is more than five times higher than the annual CO_2 outputs caused by construction, renovation and demolition activities in this sector.

LOSS OF VALUE AND DOWNCYCLING: A MISSED OPPORTUNITY

In addition to environmental impacts, loss of economic value is also a consequence of linear construction activities. During current demolition methods, building elements are reduced to raw materials instead of components, and as indicated above, these raw materials are often not maintained at high value. The cause can be attributed to construction methods of the past, focused on demolishing buildings at the end of the life cycle, and the still relatively small market for secondary components and building materials.

INTERVENTIONS FOR A CIRCULAR CONSTRUCTION SECTOR

There are two key objectives for a circular construction sector in Rotterdam:

- Manage and preserve as best as possible the value of existing buildings and the stored materials they contain, including prolonging service life reuse of entire buildings. With this, the demand for new raw materials will be greatly reduced.
- Circular and sustainable design of all new buildings so that they are more suitable for high quality reuse, have a low impact in the use phase, and as few choices of materials as possible have an impact on the environment through the extraction of raw materials, and production.

If we can reduce the current raw material flows and the footprint of the Rotterdam construction sector we can translate the above objectives to a number of specific objectives:

- Preventing, where possible, demolition and new construction, and the associated impacts and value losses, as long as the quality of life and impact of buildings in the use phase is not affected.
- Demolition and disassembly of existing buildings in such a way that the reuse of components and materials is maximized;
- Creating a market for reuse and recycling of extracted and reclaimed building materials in a high-quality way that goes beyond applications in the foundation of infrastructure;
- Designing new buildings for:
  - Low-impact materials and construction processes
  - Flexibility and adaptability throughout the entire use phase
  - A low impact during the use phase, on the areas of energy, water and waste streams
  - Disassembly and reassembly at the end of the life cycle

All these objectives are to be achieved by a way in which the different players in the construction sector can create new value and jobs for all parties involved in the chain.

In Figure 23 we present a range of possible interventions that can be implemented to achieve these objectives. We have organized the interventions according to the flow or impact they may be able to mitigate, and have estimated the total amount of impact which can be reduced. The most promising interventions are described in more detail.

NR.	IMPACT FOCUS	INTERVENTION	TYPE	FEASI-BILITY	POTEN-TIAL FOR IMPACT REDUC-TION	POTEN-TIAL FOR JOB CRE-ATION	POTEN-TIAL FOR JOB LOSS	LINK TO VISION
B1	Building materials and greenhouse gases	Lifetime extension existing buildings	Reduce	Medium	High	Neutral	Low	Materials, energy
B2	Different construction materials	A central building hub	Reduce	High	Medium	Neutral	Neutral	Materials
B3	Construction and demolition waste	Circular concrete covenant	Synergy	High	High	Neutral	Neutral	Energy, health and well-being
B4	Greenhouse gases and fine dust	Encourage disassembly and circular demolition	Synergy	Medium	Medium	Neutral	Neutral	Materials
B5	Concrete and stony debris	Circular tendering and procurement	Production and purchasing	High	High	High	Neutral	Materials
B6	Construction and demolition waste	Make materials passports mandatory for new buildings	Management	High	Medium	Neutral	Neutral	Materials, energy, biodiversity and ecosystems, health and well-being, value, resilience and adaptivity
B7	Systemic measure	Physical marketplace for secondary building materials	Synergy	Medium	Medium	Neutral	Neutral	Materials
B8	Systemic measure	Improved sorting techniques for construction and demolition waste	Synergy	Medium	Medium	Medium	Neutral	Materials
B9	Construction and demolition waste	Stonecycling: valuing stony rubble	Synergy	High	High	Neutral	Neutral	Materials
B10	Construction and demolition waste	Research performance and secondary properties of construction materials	Management	High	Medium	Neutral	Neutral	Materials
B11	Stony rubble	Research performance and secondary properties of construction materials	Production and purchasing	High	Low	Neutral	Neutral	Materials
B12	Systemic measure	R & D investment in bioprocessing tech	Synergy	Medium	High	High	Neutral	Materials, energy, biodiversity, value

Figure 23: Possible interventions in construction

INTERVENTIONS

A lot of construction and demolition waste is currently being downcycled. Circular material management in construction can be tackled before and after waste treatment. In order to recycle at high-value, it is important that materials are recovered separately.and that the degree of contamination in different substance streams remains low. This can partially be done by demolishing more consciously, but the design choices made prior to construction made are ultimately pivotal here. Buildings and infrastructure should be designed primarily for simple degradation, for example by, where possible use non-chemical adhesives. The different processes operating under the umbrella approach 'design for disassembly and reconstruction' will not come automatically. Switching to these methods requires explicit requirements from architects and developers, and the successful development of appropriate business models and incentive structures that can facilitate the transition.

REDUCE

Building materials

INTERVENTION B1.

LIFE EXTENSION OF EXISTING BUILDINGS

- **What:** The high quality reuse of construction and demolition waste is a solution to a problem that we want to prevent in the first place, by making use of existing buildings. Good maintenance and life extension renovations are essential in this respect.
- **Impact:** The exact impact of this intervention is difficult to quantify: it depends on the total number of years by which the functional life of (parts of) buildings may be extended. For both office buildings as well as (social) housing construction, life span extension in combination with substantial improvement in energy performance of buildings has a positive impact on people and the environment (W/E Advisers, 2010; Kortman et al., 2016). Where energy performance has not been significantly improved, the impact on the environment is not more favourable for all renovations than demolition and new construction (at least according to the current emission standards attached to building materials). To give an indication of the direct impact, aside from the enormous energy savings and emissions paired with lifetime extension, we can look at averted new building materials. Theoretically, as all demolition activities are prevented and converted into renovation, this would mean that the surface area of new-build homes and offices, and thus incoming material flows, would decrease by about 86%. This would then save more than 330,000 tons of building materials, and over 77,000 tons of embodied CO_2 emissions. This is likely another conservative estimate: since bricks and concrete are responsible for the most of the embodied CO_2 emissions and these are used in the supporting structures of a new-build.
- **Feasibility:** For the portion of the building stock that is in (semi) public hands, life span extension is easy to implement through a policy change. However, this requires looking further than only the short-term financial benefits, but in principle the social business case for renovation is major, provided it is accompanied by drastic energy performance improvements (W/E Advisers, 2010). The different authorities have little influence over the actions of private homeowners, but here too there are sufficient initiatives, and economic incentives, which encourage residents to renovate their homes and to make them more sustainable (see for example: ThuisBaas, n.d.)
- **Employment:** The renovation and repair of homes and buildings will undoubtedly deliver construction jobs, while in the long run it is expected that employment from demolition and new construction will decrease if lifetime extension is to be applied broadly across the sector. It must be said that currently, for the most part, demolition is largely mechanized, and when circular demolition and decommissioning are chosen instead, this process will become more labor intensive and employment will increase. Especially in combination with interventions B2 and B6, expectations are therefore favorable.
- **Relevance to Rotterdam's context:** For housing corporations, lifetime extension and renovation of the existing housing stock has long been part of the policy. However, this is not to say that the choice between renovation and new construction is a simple one. Some cases are deliberately chosen for demolition. However, the above analysis clearly brings to light that the potential for renovation rather than demolition should not be underestimated, and should be looked at carefully on a case by-case basis.

Building waste

INTERVENTION B3.

RESPONSIBILITY WITH THE PUBLISHING OF DEMOLITION LICENSES

- **What:** Rotterdam has more demolition than the average city. For every 100 new homes built in Rotterdam, no less than 110 homes are demolished. For comparison, in cities like Amsterdam (9), The Hague (12), and Utrecht (2) the number of demolished dwellings is a factor 10 to 50 smaller. And also compared with the provincial average of 24 demolished homes per 100 newly built, Rotterdam scores extremely high. By reducing and slowing down the demolition of homes, large waste flows in construction can be minimized, and buildings can be maintained, drastically reducing construction and demolition waste. Certainly also because downcycling of BSA in the form of road foundations and other low-value applications is now more a rule than an exception, it can be a great loss of economic value.
- **Impact:** The potential impact of such a measure is large. If Rotterdam could reduce the percentage of demolished homes even to half (thus still allowing the city to demolish twice as many houses as the provincial average in Zuid-Holland), that already saves - on an annual basis - some 195,000 tons of construction and demolition waste. If working towards the Hague standard, then, on an annual basis, 350,000 tons of residual flows are prevented. If we assume that with reduction of demolition the need for new construction also decreases proportionally, a significant amount of embodied environmental impacts and energy consumption is prevented too.

- **Feasibility:** The feasibility of this measure will not be a problem in itself, but there must be motivation for fewer demolition permits to be issued. When a building really no longer meets the quality of life and safety requirements, demolition is of course the only way. Nevertheless, in many cases little is known about what is wrong with the outer building facade and bearing structures, and often a large part of the house can be renovated and conserved, preventing associated waste streams (Anink et al, 2010; IVAM and Planmaat, 2016).
- **Employment:** The impact of this measure is difficult to quantify. Jobs in demolition will disappear, while on the other hand, renovation jobs will increase. Especially when extensive renovation is chosen in place of demolition, which, in order to avoid impact in the use phase, is recommended, there will be a net positive impact on employment, as renovation work is more labour-intensive than conventional demolition. This perspective is in line with the findings of the Economic Institute for Construction (EIB), which states that renovation runs faster increases in terms of employment than Total demolition (Economic Institute for Building, 2014).
- **Relevance to Rotterdam's context:** Where time and space is offered by delaying or preventing demolition, Rotterdammers deal creatively and productively with with the space in the city. A good example of this the developments around the Schieblock, near the Central Station, where the ZUS architectural firm is striving towards symbiosis in the city (de Architect, 2014). The city is actively committed to taking these developments further (City of Rotterdam, 2016b).

Emissions (Particulate matter, greenhouse gases, NOx, SOx)

INTERVENTION B4.

A CENTRAL CONSTRUCTION HUB

- **What:** Much of the direct CO2 emissions (as well as other emissions and particulates) in construction originate from transport movements and logistics. These emissions can of course be reduced by making transport more sustainable (electrification) or they may directly prevented by the number of transport movements in the sector, and in particular the number of reduced transport movements in the city centre. A construction hub, a central point outside the city from which building materials and supplies are distributed, can play a crucial role in this.
- **Impact:** According to the Logistics in the Construction platform approximately 30% of road freight is transport construction, and construction traffic is responsible for nuisance, congestion and emissions (Sustainable GWW, 2014). This building traffic is not only associated with greenhouse gas emissions, but also with the emissions of large quantities of particulate matter. TNO research (in collaboration with TU Delft and Hogeschool Utrecht) has shown that a construction hub in combination with clean transport to and from the construction site will cause less harm to the environment, less air pollution, more efficient construction and lower construction costs: 69% fewer trips to the construction site, 69% less kilometres of construction traffic and 68% reduction in greenhouse gas emissions (from Merrinboer, 2016). CE Delft research estimates that transport and logistics are responsible for 18% of the total climate impact of the Dutch construction and demolition activities. Therefore a construction hub can resolve 68% of 18% of the total greenhouse gas emissions from construction, which represents slightly more than 12% of the total emissions from the Rotterdam construction sector. For the emissions of particulate matter, NOx and SOx, in the city centre a similar reduction is to be expected, where the impact on public health is still far from negligible.
- **Feasibility:** In the abovementioned research project, new building logistics concepts and chain management systems are applied to two concrete construction projects by TBI in Amsterdam (Hotel Amstelkwartier) and VolkerWessels in cooperation with Boele, and J.P. Van Eesteren (The Trip). This is therefore also a real possibility in Rotterdam.
- **Employment:** The impact of this intervention on employment depends on the precise set of measures and logistical concepts that is applied. This cannot be quantified in advance.
- **Relevance to Rotterdam's context:** On 2 October this year, in the Ahoy, the Green Deal Construction Logistics will be signed by the City of Rotterdam (as the only of the four major cities) and 20 other parties from the chain (Dijkhuizen, 2017). The deal will lead to smarter and more efficient building logistics. The Green Deal creates the obligation for chain parties to submit annual reports for at least five construction projects that should aim to achieve smart construction logistics, and thus provides a nice incentive to continue working on this issue.

SYNERGY

Better valorization of concrete and stony rubble

INTERVENTION B5.

CLOSING A CIRCULAR CONCRETE COVENANT

- **What:** Concrete and stony rubble are responsible for the greater portion of the mass of construction and demolition waste. Currently, the vast majority of these residual flows, however, are recycled at a lower value. A sustainable and circular concrete covenant can bring partners from the chain together to change this, simply making concrete from concrete, while preserving value, and reducing environmental impacts associated with concrete production up until now.
- **Impact:** Similar initiatives in Twente and The Northern Netherlands are striving to produce a granulate percentage of 30% in new concrete. This would lead to annual savings of 67,000 tons of concrete otherwise based on primary the production of raw materials, and thus also a saving of more than 6,250 tons of CO_2 emissions related to the production of concrete.
- **Feasibility:** Such initiatives have already been successfully implemented in other regions and can therefore also be realized in Rotterdam in the short term. The technology for the processing of concrete granules in new concrete has been tried and tested, and can be applied on a scale.
- **Employment:** The effect on employment in Rotterdam will probably be neither positive nor negative: with circular concrete, raw materials are still being produced. This concrete simply comes from other sources.
- **Relevance to Rotterdam's context:** Although Rotterdam does not yet have a covenant in the field of sustainable concrete, the city is already innovating together with TU Delft on other points in the concrete chain - for example by producing concrete from green geopolymers (Rotterdam Circular, 2017). In this respect, it dovetails well with existing policy measures to further explore sustainable alternatives to conventional concrete. Even more important is the fact that there is large-scale demolition in Rotterdam and will be in the coming years, although we strongly recommend preventing demolition where possible. In cases where demolition is the most sustainable option, and there turns out to be a large amount of concrete debris that is released by the agreements in the covenant, this can be used at a higher quality than is currently the case.

Reduce construction waste through circular demolition

INTERVENTION B6.

STIMULATE DISASSEMBLY OF BUILDINGS AND CIRCULAR DEMOLITION

- **What:** Both in the Rotterdam and Dutch construction in general, there is a lot of demolition, but still very little is disassembled during demolition. When dealing with the demolition of building parts, installations and components not in the conventional way, but rather dismantling them, much higher quality reuse is possible.
- **Impact:** The potential impact of disassembly, or circular demolition is large. According to the NIBE, this can comprise up to 80% of the total environmental costs of various building materials (Jansen et al, 2017)[1]. Collaborative research by Metabolic with SGS Search has shown that there are important opportunities for the application of secondary building materials resulting from disassembling and circular scrapping for new construction projects, where both the demolition and new construction plans for the region - and their associated material flows - are represented on a map.[2] TNO indicates that circular demolition will bring the most environmental benefits when focusing on reinforced concrete, bricks, and non ferrous metals, copper and aluminium (Vos et al., 2017). The total impact of circular demolition is now difficult to quantify because there is no reliable data yet about the returns of circular versus conventional demolition.
- **Feasibility:** Because the majority of the existing building stock has not been designed for disassembly, it is not always possible to disassemble components and products in their entirety. Nevertheless, there are various parties already working with circular demolition

[1] To determine the environmental impact reduction in direct reuse, a fair environmental comparison must be made. In the Netherlands we have agreed that we will make this comparison on the basis of a life cycle analysis (LCA [1]). An LCA calculates the environmental effects caused by a material throughout its life. In total, 11 environmental effects are included in the Netherlands. For example the greenhouse effect (global warming), depletion of the ozone layer and the depletion of raw materials. In order to be able to easily compare the products in the environmental field, the environmental effects are weighted and then added to comprise a number: the shadow price. Shadow price is defined as: the theoretical estimate of the costs that the government has to incur to prevent or remedy the environmental damage.

[2] Research has been carried out for both municipalities around Utrecht and the Municipality of Amersfoort.

and disassembly. It is therefore certainly feasible to put circular demolition into practice in Rotterdam tomorrow. As time passes, circular demolition is becoming increasingly better implemented and more profitable, designing buildings from the beginning that can be disassembled. Various construction companies are already experimenting with this type of design and can already build buildings, including social housing, of which 70% of the components are detachable and high-quality reusable (Bouwwereld, 2017).

- **Employment:** The demolition and disassembly of buildings is more labor intensive than traditional demolition, thus creating employment. The exact increase in the number of jobs due to disassembly instead of demolition in construction depends on the economic growth in the construction sector as a whole, but an analysis based on economic input output tables in a survey by Circle Economy, TNO and Fabric for Amsterdam, shows that net job growth is to be expected (Municipality of Amsterdam, 2017b).
- **Relevance to Rotterdam's context:** In Rotterdam, several companies are active in the field of circular demolition. One of the most visible front runners in this area is perhaps New Horizon, which includes all demolition trajectories of housing corporation Woonbron (Woonbron, n.d.).

PRODUCTION AND PURCHASING

Materials, Energy

INTERVENTION B7.

CIRCULAR TENDERING AND PROCUREMENT

- **What:** Circular demolition, applying secondary raw materials such as concrete granulate, energy-efficient build for a long life: all beautiful solutions, but whether they are applied depends largely on the demand from clients to the market. Strong consideration for circular criteria for buildings and the area is therefore crucial in the transition to a circular construction sector.
- **Impact:** The potential of this intervention is great: the government can certainly do it in cases where it itself can influence the design of the built environment at an early stage. Total impact and its quantification depends on demand by the municipality or other clients.
- **Feasibility:** Circular tendering is garnering full attention at both a national and local level. There are a large number of instruments and tender criteria, as well as procedures, which can be developed and awarded on the basis of circularity. One offers more specific and quantitative handles (Municipality Amsterdam, 2017a), while the other focuses more on the tendering process (Copper8, 2017; Ahsmann, 2017).
- **Feasibility:** There is no reason to believe that a change in the focus of tender procedures with different authorities would have a net positive or negative effect on employment.
- **Relevance to Rotterdam's context:** Circular Tendering has been on the City of Rotterdam's administrative agenda for a long time (Rotterdam Circular & City of Rotterdam, 2017), which means that this measure fits well with the existing policy.

MANAGEMENT

INTERVENTION B8.

MAKE MATERIAL PASSPORTS REQUIRED FOR ALL NEW BUILDING PROJECTS

- **What:** Whether it concerns design, or circular demolition and disassembly of buildings, information about the materials and components stored in buildings is essential in a circular economy. A materials passport is indispensable to a circular construction sector. In addition to the quantity and type of material, it is possible to put what the environmental cost indication (MKI score) of the material is, on the card. With different sensing technologies becoming cheaper, even the life course of a material and the impact of this on its functional lifespan is possible to include (see for example: Jongeleen, 2017).
- **Impact:** This intervention helps to both reuse and recover materials in the future (for example, to map the financial value of materials), as well as the impact of purchased materials, and the actual value and status of insight into materials and components. Circular demolition and construction is often difficult to implement because of a shortage of information: now the materials needed and available for the future can be more adequately estimated: when all buildings have a material passport, this is no longer a question of guessing, but of knowing. With this, demolition and new construction can be more attuned to each other, and can accommodate buildings in the true sense of the word when materials banks start functioning.
- **Feasibility:** There are a large number of different parties working on a standard format for materials passports. The Madaster Foundation has committed itself the goal of a 'cadastre for materials' (Madaster, 2017), and under the direction of the NEN a large group of experts and companies is working on some materials

passports and circular construction standards (van Odijk and van Bovene, 2014).

- **Employment:** With the large-scale registration of materials and their properties, asset management will gain a new meaning in construction. Managing and analyzing this data will create new jobs, just like really managing assets in the built environment.
- **Relevance to Rotterdam's context:** Rotterdam can play an important role in retrieving the data required for material passports, not only for new buildings, but also for the existing built environment. Companies like Rotterdam New-Horizon can also be of use in mapping out which materials are stored in buildings in the existing built environment (Residential source, n.d.). This information is essential because precisely in renovating and partly demolishing the existing ones, a large flow of released materials can be expected in the future, and great potential lies in using these materials at high quality.

Construction materials

INTERVENTION B2:

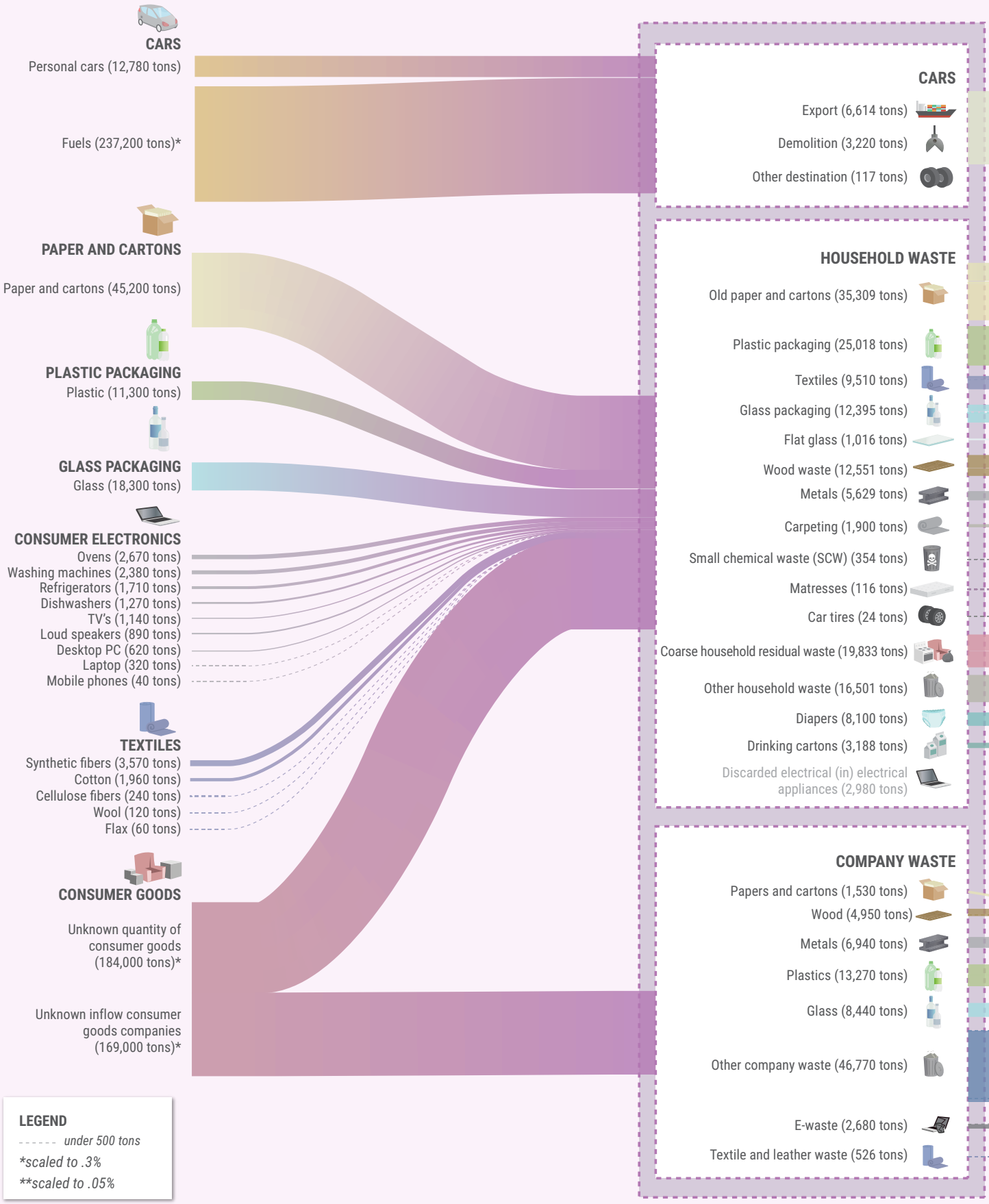
TAXATION ON MATERIAL USE INSTEAD OF LABOR

- **What:** When new construction (whether or not in combination with demolition) is necessary, one should look at the potential to adjust the volume of materials use as much as possible. The government can contribute to this by shifting the tax burden from wages and labor to material use. The calculated environmental damage caused by resource use for and in the Dutch economy, is now according to the Planning Office for the Living Environment (PBL) insufficiently priced and taxed (Dijk et al., 2017). If this is corrected it becomes automatically more financially attractive for all players in the construction chain to the reduce the environmental impact of used materials. The PBL concludes that all metal ores and limestone for the production of cement require a regulatory tax because these are the raw materials that are used in the production processes that contribute most to environmental damage.
- **Impact:** According to the PBL, a shift in the tax burden can deliver great profit in the area of sustainability, but it is difficult to quantify the exact impact of these measures for the construction sector. It is clear that the environmental damage resulting from the production of final products and semi-finished products is great: for iron and steel, the calculated annual environmental damage is even greater than the production value (almost 135 percent). In principle, we can define the theoretical upper limit of this measure with the total number of embodied impacts related to building materials, if we assume that there would be a substitute for every material with an MKI score equal to zero. This is not the case. Moreover, the savings for each set of used materials and potential substitutes are different, and depending on the price elasticity (the degree to which changing tax influences demand of a material), the impact of this measure cannot not be quantified.
- **Feasibility:** Given the recommendations from PBL, the current circumstance seems ripe for a review of the relationship between fiscal pressure and environmental performance. At the same time it is not possible for Rotterdam to make these changes alone. In the long term, and in coordination with the national government and the EU, this intervention is sure to perform.
- **Employment:** It is impossible to attach a quantitative impact to these measures, but as long as the tax on materials is not so high that the growth of added value for the entire construction sector is under pressure, the expectation is that lower labor taxes will lead to more employment.
- **Relevance to Rotterdam's context:** There is one important relationship between a review of the tax system as presented here and the potential for other measures as proposed here (B1, B4, B5, B6): the higher the costs for primary material production, the better the business case for, for example circular demolition, lifetime extension and the preservation of buildings and so on. In this sense, this intervention specifically creates space for a fundamental transition in the construction sector.

CHAPTER 07

CONSUMER GOODS

CONSUMER GOODS IN ROTTERDAM 2015



METABOLIC CIRCLE ECONOMY

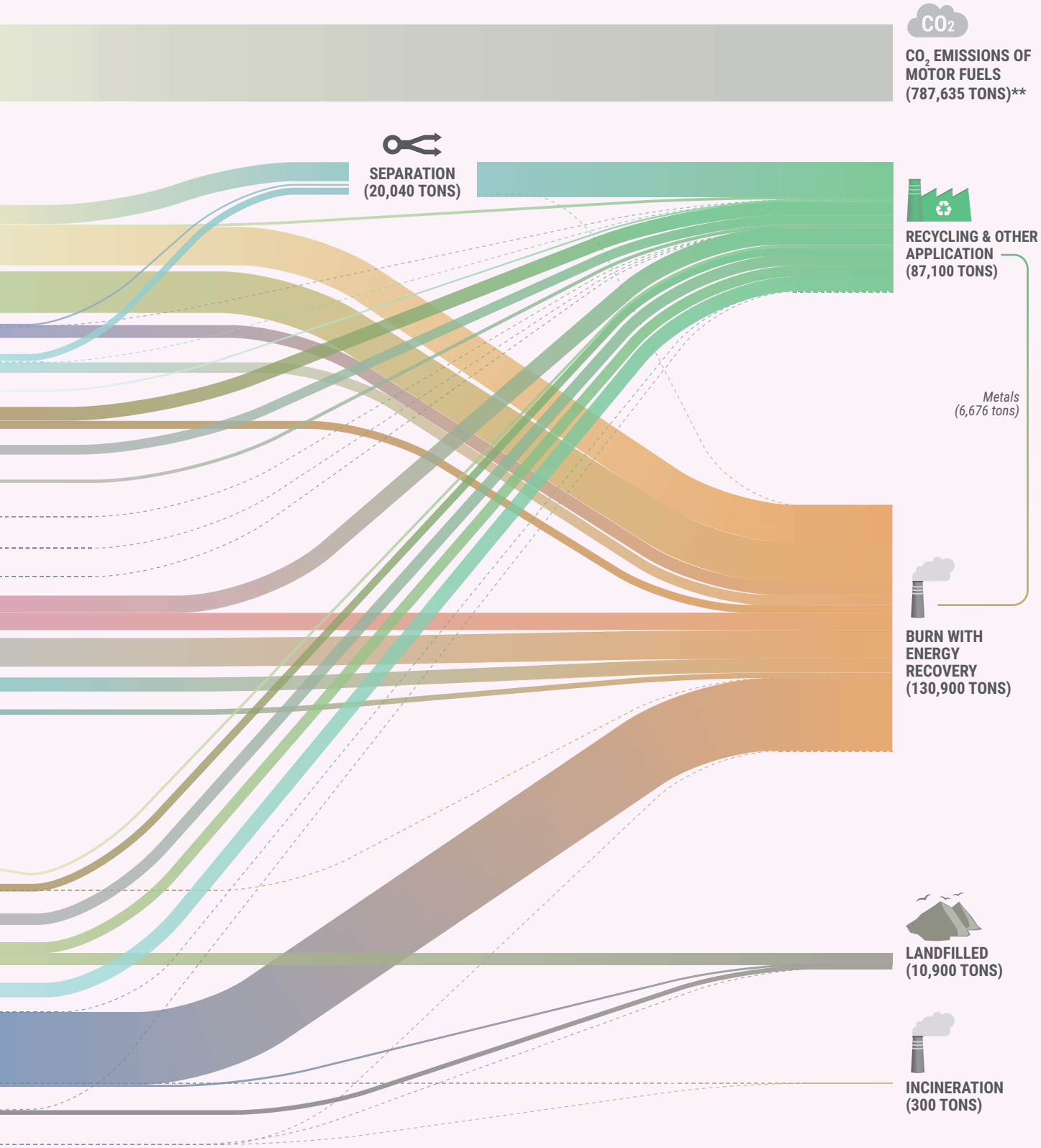


Figure 24: Material Flows: Consumer Goods Sector Rotterdam

CONSUMER GOODS IN ROTTERDAM

There are two types of consumer goods that we have used in the scope of our material flow analysis:

- Consumer goods in use for more than one year (textiles, electronics, household appliances, computers, cars, etc.).
- Consumer goods with a life cycle shorter than one year (non-sustainable consumer goods): paper, diapers, drinks cartons, petrol (excluding food, including packaging).

The waste data in the figure are actual figures supplied by the City of Rotterdam. The input data are, however, mainly based on estimates of consumption quantities of products. The flows of consumer goods are usually very general and even excluded from urban MFAs. The reasons for this include the high variation of products, insufficient insight into the material composition of these products, and lack of data at the appropriate scale or detail level. To fully gain insight into the flows of consumer goods throughout the city we would need detailed sales information from all relevant shops (of which there are about 11,000 in Rotterdam).

Although this analysis can provide some insights on high level on priorities and focus areas which Rotterdam can focus on in order to create a circular consumer goods sector, we recommend collecting more detailed data and information on this sector in the years to come.

HIDDEN TREASURES

Our estimates of the quantity and type of consumer goods purchased in the city show that this is probably the greatest 'goldmine' of complex and valuable material flows in Rotterdam. Transport means, consumer electronics, household appliances, clothing and even plastic packaging all represent higher than average value per kilogram of volume, especially in comparison with sectors such as construction and agri-food. The metals used in cars, packaging, and electronics sold annually give an indication of the amount of metal that can be found in consumer products out there in the urban stock.

Within the 12,780 tons of cars, 11,000 tons of electronics and white goods and 5,600 tons of metal packaging sold in Rotterdam annually, there is 8,000 tons of metal - almost as much as the 9,200 tons of metal used in the same year in the construction sector. Of course within electronics, also part of every contemporary car, there are also many scarce and valuable materials that have a much higher value than common metals like steel.

A LINEAR SYSTEM

Despite the high inherent value of the raw materials in consumer goods, the vast majority of these end up as unsorted municipal waste, most of which is eventually burned. Of the consumer goods sold to both households and offices, only about 30% is recycled. Although only 4% of the materials are sent to the landfill, 66% is incinerated, which still represents a loss of value, despite the energy produced during the combustion.

The largest waste stream - in terms of volume - is packaging waste, with approximately 68,000 tons of paper, plastic, glass and metal. This is 35% of the total volume. The metal portion can be recovered after burning, but ideally, all these materials should be collected separately. The mass of packaging waste is about twice the size of durable goods which are consumed.

A number of specific waste streams are also monitored separately, including household waste such as furniture (19,833 tons), textiles (9,519 tonnes), diapers (8,000 tonnes), drinks cartons (3,188 tonnes), floor covering (1,900 tonnes), mattresses (116 tonnes), and tyres (24 tonnes). As discussed in the interventions section, thanks to new advanced recycling technologies, it is now possible to recycle these materials at high-quality where it was not possible in the past.

ENERGY-CONSUMING PRODUCTS

Although it is not entirely clear in the MFA diagram, it is important to note that a large portion of consumer goods fall into the category 'energy consuming products'. Household appliances such as refrigerators, washing machines and lighting are responsible for significant proportions of household energy consumption in the Netherlands. For this reason keeping old, inefficient products in circulation for longer to save on materials can be at odds with long term climate targets.

In the case of cars, the most energy-intensive product group in this subcategory, the construction of collective infrastructure such as roads and public transport is the biggest influencing factor behind the individual choice to drive a car, and how much energy will eventually be consumed by these products. The significant energy demands of consumer goods are made clear by the fact that, measured in total mass, 85% consists of fuel for means of transport - which alone results in approximately one million tons of CO_2 emissions.

If we are to transition towards a circular economy, the energy needs of consumer goods must be taken into account. Share and lease plans, and initiatives that focus on Extended Producer Responsibility, can simultaneously contribute to tackling material and energy impacts in the consumer goods sector.

CIRCULAR JOBS

The jobs analysis focuses on jobs related to production, retail, repair and waste processing. The economic activity around consumer goods provides Rotterdam with almost 25,000 jobs. Of these, more than 4,700 can be considered circular, a good 19% of all consumer goods-related jobs. Almost one quarter of jobs in consumer goods are related to the production, trade and repair of cars. Repair activities make up about half of circular jobs in consumer goods.

There is large potential for circular employment around consumer goods in Rotterdam. Thanks to the proximity of the port, Rotterdam specializes in wholesale activities, and this specialism is growing (Statline, 2012).

In addition, many current circular jobs relate to repair and leasing activities, and to the use of green energy. This link with direct circular activity explains the relatively high proportion of circular jobs in a sector that does not directly belong in the circular economy. Repair and leasing activities are central to a circular economy and they can complement and partly replace trade in consumer goods. Therefore, there is a strong connection between 'extend the life of existing products' and 'consider new business model' strategies for a circular economy.

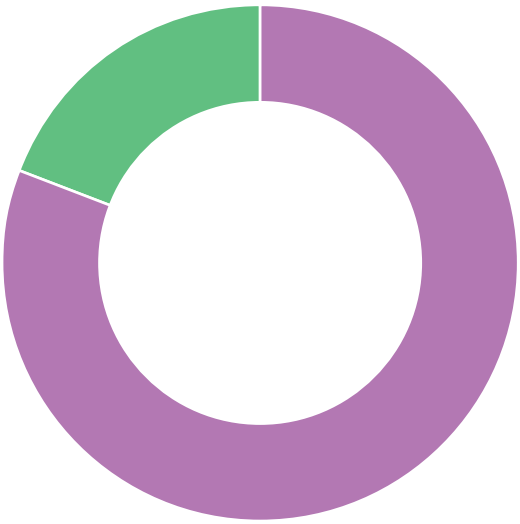


Figure 25:Jobs in the Consumer Goods Sector

IMPACT OF CONSUMER GOODS

The ecological and humanitarian impacts of consumer goods are equally as far-reaching and diverse as the products themselves. Many of the product categories have a very high embodied impact in terms of both raw materials and emissions. As discussed, many of them consume energy during their use phase. Due to underdeveloped standards in product design and production, some product groups also include toxic chemicals and carcinogenic substances, which causes problems for material recycling too.

To understand the impact of consumer goods, we take a product group as an example. Textile products have one of the biggest impact profiles on both environment and people's prosperity. Although textile-related agriculture accounts for about 2% of the total agricultural area available, it is responsible for about 20% of the total agricultural water consumption. The vast majority of these agricultural areas are located in areas with many water shortages and salinization, which only increases water consumption. Cotton, viscose and silk production are collectively responsible for a quarter of India's water print and 51% in China (OEKO Textiles, 2011). Meanwhile dyeing and processing of textiles accounts for 20% of the total global water pollution (Textile Exchange, 2012). The sector is notorious for its poor working conditions and the relatively high degree of child labor.

A recent concern about this type of consumer goods, including textiles, is the accumulation of microplastics in the environment. Any plastic product that experiences friction, or makes up the sole of your shoe, the brush of your broom, or synthetic clothing, loses tiny particles of plastic, often only a few nanometres in size. These synthetic materials, often connected to materials with toxic substances, can not be filtered from waste water given the current filtering techniques we have available. In this way they spread through our environment and our food cycle, and have a major impact on the health of people.

It is clear that the impact of consumer goods is difficult to quantify, but the scale of these impacts is worrying. Some of the largest challenges in the transition to a circular economy lie in the consumer goods sector, and it will require a complete redesign of the system as a whole, as well as of the products themselves.

INTERVENTIONS FOR A CIRCULAR CONSUMER GOODS SECTOR

The material flow analysis shows that there are a number of things that need to be prioritized in order to make Rotterdam's consumer goods sector circular:

- **Reduce the total quantity of waste generated.** This can be done, for example, by introducing leasing models for products, increasing product productivity through sharing platforms, supporting the development of 'zero-waste' stores, encouraging repair and refurbishment activities, and adopting innovations in the field of packaging and product design.
- **Increasing the percentage of waste that is collected separately.** As with the collection of bio-waste, separate collection of consumer goods can be stimulated by Pay-As-You-Throw charges and door-to-door collection where possible.
- **Implement new processing technologies for waste.** There are many emerging sorting and processing technologies for both poly material streams such as plastics, as well as more specific sub-flows such as diapers.
- **Generate demand for the use of recycled materials in new products.** Guaranteed consistent supply of high quality post-consumption materials is the first condition to implement this approach. It can be further stimulated by the creation of trade platforms and tax incentives.
- **Reduce embodied impacts of consumer goods.** This can be done by purchasing in the public sector, making reporting on the embodied impacts of products a requirement, increased taxes on high-impact products, and information campaigns.

Of all the sectors we have examined in this research, consumer goods is the sector for which we have been able to obtain the least data about the exact quantities and types of products that are consumed. For this reason, it is difficult to make quantitative assessments about the impact of some of the interventions we propose, especially on the input side. However, we have done our best to estimate the overall potential impacts. In Figure 26 we present a range of possible interventions that can be implemented to achieve these objectives. We have organized the interventions according to the flow or impact they may be able to mitigate and have made estimates for the total amount of impact which can be reduced. The most promising interventions are described in more detail.

SYSTEMIC CHALLENGES

Probably the biggest difficulty in closing consumer goods cycles is the problem of product design. As it currently stands, even if all the residual materials from consumer goods are collected separately, it is still extremely difficult to achieve high quality recycling. There are several reasons for this, including a diversity of materials, lack of material and component labelling, and the fact that products are complex and are rarely designed for disassembly.

The negative consequences of our product design choices are not yet entirely clear, and many of us are only beginning to understand it now. In past years, public awareness about accumulation of plastic waste increased significantly. The proposition that in 2050 there will be more plastic than fish in the sea is regularly cited since it first appeared in a report by the Ellen MacArthur Foundation (Harrington, 2017). Recently, concerns about microplastics reached a new level when Orb Media (Tyree and Morrison, 2017) published the results of an analysis in which micro-plastics were found in 83% of all drinking water samples worldwide.

To address these difficulties, systemic interventions are needed at a national, European and even global level. In order to achieve its circular economy ambitions, Rotterdam must take an active role in gaining insight into the problems, and lobbying for the most promising solutions in the private sector and the policy space. Ideally, the City of Rotterdam would also gain more insight into the waste generated by its consumer goods flows through more detailed data collection processes, and the tightening of interventions on the basis of more accurate local data. That said, there are already a lot of things Rotterdam can undertake within the city limits and using the knowledge that is already available. Again we start with prevention, through its potential to reduce the impacts of the overall flow of materials in the city, with a special focus on waste streams.

NR.	IMPACT FOCUS	INTERVENTION	TYPE	FEASI-BILITY	POTEN-TIAL FOR IMPACT REDUC-TION	POTEN-TIAL FOR JOB CRE-ATION	POTEN-TIAL FOR JOB LOSS	LINK TO VISION
C1	Mixed waste	Pay-As-You-Throw levy	Synergy	High	High	Low	Neutral	Materials
C2	Beverage cartons	Tetrapak recycling facility	Synergy	Medium	High	Medium	Neutral	Materials
C3	Textiles	Integrated textile recycling Centre	Synergy	Low	High	Medium	Neutral	Materials, value
C4	Mixed waste	Door-to-door waste collection	Synergy	Medium	High	Medium	Neutral	Materials
C5	Autobanden	Black Bear Carbon recycling for car tires	Synergy	Medium	High	Low	Neutral	Materials
C6	Consumer goods	Upcycle Mall	Production & purchasing	Medium	Low	High	Low	Materials, value
C7	Consumer goods	Stimulate use of sharing platforms	Reduce	Medium	Low	Medium	Low	Materials, value
C8	Diapers	Diaper recycling facility	Synergy	Medium	High	Low	Neutral	Materials
C9	Plastic packaging	Advanced plastic recycling facility	Synergy	Medium	Low	Medium	Medium	Materials
C10	Auto's en consumenten-elektronica	Full service living concept	Production & purchasing	Low	Low	Medium	Neutral	Materials, value, health, energy
C11	Consumer electronics	Subsidize leasing of electronics & devices	Production & purchasing	Medium	Medium	Low	Low	Materials, value, biodiversity
C12	Packaging	Packaging R & D	Production & purchasing	Low	Medium	Medium	Neutral	Materials, valule, biodiversity, health
C13	Packaging	Recycling guidelines & campaign	Synergy	High	Medium	Neutral	Neutral	Materials
C14	Textiles	Microplastics filtering R & D	Synergy	Medium	Low	Low	Neutral	biodiversiteit, gezondheid
C15	Packaging	Support Zero-Waste stores	Reduce	Low	Low	Medium	Medium	materialen, biodiversiteit
C16	Packaging	Reusable packaging for e-commmerce	Reduce	Medium	Low	Neutral	Neutral	materialen
C17	Consumer electronics	Social housing corporations pay 20% energy bill	Supply	Low	Low	Neutral	Neutral	Materials, energy
C18	Textiles	Fast Fashion levy	Reduce	Low	Low	Neutral	Low	Materials, value, biodiversity
C19	Products and packaging	Circular procurement policy for recycled products	Production & purchasing	High	Low	Neutral	Neutral	Materials, energy, value, biodiversity

Figure 26: Possible consumer goods interventions

REDUCE

A large portion of the 195,000 tons of mixed, non-organic, post-consumption waste thrown away in Rotterdam in 2015 could have been prevented through a combination of policy interventions, new business models and technical innovations.

Possible strategies include: switching to leasing models for products, making more use of sharing platforms for the use of products, stimulating the development of zero-waste stores, supporting repair and refurbishment activities, and adopting innovations for product packaging and design. Below, we describe some of the these possibilities, focusing on the largest and most impactful waste streams.

Packaging waste: 75,000 tonnes

The largest waste stream within consumer goods in Rotterdam, with about 35% of the total mass, is packaging waste. This can be greatly reduced by moving to packaging-free shops (intervention C15), an emerging trend that is becoming more and more apparent in the news, but structural support is needed in order for it to be successful (Palmer, 2017).

INTERVENTION C15.

PACKAGING-FREE SHOPS

- **What:** So-called packaging-free shops are supermarkets where consumers can buy and transport their food and groceries in their own glass jars, boxes, sacks or bags that they've brought along. This can eliminate a large portion of all single-use packaging. Rotterdam can encourage existing supermarkets to offer their customers the option of bringing their own reusable packaging with them from home or stimulate the development of new, packaging-free shops in the city. Although plastic bags are no longer free, bags and disposable containers that are offered inside the supermarket for the carriage of bulk commodities may also be subject to charges, which will further stimulate reusable packaging.
- **Impact:** Food packaging accounts for approximately 42% of all packaging sales. Rotterdam can avoid 31,500 tonnes of packaging waste if single-use packaging material is eliminated completely. If a more achievable 30% would be eliminated, this would mean a saving of 9,500 tonnes of packaging waste. Of course, this also requires collaboration with large supermarket chains.
- **Feasibility:** Packaging-free shops have difficulty getting a foothold in the Netherlands. The crowdfunded zero-waste store Opgeweckt Noord was only open one year before it closed its doors. But there are also other ways to continue the zero-waste trend. From November 2017 Carrefour implores its customers throughout Belgium to bring their own reusable packaging containers with them, which, according to the retail chain, is already a major success. Rotterdam can collaborate with existing retail chains, and encourage them to allow the use of reusable packaging for products sold in bulk.
- **Employment:** This intervention would likely lead to no increase in employment if it were to be implemented in existing shops. As new packaging-free stores would open in Rotterdam, this would create new jobs, although these shops should compete with existing stores.
- **Relevance to Rotterdam's context:** According to Bepakt.com, a register of packaging-free shops worldwide, there are only a few of these types of shops in the Netherlands, and none in Rotterdam. However, according to ZeroWaste Project, customers of Samsel, Dill and Kamille can take their own re-usable bags. The Retail Innovation in Rotterdam would be a be a good partner to take include in the discussion on how packaging-free shopping in Rotterdam can be made easier and more attractive.

Other possible ways to reduce packaging waste are to encourage reusable packaging in e-commerce, an option now offered by companies such as RePack and Returnity (intervention C16).

INTERVENTION C16.

REUSABLE PACKAGING FOR E-COMMERCE

- **What:** With the increasing popularity of online shopping, household cardboard waste has increased, putting local waste collection and recycling under pressure. Some cities have 30% more cardboard waste than in previous years (Sottile and Kent, 2017). With this intervention, products are sent in reusable pouches or even custom-made packages for certain product types. This reusable packaging can be purchased at post offices and returned for reuse.
- **Impact:** Reusable packaging for e-commerce packages, mainly cardboard and paper fractions of the packaging streams to (about 50% of the total). RePack estimates that its packaging save up to 80% greenhouse gas emissions compared to conventional single-use packaging options. If 30% of all household and commercial cardboard waste can be eliminated by reusable packaging options, this could lead to a saving of 13,500 tons.
- **Feasibility:** One of the challenges for implementing this is that not all retailers are adopting this option.

Rotterdam could, however, stimulate adoption by making it the standard for all public purchasing (as far as possible), by encouraging local retailers to do the same, and by informing the public about the alternative opportunities through campaigns. Municipal purchasing offices can insist on reusable packaging services for common purchasing, creating a market for this service.

- **Employment:** This intervention would lead to a minimum increase in the number of jobs, but it would also not destroy jobs.
- **Relevance to Rotterdam's context:** As far as we know there are no specific ongoing projects in Rotterdam to which this can be linked.

Bulky household waste: 20,000 tons

In 2015, almost 20,000 tons of bulky household waste was discarded in Rotterdam, consisting mainly of furniture and devices. A large fraction of this could possibly be repaired, refurbished, or would be immediately suitable for reuse. Here we look at the possibilities for setting up an Upcycle Mall in Rotterdam, which can act as a focal point for both knowledge development and product repair and exchange (intervention C6), and can lead to a reduction of these waste streams.

INTERVENTION C6.

UPCYCLE MALL

- **What:** Earlier this year in Eskilstuna, Sweden, the world's first shopping centre for repaired and recycled products was established. The shopping centre consists of 14 shops and a small recycling center to which customers donate things that they no longer want. There is also a cafe, restaurant, conference room, exhibition space and a training centre for the repair of products. Rotterdam would be a similar center within which to focus on local products and skills. Through the local community of creatives and entrepreneurs, the Rotterdam Upcycle Mall is not only a practical solution to a problem, but could also serve as a new hub for creative development.
- **Impact:** WRAP UK has conducted a study in Great Britain on the potential for reuse of bulky household waste. The study indicates that of all the bulky waste in the country, 42% consisted of furniture, 19% of textiles, and 19% of electronic devices (WEEE). Of the furniture, 20% was immediately reusable and another 25% reusable after minor repairs (WRAP, 2012). In terms of WEEE, including televisions, refrigerators and washing machines, about 60% were reusable immediately or after a minor repair (WRAP, 2012). If 50% of all the local bulky waste could be upcycled instead of thrown away, this could lead to savings of up to 10,000 tons of materials per year.
- **Feasibility:** Setting up an Upcycle Mall is something the municipality may unilaterally decide to do, making it more feasible than many other interventions. Some difficulties will include finding a suitable location, and finding and freeing up enough budget for the project.

  To stimulate participation in the project, additional measures might help. For example, Sweden provides tax benefits on repairs for bicycles, refrigerators and washing machines (Starritt, 2016). The repair of bicycles and clothing is subject to VAT, reduced from 25% to 12%, and on white goods, consumers can claim back the income tax that is paid to the people who do the work. The aim is to encourage residents to reduce the impact of their consumption behaviour and to extend the value of materials within the smallest possible cycles. It is expected that this will result in a loss of approximately $54 million for the state treasury which can be offset against the revenues from new taxes on, for example, harmful chemicals in new products.
- **Employment:** The Eskilstuna Upcycling Mall has created 50 new local repair and recycling jobs (Ghent, 2017). More jobs can be created if additional facilities are created, creating a platform for circular entrepreneurs to showcase their products. The project can potentially be linked to BlueCity which gives companies a place to develop their own businesses and scale up products.
- **Relationship with Rotterdam Projects:** There are various projects in Rotterdam focused on repairs, including Repair Café's, which are organized every week (Repair Café Rotterdam-North, 2016). There are also many high-end vintage and second-hand shops like ReShare, Dion Vintage, and Twice as Nice that play a central role in the shopping culture of Rotterdam. It would be good to include these projects within this intervention.

SYNERGY

As discussed earlier, for further high quality processing, it is important that the waste streams are as pure as possible, and separated in as much detail as possible.Approximately 30% of waste in Rotterdam's consumer goods sector will be collected separately. As with the collection of bio-waste, two interventions that can contribute significantly to achieving higher recycling rates for separate waste streams are Pay-As-You-Throw policy (intervention C1), where residents pay for each kilo of mixed waste they dispose of, and door-to-door collection of recyclable waste (intervention C4). For a detailed description of the second approach, see the description of intervention A1 in the Agri-Food chapter. Door-to-door collection not only leads to increased overall participation in recycling, but also to less pollution of separate waste streams (European Bioplastics, 2016).

When a system for collecting pure and consistent waste streams is set up, the foundations can be laid for investment in new technologies, and processes for the individual waste fractions. There are many emerging sorting and processing techniques that result in a higher value of material recovery, resulting in recycled waste that's more suitable as a replacement for primary raw material. TU Delft is one of the forerunners in the field of advanced plastics recycling, and has created organisations such as the Urban Mining Corp, which uses what's known as Magnetic Density Separation techniques to create sub-fractions in mixed waste (Urban Mining Corp, 2016). Rotterdam can be at the forefront of new and innovative waste treatment techniques by setting up a facility for advanced plastic recycling (intervention C9). Other specialised recycling processes are available for diapers (intervention C8), Tetrapak drinks cartons (intervention C2), and car tyres (intervention C5). It does not make sense to implement all of these processes at a city level, but when waste fractions can be collected separately, they should ideally processed by the most advanced available technology. Another high-grade fraction that can be recovered more optimally is that of textiles, which we discuss in more detail below.

Textile Waste: 9,500 tons

Although textile waste constitutes only 9,500 tons of the total Rotterdam's consumer goods waste stream - about 5% of the total - it is a highly impactful product category. On average, this amounts to 15 kilograms per year of textiles discarded by Rotterdam residents. Textile consumption has increased sharply per capita in the Western world since the rise of so-called fast fashion. Companies like H&M, Zara, Pull&Bear, River Island and others are continuously trying to shorten the duration of the fashion 'seasons', so as to create new variations of mass-produced clothes and cheap clothing offers. Low price tags make it easy to buy the clothes and also easy to throw away again. A possible solution for the high material throughput of textiles is the introduction of an eco-tax on fast fashion (intervention C18). But textile waste will never be completely eliminated unless it is possible to get more value out of it. It is possible to get more value from this material flow than is currently the case by setting up an integrated textile processing centre which can help the whole region.

INTERVENTION C3.

INTEGRATED TEXTILE RECYCLING CENTER

- **What:** Rotterdam can play a pioneering role through an integrated textiles recycling center which ideally should be a combination of the two technologies: both advanced mechanical sorting options as well as chemical recycling methods for different textile types. The Fibersort technology, introduced by Valvan Baling Systems (Valvan Baling Systems, 2017), uses optical sorting of different types of textiles based on layout and color - the first step towards suitable inputs for recycling. Texperium, the open innovation centre for textile recycling in Haaksbergen, has made great progress when it comes to leading recycling techniques (Texperium, 2017). The EU subsidised FIBERSORT consortium, led by Circle Economy, is currently researching the potential to scale up these techniques (Circle Economy, 2016). The results of this study can be applied directly to this center in the Rotterdam region.
- **Impact:** According to Wieland Textiles, a company that specializes in textile recycling, around 52.3% of the textiles discarded in the Netherlands can be directly reused as clothing. However, 37.2% of textile waste cannot have any further application other than textiles recycling. This fraction can be converted into new raw materials. With an integrated recycling centre, almost all the collected textiles (95%) can be kept in high quality cycles - both recycling and reuse, which could lead to a potential saving of 9000 tons of textile waste for Rotterdam.
- **Feasibility:** There are a number of difficulties that have to be bridged before implementing this intervention. The most important of these are the technological availability and financial feasibility. However, these points are currently being actively investigated. Once they have been solved, it is possible to put Rotterdam in contact with commercial partners, including fashion chains such as H&M and C&A, to co-finance these developments.
- **Employment:** An integrated recycling facility would create jobs for manual sorting of wearable and

non-wearable clothing (of which the wearable portion ideally comes back to Rotterdam for sale in Rotterdam's Upcycle Mall). In addition, the collection and processing of textiles in the center accounts for dozens of jobs. The mix of skills needed for this employment would range from relatively simple activities carried out by people at a disadvantage in the labour market, to specialized activities that require skills and knowledge.

- **Relevance to Rotterdam's context:** Next to Rotterdam's entrepreneurs who are actively involved in circular fashion, it is also interesting to note the huge flows of raw materials flowing through the port which may be directed back to the textile processing centre. The port already trades large volumes of textile waste that could be intercepted are on their way to emerging countries, where they are are often burned or landfilled. A connection can also be made with the Rotterdam Circularity Center in the port.

PRODUCTION AND PURCHASING

One of the biggest challenges in the transition to a circular economy in the consumer goods sector is that producers do not like recycled materials. In the past, this was about quality and consistency monitoring. For example, it is difficult to guarantee the exact quality of plastic as it is a combination of all kinds of different plastics waste streams. Often, recycled materials are also more expensive than primary raw materials, making the latter an easy choice for producers. It is therefore important that, in addition to realizing pure waste streams, we create a market for for these materials, in order to accelerate the recycling of plastics.

Another important consideration for purchasing is reducing the environmental impact of purchased products and materials. This applies to both the consumer goods sector as well as for other sectors. This can be done by tightening up purchasing policies, monitoring the pricing of so-called externalities, tax incentives, and information campaigns that appeal to both companies as consumers. It is often the case that to purchase alternatives that have a lower environmental impact, it is also necessary to invest in R&D for the development of these alternatives.

Packaging waste: 75,000 tonnes

To address the global problem of packaging waste, a large amount of innovation is needed to make packaging materials sustainable. The company MonoSol has an innovative packaging material solution which is already in use in dishwasher tablets and detergent, and can also serve as 'edible packaging' instead of single food packaging (Fast Company, 2012). Comparable packaging solutions for personal care products are also being researched (Wischhover, 2017). Another approach by Ecovative design involves the development of a biodegradable alternative for Styrofoam by growing mushrooms on agricultural waste to make a mycelium-based material. This packaging material breaks down completely in one month's time under natural conditions (Ecovative Design, 2017).

INTERVENTION C12.

SUPPORTING R&D FOR PACKAGING

- **What:** Rotterdam can support R&D towards biodegradable, soluble mono-material or other low-impact packaging by supporting local innovation activities in the city by, for example, students of Industrial Design at the TU Delft training programme. The municipality can also organize round table sessions with local industries, and promote alternatives for the adoption of low-impact packaging.
- **Impact:** Even if the demand for packaging decreased dramatically due to adoption from zero-waste stores and product redesign, there will always be a need for packaging. Ideally all packaging entering Rotterdam would be designed according to circular principles (easily recyclable and biodegradable). Although for this purpose a systemic change is needed in order to completely transform specific supply chains. The city can play a facilitatory role in triggering this change. The exact impacts cannot be be quantified due to this intervention's diverse character and its global scale.
- **Feasibility:** A focused innovation program supported by the municipality would be the most feasible for the city, although it may be outside the scope of the city's regular activities. Therefore, it is important to develop strong partnerships to set up such programmes. Activities could partly be organized at BlueCity.
- **Employment:** If properly implemented, this intervention could lead to a new cluster of local companies that have the global market as their scope.
- **Relevance to Rotterdam's context:** The main relationship with existing Rotterdam projects is through appealing to local students and entrepreneurs, many of which are already actively engaged in circular economy.

INTERVENTION C19.

STIMULATING RECYCLED PRODUCTS BY MEANS OF MUNICIPAL PROCUREMENT POLICY

- **What:** Rotterdam can adopt a stricter circular procurement policy which gives preference to products which can be recycled. It is important that a circular purchasing policy looks at multiple environment impacts and takes into account the further recyclability of purchased products. These can however, be an important step in promoting and supporting a market for recycled materials.
- **Impacts:** Although the exact impact of this intervention is difficult to quantify, public procurement guidelines are generally seen as an effective way to bring about market changes due to the large quantity of products which government bodies usually buy in.
- **Feasibility:** Rotterdam is in some areas already actively engaged in circular procurement guidelines, such as with buildings and infrastructure. This can be extended to the purchase of consumer goods like office supplies, coffee and furniture, in the areas where this has not yet been implemented.
- **Employment:** Local job creation through this intervention will be small, except if Rotterdam also includes a requirement for local production in their guidelines.
- **Relevance to Rotterdam's context:** This initiative can be connected to and build on the existing commitment by the municipality to procure circularly.

MANAGEMENT

Different tools can be used to provide continuous feedback on the circular economy performance of Rotterdam's consumer goods sector. One way of doing this is by means of small chips (RFID) in products with a detailed breakdown of the components and materials it comprises of. This approach however, involves a broad system transformation of both producers and post-consumption companies.

Other possibilities are to develop circular economy performance and feedback through the use of dashboards that give consumers insight into their own recycling performance, and potentially even give coins or tokens to users as a reward for the effective sorting of their waste (as the vision section of this report has described). Further interventions in this area are, among other things, the creation of an online marketplace for trading different processed goods flows.

Although it is already possible to invest in these interventions, it is likely that this will be more appropriate and effective when the earlier mentioned interventions have been successfully implemented.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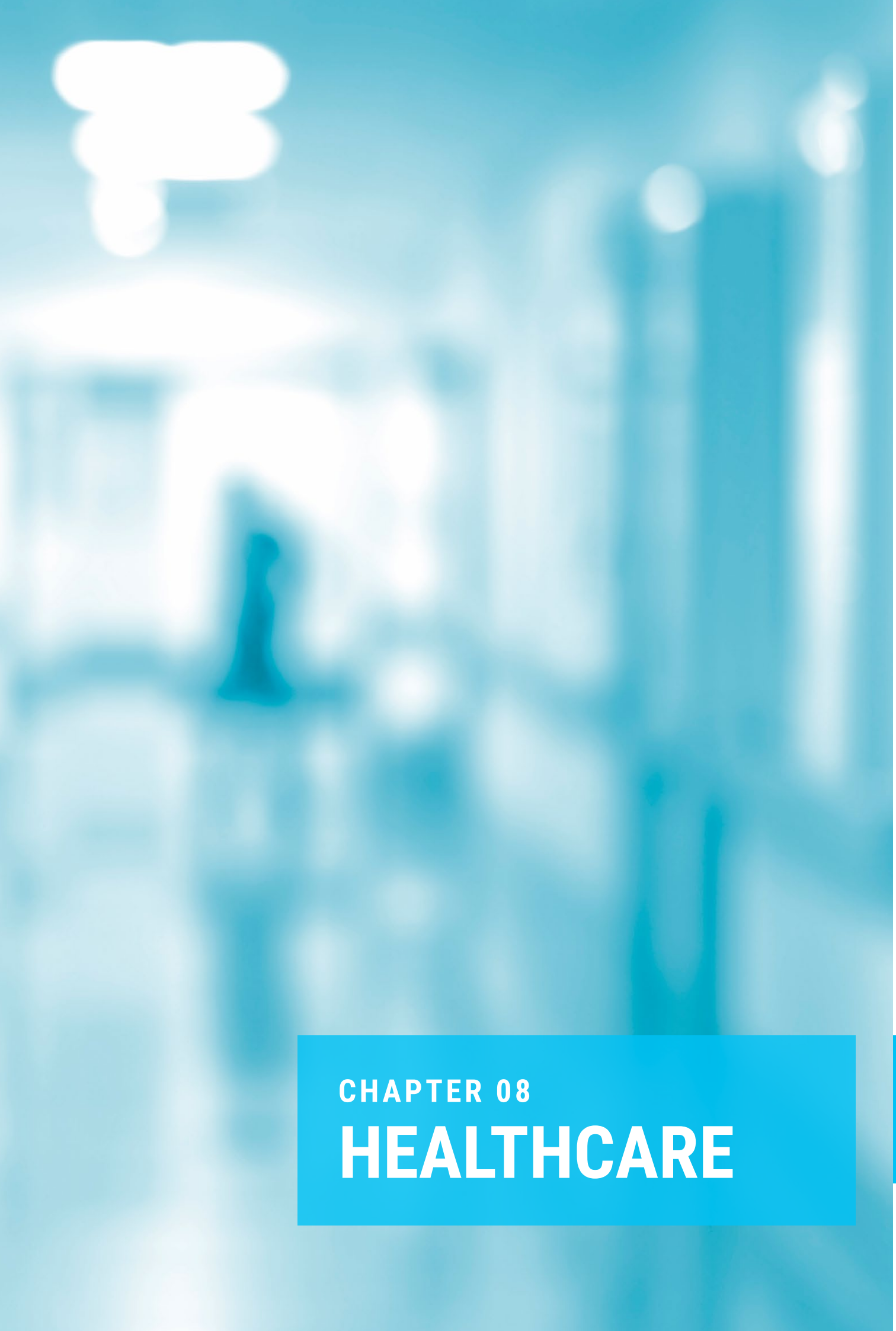
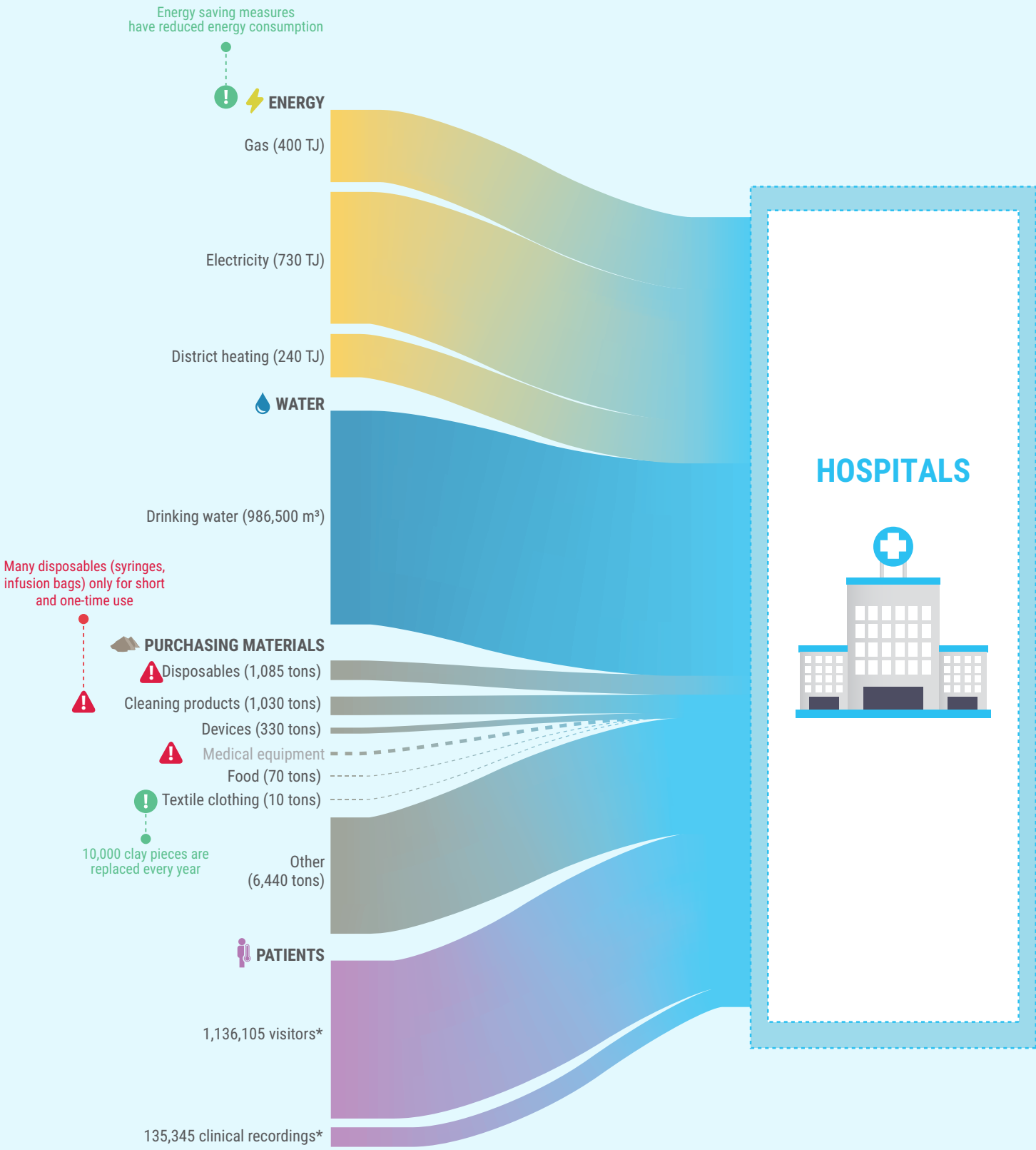


CHAPTER 08

HEALTHCARE

HEALTHCARE (HOSPITALS) IN ROTTERDAM 2015



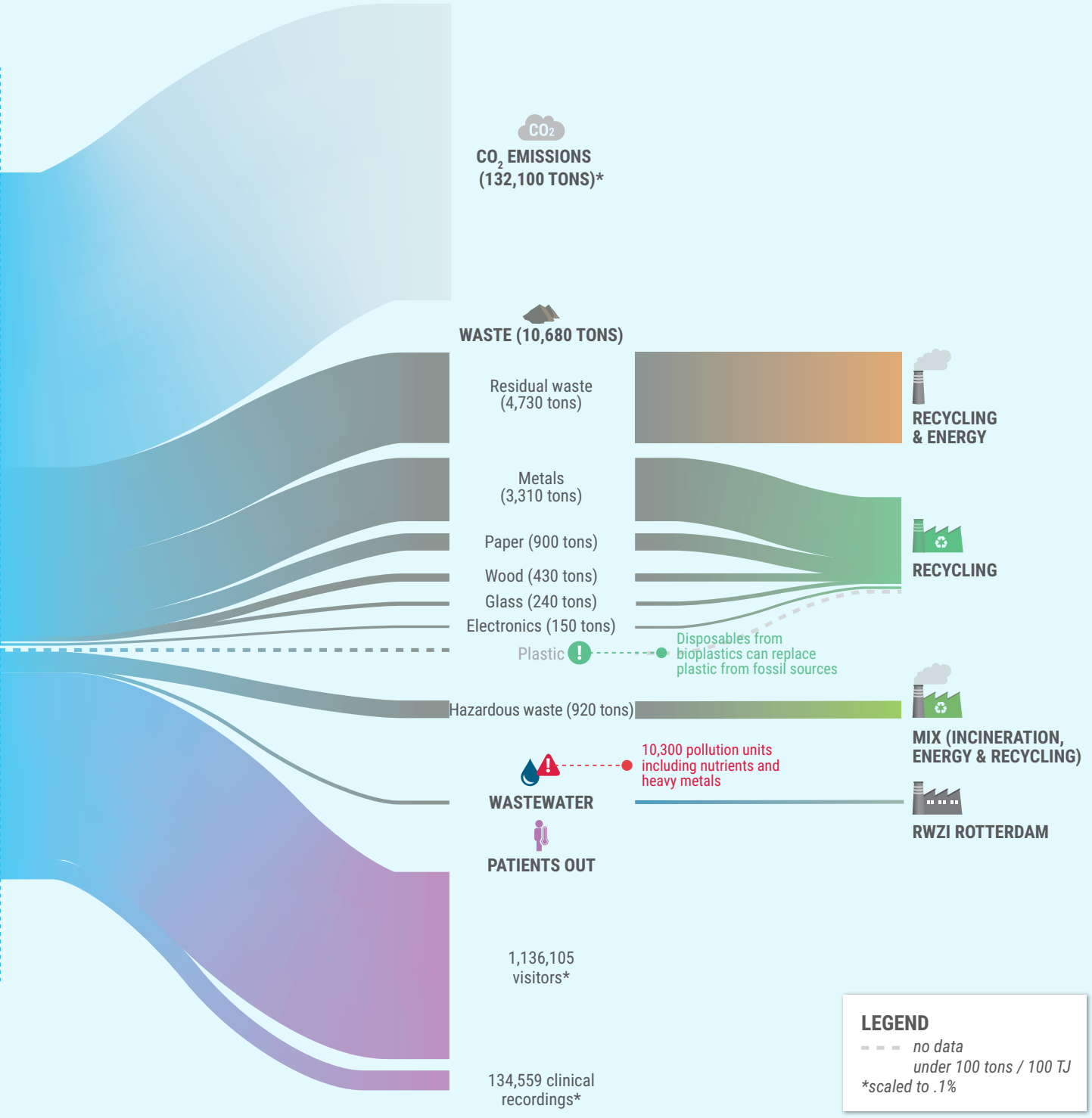


Figure 27: Materials Flows for Rotterdam's Hospitals

HEALTHCARE IN ROTTERDAM

Rotterdam is a globally emerging frontrunner in the healthcare and medical industry. The city is home to the Erasmus Medical Centre (MC), one of Europe's leading university MCs. The city offers high quality research facilities to both start-ups and established companies, including the Rotterdam Science Tower, LabHotel, and the ZorgBoulevard (a one-stop location for all aspects of care and well-being). The city is a hotspot for bio-energy, technology, virology, and pharmacology, and has strong connections with medtech, applied chemistry and supporting activities for the life sciences. The medical sector in Rotterdam consists of 2,800 companies, 10 hospitals (five of which are for specialising), and 13 care institutions. For this MFA we only have included the hospitals in Rotterdam. The dates are extrapolated from data available from the Erasmus MC and supplemented where necessary with data from other hospitals.

1.27 MILLION VISITS TO ROTTERDAM HOSPITALS IN 2015

In 2015, hospitals in Rotterdam had a total of 1.27 million patients visit. 1.14 million of these were patients for the outpatient clinic. 135,000 admissions took place in 2015. Erasmus MC is by far the largest hospital. These visits of course have an influence on the metabolism of hospitals. Energy is for the most part building-bound, but water, medicine and disposables are dependent on the number of patients. Each visit was associated with almost one kilogram of medical disposables such as infusion bags, needles and plasters. Furthermore, an average of 775 litres of drinking water was used per visit, mainly for plumbing, hygiene, cleaning, the cooling towers and a small quantity for drinking and other uses. A total of more than 10 000 tons of waste was generated, of which 920 tons is hazardous waste which should be treated separately. A large part of the waste is metals. This is mainly old furniture, which must be replaced regularly. In addition, a large stream of waste leaves hospitals in mixed form, which can therefore not be further recycled and is burned.

LARGE ENERGY USERS

Although the energy demand of hospitals has fallen in past years, hospitals still use an enormous amount of energy. 730 terajoules electricity is comparable to the energy usage of more than 84,000 Rotterdam homes. The heat demand of hospitals supplied by gas and district heating is as high as about 21,700 average households. Since the energy is not from renewable energy sources, energy demand from hospitals leads to a lot of CO_2 emissions.

CIRCULAR JOBS IN HEALTHCARE

The healthcare sector accounts for roughly 48,000 jobs and is thus a very important employer for Rotterdam. The hospitals - with emphasis on Erasmus MC - form par excellence the biggest employers. Of all jobs in the healthcare sector, only 3% are circular, which amounts to a small 1,300 jobs. Although the healthcare sector is an important employer, it provides few jobs in the circular economy. On the one hand, this has to do with the fact that the healthcare sector has in no way direct circular activities and, on the other hand, that healthcare laws and regulations are very strict and circularity is more difficult. The current circular share of the Rotterdam healthcare sector is currently limited to interaction with waste processing companies.

ENVIRONMENTAL IMPACT OF ROTTERDAM'S HOSPITALS

The healthcare sector is seen economically as one of the strongest sectors in the Rotterdam region, and one of the largest employers. The Erasmus MC is the biggest employer in the city. Healthcare institutions are natural agglomerations of purchasing and waste flows; a node of now mostly linear flows. The hospitals in Rotterdam have been working for years to make their business operations more sustainable and are frontrunners in the Netherlands and Europe for, among other things, applying the latest technologies. Yet there are still plenty of opportunities to make the hospitals in the city more circular.

First, the energy flows of the hospitals largely come from non-renewable sources such as natural gas and electricity from coal and gas. In addition, the waste chain is very problematic. Some waste streams can be prevented (such as unnecessary packaging materials), but reusing waste materials in healthcare is not easy. This is partly due to regulations on patient safety and hygiene. In part, the residual flows and industrial waste in healthcare are comparable to household waste. In principle, this is largely recycled. But a big part of the waste in the healthcare sector is classified as (infectious) hazardous specific hospital waste (SZA) and can not be recycled yet. This one stream can only be burned.

Wastewater also contains more and more residues of medicines that are difficult to remove. To become circular, it is essential to contain the emissions of these medicines. This may be achieved by stepping up prevention, so that fewer medicines are needed at all. But there is also a lot to be gained in dealing within residual

waste from medication. It is now often a problem that pharmacies prefer not to take back medicines, because it costs them money to dispose of them. This leaves the patient with the problem, who usually throws away medicines or flushes them down the toilet. This way a lot of hazardous and chemical substances enter waste water or even surface water.

One of the main underlying causes of hospital waste streams is naturally the number of patients. And since health of the Rotterdammers is below the average, more attention should be paid regarding preventive care in order to reduce the energy, water, material and waste streams, but also in order to increase resilience of society. We will achieve true systemic impact not only through the interventions that solve environmental problems, but by focusing on measures to drastically reduce the number of patients in the coming years. Therefore, the following are interventions that specialise in this very area.

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INTERVENTIONS FOR A CIRCULAR HEALTHCARE SECTOR

A circular healthcare sector without waste is quite a challenge. Safety must remain paramount. Yet there is already a lot happening in this area in the city, and there are ambitious plans. Care institutions such as Erasmus MC are taking the lead. The most significant bottlenecks found in the energy flows are on the purchase side and in dealing with waste streams. Understandably, hospitals and healthcare institutions have many products, such as cleaning products, textiles and disposables, all with short lifespans. In addition, it is important to look critically to reduce the number of patients, and make sure that if they have to come to the hospital, their stay is kept as short as possible. In Figure 29 we elaborate on a number of interesting interventions.

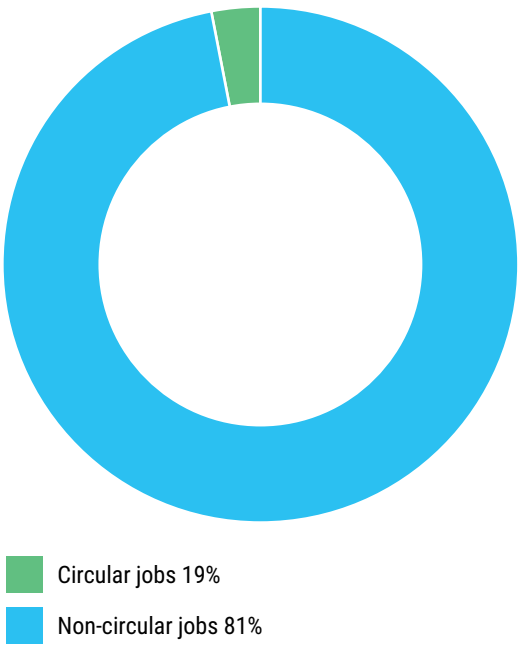


Figure 28: Jobs in the healthcare sector

NR.	IMPACT FOCUS	INTERVENTION	TYPE	FEASI-BILITY	POTEN-TIAL FOR IMPACT REDUC-TION	POTEN-TIAL FOR JOB CRE-ATION	POTEN-TIAL FOR JOB LOSS	LINK TO VISION
D1	Systemic measure	Improve nutrition in hospitals	Reduce	High	Medium	Medium	Neutral	Materials, health and welfare
D2	Systemic measure	Improve health of inhabitants	Reduce	Medium	High	High	Neutral	Materials, health and welfare
D3	Systemic measure	Create healthy surroundings	Reduce	Medium	Medium	Low	Neutral	Materials, health and welfare
D4	Drinking water	Reduce the number of taps	Reduce	High	Medium	Neutral	Neutral	Materials, energy
D5	Cleaning products	Car wash for beds and other furniture	Reducer	Medium	Medium	Low	Medium	Materials, biodiversity and ecosystems, health and welfare
D6	Waste water	Implement the pharmafilter	Synergy	High	High	Neutral	Neutral	Health and welfare, energy
D7	Residual waste	Better separation of waste	Synergy	High	Medium	Medium	Neutral	Materials
D8	Cleaning agents	Buy cleaning products with an eco-label	Production and purchasing	Medium	Low	Neutral	Neutral	Biodiversity and ecosystems
D9	Metals	Lease structure for furniture	Production and purchasing	Low	High	High	Neutral	Materials
D10	Energy	Purchasing sustainable energy	Production and purchasing	High	High	Neutral	Neutral	Energy

Figurer 29: Possible healthcare sector interventions

REDUCE

Interventions that focus on reducing the material requirements of hospitals have to deal with the complicating factor of risk (or the perception that there is a risk) that reducing material use in a hospital itself can translate to lower quality care. Care provision staff must, of course, have at their disposal all the resources needed to provide the care that the patient. An important way to reduce material flows and waste streams in hospitals, without jeopardising the quality of care, is to improve the health of the inhabitants. New data from the RIVM and the Municipal Health Service show that the health of the average Rotterdammer is below the national average and below the average of other major cities in the Netherlands (Statline, 2017b). Also, the percentage of the population that is no longer fit for work for health reasons is a bit higher than in the rest of the country, both in terms of young and old people. One of the reasons for this is that in the city more people smoke, and more people are suffering from an alcohol addiction (City of Rotterdam, 2017a). The percentage of overweight people is also much higher than in Amsterdam or Utrecht.

The first set of interventions therefore focus on improving the overall average health of the inhabitants of Rotterdam, with the idea that this will indirectly lead to a reduction in the number of patient days, which translates directly into a reduction in the material requirements of Rotterdam hospitals, and a reduction in environmental impact.

Patients visits: 1.27 million

These interventions are aimed at improving the speed with which patients are treated and healed within hospitals, reducing time spent in hospital, and in the long run improving the overall health of Rotterdam's citizens so that there fewer hospital visits are needed.

INTERVENTION D1.

IMPROVE THE NUTRITION OF PATIENTS IN HOSPITALS

- **What:** The influx of materials and water into Rotterdam hospitals is strongly correlated with the number of patients in the hospital and the average duration of their stay there. Shortening outpatient visits can therefore have a strong effect on a hospital's environmental footprint. Good, healthy and varied nutrition can contribute enormously to the recovery of patients.

- **Impact:** The effects of good and healthy nutrition in hospitals are significant. Patients who have not received good food stay on average two to three days longer in hospital (Murphy, Tracy, and HealthCareCAN Consultant, 2017).
- **Feasibility:** Improving the nutrition can make logistics a lot more complicated. But there are examples to learn from. The hospital Gelderse Vallei in Ede, for example, has created an extensive menu and works with flexible eating times. Patients can therefore eat when and what they want. That patients themselves can choose what they like or what they are used to, appears to be important for recovery. Patients eat more, and better, because of this. The hospital also does research into protein-rich snacks for the elderly in cooperation with Wageningen University.
- **Employment:** The effect on jobs is not measured quantitatively, but directly there are more jobs in the kitchens of hospitals, and this indirectly stimulates the economy across the board, because patients recover earlier.
- **Relevance to Rotterdam's context:** There are not many hospitals in Rotterdam that explicitly focus on innovation in nutrition, but certainly given the diverse background of the population, it may be interesting for the city to experiment with food in the hospitals.

INTERVENTION D2.

IMPROVE THE HEALTH OF CITIZENS

- **What:** In comparison to the rest of the country and other major cities the health of Rotterdammers can be improved even further. The number of hospital visits can be reduced by, for example, launching comprehensive information campaigns to help raise awareness of the importance of a healthy diet and enough exercise. Also, campaigns could help to stop citizens smoking, but health can also be improved by focusing on interventions that improve air quality.
- **Impact:** The number of hospital treatments per inhabitant of Rotterdam was 13% higher than the national average (Public health care. 2017) in 2010. If the campaigns can bring treatment volumes down to the national average, substantial savings can be achieved.
- **Feasibility:** This intervention requires an integral approach and a longer timeline. Health improvement will not be noticeable in the short term. The environmental zone that the city introduced last year shows a positive effect on air quality. Eindhoven is now running a test to purify the air with particulate filters. Other smart technology to better monitor air quality is now being tested in Utrecht. Advertisement boards from JCDecaux contain sensors that measure indoor air quality in real time in the city centre.
- **Employment:** Improving health of the population will require a lot of coaching and information. Setting up an information campaign will at most offer a few people direct work, but this can trigger a health wave that indirectly creates a lot more employment.
- **Relevance to Rotterdam's context:** The municipality is aware of the room for improvement and will bring these into play in the policy for Public Health 2016-2020 and come with solutions to tackle problems (City of Rotterdam, 2016b).

INTERVENTION D3.

CREATE A HEALTHY ENVIRONMENT IN HOSPITALS

- **What:** A healthy and pleasant environment can also contribute to a faster recovery for patients. Especially spaces with lots of green, sufficient daylight, healthy air and low noise pollution can have a positive impact on patients and staff (Huisman et al., 2012), resulting in fewer patient days, and a lower material requirement.
- **Impact:** As with the first intervention, this intervention must contribute to patients being dismissed earlier, which has an impact on the material and water usage at the hospital. There are also indications that the health of the staff improves when there is a lot of green space.
- **Feasibility:** Several hospitals (in Rotterdam) apply these principles to new buildings. The application of this in existing construction is somewhat more limited, but the air quality in the building can be improved there.
- **Employment:** The potential for job creation is low, although some jobs can be created for maintaining the greenery. This intervention also creates demand for interior designers.
- **Relevance to Rotterdam's context:** Erasmus MC has applied a number of these principles to the construction of new buildings in 2018. There is a large green roof and there will be many individual rooms so that patients can have an optimal night's sleep.

Drinking water: 886,500 m^3

Hospitals consume a lot of water -- about 775 litres water average per visit, is shown by the analysis. To reduce drinking water consumption there are several options that can have a major impact. Water-saving taps and efficient toilets are, for example, effective interventions which can drastically reduce water consumption.

INTERVENTION D4.

REDUCE THE NUMBER OF TAPS WHICH MUST BE FLUSHED THROUGH

- **What:** Water saving often remains underexposed in hospitals. After all, hygiene is paramount. Yet there are many opportunities to reduce water consumption without having any effect on health, or patient and staff safety. An example of how this can be done is by reducing the number of water points that need to be flushed weekly in order to to prevent a legionella outbreak.
- **Impact:** The Martini Hospital in Groningen wanted to substantially reduce its water consumption by 2015 (Martini Hospital, 2015). Through its efforts, the hospital managed to save about 25 million litres of water per year. That is 25% of the total drinking water consumption.
- **Feasibility:** This intervention requires adjustments on the pipes. Some of these can probably be done without thorough renovation, but other parts probably needs to be combined with planned conversions.
- **Employment:** This intervention mainly provides more temporary jobs in terms of installing technology and adapting the pipelines.
- **Relevance to Rotterdam's context:** The Port hospital in Rotterdam already has water-saving taps installed, but the impact of this is not known.

Cleaning products: 1,030 tons

Of course there are many detergents used in hospitals to wash hands, mop floors and clean equipment. In terms of reduction, there is a new intervention that is already being applied in the Erasmus, allowing the use of less cleaning agents and even increasing hygiene.

INTERVENTION D5.

CAR WASH FOR BEDS AND OTHER EQUIPMENT

- **What:** Erasmus MC is the first hospital in the world to install a car wash for beds. With compressed air and a high-pressure cleaner, beds are optimally cleaned by robots. As a result, there is no more detergent needed to clean the beds. There are also ideas for the car wash to be extended for other utilitarian objects in the hospital that needs to be cleaned regularly.
- **Impact:** The impact of the bed-washing line on the total quantity of detergents used for cleaning calls for further quantitative elaboration.
- **Feasibility:** In Erasmus, this intervention already appears to be feasible, but more financial research is needed to see if this is also valid for smaller hospitals in the city.
- **Employment:** Robotisation has a negative connotation in relation to employment. This way of cleaning can make sure that fewer cleaners are needed. But on the other hand create other jobs in automation and the production and design of the devices. In addition, it may also release resources that can mean more hands at patients' bedsides.
- **Relevance to Rotterdam's context:** Erasmus MC is already a worldwide leader, but this technique could be shared with other hospitals in the city and can be extended so that there are even fewer detergents are required.

SYNERGY

Much of the waste in healthcare is likely to be largely inevitable to working safely and efficiently. It is therefore important to ensure that waste created is reused at the highest possible quality. In the area of synergy in hospitals there are two main streams that can be improved: waste water and residual waste.

Waste water: 10,300 pollution units

One of the greatest impacts associated with hospitals is the high number of pollutants contained in the waste water, for example bacteria, medicines, and other harmful substances which (unintentionally) get flushed into the waste stream. Many of these substances, in particular medicines, are difficult to remove from the water. By addressing this impact at source, purification of wastewater is much more effective than central treatment.

INTERVENTION D6.

CLEAN ALL THE WASTE WATER WITH PHARMAFILTER

- **What:** To reduce the pollution of waste water from hospitals, there is a new Dutch technology available. Pharmafilter is a company which has developed an installation specifically for hospitals, which purifies wastewater and all kinds of other waste streams, converting it into energy and also supplying clean drinking water. The first installation was installed a few years ago in the Reinier de Graaf Hospital in Delft.
- **Impact:** After processing, drug residues and endocrine disrupting residues are no longer traceable in the

waste water. Additional advantages are that staff can also work more efficiently. The wastewater is so clean that it can be reused again for flushing the toilets, for example. In Reinier de Graaf Hospital this means saving 40% of drinking water (Symposium Water & Health, 2017).

- **Feasibility:** Pharmafilter has already been successfully applied, but it does require adjustments to the infrastructure of the hospital. Erasmus has been talking to Pharmafilter for a number of years and the technology will be implemented in its new building in 2018.
- **Employment:** This intervention has no direct impact on employment, but strengthens the position of Rotterdam and Zuid-Holland as leaders in the field of sustainability in healthcare.
- **Relevance to Rotterdam's context:** In 2016 there was already a Pharmafilter installed in the Franciscus Gasthuis. Erasmus MC will put the system into use in 2018. The Pharmafilter can also be used at other Rotterdam hospitals.

Residual waste: 4,730 tons

The residual waste generated by hospitals in Rotterdam is similar to the residual waste from almost 14,500 households. Better sorting of this type of waste can result in a higher percentage of it being reused at high quality.

INTERVENTION D7.

BETTER WASTE SEPARATION

- **What:** Residual waste from hospitals consists of organic waste and plastic. Through separating these waste streams, much higher quality reuse is possible - such as fermentation, composting and recycling - as opposed to incineration and energy production. In view of the large amount of waste that hospitals produce, they can play a leading role in Rotterdam.
- **Impact:** Approximately 6% of residual waste in the care sector is organic waste. 24% consists of plastic packaging and foils, and 10% is paper and cardboard that is not is well separated (Stimular, 2016; Ministry of Infrastructure and Water Management, 2016). By keeping everything strictly separated, residual waste can be reduced by 40%.
- **Feasibility:** Separating waste is a relatively simple process.There is no new technology needed, though possible practical objections should be examined.
- **Employment:** The potential for job creation through better separation of residual waste is minimal. The waste streams contribute indirectly to employment through high-quality processing of the flows.
- **Relevance to Rotterdam's context:** The Havenziekenhuis tries to separate all its waste, but it is not exactly known what the results and experiences have been.

PRODUCTION AND PROCUREMENT

The procurement policy of hospitals can have a major effect on the waste that is eventually generated, for example by choosing products that come from renewable sources or products which can easily become high quality again through being reused, repaired or adapted. In terms of interventions, there is a focus on three different types of flows: cleaning products, metals and energy.

Cleaning products: 1,030 tons

Large amount of detergents are largely unavoidable, but choice of detergents can also improve environmental impact.

INTERVENTION D8.

USE OF CLEANING AGENTS WITH AN ECO-LABEL

- **What:** Due to the high demands for hygiene in hospitals, many detergents are used. Reducing the use is often difficult because the safety of patients and staff may be at risk. But the impact that the cleaning products have on the environment can be curtailed significantly by purchasing cleaning products which have an eco-label. These types of products have an additional advantage in that they often have fewer allergens that cause reactions to the skin of patients, if these are also used to wash patients.
- **Impact:** The impact of detergents with an eco-label depends on the degree of applicability. Further research should show what the total effect might be.
- **Feasibility:** Not all cleaners can be replaced by biodegradable variants. Think of use in operating theatres or sterile environments. But for regular cleaning work such as mopping, cleaning toilets and in kitchens, detergents with an eco-label can work well. Also, ecological soap can be used to wash patients.
- **Employment:** This intervention has no effect on the number of local jobs. However, it does stimulate the production of responsible cleaning products.

- **Relevance to Rotterdam's context:** The Port hospital already uses ecological soaps and was, partly because of this, the first hospital in The Netherlands to receive a Green Key certificate in 2016.

Metals: 3,310 tons

The metals that hospitals output in the form of waste come mainly from old furniture. This is not a constant flow, but fluctuates over the years. It is a remarkably large flow and that is probably due to the fact that there is so much metal-based furniture in hospitals (beds, chairs, tables, etc.).

INTERVENTION D9.

LEASING MODELS FOR FURNITURE

- **What:** One of the largest waste streams from hospitals are metals. According to the CSR report of Erasmus MC, this is, to a large extent, old furniture. By leasing instead of buying furniture, the manufacturer maintains ownership. This provides an incentive for the producer to provide good quality models which are also easy to repair and replace or can be given a new life or recycled.
- **Impact:** The metals are now being recycled and melted down into new products. This is a better destination than landfill or incineration, but furniture leasing can extend the life of the frames and legs of the furniture.
- **Feasibility:** There is a lot of attention for these new business models. Turntoo of Thomas Rau focuses specifically on circular equipment. For hospitals no specific examples are yet known.
- **Employment:** This type of leasing model can create many new circular jobs. The maintenance, repair and management of furniture is quite labour-intensive.
- **Relevance to Rotterdam's context:** These kinds of leasing models are still quite new, not only in Rotterdam but in the Netherlands and even abroad. It's possible that the hospitals in Rotterdam or eventually Zuid-Holland could join forces to set up such a lease structure with suppliers.

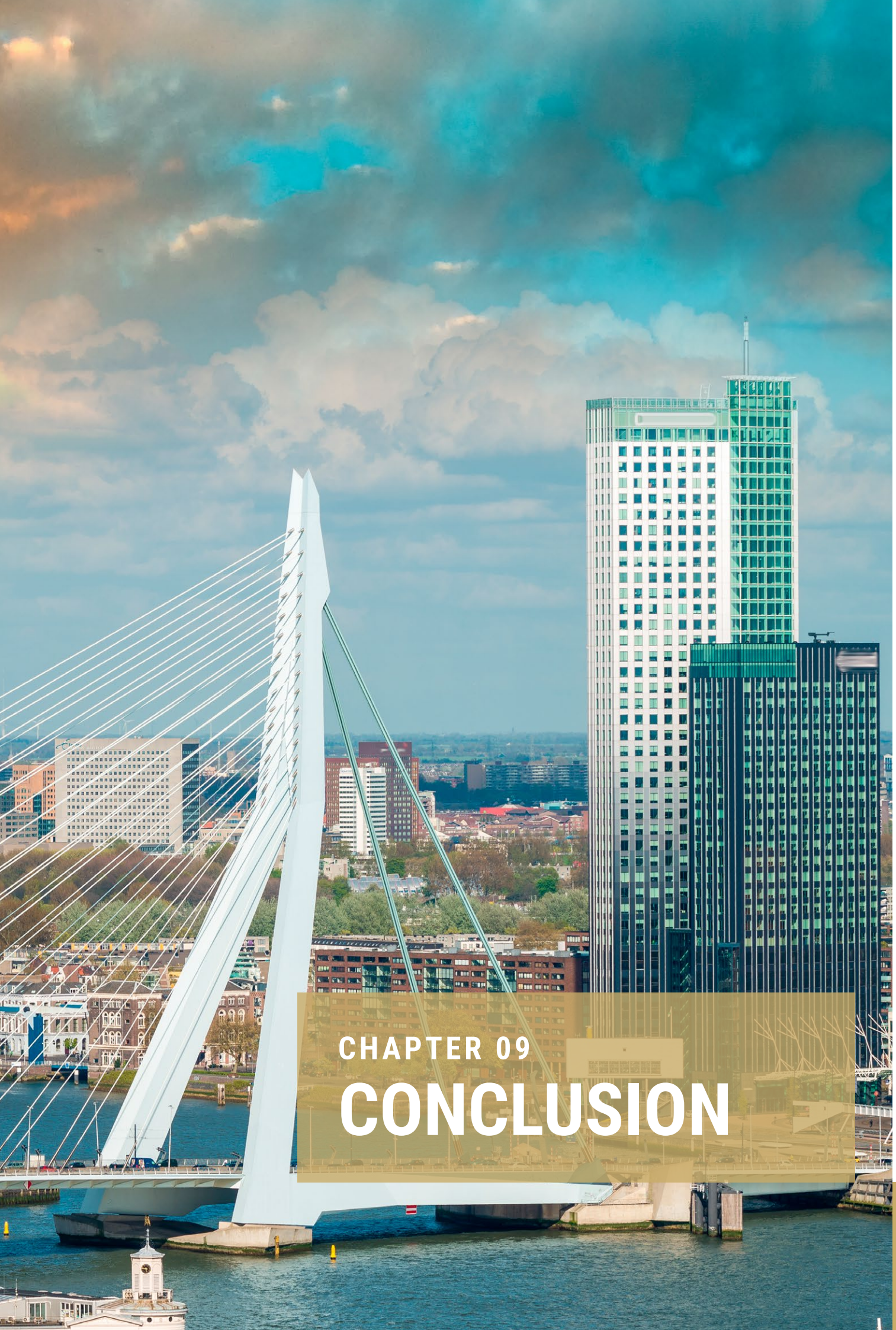
Energy: 1,370 TJ

Energy consumption in hospitals is relatively high and electricity comes mainly from fossil fuels. By purchasing energy differently, a substantial amount of emissions can be reduced.

INTERVENTION D10.

PURCHASE RENEWABLE ENERGY

- **What:** To reduce energy use emissions, hospitals should switch to green energy. Local production with solar panels on the roof primarily have a symbolic value. The 845 solar panels on the roof of St. Jansdal hospital in Harderwijk supply about 200,000 kWh per year (St Jansdal Hospital, 2017). That is just as much as the average electricity consumption of 81 Rotterdam households, but only 0.1% of the total electricity consumption of hospitals. Purchasing wind energy can therefore have broader impact.
- **Impact:** Because in producing electricity almost 50% of the potential energy is lost, the CO_2 emissions for one kWh of electricity is much higher than one kWh of gas. Purchasing 100% sustainable electricity can reduce the total CO_2 emissions from hospitals by 100,000 tons. In other words, a saving of 75%.
- **Feasibility:** The OLVG has been 100% operational on green wind energy since 2009 and is therefore at the forefront of the Netherlands (OLVG, n.d.). This example in mind, it should also be possible for Rotterdam hospitals to switch to renewable energy.
- **Employment:** Procurement of renewable energy has no impact on direct local jobs. However, since hospitals are large consumers, this encourages employment in the renewable energy sector.
- **Relevance to Rotterdam's context:** Rotterdam hospitals are not yet doing much in the field of renewable energy, but elsewhere in the country, hospitals are taking steps towards this goal.



CHAPTER 09

CONCLUSION

CONCLUSION AND RECOMMENDATIONS

In this first phase of this research we have provided a systemic overview of Rotterdam's performance in the are of circular economy, a holistic set of indicators, and identified interventions that the city can initiate or support to become more circular and reduce waste flows.

It is important to note that many of the interventions that we have identified are already being implemented to a certain extent in the city. This is a good sign, showing that Rotterdam is already taking concrete steps in the right direction. Our analysis highlights the action points that remain a priority. Although some activities have been going on for years (for example attempts to achieve more separated waste collection streams), our recommendation is to make a number of strategic steps for greater impact on the entire sector. Waste reused for high value creation is where the potential for job creation can really be achieved.

INTERVENTIONS AND EMPLOYMENT OPPORTUNITIES

The City of Rotterdam is targeting 7,500 circular jobs created by 2030, which is 25% more than the current number of circular jobs in Rotterdam (31,000). For each of the proposed interventions, we show where there is potential for new jobs, and also where there might be job losses. An overall conclusion of our research is that the most of the interventions create additional jobs in the region. Circular activities in the 'Synergy' category have the greatest opportunity to create job creation, while reduction strategies often remained neutral in terms of job potential.

RECOMMENDATIONS BY SECTOR

There are plenty of opportunities for Rotterdam to become a zero-waste city and generate 7,500 new jobs. But it requires investment in innovation and cooperation to reach these ambitious goals. In the following sections we summarize the key conclusions of the analysis together for each sector, focusing on the measures which simultaneously:

- Reduce the amount of waste (including all sub-optimal applications of resources such as combustion and low-grade recycling)
- Reduce the environmental impact
- Improve the health of the residents structurally
- Create new jobs that contribute to a circular economy

AGRI-FOOD & GREEN FLOWS

From the analysis of possible strategies for the agrifood sector in Rotterdam, it appears that there are various ways to close most leaks in the current linear system. In particular, a combination of interventions is necessary to bring about systemic changes, although some are more difficult to implement than others. Most interventions result in extra circular jobs. One of the most important measures is the activity to introduce policy measures and systems that stimulate separate waste collection, such as Pay-As-You-Throw and door-to-door Bio-waste collection. Without the necessary investments to implement these interventions it will be impossible to take the next steps towards a circular material management system.

As soon as separate collection methods are a reality, the next essential step is to implement and broaden processing techniques for bio-waste. This includes composting, Waste-to-Chemical production, and Biogas Production. The proposed food waste reduction measures can prevent up to 50% of the current volumes of food waste, which can lead to significant impact savings and new economic value, and provide the poorest residents of Rotterdam with much-needed help. These approaches do not generate significant employment, but do provide systemic benefits such as reduced greenhouse gas emissions and less land use. In addition, there are strategies for increasing local sustainable food production and incentives for healthier and more sustainable diets that can lead to large upstream impact reductions and stimulate new local economic clusters. These strategies can build on existing momentum among Rotterdam entrepreneurs and further improve the image of the city.

CONSTRUCTION

The analysis of Rotterdam's construction sector shows that it is still very linear. It would be a significan job for the construction industry to make the transition to a zero waste sector within 10 years. But there are also a number of significant opportunities to stimulate the transition to a circular economy.

In line with the recommendations of the Netherlands Environmental Assessment Agency, the building sector in Rotterdam can be a nice testing ground for fiscal greening. Taxing materials instead of labor does

not just take care of circular revenue models and sustainable construction, but also has the potential to create structural employment for the city. In addition to these systemic measures, it is particularly important for Rotterdam to reduce building and demolition waste, through its lifespan of buildings and reduced scrapping permits, as long as safety, quality of life and advancement in the housing market do not get in the way. If Rotterdam could reduce the percentage of demolished homes by half, that makes a difference on an annual basis of some 190,000 tons of construction and demolition waste. If the city could achieve the same percentage of demolished homes as occurs in The Hague, then 350,000 tons of waste streams would be saved annually.

When there is need for demolition, Rotterdam can create new jobs and value by structurally stimulating circular demolition because this is a much more labor-intensive process then conventional demolition. Through circular tenders, the city can also ensure that activities in the future yield even more benefit.

Where demolition waste can not be prevented, city-wide initiatives such as circular concrete can make a big difference and lead to annual savings of about 75,000 tons of concrete. Circular demolition and new construction will still be coupled with logistics and transport movements. This could mean a central construction hub on the outskirts of the city, in combination with clean transport to and from the construction site, ensuring less nuisance for residents, less air pollution, more efficient building, and lower construction costs. Finally Rotterdam's construction sector emissions could be reduced by 12%. This does not only save time and money, but also ensures a more sustainable and cleaner city and more employment.

If the sector really wants to transform from one of the biggest consumers of materials and producers of waste, they have to target value creation in multiple areas over the long term, as well as reducing a combination of measures that have negative side effects throughout the supply chain.

CONSUMER GOODS

The consumer goods sector is the most complex of the sectors we have studied, for the most part because there is insufficient data available on the consumption habits of people. We recommend that Rotterdam takes steps to collect more data to better understand this topic.

Despite the data limitations, it seems almost 50% of the metals and a majority of the scarce materials are in this material stream. Because many consumer goods also consume a lot of energy, there is significant overlap between objectives for material management and material recovery (for example, extending product life cycles through sub-platforms) and ensuring products are replaced when needed.

Packaging materials account for 35% of all current waste streams in this sector, mostly being burned for energy production. The total amount of packaging can be reduced to 40% through changes such as waste-free food stores implemented as the norm in the city, which would see a total reduction of 30,000 tons of materials per year. The packaging that remains would ideally be designed to be biodegradable, or for optimal recycling.

Although this involves a systemic change and adjustments to distribution chains would be necessary beyond the borders of Rotterdam, the city can still stimulate local innovation and new business around this design challenge. Pay-As-You-Throw levies and door-to-door collection could see a reduction in mixed waste flows of 87,000 tons per year.

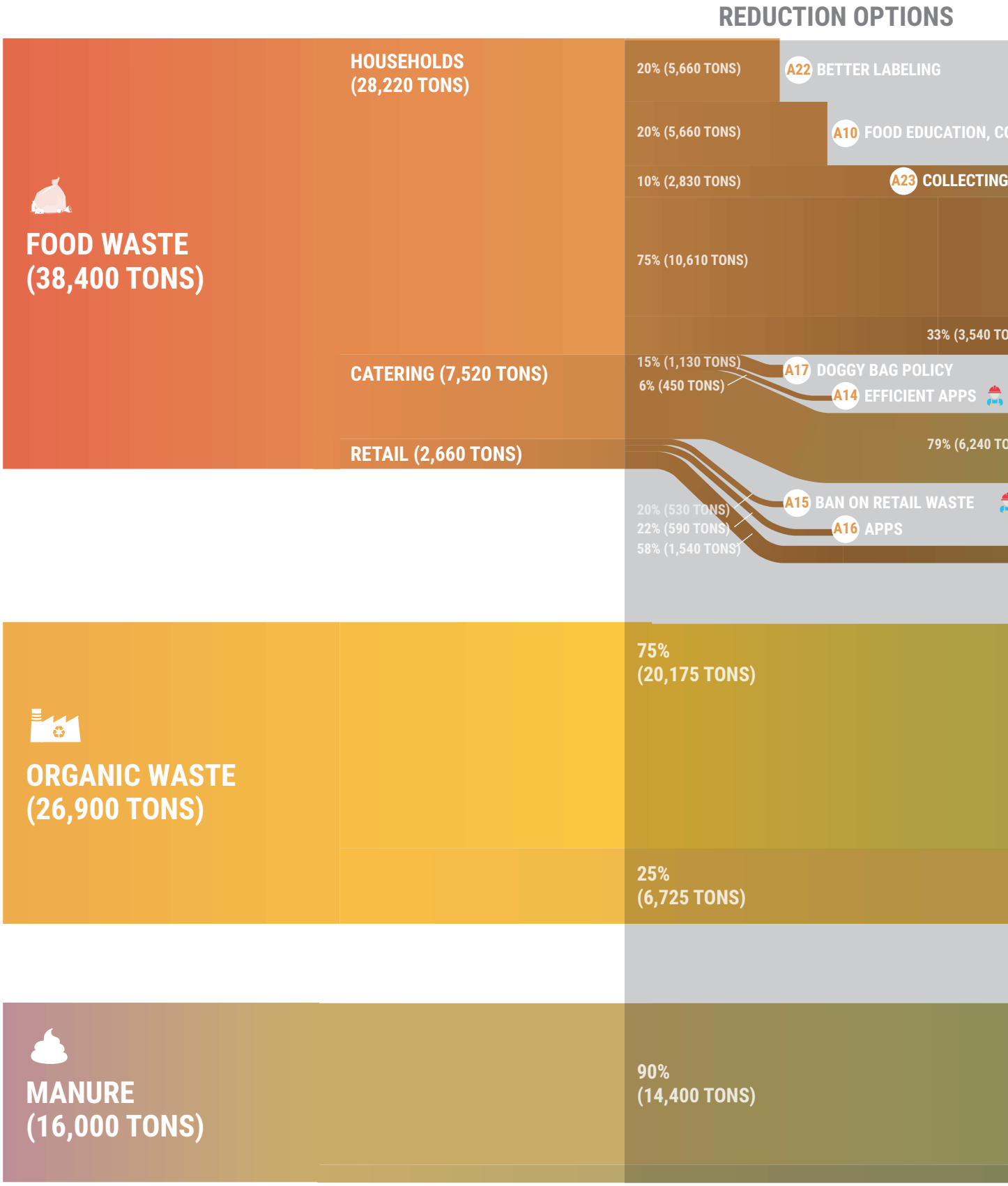
In addition, we recommend a local Upcycle Mall and specialized recycling facilities for textiles, beverage cartons, diapers, plastic, and car tires. Together these measures can lead to the reuse or recycling of a total of around 35,000 tons of materials. Not all of these facilities are suitable for the scale of the city level of Rotterdam, but establishing them close to the port area can also serve the wider region, since the port already has an existing logistics hub.

This last category of interventions also has the greatest potential for job creation for workers of all levels of education. Further research, in combination with more detailed information about the exact composition of the flow of different consumer goods, are needed to show how feasible the different interventions are.

HEALTHCARE

Hospitals in Rotterdam are leaders in the field of sustainability, but much can be improved. The healthcare sector accounts for roughly 48,000 jobs and is thus a very important employer for Rotterdam. Of all jobs in the healthcare sector, only 3% are circular, which amounts to 1,300 jobs. Hospitals almost completely rely on non-renewable energy sources such as natural gas and electricity from coal and gas. One of the most obvious interventions is therefore to switch to renewable, sustainable energy.

ZERO WASTE AGRI-FOOD & GREEN FLOWS



METABOLIC CIRCLE ECONOMY

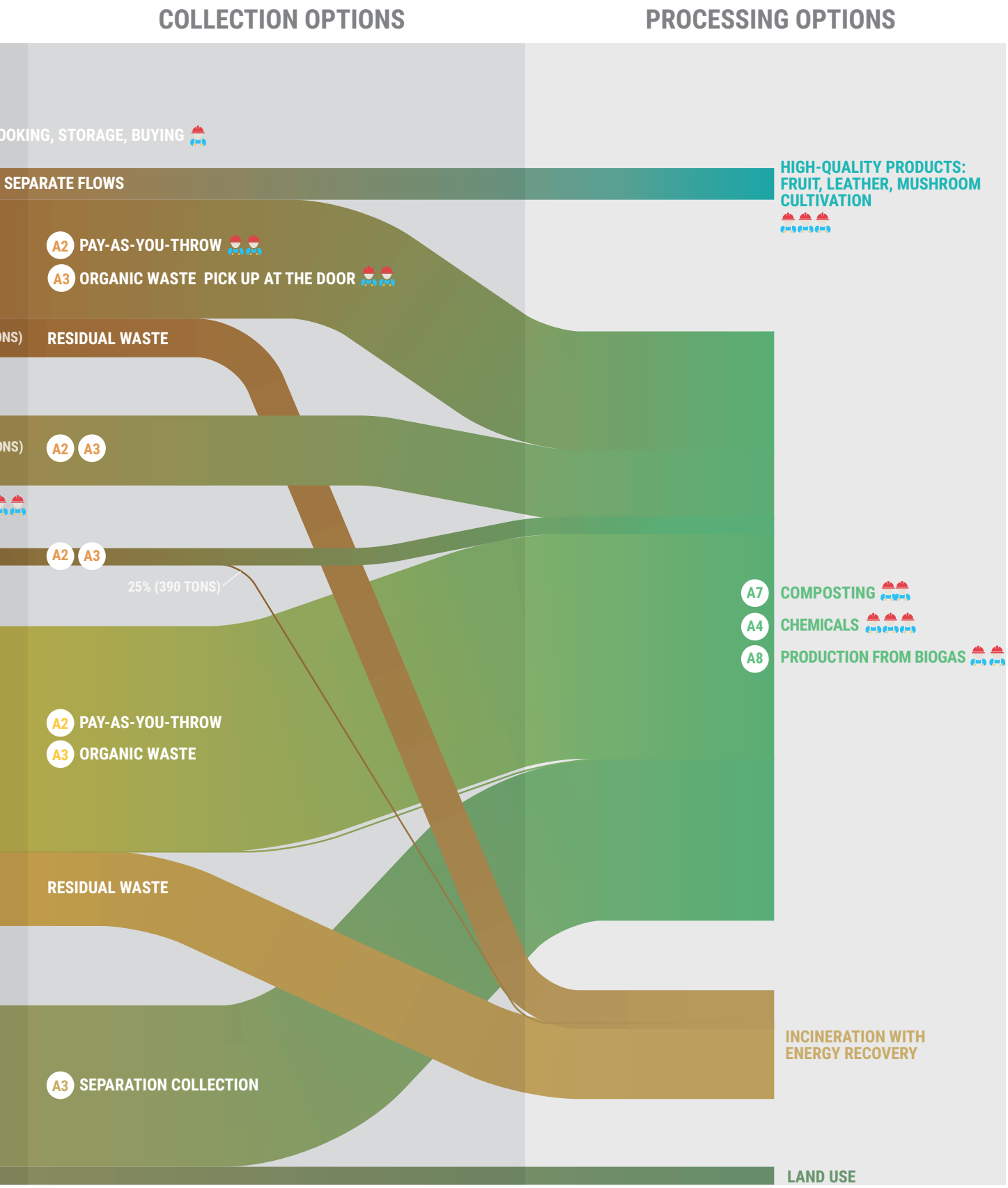


Figure 30: In this overview we illustrate the circular potential of some core interventions that were proposed in Figure 20 for a circular agrifood sector in Rotterdam. The waste reduction strategies can account for almost 50% of the reduction of food waste, and the total mass of waste that goes to incinerators for energy production can be reduced by 80%. The different interventions are labeled in the graph along with their potential for impact reduction, and icons indicating which activities have the greatest jobs potential.

A circular healthcare sector without waste is a challenge, and safety is clearly the top priority. The challenge for hospitals is tackling the total material flow, and to reduce the associated impacts without compromising on the quality of care. That is why it is important that preventative care becomes the norm. One of the main ways to do this is to ensure that people are initially less likely to become ill. The average health of Rotterdammers is below the national average, and below the average of other major cities in the Netherlands. This results indirectly in more hospital visits, and therefore in larger material requirements and environmental impact. In addition, another goal can be to try and reduce the average time that patients spend in the hospital, and through creating a healthy, soothing, natural, and pleasant environment within the hospital.

Healthcare institutions are natural agglomerations of purchasing and waste flows; a junction of mostly linear flows. One of the biggest impacts caused by hospitals is polluted wastewater, including residues of medicines that are almost impossible to get out of the water. An important way to reduce this environmental pressure for example would be to install a Pharmafilter, which prevents harmful substances and medicines from ending up in the wastewater, and do this so successfully that the wastewater after filtering can be used in the toilets of hospitals. In addition, many hospitals can reduce their water-related impacts by using ecologically-friendly cleaning products. It is also important that hospitals better deal with their waste streams, for example by contracting leases for their furniture, or by better separating their waste so that the value of the waste flows increases.

NEXT STEPS

Our analysis and list of possible interventions is only the first step in a larger process. In the next phase we will engage with stakeholders in each of the key sectors to scrutinize and refine the recommendations. Our findings will serve as input for a series of workshops. Participants will critically evaluate and possibly add their own ideas to our list of interventions. We will identify the bottlenecks for implementation and try to create cross-pollinations between sectors to meet these challenges.

The overarching goal of this process is to analyze and then proceed to action, and thereby harness the entrepreneurial spirit of Rotterdammers to take on this challenge and enjoy the fruits of a truly circular economy.

APPENDIX:

JOBS

METHOD - SHORT

The method applied is based on a subdivision of the economy into sectors. Based on the seven basic principles of the circular economy (Ramkumar, 2017, page 4), more than 1,400 sectors are distinguished and classified according to primary, supporting, and indirectly circular categories. All jobs in primary circular sectors are considered circular. However, this is not the case for the supporting and indirect circular jobs. For the latter two, the share of jobs that is approached circularly is due to the share of the turnover of these sectors going from and to primary circular sectors.

METHOD - IN DETAIL

Data

The data used for the analysis presented here comes from the City of Rotterdam. These databases were chosen because they contained employment data from all branches in the studied regions, high level of detail concerning sectors (SBI08, fourth digit) and location (postcode sixth digit). This makes it possible to analyze not only the nature of the circular employment, but also the geography of it.

Definition

The definition of circular jobs that was used is based on a literature study that Circle Economy performed to map the language use of the circular economy. In Making Sense of the Circular Economy: The 7 Key Elements terms and definitions of more than twenty organizations - NGOs, government agencies, academia, consultancy companies, etc. - are collected and categorized according to a framework of seven basic principles (Ramkumar, 2017, p. 4).

Definition of circular jobs

Circular jobs are all full- or part-time jobs that are related to one of the seven basic principles of circular employment.

Direct circular jobs are jobs that follow primary and supporting circular strategies.

Indirect circular jobs are jobs that facilitate direct circular jobs.

Sector Classification

On the basis of the above definition, all sectors from the databases are classified as primary circular, supporting circular, or indirectly circular. This classification is based on how well a sector is connected and contributes to the seven basic principles of the circular economy. From sectors that follow basic circular principles, it is assumed that all jobs are circular. However, this is not the case for supporting and indirect circular activities. For the latter it is necessary first to determine which share is circular or not. This is done through input-output analysis.

		BASIC PRINCIPLES	EXAMPLE SECTOR
Direct circular	Primary basic principles	Prioritize renewable sources	Renewable energy
		Lifetime extension	Repair
		From waste to raw material	Recycling
		New business models	Renting and leasing
	Supporting basic principles	Working together for value creation	Industry and network organizations
		Design for the future	Industrial design and architecture
		Integration of digital technology	Digital technology
Indirect circular			Education, government services

Input-Output Analysis The number of circular jobs within supporting and indirectly circular sectors is approximated by the share in the turnover of these sectors that goes from and to directly circular sectors. That share is determined on the basis of an input-output analysis. Input-output tables contain monetary values of transactions between sectors, with sectors in the rows providing services to sectors in the columns. In this way, a column represents all inputs of a sector, while a row represents all outputs of a sector. An input-output table thus shows dependencies between sectors, both as a customer of a sector and as a supplier of a sector. Based on the previous sector classification, the input-output tables are classified as illustrated in the following table.

	PRIMARY CIRCULAR SECTOR	SUPPORTING CIRCULAR SECTOR	INDIRECT CIRCULAR SECTOR	
PRIMARY CIRCULAR SECTOR		B Primary circular services delivered to supporting circular sectors		Row total
SUPPORTING CIRCULAR SECTOR	C Supporting circular services delivered toprimary circular sectors	D OSupportive circular services delivered to supporting circular sectors		
INDIRECT CIRCULAR SECTOR	E Indirect circular services delivered to primary and supporting circular sectors			
	Column total			

To determine the proportion of jobs in supporting circular sectors, the monetary value of primary circular services delivered to supporting circular services, supporting circular services delivered to supporting circular sectors, and primarily circular services delivered to supporting circular sectors are taken into account:

{(B + D) + (C + D)} / {row total + column total} =% supporting circular jobs

The share of jobs in primary circular sectors that can be determined as circular takes into account the monetary value of indirect circular services delivered to both primary and supporting circular sectors:

E / column total =% indirect circular jobs

These percentages are based on fixed input proportions, although the reciprocity of the interactions between industries leads to trickle-down effects that can not be recorded in the single, initial interaction. The exact magnitude of this multiplication effect is determined on the basis of a Leontief inverse in a Markov chain analysis of the sectors in the input-output tables after a Euro extra question in primary circular output. The resulting percentages are then applied per sector to the OIS and LISA data, controlling for productivity (output / jobs) to calculate the final number of circular jobs.

MFA METHOD

When drawing up the material flow analyses, numerous different sources were used and assumptions were made to arrive at the most complete overview possible. In this document we explain briefly what our methodology has been for each sector.

AGRI-FOOD MFA

The six different streams for the production of crops and animal products (water, phosphate, nitrogen, pesticides, antibiotics and animal feed) both within and outside the municipality are based on average Dutch values for food production and are used in the research of Van Odijk et al. (2016). The share of local production comes from the Central Bureau for Statistics (CBS) (Statline, 2017a). Local crop production is based on surface area and typical yields in the region. For the production of local animal products the number of animals is taken from Statistics Netherlands, and the distribution of milk / meat cattle is based on national data. The amount of manure comes directly from CBS data. Furthermore, it is assumed that this local food also serves local consumption. The total amount of food that must be produced for the city is based on the food consumption of the Rotterdammers, based on national averages from the National Institute for Public Health and the Environment (2016). Information about green space comes directly from the municipality itself. The size of the organic waste flow is based on data from the municipality and contains the green waste in the mixed household waste as well as the large garden waste supplied by private individuals. The industrial waste from the food processing industry is one of the streams with the least data available. 80% of the organic waste is composted and 20% used for the production of biogas (City of Rotterdam, 2016a). The CO_2 from crops and animals are based on national averages.

CONSTRUCTION MFA

Figures on newly built residential and non-residential construction and demolition in 2015 are based on data from Statistics Netherlands (Centraal Bureau voor de Statistiek, 2017). These numbers were then multiplied by the average number of square meters per type of building and supplemented where necessary with data from the municipality. The materials that enter and exit the construction sector come from a model developed by Metabolic, in collaboration with partners specialized in the Dutch construction sector, expressed in kilos per square meter. Embedded impacts and energy consumption also come from this model.

CONSUMER GOODS MFA

A list of consumer goods that fall within this scope is based on the largest waste streams, and there are also categories that have a high impact such as smartphones or electronic products. The data about the household waste comes from the City of Rotterdam. For industrial waste, we only included the waste that comes under EURAL code 20, which is described as urban waste and the household waste fraction of the industrial waste. On the inflow side, no specific data were available for Rotterdam and therefore estimates have been made based on national public data or commercial data (Statista, 2017). The number of cars entering and leaving the city comes from Statistics Netherlands, while the amount of fuel is based on the energy consumption of transport from the Climate Monitor. Due to the complexity and diversity of the flows there is still a large amount of unknown consumer goods. The remaining amount of unknown consumer goods is an estimate based on experience from Metabolic experts.

HEALTHCARE MFA

Material flow analysis of healthcare only focuses on the five large hospitals (Erasmus MC, Havenziekenhuis, Ikazia Hospital, Maasstad Hospital, Sint Franciscus Gasthuis), as hospitals are expected to be responsible for by far the largest amount of energy and materials. The energy data and the waste flows are based on the extensive CSR 2016 annual report of the Erasmus MC, which is by far the largest hospital in the municipality. In addition, a footprint per patient has been developed based on information from the Radboud hospital in Nijmegen. Due to lack of data on the purchase of materials, estimates have been made and these numbers may deviate from the actual inputs.

Overall MFA

The overall waste flow analysis of the city is based on data from the four sectors that have been specifically analyzed, and also complemented with energy and water data. The energy consumption is calculated on the basis of the total energy consumption excluding the electricity and heat demand (gas) of the industry and the fuels for shipping and fishing. The energy is calculated on the basis of the Climate Monitor at municipal and district level. By looking at these two scales, the energy demand of both gas and the port could be subtracted from the total energy demand of the municipality. The water flows are based on the Urban Metabolism Study on the occasion of the IABR from 2014.

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METABOLIC CIRCLE ECONOMY BLUE CITY

Phase 2:

DIALOGUE WITH STAKEHOLDERS

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INTRODUCTION

Rotterdam aims to become a leader in the circular economy. The city is targeting reduction of the primary use of raw materials by 50% in 2030 compared to today. In addition, Rotterdam wants to create 3,500 to 7,000 jobs that directly contribute to the circular economy. Today, there are already many leaders in the city who are working on initiatives and experiments in this field. But how do we make the circular economy something for everyone, and how do we achieve these goals within 13 years?

Metabolic, Economy Circle, Spring Associates and Blue City have been commissioned by the municipality to plan an optimal set of measures, projects and conditions so the government and industry can put their shoulders to the wheel.

WHERE ARE WE NOW?

Our analysis of the current circularity, waste levels and potential solutions are complemented by an assessment of employment opportunities. Based on this, a series of insights and possible interventions have been put together. Subsequently, during two stakeholder sessions at BlueCity, we received a lot of input, and developed concrete plans based on these interventions.

The first stakeholder session on February 6 was focused on making interventions more complete, to prioritize which interventions to bring forward per sector, and to map the barriers for each. On the basis of this session, 15 interventions were selected, on which we continued to work during the second session on February 14. There was also brainstorming about what is generally needed to speed up the transition to a circular Rotterdam.

IN THIS SECTION, YOU WILL FIND:

1. A list of sector-wide recommendations, comments and ideas that were brought to the table.
2. Following input from the two stakeholder sessions, a list of the seven chosen interventions for which a cost-benefit analysis has been calculated

WHAT DOES A CIRCULAR ROTTERDAM NEED?

SECTOR-WIDE RECOMMENDATIONS, COMMENTS AND IDEAS

During the second workshop, we asked the group of participants: "What does a circular Rotterdam need?" During the first workshop, there were several ideas and comments. Below is a concise overview of those ideas.

Policy and regulations

- Circular procurement in all areas is, according to the stakeholders, a must. Can the municipality become a 'launchpad' for the most innovative, circular products and services?
- Could there be a tax benefit that is linked to circular practices and processes? Or even more radical: can we design a value system that rewards and stimulates local access to circular raw materials?
- Permits and criteria are also mentioned as opportunities. For example:
  - Can we ban the establishment of polluting companies?
  - Can changing the demolition permit criteria improve reuse?
  - Can requirements be set in the area of circularity in the way festivals are organized?
- Subsidy assessment was discussed. Can this be done more on the basis of 'impact' of this task via a clear tool, using a trade-off matrix and a 'circular ladder' such as the CO_2 ladder.
- Assisting a cluster or waste streams with specialists from the professional field who work closely with the municipal organization. This is connected with the suggestion to work with chain directors that can help for example in community building through continuous dialogue.

Data

In general data and disclosure of information came in the form of four specific types:

1. An expansion and deepening of the current dataset - especially with regard to the residual flows of the business sector (and the impact potential of the better processing of these).
2. A transparent methodology/standard at the product and chain level
3. A tool that guides users through the available data and helps to make it useable.
4. A way in which there is a dynamic feedback at district level of what is going on in waste and material through the district.

Inclusiveness

A theme that came through in both sessions is inclusiveness. If we continue working on a circular Rotterdam, it will have to be done in a social way. An Upcycle Mall that provides employment for more vulnerable groups is an example of this.

Top-down and bottom-up

At various moments, it is emphasized that it is important that this task should be approached both 'top-down' and 'bottom-up', with attention to big business on the one hand and local communities on the other. Especially when it comes to awareness and inclusive processes, the latter should not be forgotten.

Start and accelerate

According to some stakeholders, it would be good if more resources were used to start and accelerate initiatives. Suggestions include a scaling-up fund for student projects, and a kick-start budget for circular projects.

Communication & PR

Some of the participants wanted more communication and campaigning about circularity in the city. They prioritized working on awareness - for example through visualizations of different streams of waste, or appointing a mayor of circularity. It is also indicated that initiatives in this area would have a lot of support so that they can reach a wider audience. A campaign could ensure that the stigma is removed from waste, as is suggested. Another idea that arises is to set up a Rotterdam Urban Mining Week (RUM/RUW), and to involve people across the city in the 'treasury of Rotterdam'.

Education

The importance of the interweaving of these ambitions into education is emphasized. Specifically, it would be good if there is a clear place where information can be gathered, where modules can be found, and where educational institutions can find content.

Community & podium

A cluster of suggestions and recommendations have formed around a need for community. For many initiatives, the conversation should continue (between each other and the City) and stimulate mutual connections between people working on a particular theme. Suggestions are for example a 'circular business club' and 'more BlueCity's'. The need is emphasized for places that offer a stage for people to come together and experiment.

Connection to the port

A large portion of the stakeholders actively miss the port in the analysis in Phase 1 and see possibilities to put activities in synergy with activities in the port. There is a question about the relationship and the connection of what happens in the port with what goes on in the city.

SEVEN INTERVENTIONS FOR COST-BENEFIT ANALYSIS

Based on the outcomes of the two stakeholder workshops, the following seven interventions were ultimately chosen for which we will draw up a cost-benefit analysis and roadmap in the third and final phase of this research.

Household waste and organic waste

Increasing the amount of organic waste that is collected separately is essential to realize high-quality reuse. How can residents be encouraged to separate their organic waste better? And what role can bio-fermentation play in the energy system of Rotterdam?

Valorizing uniform organic flows

The knowledge in the field of chemistry in the port is at an extremely high level, but developments in the processing of organic waste streams can be further improved. Which products could all be made from organic waste and could Rotterdam become the leader in this area?

Encouraging circular building

Instead of demolish building parts in a conventional manner, dismantling them means much higher-quality reuse is possible. To encourage this, disassembly must be taken into account during construction. How does the municipality stimulate this transition to circular building?

Setting up a marketplace for building materials

A physical marketplace for reusable building materials could reduce the use of new materials. However, there are still questions: how do you guarantee the safety of the use of the building materials and how do you ensure that the materials are used?

Better separating of plastic types

There are many different types of plastics in circulation, each with different properties. If these are mixed recyclables, high quality products can no longer be made. How could advanced plastic recycling take place in or around the city?

Starting an upcycle mall

Earlier this year, the first shopping center in the world was set up in Sweden for repaired and recycled products. Rotterdam could focus on a similar center. How can this Mall not only provide practical solutions, but serve as a new hub for creative development?

Installing pharma filters

To reduce the pollution of waste water from hospitals, one can implement 'Pharmafilters'. These purify the wastewater, partly convert this into energy and supply clean surface water. Two Rotterdam hospitals are already working on this. What is the potential of this innovation for the entire city?

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Phase 3:

ROADMAP AND COST-BENEFIT ANALYSIS

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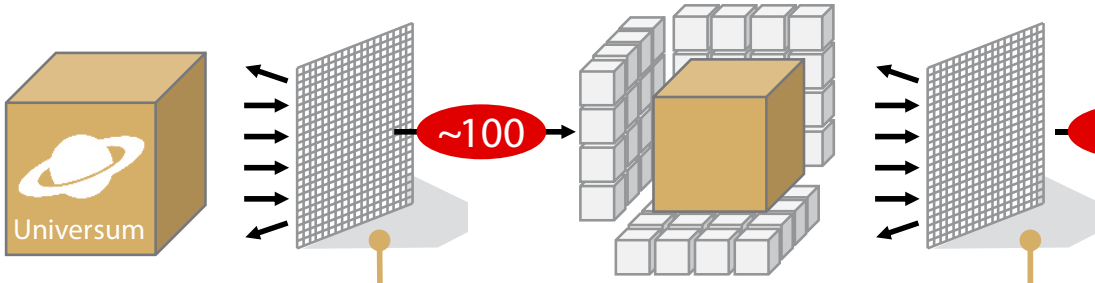
SELECTION PROCESS COST-BENEFIT ANALYSIS

Selec

Phase | Phase I

Output | Report

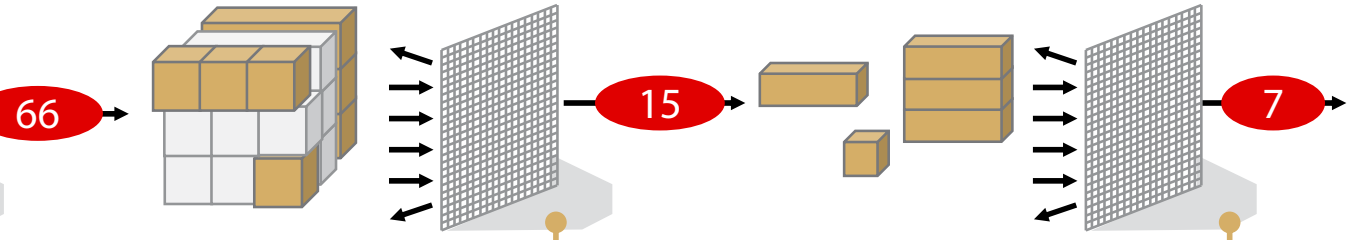


Scope | All interventions possible in a city | Relevant and feasiblein Rotterdam

ction process

Phase II
Stakeholder sessions

Phase III
Analyse & roadmap



Support from relevant stakeholders

Short-list of interventions [1]

- Household Organic waste
- Valorizing uniform organic flows
- Circular construction and demolition stimulation
- Marketplace to set up building materials
- Better plastic separation
- Launch upcycle mall
- Install pharmafilters

METHODOLOGY

Dimension	Costs and benefits	Circularity impact
Methodology	Costs are estimated by determining the investment costs (Capex, for example, material costs development, construction time) and operational costs (Opex, for example, maintenance costs). Benefits are estimated by determining operational savings (for example, in materials), added value in the chain and synergy with existing business models.	For each intervention, it is estimated what a realistic percentage of the material flow is saved, based on the Metabolic report from phase I. In addition, other material flows that decrease as a result of implementing an intervention, such as a reduction of raw materials or a decrease in CO_2 emissions are included.

- With the above methodology rough estimates are made of the impact of an intervention
- For each intervention, this general methodology is further specified and supplemented wit
- This approach ensures consistency in the way to estimate the potential
- The outcomes are tested with market parties
- The outcomes are indicative; more detailed research is needed for more accurate estimate
- The cost-benefit analysis is developed without assigning the specific stakeholders that ma business cases are not set up in a way that the municipality is the responsible party to ma cost-benefit analysis is to show what the different projects would cost and earn as a whole model has to be developed in which it is clear which parties make the investments and wh municipality or a private party.

Job creation

For job creation we look at both development and operational state. A distinction is made between jobs for high and low educated people.

Job creation is estimated by analyzing practical examples or using a percentage of the costs as salary.

h assumptions

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ake the investments or earn the profits. The
ke the investments. The purpose of the
e. Moving forward, a specific business case
ich ones get the return. This can be the

AGRI-FOOD AND GREEN FLOWS

AGRI-FOOD AND GREEN FLOWS

For the agrifood sector, eight interventions in total have been prioritized. The action points are based on basic conversations with stakeholders, workshops in Phases 1 and 2 and the barriers that are displayed on the right.

The action points are displayed in the roadmap on the right side of the page. This indicates whether they should be implemented in the short, medium or long term. The action points have been further developed on the page below.

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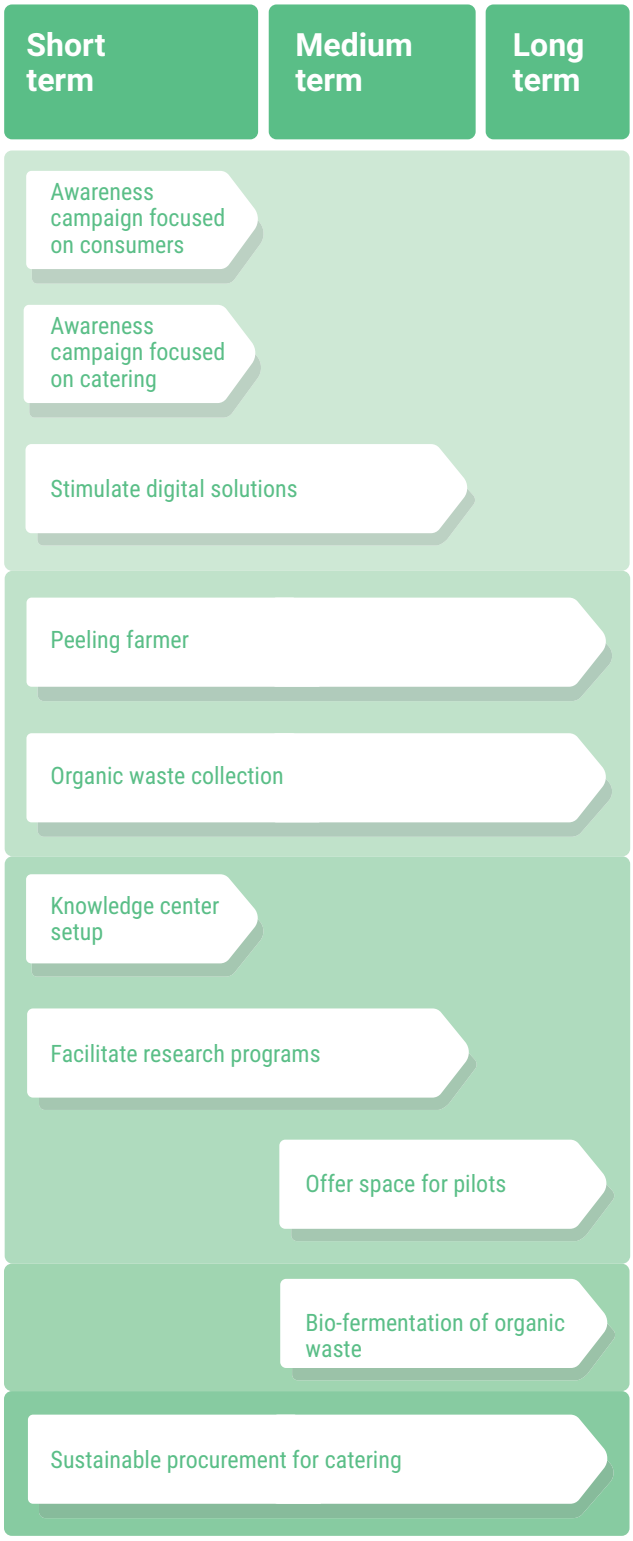

BARRIERS

- There is still a lot of waste taking place among consumers because there are insufficient incentives for behaviour change.
- The supply of organic waste streams is very spread out, both geographically and over time (including by seasonal variations in green waste such as roadside grass), which poses a barrier for the development of the business case.
- High-quality biorefinery technologies and complex innovations for source separation are in the early stages of development. For upscaling, additional research and development (R&D) is needed.
- Both national and European regulations make it more difficult for certain applications and innovations, due to long pathways for permit applications, limitations on products for human consumption, by fertilizer guidelines.

INTERVENTIONS

1. AWARENESS CAMPAIGN

- Households are responsible for 42% of food waste. A public campaign focused on consumers can increase awareness around responsible food management. Campaigns can focus on reduction (buy smaller amounts, do not prepare too much and buy food that keeps well) or on recycling (from separation to worm hotels).
- There are several possibilities to counteract food waste in the hospitality industry, from a doggy bag policy (as in France) to the preparation of smaller portions, processing of remaining ingredients in long-life dishes and making left over meals available when restaurants close. A campaign focused on the catering industry and its customers can draw attention to these opportunities.
- In addition to such campaigns, there are many available apps aimed at preventing food waste, from the Too Good To Go app that sells meals from restaurants that are about to close, to professional apps for efficient kitchen and inventory management (such as Unilever's Wise Up). A local hackathon can encourage local developers to provide these and new services available for Rotterdam.

Stakeholders involved

- British research institution WRAP, with extensive experience in public campaigns about waste reduction
- Horeca Nederland, Rotterdam department
- Unilever

2. SEPARATE COLLECTION

- Rotterdam is increasingly investing in the collection of organic waste in households. Through this transition, even for the urban neighborhoods where collection is more difficult, costs are saved on waste incineration and more compost and energy produced.
- In addition to the more generic organic waste, a number of Dutch cities including Rotterdam are experimenting with the collection of kitchen waste from households by a 'peeling farmer'. This waste fraction is more valuable than organic waste because processing possibilities for sugars, bioplastics, proteins and other chemical raw materials are possible. To scale up this investment in the required infrastructure and processing options are being investigated.
- Green waste from the government itself also offers enormous opportunities for separate collection and processing. For example, verge cuttings, leaves and pruning waste.

Stakeholders involved

- 'Clean City' section of the municipality
- Knowledge institutions such as WUR and TNO
- Port of Rotterdam Authority

3. STIMULATE R & D BIOREFINERY

There are many processing methods for biomass under development, working together towards the introduction of biorefining as an alternative to petrochemical refining. These methods are mostly not yet available on a commercial scale. A number of technologies, such as the extraction of bio-aromatics in Amsterdam or the extraction of plastics from water plants in Almere, are currently being tested. Rotterdam could also invest in attracting such pilot plants to strengthen the local cleantech sector.

- The business case for rotterdamFoodCluster worked out for the valuation of fruit and vegetables food processors and products in the region. Further elaboration and approach of the market is needed here. The department of economics can continue to focus on Urban forest management, RWS and recreational activities.

Stakeholders involved

- Port of Rotterdam Authority
- CleanTech Delta
- SUEZ
- BioHorizon program

4. BIOFERMENTATION OF ORGANIC WASTE

At the moment Rotterdam's collected organic waste is composted. By applying bio-fermentation, which can include green gas, more value can derived from the organic waste. A number of waste processors are actively working on this, i.e. Meerlanden. The investments for this technology are considerable, but it also provides great environmental benefit. It is important that the right preconditions are created so that companies are willing to invest in this technology.

Stakeholders involved

- AVR Waste, SUEZ, Van Gansen Store, DCMR, Port of Rotterdam

CONSTRUCTION

CONSTRUCTION

For the construction sector, eight interventions in total have been prioritised. The action points are based on basic conversations with stakeholders, workshops in Phases 1 and 2 and the barriers that are displayed below.

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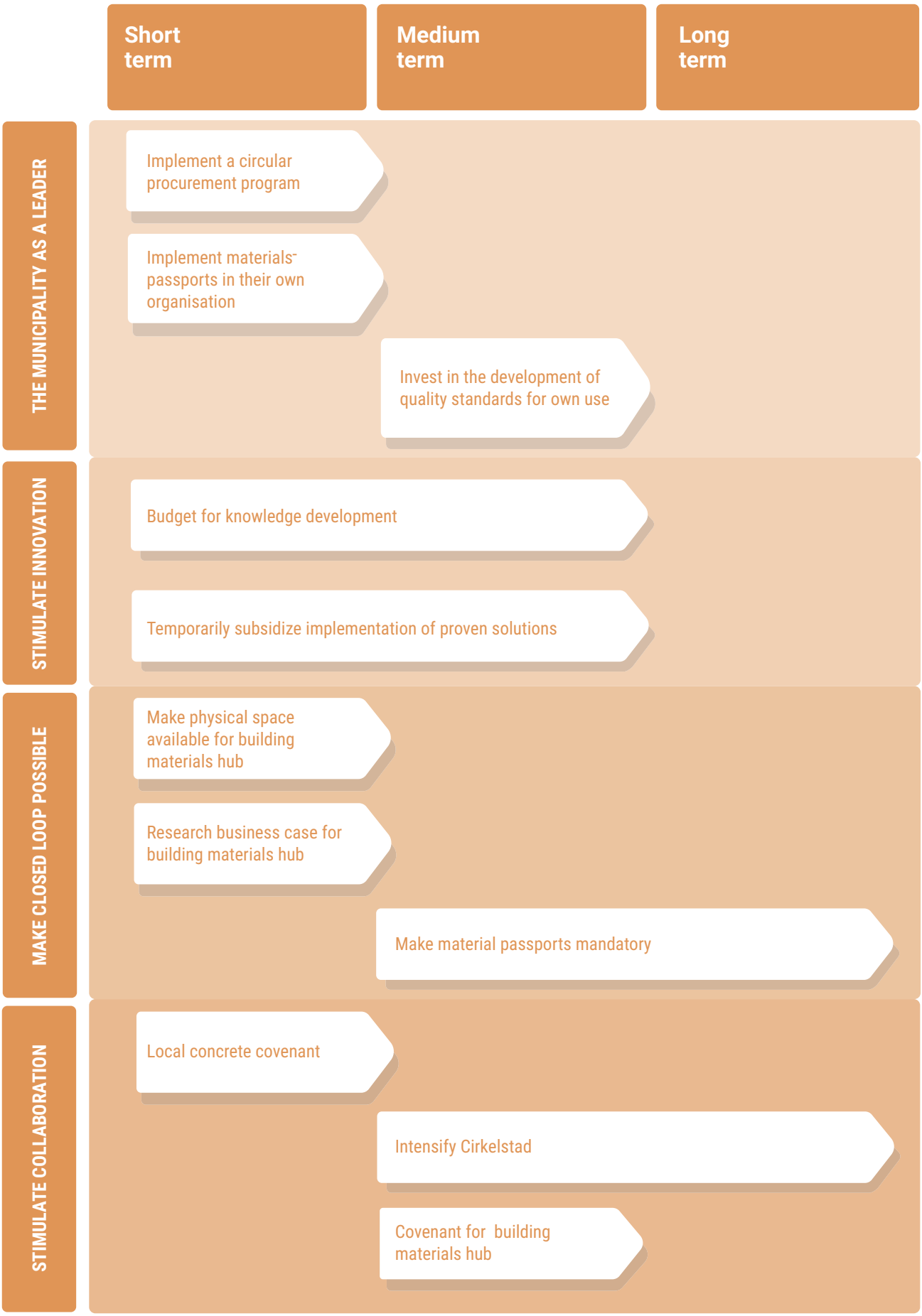
BARRIERS

- Buildings and infrastructure have a long life span, which allows new technology to be used in the long term. This makes investing in technology difficult. It also creates split incentives.
- There is no market for recycled building materials and recycled construction products yet, partly because there is insufficient information available on the volume, availability and quality of releases materials and products. Lack of transparency encourages high transaction costs.
- Without implementation of new technology and design principles, disassembly is labor-intensive and is therefore expensive.
- The sector is conservative, fragmented and focused on risk management.


Short term
Medium term
Long term
THE MUNICIPALITY AS A LEADER
Implement a circular procurement program
Implement materials-passports in their own organisation
Invest in the development of quality standards for own use
STIMULATE INNOVATION
Budget for knowledge development
Temporarily subsidize implementation of proven solutions
MAKE CLOSED LOOP POSSIBLE
Make physical space available for building materials hub
Research business case for building materials hub
Make material passports mandatory
STIMULATE COLLABORATION
Local concrete covenant
Intensify Cirkelstad
Covenant for building materials hub

INTERVENTIONS

1. FACILITATE THE DEVELOPMENT AND IMPLEMENTATION OF STANDARDS THROUGH CIRCULAR PURCHASING AND ASSET MANAGEMENT

As one of the first municipalities in the Netherlands to develop and implement circular standards, Rotterdam can play an important role in developing new technologies and exploring new ways of working. By paying a premium as a launching customer, reducing risks for businesses through development and testing of standards, and offering start-ups a launching customer, a viable market can emerge.

- Implement a circular procurement program
- Experiment with and be the first to implement a material passport
- Invest in the development of quality standards for personal use, as an example for the industry.

Stakeholders involved

- Purchasing department
- NEN, Copper8
- Suppliers of new products and services, such as StoneCycle, New Horizon

2. CONTINUE TO INVEST IN KNOWLEDGE DEVELOPMENT AND SHARING

Continue to invest in existing and new platforms such as Cirkelstad, and invest in dissemination of experiences, both from the municipality itself and other frontrunners, e.g. by organising round tables, congresses, and other meetings. Stimulate dialogue around the errors that are made, the obstacles that are experienced and the innovations that are essential to (continue to) make progress.

Stakeholders involved

- Circkelstad
- CSR Netherlands
- TU Delft

3. MAKE MATERIAL PASSPORTS OBLIGATORY

Due to the long life span of buildings and infrastructure, there is no incentive for designers, builders and investors to attach great importance to storing and making data available about products and materials in a building. In the first instance, material passports can be made obligatory for new construction, while in the longer term, (estimated) material passports for existing buildings can be required.

Stakeholders involved

- Madaster
- ArchitectenCie
- TNO
- SGS Search

4. ACCELERATE REPURPOSING PROCEDURES

Time is money, and that certainly applies to construction. For certain construction projects long-term changes to the zoning plan must be requested and implemented, for example the transformation of offices to student residences in places where the current destination does not allow homes. The municipality can give priority to these procedures and accelerate them where possible, so that reallocation becomes a more attractive option for project developers that are considering demolition, renovation and redevelopment.

Stakeholders involved

- The province
- Municipal departments involved

5. SET ADDITIONAL CONDITIONS FOR DEMOLITION PERMITS

In Rotterdam, there is proportionately more demolition and new construction, at the expense of renovation, repurposing and regular new construction. Once as much as possible has been done to make re-use more attractive, consideration could also be given to imposing additional conditions on demolition permits such as the requirement that a reconnaissance has to first be completed to the assess possibilities for renovation and redevelopment.

Stakeholders involved

- The province
- Municipal departments involved

6. INVEST AND CREATE SPACE FOR A BUILDING MATERIALS HUB

By means of a building materials hub, secondary materials can be re-traded, and effectively become get a

new life. This hub gives building materials, but also street furniture and paving material a new life. Essential for a hub is the provision of physical space where materials can be traded.

- Make physical space available, e.g. in the port, for the construction of a building materials hub where reusable materials, products and building elements can be stored, reprocessed and traded. To support the physical space, room must also be created for pilots in terms of policy.
- Facilitate the development of a business case by investing in the estimation of market volumes and other relevant information.
- The Municipality can strengthen the demand for secondary materials by becoming a customer of the hub, thereby setting a good example.

Stakeholders involved

- Port of Rotterdam Authority
- Volker Wessels
- TNO

7. SUBSIDIZE THE IMPLEMENTATION OF PROVEN SOLUTIONS BY BUILDING OWNERS

To use subsidies effectively on proven solutions, a number of steps are required: Gather information about proven solutions, the parties offering these solutions, and offer a limited subsidy on proven solutions (such as rainwater collection, repurposing of empty buildings, or use of reused building materials and products). In this way scaling up, and thus price decline and an end to the subsidies, is accelerated.

Stakeholders involved

- NewHorizon
- Home Boss
- Cirkelstad

8. INTENSIFY THE REGIONAL COOPERATION IN THE SECTOR WITH COVENANTS

Commitment to regional cooperation, with different covenants, can strongly accelerate circularity across different sectors.

- At national level, a broad group of stakeholders is working towards a concrete accord in which preservation and circular ambitions are central. Because concrete in particular is granulate, which is a local market, it is necessary to iron out an agreement that will have a local impact in the region. In parallel with the national discussions, Rotterdam can start working on this.
- Cirkelstad, which originally started in Rotterdam, has grown strongly towards other cities.
- For the time being, Cirkelstad is a voluntary cooperation between sector parties. Laying out ambitions for Cirkelstad and corresponding commitment of parties (e.g. In exchange for budget or a chance of municipality projects) can provide a serious motivation for local cooperation in the chain.
- A construction hub can only be commercially viable if sufficient market size can be guaranteed for a third party investment. This could be enforced by local or national regulations, but it is probably more desirable to use a covenant to make agreements with local building contractors about the use of a construction hub..

Stakeholders involved

- Cirkelstad
- CSR Netherlands
- Volkers Wessels
- Local builders

9. REVIEW THE CONDITIONS FOR DEMOLITION PERMITS AND LAND TENDERING

The municipality has a clear role to play in the initiating local construction projects through the issue of (construction) land and demolition permits. Currently multiple cities, including Amsterdam, are already looking for possibilities to set additional conditions (e.g. low MPG scores) for land distribution in order to promote sustainable and circular construction. In addition, a critical look at the issue of demolition permits is required, and for example it may be required that a tender is first examined examined to see whether the same transformation can be achieved through renovation and redevelopment of the current buildings.

Stakeholders involved

- W/E consultants

CONSUMER GOODS

CONSUMER GOODS

For the consumer goods sector, eight interventions in total have been prioritised. The action points are based on basic conversations with stakeholders, workshops in Phases 1 and 2 and the barriers that are displayed below.

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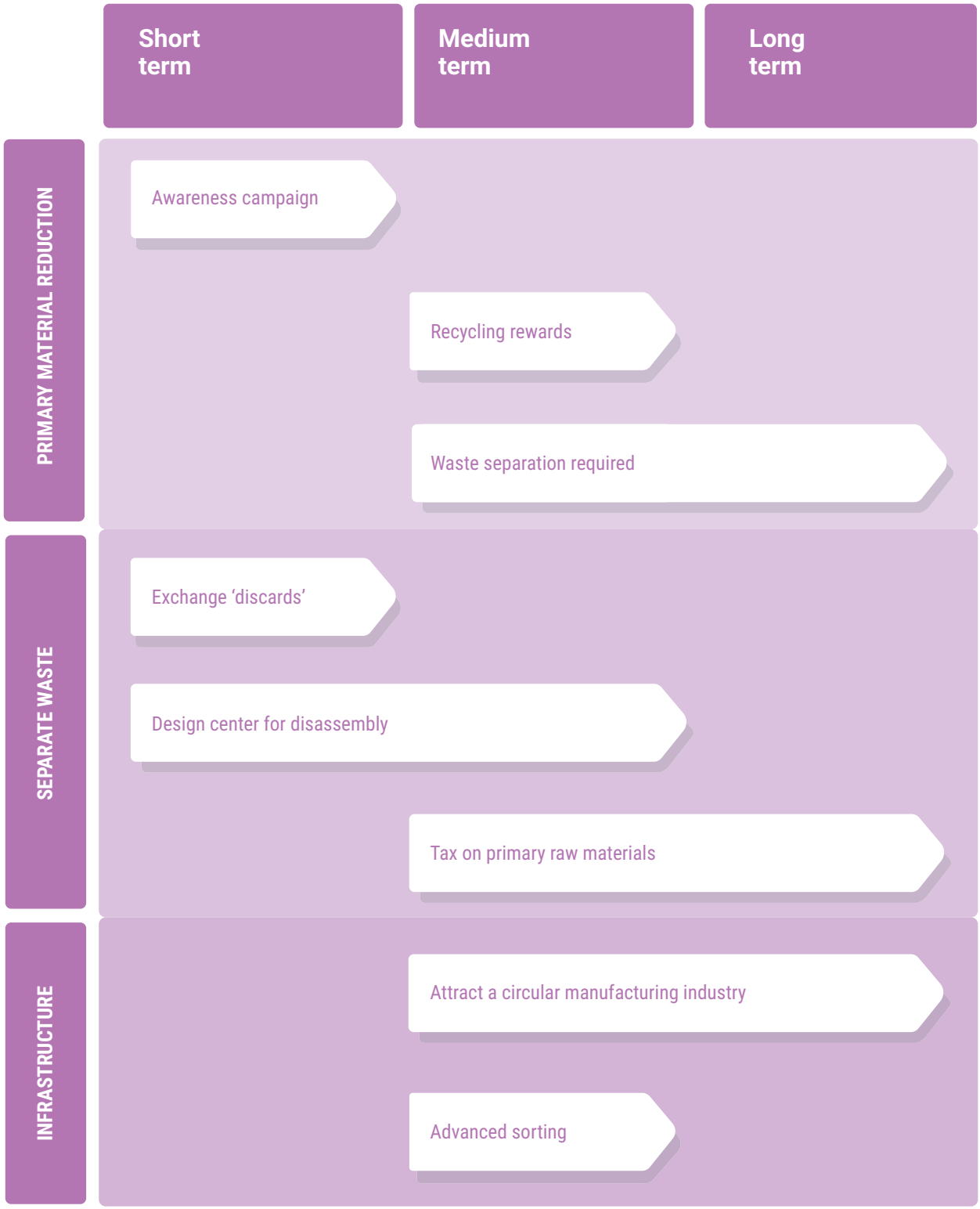
BARRIERS

Many of the products that flow into the city are produced on a global scale and these types of interventions can quickly fall outside the sphere of influence of the City. However, the City can still play a role. The research in Phase 1 and the workshops in Phase 2 shows three main barriers where the municipality can be of significance to make consumer goods flows more circular...

- The very first priority is to reduce the 'consumption' of consumer goods. Current consumerism patterns are leading to the depletion of finite raw materials on one side of the chain, and mountains of waste on the other hand. The majority of used consumer goods are, at present, burned. The use phase of products can be extended. A necessary systemic change is that product designers ultimately also fundamentally redesign. On the longer term, financial incentives must also change.
- A second priority is to reuse the waste that is generated at as high value as possible. Separated handling of waste is necessary for this, and the amount of waste that is collected separately can be further improved. In addition, information and education are also very important.
- Finally, the right infrastructure and space is very important. A circular economy also requires space for new companies and the right infrastructure. Attracting companies that are putting the circular economy into practice on a larger scale is important for the city. In addition, more advanced post-separation is needed to separate multiple flows which can then be reused in a higher quality way.


Short term
Medium term
Long term
PRIMARY MATERIAL REDUCTION
Awareness campaign
Recycling rewards
Waste separation required
SEPARATE WASTE
Exchange 'discards'
Design center for disassembly
Tax on primary raw materials
INFRASTRUCTURE
Attract a circular manufacturing industry
Advanced sorting

INTERVENTIONS

1. STIMULATING EXCHANGE OF 'DISCARDED' CONSUMER GOODS

Consumer goods often end up in the rubbish bin before the actual life span is reached. Some people are going to want a new model, while others would be happy with the current one. Recycle shops now partly fulfil this role. An upcycle mall like in Sweden attracts a wider audience. The concept in Sweden consists of fourteen specialized shops with second-hand clothing, electronics, furniture, bicycles, etc. Visitors can bring their stuff to the center and a team checks and sorts the stuff. There is also a café and an education centre. In Sweden, the municipality cooperates with entrepreneurs and non-profit organisations. The municipality manages the space, but the shops are operated by the entrepreneurs. The municipality can also be a customer of this mall.

Stakeholders involved

Purchasing department, local entrepreneurs, non-profit organisations, residents

2. STIMULATE EXCHANGE OF KNOWLEDGE ON DESIGN FOR DISASSEMBLY

By 2030 all products on the market must be designed according to circular principles (National Transition-agenda consumer goods). This requires new knowledge development among students and existing designers. The municipality can play a facilitatory role in knowledge development and exchange. At a local level the municipality can help build the existing knowledge of companies. Better Future Factory is an inspirational example that has developed circular design principles already and is located in BlueCity. The municipality can also play a role in helping organize international conferences about circular design. Due to its the location and current economic activity, Rotterdam is a very suitable city for universities, businesses and designers to come together.

Stakeholders involved

Tu Delft, Industrial design agencies, Better Future Factory, product developers, Circular Design Europe

3.TAXES ON PRODUCTS MADE OF PRIMARY RAW MATERIALS AND CONTAINING RARE METALS

In order to achieve the longer-term goals set out in the transition agendas for circular economy or the Climate Agreement, strong incentives are needed. In order to encourage careful handling of primary raw materials and rare materials, raw materials should be taxed more. According to recent research by PBL, it is much more effective to tax producers than consumers. Because there is a lot of manufacturing in the city, this intervention can have a significant impact. There is a danger that producers will leave the municipality if other municipalities do not take these measures.

This can be compensated by tax on labour. Given the international character of Rotterdam's economy, including the port, it is perhaps more feasible to closely coordinate and introduce this intervention at a national or European level. Nevertheless, the city can contribute to development by providing scope for a pilot.

Stakeholders involved

Producers of consumer goods, suppliers from raw materials

4. INCREASE SEPARATE COLLECTION OF WASTE

Many people still don't know why and how waste streams such as plastic must be recycled. The Estonian capital of Tallinn, one of the leaders in the field of recycling, has set up a special education program for children. In Ljubljana, another European leader has set up the campaign 'Get used to reusing'. These campaigns were rolled out nationally.

Stakeholders involved

Communication department, waste management, external advertising firm

5. STIMULATING RECYCLING THROUGH A REWARD SYSTEM

Another way to help residents find their way to a to a recycling point is through rewarding good behaviour. The organization Wasted Lab has set up a reward system for separate waste collection with the municipality of Amsterdam. Every time you upload a photo of your separated garbage bag you receive a digital coin. These coins can be used at affiliated entrepreneurs. This could be a discount for a second-hand shop or organic coffee, but the Albert Heijn branch is also connected. It is important that Rotterdam develops a system that fits in the context of the city and thereby learns from others. It can also start with a pilot project in a district where recycling is currently lagging behind the rest of the city. This intervention is temporary and should be seen as a first incentive to encourage people towards recycling bins.

Stakeholders involved

Nedvang, Wasted Lab, local entrepreneurs

6. COMPULSORY WASTE SEPARATION AND DOOR-TO-DOOR PICK-UP FOR HOUSEHOLDS AND COMPANIES

There are several policy options to promote the separation of waste. A European study on policy and waste collection systems in 28 capitals late shows that compulsory separate collection is the most effective. In addition, the collection of separate waste door-to-door also brings ahigher yield. Ljubljana, Tallinn and Dublin are currently at the forefront in the field of separated waste collection separated fraction percentages above 60% for plastic and above 80% for paper and glass.

Stakeholders involved

Waste treatment operators, DCMR, environmental parks

7. INVESTING IN ADVANCED SORTING AND PROCESSING FACILITIES

Due to the large number of different types of plastics that circulate (250!), it is difficult to get the highest quality during recycling. Most plastics now end up as street furniture quite quickly or garbage bags, but are no longer good to use for the function for which they were originally designed.

At the moment there are only four types of plastics recycled. Urban Mining Corp, a Rotterdam company has developed a new technology in which 25 to 75 different plastics can be separated. The fees and agreements that apply in this case are complex and require further, more elaborate research by the municipality.

Stakeholders involved

Urban mining corp, waste processing

8. ATTRACTING CIRCULAR MANUFACTURING

A circular manufacturing industry demands new activity which places the large-scale upgrading and repairing of products on the market again. Urban development has already recently launched the Merwe Vierhavens, appointed for innovative creators in the industry. In Gothenburg, Alelyckan has set up a pioneering Recycling Park where discarded materials and consumer goods are repaired and resold. In addition, Rotterdam can be a suitable location globally for large-scale, innovative technologies such as a disassembly plant for iPhones, which Apple is currently working on. Such installations can give the city international prestige in the area of circular design and reuse.

Stakeholders involved

Urban development

HEALTHCARE

HEALTHCARE

A total of six interventions were prioritized for the care and health sector. The action points are based on basic discussions with stakeholders, workshops in phase 1 and 2, and the barriers listed below. The action points are shown in the roadmap on the right-hand side of the page. This indicates whether they should be started in the short, medium or long term. The action points are further explained on the page below. In addition, a process has been followed to arrive at the most important interventions. After the creation of a long-list, ideas in a broader group were assessed for attractiveness. Subsequently, these have been further tested for feasibility and local character, and two action points have been prioritized. These are elaborated in more detail and shown at the end of this document. For each of these interventions, the circularity, job creation potential, and costs have been calculated.

BARRIERS

- Large quantities of materials flow into the Rotterdam hospitals and specific waste streams also emerge. The waste water contains, for example, high concentrations of endocrine disrupting substances and medicine residues that now end up in the sewer.
- Many hospitals in the city are taking initiatives to make things more sustainable, but the first two phases show that communication between them is often lacking:
- If we zoom out more, then we see that significant improvements are possible to make the city healthier. The health of the residents of Rotterdam is below the national average. There is more obesity and residents smoke and drink more on average. Moreover, the air quality is also inadequate thanks to traffic and the port. Another more common problem is that recovery and rehabilitation of patients often takes longer than necessary. The city already has an extensive program to improve health, but here are a few additional recommendations.

INTERVENTIONS

1. SUPPORTING IMPLEMENTATION OF PHARMAFILTERS IN ALL HOSPITALS

The Pharmafilter purifies endocrine-disrupting substances and medicine residues from hospital wastewater. This technology is already being used in the construction of a number of hospitals in the city, but the municipality can support smaller hospitals in the municipality with funding for the Pharmafilter. This has a significant impact on water quality.

Stakeholders involved
Pharmafilter, Rotterdam hospitals

2. SHARING PLATFORM FOR MEDICAL EQUIPMENT

To ensure the use of materials in equipment, equipment, expertise, capacity and even personnel can be shared. Floow2 is an online platform that facilitates this kind of business-to-business exchange. The municipality can investigate this further and help the hospitals to actively use this. The Radboudumc has already set up an internal marketplace via the Floow2 platform.

Stakeholders involved

Rotterdam hospitals, sub-platform as Floow2

3. KNOWLEDGE EXCHANGE HOSPITALS

Although the influence of the municipality on the circularization of hospitals is limited, the municipality can support innovation and knowledge exchange. For example, by appointing a director, the municipality can link hospitals and share initiatives and acquired knowledge. If successful, this can also be extended to surrounding municipalities.

Stakeholders involved

Rotterdam hospitals, coordinator from the municipality

4. MORE GREEN IN THE CITY

A more systemic intervention that has a positive effect on the healthcare sector is to make the city a lot greener. Greenery provides important psychological benefits and leads to less stress. Nijmegen, nominated for the European Green Capital award, has set up a participation card with 280 projects from residents in the public space. Rotterdam can make more room for green space itself, but also encourage residents to participate.

Stakeholders involved

Residents, green management

5.PROHIBITIONS OF FOSSIL FUEL VEHICLES IN THE CITY

The emission of exhaust fumes from cars, trucks and scooters has a significantly adverse effect on air quality. The city has already set up an environmental zone, but more far-reaching measures are desirable in the long term. Paris has already announced that from 2030 all fossi-fuel powered traffic will be banned in the city. Oxford will ban vehicles running on petrol and diesel from 2019. This measure may affect the (international) freight traffic flowing through the municipality, and coordination with the port is therefore important.

Stakeholders involved

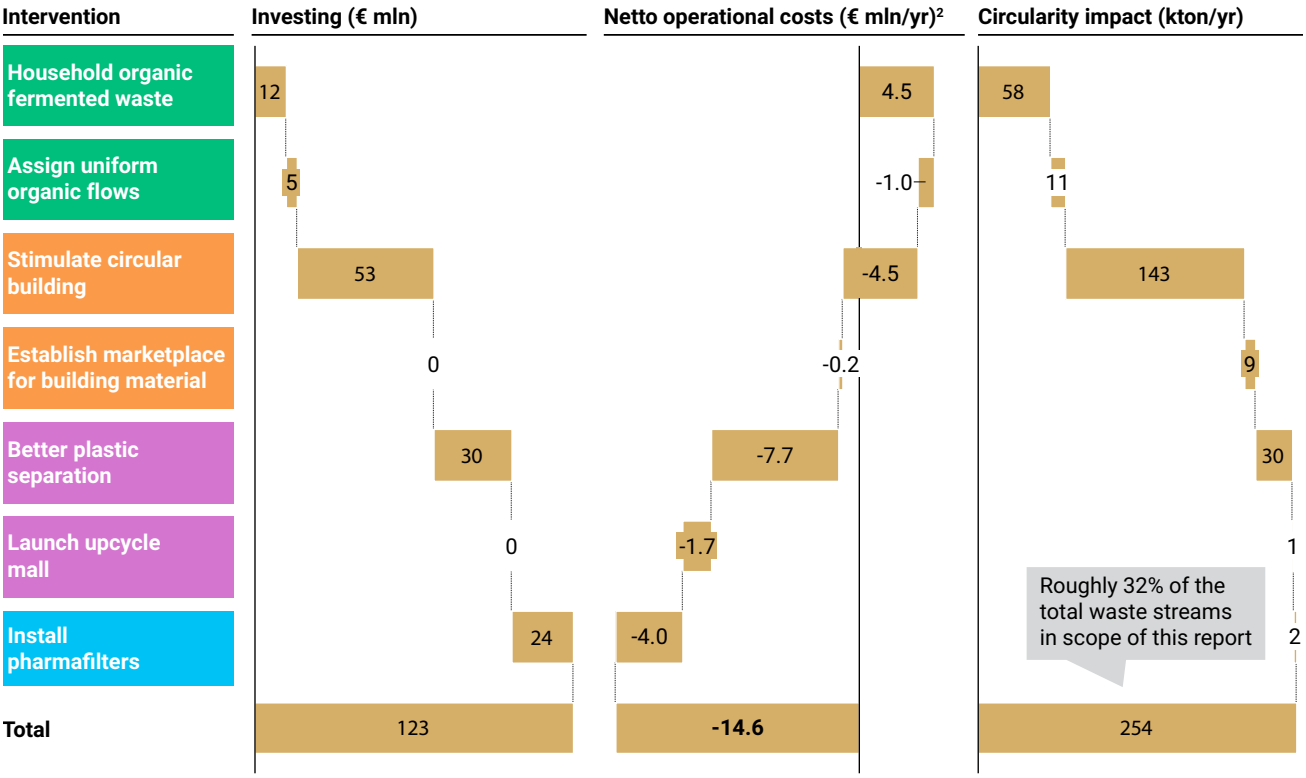
DCMR, Stadstoezicht, BOVAG, ANWB, Rotterdams port company

6. CITY-WIDE PROGRAM FOR IMPROVING REHABILITATION AND RECOVERY IN HOSPITALS

The recovery and rehabilitation of sick and elderly people can be accelerated in various ways. Thanks to better nutrition as well as more green and pleasant rooms, substantial savings can be realized. Patients who have not received proper nutrition in the hospital stay on average two to three days longer in the hospital (Murphy, Tracy, and HealthCareCAN Consultant, 2017). Gelderse Vallei in Ede, for example, has drawn up an extensive menu and works with flexible eating moments. Spaces with lots of greenery, sufficient daylight, healthy air and little noise pollution can have a positive effect on patients and staff (Huisman et al., 2012), resulting in fewer patient days and a lower material requirement. The municipality can provide subsidies for initiatives to improve the rehabilitation period. Not only for hospitals, but also in the elderly and care homes.

COST-BENEFIT ANALYSIS: CONCLUSION

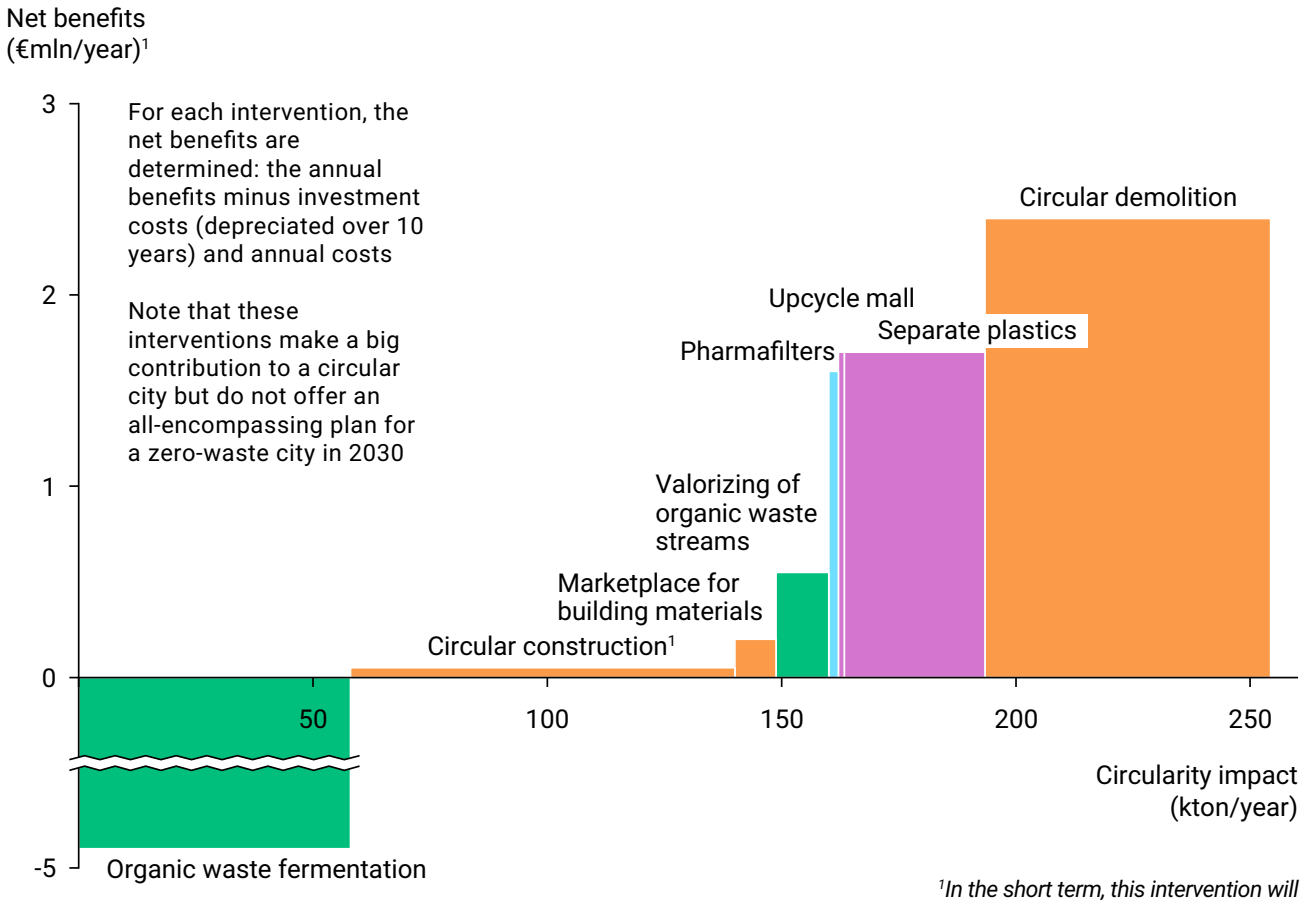
Aggregated, an investment of more than € 120 million is required to cover a 32% reduction in the total waste stream



[1]Investment for circular construction must be made annually
[2]Net operational costs are yearly costs (excl. investment) minus yearly benefits. A negative outcome therefore means delivers net operational benefit.

The lion's share of the 280 kton annual waste reduction also provides a financial perspective.

Circularity impact interventions (kton / year) vs. Net income (€ million / year)



[1]In the short term, this intervention will cost money because the benefit is only realized during use (energy saving) and in demolition (material yield). The net benefit for circular construction can be calculated by dividing the NPV by the average lifespan of a building.

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