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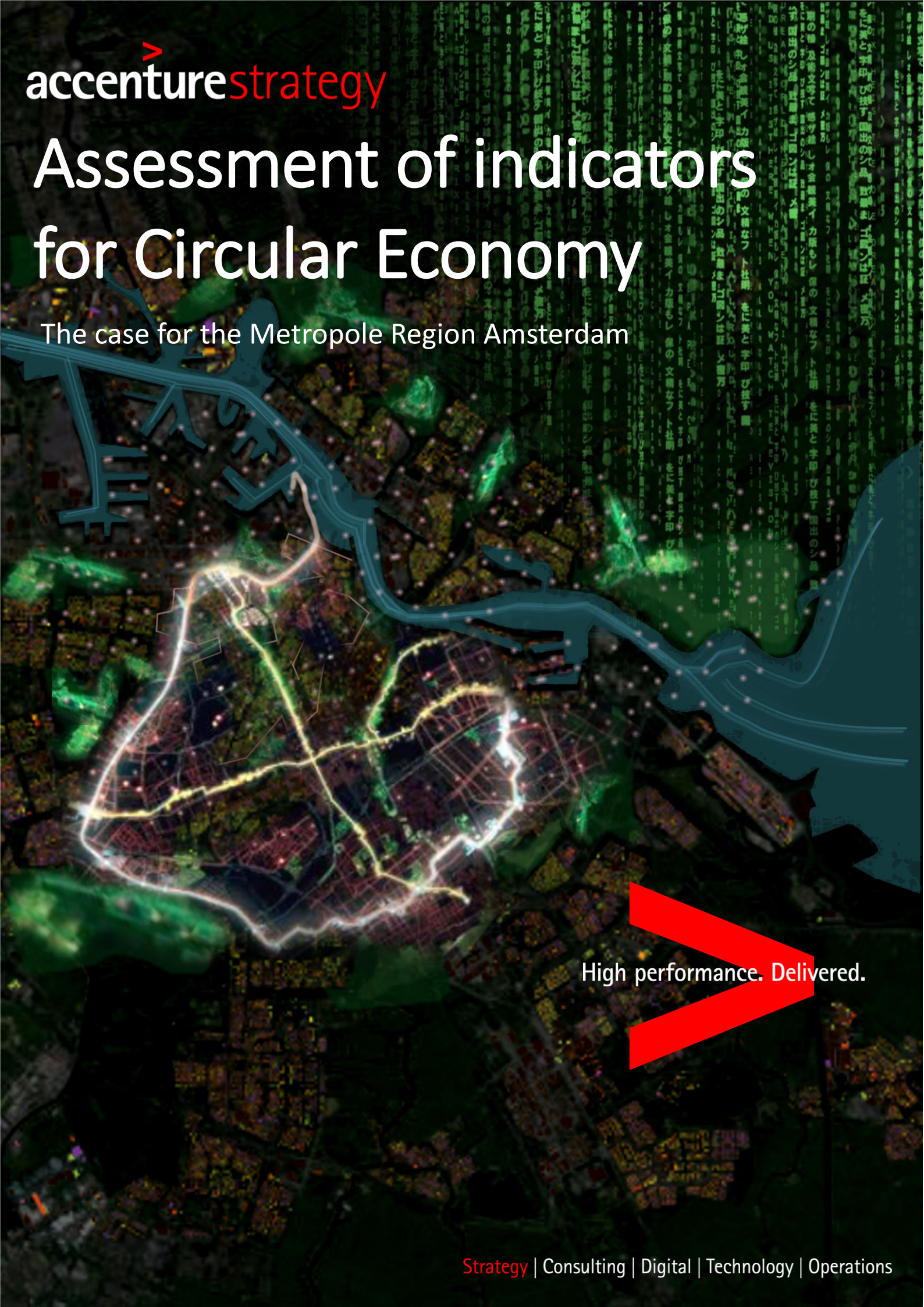
Assessment of indicators for Circular Economy

The case for the Metropole Region Amsterdam



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Master's Thesis internship – Sustainable Business and Innovation

Assessment of circular economy indicators in a region: The case of the Metropole Region Amsterdam

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Abstract

Circular Economy is receiving worldwide increased attention as a way to decouple economic growth from the consumption of finite resources. Cities and urban regions are a growing source of resource consumption and are increasingly recognized by national and regional governments as an arena to mitigate resource problems associated with urbanization. Coordinating this transition in this urban regions implies the need for tools that can monitor the environmental, social, and economic impacts of established targets. However, currently there is a lack of knowledge on how to design regional indicators which are scientifically sound, relevant, and easy to use in practice. This thesis presents method for the rigorous validation process of region specific criteria which guarantees the indicators are scientific, relevant, and useful. The method comprises a validation of criteria in three stages: desk research (self-validation); expert interviews (scientific validation); focus group (social validation). The results from the case study in the Metropole Region of Amsterdam suggest that the purpose of using indicators is to among others *encourage economic activity, attract talent companies and investors, enable benchmarking, and support political action*. The indicators should measure one of the following drivers, i.e. *knowledge dissemination, circular procurement, resource utilization,* and *cluster development*. Furthermore, the indicators should be based on the CE principles, i.e. *modular design, zero waste, closing loops, new business* models. A credible indicator*, provides early warnings transparency in method*. Robustness of the indicator is guaranteed by an *international standardized method, statistically validated data, and sensitive data.* Furthermore, the indicator should be *easy to understand* and data should be collected at *reasonable time and costs*. Some strengths of applying the 3S methodology prove to be that a detailed self-validation phase can help to become more familiar with the regional CE strategies, which facilitates interpretation during the scientific- and social validation phases. Furthermore, incorporation of independent experts' judgements through the use of in depth interviews can help to bring scientific credibility to the indicator selection process. The results from the desk research and the interviews show that the various stakeholders engaged in the process hold different preferences and values regarding the purpose of indicators and the aspects that should be measured in the region. The focus group shows that consensus can be built among stakeholders regarding these opinions. Concluding, this method offers an opportunity for planners, policymakers, and researchers to identify key criteria for a regional CE indicator framework; thus providing a first step to develop a scientific, relevant, and useful set of CE indicators for a region.

"Some people don't like change, but you need to embrace change if the alternative is disaster."
Elon Musk

Preface

As son of a farmer, I grew up at a ranch just outside Biddinghuizen, a small village in Flevoland. The area is characterized by wide fields with crops, cows, and windmills. When I think back of that period, I remember I eventually got really sick and tired of cycling miles and miles every day, from home to school….and back. This period I cycled at least 35 kilometers a day, sometimes the entire way against the wind. At this point, I did not see the beauty of the cows in the meadow, the farmers working at the countryside or the birds flying through the bright sky. But that changed…..

During my Bachelor Science and Innovation Management, I became inspired by one professor who taught us the basic principles of how, why and at what rate new ideas and technology spread. Especially the element of how the social system influences the rate of adoption made me wonder if this concept could be used in different contexts as well. At that time, I became more and more interested in social sciences and human behavior. It was at that time that I became interested in the concept sustainability. I started thinking about my own (unsustainable) behavior and that of friends and family as well. It made me think back of the place I grew up which I left for the city of Rotterdam and later Utrecht.

During this research, I met a lot of interesting, smart, and wonderful people with different backgrounds, and interests. A lot of these people were interested in sustainability and circular economy related topics. What me actually frustrated sometimes, was that these same people didn't do anything about it. The few people that were actually working in this domain were all struggling with the same problems: how can we convince people this is important? How can we convince industries to change? How can we work together and solve the problems we have created ourselves? But on the same time, many great initiatives are popping up in the region of Amsterdam. I knew all the time that there was a transition coming, but how long would it take? Now suddenly, I'm in the middle of it. In Amsterdam actually really things are changing which is great to see. This made the journey of writing my thesis about the MRA a great experience which I will remember for a long time.

In the first place, I would like to thank my parents for supporting me anywhere, anytime. I owe thanks to many other people; the people of the Amsterdam Economic Board who supported me in many ways during the data gathering, the interviewees for taking the time and meet me in person, my colleagues by providing me feedback, my friends and family of course for providing me sometimes with relaxation and fun when I needed it. I would like to take this moment to thank three people in particular. First, Alexander Peine, my supervisor from Utrecht University, who provided me with constructive feedback and who was always very flexible and open-minded. Second, Jacqueline Cramer, one of the most inspiring and bright woman I know. She not only opened doors, she opened up my world and inspired me to follow my instinct. Third, Joost Brinkman and Ivo Wenzler from Accenture who supported me in many ways at Accenture and offered guidance during the process of writing. Joost learned me how to translate sustainability into practice by offering me a lot of freedom to explore the opportunities of Accenture in sustainability, which is great.

Erik Wisse

Amsterdam, 2th of August 2016

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1. Introduction

In the 21st century, rising material use due to population growth and simultaneously the increase in prosperity in many parts of the world caused a growing demand for global resources (Georgiadis & Besiou, 2008; Zaman & Lehmann, 2013). This led to an increase in production of waste, growing scarcity of key resources, and more volatile prices (Cramer, 2014).

Due to these developments, resource efficiency will become one of the major challenges for the coming decades (Cramer, 2014; T. Jackson, 2014). The current economic system is based on a linear take-make-waste model in which non-renewable resources are mined, processed, and used by an end customer (Andersen, 2006; Zaman & Lehmann, 2013). It is increasingly recognized that this linear economic system has been detrimental to economic, environmental, and social aspects (Lozano, 2008). The concept of Sustainable Development (SD) has been introduced to address the complex dynamic interrelations among these aspects and is defined by the The World Commission on Environment and Development (WCED) as '*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987, p.8). The concept of Circular Economy (CE) is seen as a new approach expected to lead to a more sustainable development and a balanced society (Ghisellini, Cialani, & Ulgiati, 2015). CE represents an economy in which resources are used in a more environmentally sound way and is characterized by the creation of new business models, new innovative employment opportunities, improved wellbeing, and clear impacts on equity in terms of both resource use and access (Stahel, 2014). CE describes an industrial economy which designs out of waste and aims at the reduction, reuse, and recycling of biological and technical nutrients (Ghisellini et al., 2015). In order to increase the resource efficiency of the system, there is a need to decouple economic growth and prosperity from the consumption of finite resources (Cramer, 2014).

1.1 Problem description

The shift from the current linear economic system to a more sustainable CE can be perceived as a structural transformation or transition, i.e. *'a long-term process of change during which a society or a subsystem of society fundamentally changes'* (Loorbach & Rotmans, 2006, p.188). Such a transition is complex, unstructured, uncertain, and involves conflicts between values, ambitions and goals of a myriad of stakeholders (Loorbach & Rotmans, 2006). Transition management (TM) emphasizes that although a transition can't be controlled, it can be influenced and adjusted (direct or indirect) through the use of markets, plans, and institutions (Loorbach & Rotmans, 2006). TM aims to better organise and coordinate these processes at a societal level and steer them in a more sustainable direction (Loorbach & Rotmans, 2006).

Achieving a CE is a continuous process which requires the constant monitoring of economic, social, and environmental impacts, introducing preventive and corrective action whenever necessary (UNEP, 2011). Therefore, successful development of CE requires monitoring and evaluation tools such as indicators (Su, Heshmati, Geng, & Yu, 2013).

An indicator is *'a sign or signal that relays a complex message, potentially from numerous sources, in a simplified and useful manner'* (L. E. Jackson, Kurtz, & FIsher, 2000, p.vii). The main features of an indicator is its ability to summarize, focus and condense the complexity of the dynamic environment to a manageable amount of meaningful knowledge (Singh et al., 2009). Each kind of indicator can contribute particular information about the entity that is measured and it is therefore usually part of a framework of indicators (Gudmundsson, 2003). This indicator framework *'conveys a broader purpose and significance to the individual indicator and provides a comprehensive picture of some problem or*

entity' (Gudmundsson, 2003, p.201). A unified set of CE indicators enables researchers and policy makers to monitor the full development of CE at different levels (Ghisellini et al., 2015).

A successful implementation of CE requires efforts at three levels: national-level, regional-level, and local-level (Geng, Fu, Sarkis, & Xue, 2012; Su et al., 2013). However, different implementation levels of CE imply different characteristics of nations, regions, and firms, which require different indicator frameworks (Su et al., 2013). In the past decades, governments and scholars have studied the development of CE indicator frameworks at these levels (Geng et al., 2012; Ghisellini et al., 2015). However, only a few research studies can be found that describe indicator frameworks which measure CE development at regional level (Su et al., 2013). In Asia, a few case studies exist which propose an indicator framework for measuring CE at eco-industrial park level (EIPs) and eco-city level (Geng et al., 2012; Ghisellini et al., 2015). In Europe, only the EIP Kalundborg is widely studied, disregarding other options or achieved results (Ghisellini et al., 2015). This points out a lack of best practices in regional CE indicator framework use.

Consequently, there is little knowledge in science and practice about how to design an CE indicator framework (Ghisellini et al., 2015). Since all these CE indicator frameworks are developed with different purposes and with different scopes, it is rarely possible to take one set of indicators and use it for another purpose or scope (Donnelly, Jones, O'Mahony, & Byrne, 2007). Thus, a unified and only one standard set of indicators may fail to capture the development of CE in different regions. This provides evidence for the need of a flexible method which enables researchers and policymakers to develop a unique indicator framework which measures CE progress and informs decision-making for each specific region. Until now, such a method is lacking in CE literature which is why this research proposes one.

1.2 Aim

Every indicator framework has its own specific requirements regarding its purpose, scope, and design. This implies the necessity to ensure that all the indicators in the framework are in line with these specific criteria. Criteria, i.e. '*the intermediate points to which the information provided by the indicators can be integrated and where an interpretable assessment crystallizes'* can be useful to guarantee the indicators fit the intended scope and purpose during the indicator selection process (Prabhu, R., Colfer, C.J.P. and Dudley, 1999, p.86). This should be accompanied by a procedure in which the criteria overcomes a systematic validation process that guarantee their correct performance and credibility (Cloquell-Ballester, Cloquell-Ballester, Monterde-Díaz, & Santamarina-Siurana, 2006). Such a validation is performed by Cloquell-Ballester et al. (2006) on environmental and social indicators, who propose the 3S methodology and validate the indicators in three phases. This research presents a unique approach in the field of CE assessment by using the 3S methodology for the validation of criteria in three phases: self-validation, scientific validation, social validation. Criteria from literature are validated in each phase which leads to a final set of criteria. The final set of criteria is used to evaluate existing CE indicators and guarantees the selected indicators are scientifically sound, relevant, and useful in the final indicator framework (Bockstaller & Girardin, 2003; Cloquell-Ballester et al., 2006).

Therefore, the aim of this thesis is to present a method which describes (1) a review of SD and CE criteria; (2) a validation procedure of the criteria according to the 3S method (3) a technique for evaluating existing CE indicators against the final set of validated criteria.

1.3 Research question

In order to develop a methodology to evaluate existing CE indicators against validated criteria, the main research questions of this thesis is:

How can a set of scientifically sound, politically relevant, and practical indicators be developed for the purpose of measuring CE for a region?

To answer this question, the 3S methodology is deployed to validate criteria for the case of the Metropole Region of Amsterdam (MRA). The MRA is a region which aims to be a worldwide frontrunner in turning into a circular area (Circle Economy, TNO, & Fabric, 2015). It is recently chosen as an experimental garden to reduce its resource dependency and waste problems and provides an interesting showcase to test the suitability of the proposed 3S methodology (Circle Economy, 2014).

In practice, there is a growing need to establish appropriate CE indicators to allow decision makers to make informed judgements regarding policies, programs, plans and project (Ghisellini et al., 2015). By establishing a set of validation criteria for the MRA, the regional government is able to select CE indicators to monitor the transition towards a circular region. This can provide guidelines for improving CE policy and helps to better organize and coordinate the MRA strategy to become a worldwide frontrunner in CE (Loorbach & Rotmans, 2006; The Netherlands Circular Hotspot, 2016). It also contributes to science as there exists no clear methodology for developing validated criteria and selecting indicators for regional CE assessment accordingly.

1.4 Reading guide

The remainder of this research is organized as shown in the reading guide in figure 1 below.

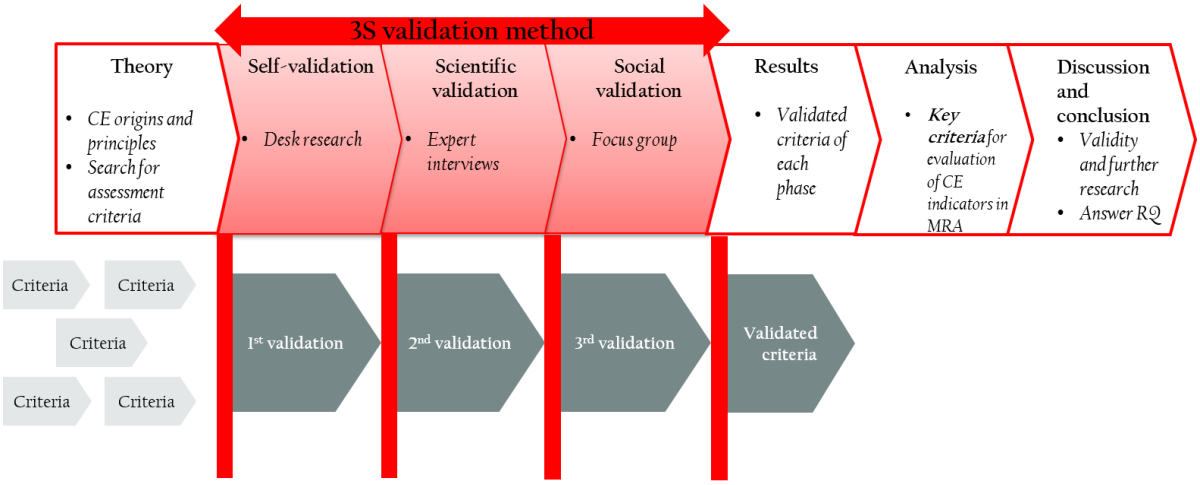


Figure 1 Reading guide thesis

In section 2, an overview is provided of the key principles and the transition of CE in cities and regions. Furthermore, existing CE indicators and frameworks are described to show how CE is currently measured and key validation criteria is introduced which serve as input for the 3S method. In section 3, the three steps in the 3S validation method are explained, showing how the data for the desk study, interviews, and focus group is collected and analysed. In section 4 the validation of the criteria is presented for the three phases. Section 5 describes the similarities and differences of the criteria amongst the phases and presents key validation criteria for evaluating indicators. In section 6, validity and reliability issues are discussed and suggestions for further research are made. Section 7 concludes how the 3S methodology enables researchers and policymakers to develop region specific criteria that enables them to select CE indicators for a regional CE indicator framework.

2. Theory

To date there is no single research document that covers all activities regions can undertake in a CE and the possibilities there are to decouple economic growth from finite resource consumption. Therefore, multiple studies are used in this thesis to clarify what a CE is, how regions can use the concept and how this is currently measured. These studies lead to the introduction of a method which can be used to develop key criteria for a regional CE indicator framework. Paragraph 2.1 provides an overview of the key principles of CE and the application of CE in a region. Paragraph 2.2 elaborates on how CE is currently measured and what knowledge gaps currently exist. Paragraph 2.3 describes how key criteria for a regional CE indicator framework are developed by means of the 3S validation process.

2.1 The Circular Economy

This section describes the origins and the underlying key principles of CE. Furthermore, the application of CE principles at regional level is explained by means of the Zero Waste framework.

2.1.1 Origins and principles of Circular Economy

The depletion of global resources, the increasing amounts of waste, and the rise of greenhouse gas emissions (GHGs) are the result of the current linear based take-make-waste models (Andersen, 2006; Zaman & Lehmann, 2013). It is increasingly recognized that this linear economic system has been detrimental to economic, environmental, and social aspects (Lozano, 2008). The concept of Sustainable Development (SD) has been introduced to address the complex dynamic interrelations among these aspects and restore the equilibria (Lozano, 2008). Current sustainability practices aim to reduce impacts and can create opportunities such as cost reduction and efficiency improvements (Young & Dhanda, 2013). However, these practices mostly continue to focus on efficiency improvements within current linear economic system (Andersen, 2006; Zaman, 2015).

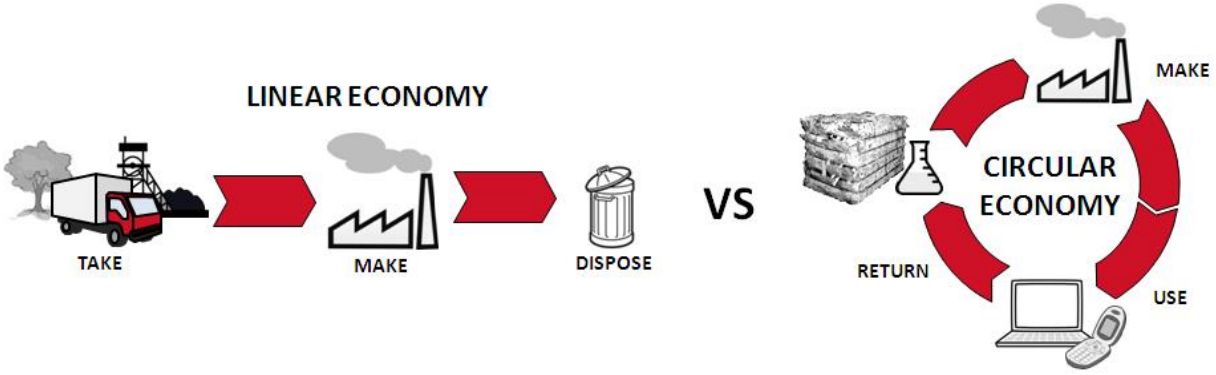


Figure 2 Transition from linear economy to circular economy (McDonough & Braungart, 2002)

The concept of Circular Economy (CE) was developed in the late 60s as a response to the unsustainable linear economic models that dominate industry as shown in figure 2 (Lyle, 1994). It promotes the adoption of closing-the-loop production patterns within an economic system, with the aim to achieve a better balance between economy, environment, and economy (Ghisellini et al., 2015). It is based on concepts such as 'regenerative design', 'performance economy', 'cradle-to-cradle', and 'industrial ecology (Lyle, 1994; McDonough & Braungart, 2002; Stahel & Reday-Mulvay, 1981). Regenerative design is a concept which describes that all systems, from agriculture onwards, could be orchestrated in a regenerative manner (Lyle, 1994). The concept of performance economy was introduced in a research report of the European Commission and sketched a vision of an economy in loops and its impact on job creation, economic competitiveness, resource savings, and waste prevention (Stahel & Reday-Mulvay, 1981). Closely linked to this idea is the concept of cradle-to-cradle which emphasizes safe and productive processes of nature's 'biological metabolism' as a model for developing a 'technical metabolism' flow of industrial materials. The model focuses particularly on precisely defining

the molecular composition of materials – '*knowing what you have, which is the basis of every quality-based materials recycling system'* (Ellen MacArthur Foundation, 2013, p.27). The study of *industrial ecology* (IE), which is perhaps the most related to the concept of CE, focuses on the flow of energy and materials through industrial systems (Preston, 2012). IE adopts a system view, building on the notion of closed-loop cycles of energy, materials, and community resources (Geng, Zhu, Doberstein, & Fujita, 2009). It is rooted in a system perspective on the interaction of natural environment and techno sphere, and focuses on the input-output analysis of material flows by production and consumption cycles (Pintér, 2006). CE builds on this concept for the analysis of the industrial system and its environment as a joint ecosystem. It can help to grasp information on three elements (Erkman, 1997, p.1):

1) '*how the industrial system works: it is a systemic, comprehensive, integrated view of all the components of the industrial economy and their relations with the Biosphere'*

2) 'how it is regulated and its interaction with the biosphere: the complex patterns of material flows within and outside the industrial system'

3) 'how it could be restructured to make it compatible with the way natural ecosystems function: *it considers the long term evolution (technological trajectories) of clusters of key technologies as a crucial (but not exclusive) element for the transition from the actual unsustainable industrial system to a viable industrial ecosystem.'*

In other words, CE is seen as a new business model expected to lead to more sustainable development and a harmonious society (Y Geng & Doberstein, 2008; Ghisellini et al., 2015; Naustdalslid, 2014; Ness, 2008). The most recent contribution to the concept of CE is provided by the leading and global organization on CE 'the Ellen MacArthur Foundation (EMF)'. They define CE as '*an industrial system that is restorative or regenerative by intention and design, which replaces the end-of-life concept with restoration shifting towards the use of renewable energy, eliminating the use toxic chemicals, impairing reuse, aiming for the elimination of waste through the superior design of materials, products, systems, and, within this, business models'* (Ellen MacArthur Foundation, 2013, p.7).

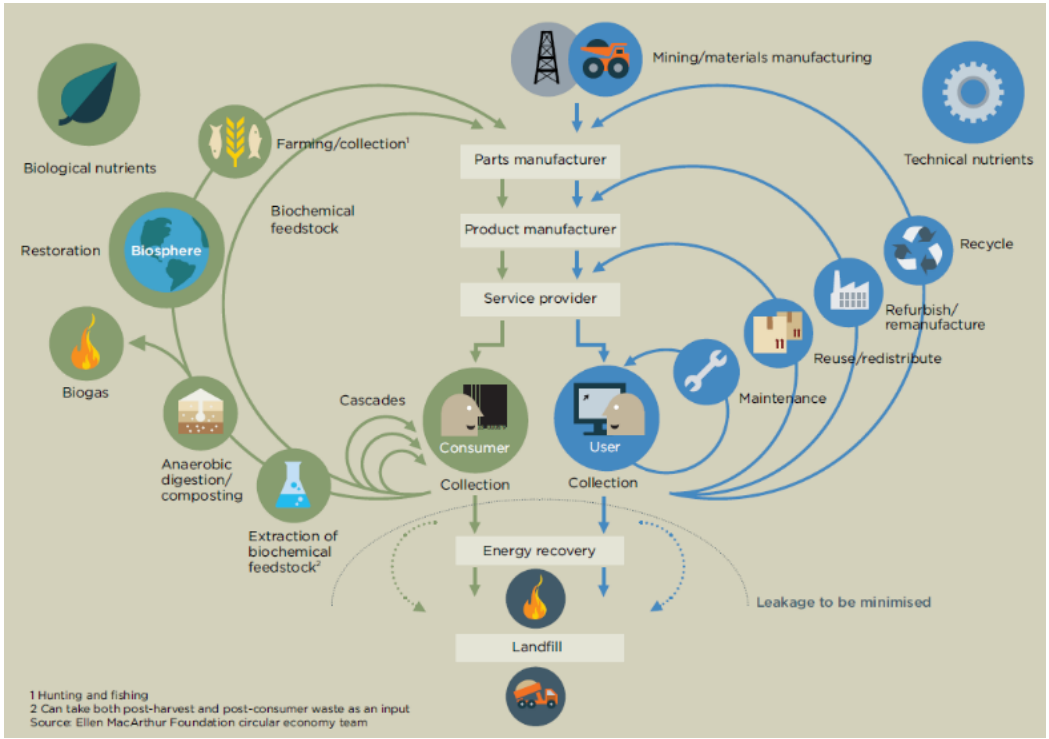


Figure 3: The Circular Economy as an industrial system which is restorative by design

This industrial system is shown in figure 3 above and consists of three different closed-loop cycles of resources: (1) *Biological nutrients;* (2) *Technical nutrients*; (3) *Energy*. The figure illustrates how technological and biological nutrient-based products and materials cycle through the economic system, each with their own set of characteristics (Ellen MacArthur Foundation, 2013).

The EMF derived 5 key principles for CE according to the various above mentioned schools of thought (Andersen, 2006; Ellen MacArthur Foundation, 2013; Lyle, 1994; McDonough & Braungart, 2002; Stahel & Reday-Mulvay, 1981). The first principle describes that resilience is built in through diversity: a *modular* production system with many connections, including tailored and decentralized solutions. The second principle states that in a CE, waste is minimized by changing the functions of resources in the economy: technical materials such as plastics and metals are designed to be reused, while nutrients in one process will be input for another, which essentially leads to *zero waste*. The third principle advocates for *zero emission energy* from renewable sources. Renewable energy is placed as the main energy source for CE, which reduces the fossil fuel dependence and enhances the adaptability of the economic system towards volatile prices and lack of supply in oil. The fourth principle stresses the importance of a systems thinking approach. The ability to *think in systems* enables to reclassify materials into 'technical' and 'nutrients'. Technical materials are designed to be reused in closed-cycles while biological nutrients return into the biosphere after product use, either directly or in a cascade of consecutive use. This leads to the fifth key principle, which stresses the importance of *closing loops* by rethinking production chains. Materials need to circle in short cycles in which the materials are kept as pure as possible and the quality remains as high as possible over the longest possible time. These principles are listed below:

1. **Modular design**: flexible design of products and product chains enhances the resilience of systems which are central in a circular economy
2. **Zero waste**: design out of waste by reducing, reusing or recycling of technical and biological nutrients
3. **Zero emission energy** from renewable sources
4. Think in **systems**: the ability to understand how parts influence on another within a whole lies at the core of non-linear, feedback rich, circular systems
5. Value is created by **closing loops**: cross-chain and cross-sector collaborations lead to an increase of effectiveness of resource allocation and utilization

For the purpose of this thesis, the definition, model, and key principles for CE developed by the EMF are used for two reasons. First of all, the model has a specific focus on resource efficiency within an industrial system which is an important aspect of CE (Ness, 2008). Second, the model has its roots in general systems theory (GST) which promotes important premises of CE i.e. holism, complexity, organizational learning and human resource development (Ghisellini et al., 2015). Although the above mentioned definition of the EMF does emphasize on important aspects of CE (i.e. resource efficiency, systems thinking, and closing loops), it does not explicitly include a geographical scope. Furthermore, since the EMF definition typically focusses on the environmental implications of CE and the innovative design of products and materials, there is reduced attention for the economic, social dimension and time dimensions. Many authors in CE literature emphasize that CE leads to a win-win relationship between socioeconomic and environmental dimensions of development (Geng et al., 2012; Lozano, 2012; Naustdalslid, 2014; Su et al., 2013). The economic aspect of CE contributes to a higher regional and domestic competitiveness through an increase in the effectiveness of resource allocation, utilization and productivity. In environmental terms, CE reduces the pressure on nature mainly by redesign of the industrial structure in an ecological way. Socially, CE has the potential to improve people's lives, resolve unemployment, and achieve equal distribution of economic growth (Su et al., 2013). The time dimension emphasizes to take long-term effects of today's

decisions into consideration. CE can be understood as an approach which aims for sustainable development and a harmonious society (Ghisellini et al., 2015). Achieving CE is a continuous process as it is a journey, path, or process to achieve sustainability (Ghisellini et al., 2015; Lozano, 2008). This also implies that, because SD is intrinsically a normative and subjective notion, the practical implementation of CE has to incorporate the conflicts between values, ambitions, and goals from a variety of stakeholders (Loorbach & Rotmans, 2006). This leads to the inclusion of 2 more principles in an addition to the aforementioned 5 principles of CE:

1. Natural resource use for **shared value** creation: different sources are used for the creation of economic, social, and environmental value in the short-, long-, and longer term
2. Diversity of new **business models** developed by stakeholders with different values, ambitions, and goals regarding CE: a variety of new business models, from `product ownership' to 'consumer as user' and performance-based payment

Overall, the 7 principles discussed in this paragraph lead to an adapted definition for CE in a region which is provided in table 1 below:

Table 1 CE definition including regional scope, shared value creation in time, and incorporation of stakeholders adapted from the EMF

'a region with geographical boundaries in which the natural resources water, materials, and energy are used by a variety of stakeholders in the living, working, and learning environment for a balanced creation of economic, social, and environmental value in the short-, long-, and longer term'

This adapted definition does not only add the geographical scope and the shared value creation in time, it also underlines the necessity to consider a variety of stakeholders when implementing CE.

2.1.2 Circular economy in regions

Cities and urban areas are the centers of resource consumption and waste production. Globally, cities consume over 75% of the world's natural resources and are estimated to be responsible for 70% of pollution and resource depletion (Spiller & Agudelo-Vera, 2011; Zaman & Lehmann, 2013). Conversion of resources into products which take place in urban areas can be perceived as urban metabolism, also defined as '*the total sum of the technical and socioeconomic processes that occur in cities, resulting in growth, production of energy, and elimination of waste*' (Kennedy, Cuddihy, & Engel-yan, 2007; Spiller & Agudelo-Vera, 2011, p2). Nowadays, most cities have a linear metabolism with *materials*, *energy*, and *water* consumption leading to *solid waste*, *wastewater* and *emissions* to the atmosphere (Zaman & Lehmann, 2013). A transition towards a more circular urban metabolism with increased efficiency through reuse and recycling principles will avoid waste and increase the resilience of urban systems which is crucial for achieving sustainability (Spiller & Agudelo-Vera, 2011).

This transition of cities and regions involves the integration of three systems: industrial, infrastructure delivering services, cultural and social system (Ghisellini et al., 2015; Ness, 2008). A concept that resonates in many ways with CE and addresses the integration of these three systems is the 'Zero Waste' concept (Ghisellini et al., 2015; Pintér, 2006). Zero Waste (ZW) is a strategic tool to address waste management at regional level and gained worldwide popularity in the past years. It is defined as '*designing and managing products and processes systematically to avoid and eliminate waste, and to recover all resources from the waste stream*' (Zaman & Lehmann, 2013). ZW design-principles go beyond traditional recycling as they focus firstly on avoidance and reduction of waste innovative product design and then on recycling and composting (Zaman & Lehmann, 2013). In a ZW city the material flow is circular which means that all materials are used over and over again and no materials are wasted or underused. In order to transform current linear cities to ZW cities, proper implementation strategies should be deployed. Zaman & Lehman (2013) proposed a series of holistic strategies based on key development principles. Table 2 below shows the

short- and long-term key drivers for transforming current cities to ZW Cities. Accordingly the development principles, the actors involved, and the system boundaries are provided.

Table 2 Short and long-term key drivers for Zero Waste Cities

Zero Waste Cities			
Long-term drivers	**System**	**Key development principles**	**Actors**
1. Awareness, Education & research	Cultural framework and social system	• Zero waste programs • Transformation Education • Zero waste research	Government and Academia
2. Sustainable consumption & behavior	Cultural framework and social system	• Collaborative consumption • Behavior change • Sustainable living	Consumer
3. New infrastructure & systems thinking	Infrastructure delivering services	• New infrastructure • New technologies • Zero waste governance	Government & Academia
Short-term drivers	**System**	**Key development principles**	**Actors**
4. Transformed industrial design	Industrial system	• Cradle to Cradle design • Cleaner production • Producer responsibility	Industry
5. Zero Depletion legislation & policies	Cultural framework and social system	• Zero-landfill Legislation • Zero-incineration Legislation • Incentives	Government and Industry
6. Prevent, reuse, recycle of natural resource assets	Infrastructure delivering services	• Reduce • Repair/Reuse • Recycling/recovery • Cascading of biotic materials	Industry, Government and Consumer

These key drivers for ZW cities can be perceived as generic strategies for cities as they integrate the industrial, infrastructural, and cultural/social system. In this context, these drivers can also be used to describe the transition of CE within a city or region. Therefore, these short- and long-term drivers are described in the context of CE below.

Driver 1: Awareness, Education and Research

This driver is on the top priority of the ZW concept. Without the right amount of environmental awareness and knowledge among governments and academia, society remains unable to achieve ZW goals. Governments and scholars play an important role to disseminate knowledge to both producers as well as consumers by ZW programs, transformative education, and research.

Driver 2: Sustainable consumption and behavior

This driver emphasis that current consumption patterns are unsustainable and need to be changed. Collaborative consumption models are recognized as an important step on the consumer side to shift from unsustainable business-as-usual (BAU) to a sustainable CE model (Ghisellini et al., 2015). Such models (i.e. sharing, lending, renting, and trading) are based on shared ownership of multiple owners.

Driver 3: New infrastructure and systems thinking

In order to transform a region in a circular one, a whole new approach is necessary as well as investments in innovative infrastructure technologies. Governments have a powerful tool to accelerate this transition by investing in Eco-innovations and infrastructure: circular procurement.

Driver 4: Transformed industrial design

This driver is concerned with the transformation of the industry in a region. New business models and production methods such as cradle-to-cradle design, eco-design, from-product-to-service, or cleaner production can transform industries gradually or radically. This driver mainly concerns the movement and actions taken by the industry within a particular region.

Driver 5: CE legislation and Policies

Governments and local authorities can play a major role in the transition towards CE. CE enabling legislation as well as incentive policies can drive producers and consumers towards a more circular economy. Prices of resources and products influence consumer and producer behavior. Thus, governments can influence this behavior by influencing prices by means of taxes and subsidies. Besides influence on prices, governments can also affect the ways in which consumers may be inclined to buy CE products. By providing CE labelling for products and companies consumer choices may also be affected (CBS, 2015).

Driver 6: Recycling and recovery of resources

In order to be able to assess the development towards a circular region, the natural resource assets and the reduction and additions to their stock need to be measured. The natural resources that flow through regions consist of biological nutrients (water, food), technical nutrients (products), and energy. Reduction, reuse, and recycling principles will increase the efficiency of regions and help avoid waste. Producers need to think about the entire lifecycle and the design of a product and which can create an optimum in recycling and recovery of products.

Figure 6 below shows the material flow through a circular region in which the short- and long-term drivers 1, 3, 5 and 6 are shown in the area surroundings. Furthermore, driver 2. *Sustainable consumption and behavior* is placed on the consumer side as it is concerned with collaborative consumption models that influence consumer decisions. 4. *Transformed industrial design* is placed on the production side as it is concerned with the creation of new production processes and business models by the industry.

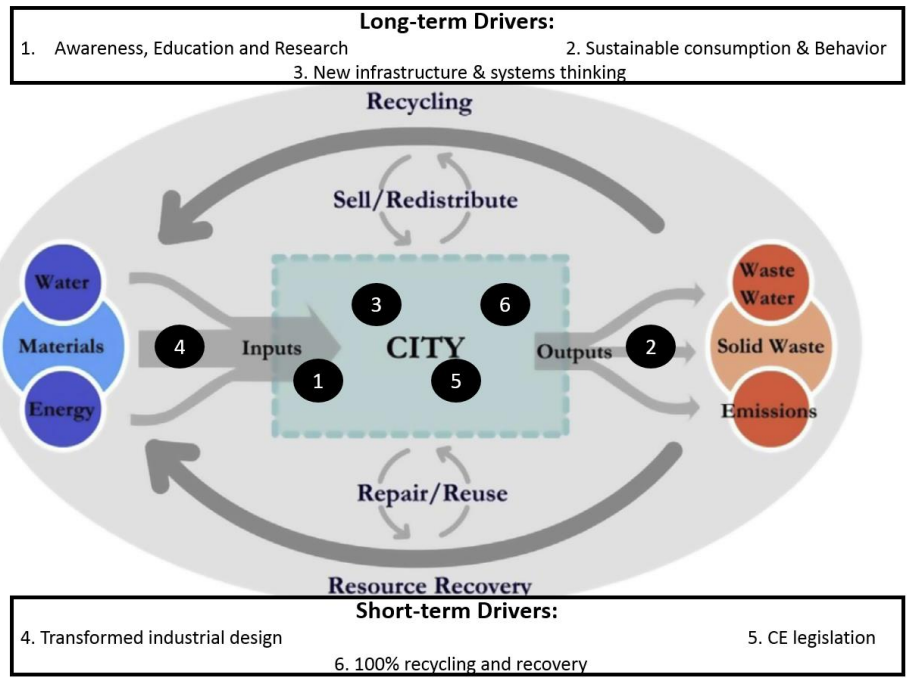


Figure 4 Material flow through a circular region and short- and long-term drivers for ZW regions (adapted from Zaman and Lehman (2013))

2.2 Circular economy indicator frameworks

In order to progress towards a more circular economy, it is important to measure the effectiveness of strategies deployed at national, regional, or local level. Therefore, it is necessary to establish a set of reliable indicators. Paragraph 2.2.1 describes what definitions, roles and objectives of indicators are described in literature. Paragraph 2.2.2 provides a working definition of an indicator framework and describes the objectives, aspects, and knowledge gaps of recently developed CE indicator frameworks.

2.2.1 Definition, role and objectives of indicators

There exist many definitions for indicators such as 'variable', 'grade', 'measurement', 'sub-index', and 'parameter' among others (Meadows, 1998; Veleva, Hart, Greiner, & Crumbley, 2001). The main feature of indicators is their ability to summarize, focus and condense the complexity of the dynamic environment to a manageable amount of meaningful knowledge (Singh et al., 2009). It can provide objective, credible information on the status of a system which is useful for governments and societies to clarify and reach desired outcomes (Pintér, 2006). In this thesis, an indicator is defined as '*a sign or signal that relays a complex message, potentially from numerous sources, in a simplified and useful manner*' (L. E. Jackson, Kurtz, & FIsher, 2000, p.vii).

In literature, the following main objectives for indicators can be observed which are provided in table 3 below (Meadows, 1998; Veleva & Ellenbecker, 2001; Veleva et al., 2001; World Resources Institute, 2005):

Table 3 Main objectives of indicators in literature

- Raise *awareness* for targets/goals
- Provide decision-makers a tool to *measure progress* toward established *goals/targets*
- *Inform* decision-making

2.2.2 Indicator frameworks and CE indicators

Circular economy is seen as a new approach expected to lead to a more sustainable development (SD) and a harmonious society (Ghisellini et al., 2015). Achieving a CE is a continuous process which requires the constant monitoring of impacts, introducing preventive and corrective action whenever necessary (UNEP, 2011). As described above, useful indicators are typically numerical measures that provide key information about development, providing guidelines for policy-makers to further develop effective policy instruments (Su et al., 2013; Veleva et al., 2001). To ensure that these indicators serve the purpose for which they are intended and to control the way they are specifically selected and developed, it is important to organize them in a consistent framework. An indicator framework entails a collection of indicators that '*conveys a broader purpose and significance to the individual indicator and provides a comprehensive picture of some problem or entity*' (Gudmundsson, 2003, p.201). Therefore, governments and academia developed various indicator frameworks that measure CE at national, regional, and local level (Geng et al., 2012; Su et al., 2013). These different levels of implementation of CE and the different characteristics of nations, regions, and companies require different indicator frameworks (Su et al., 2013).

Three prominent types of frameworks for measuring CE arise in literature: (1) Material flow accounts (MFA); (2) Eco efficiency indicator frameworks; (3) Hybrid indicator frameworks (Dietz & Neumayer, 2007; Li, Bao, Xiu, Zhang, & Xu, 2010; Pintér, 2006; Su et al., 2013; Yong, 2007). These are discussed on the next page.

2.2.2.1 Material flow accounts

MFA provides a way to determine the flow of materials and energy through the economy on multiple scales which is at the heart of the concept of CE (Fischer-Kowalski et al., 2011; Pintér, 2006). This quantitative procedure is most commonly used for CE accounting at national- and regional level (Geng et al., 2009; Pintér, 2006; Su et al., 2013). China for instance developed two sets of CE indicators based on MFA and three actions, i.e. so called 3R's principles: Reduction, Reuse and Recycle (Geng et al., 2012, 2009; Ghisellini et al., 2015). The first set of indicators is used for the general evaluation of CE development at national level. The second set is used for the assessment of CE at various eco-industrial parks (EIPs) and for more than one hundred of eco-city projects (Ghisellini et al., 2015). Both indicator sets contain the following four categories: (1) resource output, (2) resource consumption, (3) integrated resource utilization, and (3) waste disposal indicators. Japan incorporated the decoupling concept 'sound material cycle society' (SMC) in national policy. SMC is also based on the 3R principle and has many similarities with the concept of CE (European Commission, 2013; Geng et al., 2012). The main goal of SMC policy is to improve eco-efficiency and analyze production and consumption cycles as it entails the following three lead indicators: (1) resource productivity, (2) material reuse and recycling rate, (3) rate of waste for final disposal (Bringezu, Schütz, & Moll, 2003; Fischer-Kowalski et al., 2011). At regional scale, Japan adopted the eco-towns governmental program in 1997 already to reach zero emissions goals and achieve economic benefits (Ghisellini et al., 2015). The Republic of Korea launched in 2009 a national program called 'green growth' to tackle climate change, increase energy security, enhance material efficiency, and develop ecological infrastructure (Geng et al., 2012; UNEP, 2011). Indicators have been set-up between 2009 and 2013 for the purpose of increasing energy and material efficiency (Geng et al., 2012; UNEP, 2011). Some examples of eco-cities can be found in Europe as well such as Germany, Sweden, and the UK (Ghisellini et al., 2015). The EIP of Kalundborg (Denmark) is one of the most (and almost only) analyzed example in the EU (Ghisellini et al., 2015). The lack of a wider range of case studies with best practices reported in the EU may be an explanation for the absence of one unified set of indicators to assess CE at city level in the EU. Overall, these MFA-based indicators have proved to be valuable for developing environmental strategies and providing guidelines for improved CE policy at regional and national level (Geng et al., 2009; Su et al., 2013). However, some shortcomings of MFA are the need for reliable data, consideration of weight rather than quality of materials, and the reduced applicability at local level (Dietz & Neumayer, 2007; Geng et al., 2012; Pintér, 2006). Furthermore, these frameworks need substantive revision as they lack to address social development, urban/industrial symbiosis, business development, and absolute material and energy reduction (European Commission, 2013; Geng et al., 2012; Y Geng & Doberstein, 2008; Ghisellini et al., 2015).

2.2.2.2 Eco-efficiency indicator frameworks

Eco-efficiency indicators (EEis) are adopted in CE frameworks to measure environmental performance related to economic performance (Geng et al., 2012; Yong, 2007). Common methods of measurement are carbon footprints, LCA, economic and energy valuation. These indicators are used to measure water use, energy use, and waste generation as they mainly focus on individual parameters. Therefore, these unidimensional indicators are especially useful measuring CE at local scale for specific processes or products (Su et al., 2013). Research in China led to various EEIs measuring CE at product, firm, and industry-level. Chen et al. (2009) developed indicators for iron and steel firms comprising a total of four lead indicators and 78 complementary indicators focussing on water, materials, and carbon reduction. Furthermore, a few industry-wide indicator sets estimating performance of one industry were developed (Su et al., 2013). Du and Cheng (2009) claimed that the CE efficiency of the iron and steel industry in China as a whole is not high, but is increasing. This is mainly caused by the increased technical efficiency of these industries. Zhu and Qiu (2007, 2008) assessed the resource- and waste

productivity between 1990-2005 for Shanghai and China (Su et al., 2013). They listed the three most urgent problems in Shanghai, i.e. energy supply, management of gas waste, and solid waste. Furthermore, they concluded that in China the eco-efficiency of natural resources input increased from 1990-2005, but revealed not enough to decouple economic growth from natural resources (Su et al., 2013). Overall, EEis show to be effective for determining the decoupling of GDP growth from resource use (Pintér, 2006; Su et al., 2013). However, they also have their limitations as EEis alone do not indicate increases or decreases in environmental impact where 'rate of growth' may outstrip 'rate of improvement' of eco-efficiency (Pintér, 2006). Furthermore, these indicators often need to be tailored to firm or product-specific characteristics, conditions, and problems. Therefore, it can be hard to provide one unified standard set of indicators as these indicators may fail to capture the entire development of CE in different firms (Su et al., 2013). In the context of industries and regions, these unidimensional indicators are less appropriate to provide a complete picture for managing CE policy when considering the broader context and network of CE resource flows (Geng et al., 2012; Su et al., 2013)

2.2.2.3 Hybrid indicators

Hybrid indicators take an additional step of including the economic implications of material flow limits. In this way, an integrated environmental and economic measure can be developed which determines cost-effectiveness rather than efficiency (Dietz & Neumayer, 2007). Currently there are four generally acknowledged indicators systems that integrate environmental indicators with socio-economic ones i.e. Global Reporting Inititative (GRI), UN Framework, The Sustainability Metrics, and Wuppertal Sustainability Indicators (Li et al., 2010; Zhijun & Nailing, 2007). From these frameworks different hybrid indicator frameworks were developed for China at product, industrial, and regional level (Li et al., 2010). The Development Research Center of the State Council (DRCSC) and the State Environmental Protection Administration (SEPA) developed two integrated CE indicator frameworks with the following categories: resource efficiency indicators, environmental impact indicators, and economic progress indicators (Li et al., 2010). This is used to completely measure regional economy benefits, resource and energy efficiency, and cycle characteristics. Furthermore, the Institute of Process Engineering, Chinese Academy of Sciences (IPECAS) introduced the multi-objective evaluation system of the economy-environment-ecology for the purpose of high utilization of resources (Li et al., 2010). Hybrid indicator framework have also their limitations. Problems with this method arise in many contestable assumptions that must be made and interpretation of estimating monetary values (Dietz & Neumayer, 2007). Also, hybrid indicators focussed on CE measurement are merely developed in China which is still in its early stages.

2.2.2.4 Summarizing methods of CE measurement

In summary, MFA-based indicators offer a way to evaluate CE performance at national, regional, and eco-industrial park level. EEIs mainly focus on individual parameters and prove to be useful at measuring CE at process- and product-level. Therefore, both EEIs and MFA-indicators can be combined to provide a more complete picture of CE development. With hybrid indicators, scholars attempt to include economic implications of materials flows at different levels which can be a complex and sometimes contestable method (Dietz & Neumayer, 2007; Pintér, 2006). Nevertheless, whereas there is an abundancy of Asian literature and case studies (100+) on CE assessment on EIP- and city level, the EU lacks knowledge and best practices in this research area. European countries mainly focus on the Kalundborg case, disregarding other informative case studies at city/regional level (Ghisellini et al., 2015). Overall, there is an abundancy of Asian literature on CE assessment at different levels while in Europe only a few examples of regional case studies exist (Ghisellini et al., 2015). Although these regions may have some similarities, the different characteristics, conditions, and problems of Asia imply that a unified, standard set of indicators may fail to capture the full CE development in European

regions (Ghisellini et al., 2015; Naustdalslid, 2014; Su et al., 2013). This advocates the necessity for the development of knowledge and best practices on CE assessment in Europe. For the development of CE indicator frameworks for European regions, the following shortcomings in literature need to be taken into account. Frameworks developed in Asia do not always incorporate a broad range of stakeholders in the design process. This is necessary as the practical implementation of CE requires incorporation of the conflicts between values, ambitions, and goals from a variety of stakeholders (Ghisellini et al., 2015; Loorbach & Rotmans, 2006). Stakeholder engagement can be a decisive tool to reach consensus and helps to maintain transparency levels as high as possible (Cloquell-Ballester et al., 2006). Furthermore, current indicator frameworks focus solely on evaluation of the environmental and/or economic aspects, while CE stresses harmonized economic, social, and ecological relationships (Geng et al., 2012; Zhijun & Nailing, 2007). Therefore, scholars suggest a more systematic evaluation system that integrates indicators of environmental, economic, and social development (Geng et al., 2012). Until now, very few scholars studied the development of CE indicator frameworks that address the shortcomings shown in table 4 below (Su et al., 2013).

Table 4 Overview of knowledge gaps in CE assessment literature

- lack of **knowledge** and **best practices** of regional CE indicator frameworks
- lack of **stakeholder engagement** in the design process of indicator frameworks
- lack of CE indicators representing **holistic** fields

2.3 Criteria and 3S validation method

As described in the previous sections it can be noticed that there is a substantial overlap between some indicator frameworks. However, each framework has a slightly different purpose or may cover a different geographical area. Thus, different levels of implementation of CE and different characteristics of nations, regions, and companies require different indicator sets. Although there are some similarities among the indicator frameworks, it is almost impossible to take one set of indicators and use it or another purpose (Donnelly, Jones, O'Mahony, & Byrne, 2006). This is due to the fact that *criteria* for selecting appropriate CE indicators from the basis for any CE indicator framework. Criteria are defined in this thesis as '*the intermediate points to which the information provided by the indicators can be integrated and where an interpretable assessment crystallizes'*. As such, the criteria closely relate to the function and purpose of each framework (Cloquell-Ballester et al., 2006; Donnelly et al., 2006). Therefore, the selection of CE indicators should be accompanied by a rigorous validation process of criteria which guarantees that the indicators serve the purpose for which they are intended. In other words, the criteria that are used to evaluate the appropriateness of CE indicators in a specific region, should be carefully chosen according to an extensive validation process. The process of validating a set of criteria and evaluating the indicators according to these validated criteria is used in a number of other indicator assessment studies, which described by Cloquell-Ballester et al. (2006) who developed the 3S validation methodology (Cloquell-Ballester et al., 2006; Donnelly et al., 2006, 2007).

This method consists of three validation stages i.e. self-validation, scientific validation, and social validation as shown below in figure 5.

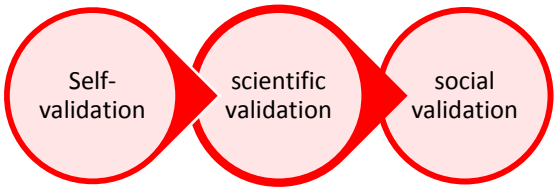


Figure 5: 3S Validation Methodology

The self-validation phase is carried out by the researcher for the purpose of: (1) internal reflection on the correct functioning of the criteria (2) assure correct documentation of the criteria which facilitates interpretation in the scientific- and social validation stages. The scientific validation stage consists of a thorough screening by independent experts. The social validation stage incorporates public participation in the process which is seen as an important tool to reach consensus among the various stakeholders involved (Bockstaller & Girardin, 2003; Cloquell-Ballester et al., 2006; Mascarenhas, Coelho, Subtil, & Ramos, 2010). It especially helps to maintain transparency levels as high as possible. Since the three validation stages complement each other, the activities and its assessment criteria remain the same in each stage. By overcoming the different stages, the criteria's credibility increases.

This bottom-up approach is characterized by the inclusion of various stakeholders during the design and selection process (i.e. civil society, NGOs, etc.) which is better suitable at local and regional level (Moriguchi, 2007; Pintér, 2006). This is especially relevant for CE as the strategic development of indicators requires integration in mainstream policy mechanisms. This is critically important since local governments, municipalities, industry, and other stakeholders have a major influence on policymaking and practice (Pintér, 2006).

The main aim of the 3S methodology is to validate criteria, which forms the basis for the evaluation of the correct performance of new indicators. To complement this method, the criteria will be evaluated from three fundamental points of view (i.e. design category, output category, end-use category) as shown in figure 6 below (Bockstaller & Girardin, 2003; Cloquell-Ballester et al., 2006). These points of view ensure that the indicators are scientifically designed, provide reliable outcomes, and be useful to end users.

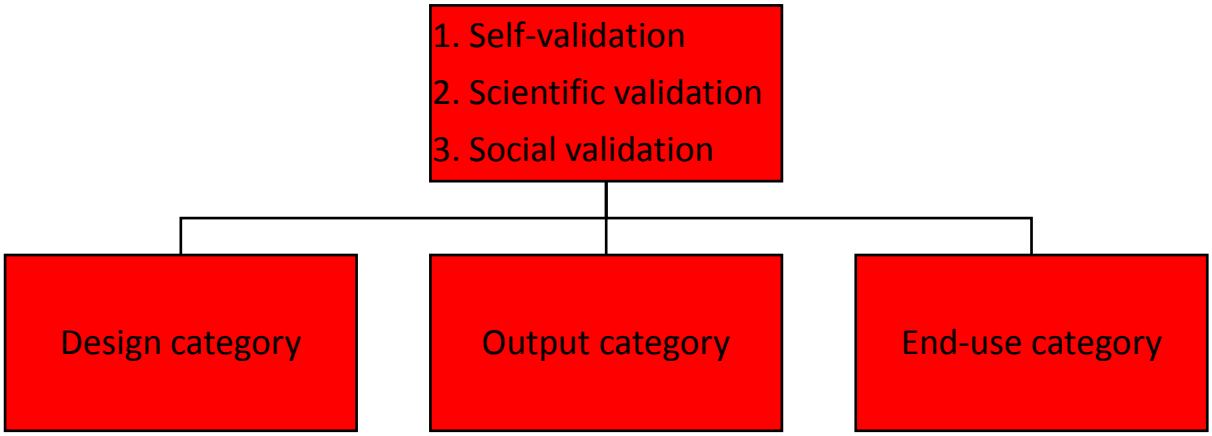


Figure 6 Evaluation of criteria in three fundamental points of views

The first point of view is the design category and relates to the conceptual coherence of an indicator. This category entails criteria which ensures that there is a correct relation between the indicator and the measuring object. The second point of view is the output category and relates to the operational coherence. This category entails criteria which determines the correct definition of the internal operations of the measuring instrument. The third point of view is the end-use category and relates to the utility of an indicator. This category encompasses criteria for determining the indicators' applicability in practice.

Although the abovementioned points of view provide a good direction for the evaluation of criteria, they do not provide concrete sub-criteria to assess indicators on a greater level of detail. However, in literature there exist many different detailed indicator sub-criteria, from short concise acronyms to detailed all-encompassing lists. Although it can be useful to provide an extensive list of criteria, there is a need for compromise between maintaining a sufficient level of detail whilst achieving simplification for manageability (Shekhawat, 2016). Therefore, the RACRE-criteria (Relevant, Acceptable, Credible, Robust, Easy) is introduced. The RACRE framework enables to maintain a sufficient level of detail without compromising the manageability. RACRE provides an encompassing but still concise and practical breakdown of indicator selection criteria to evaluate the suitability of resource efficiency indicators in policy (European Commission, 2013). It is an evaluation framework developed for assessing the value of scientific tools for use in policymaking which makes it an appropriate tool to use in this thesis. It has been used in a recent report from the European Commission '*Commission's Roadmap to Resource Efficient Europe'* and is useful for the development of practical and pragmatic indicators (European Commission, 2013).

The RACER-criteria presented above are classified into the earlier introduced three points of view and adjusted to RACRE as shown in figure 7 below. The design category encompasses the criteria *relevant* and *acceptable* as the indicator should be designed in accordance with the scientific community and the political context. The output category entails the criteria *credibility* and *robustness* as these criteria relate to the reliability of information the indicator provides. In the end-use category, the criteria *easy* describes the usefulness and practical use of the indicator. Additionally, sub-criteria is developed with the aim at making the meaning of each RACRE criterion more explicit and tailor it to the specific objectives of this thesis. The classification of the RACRE-criteria in the three fundamental points of view and the corresponding sub-criteria is elaborated more extensively below.

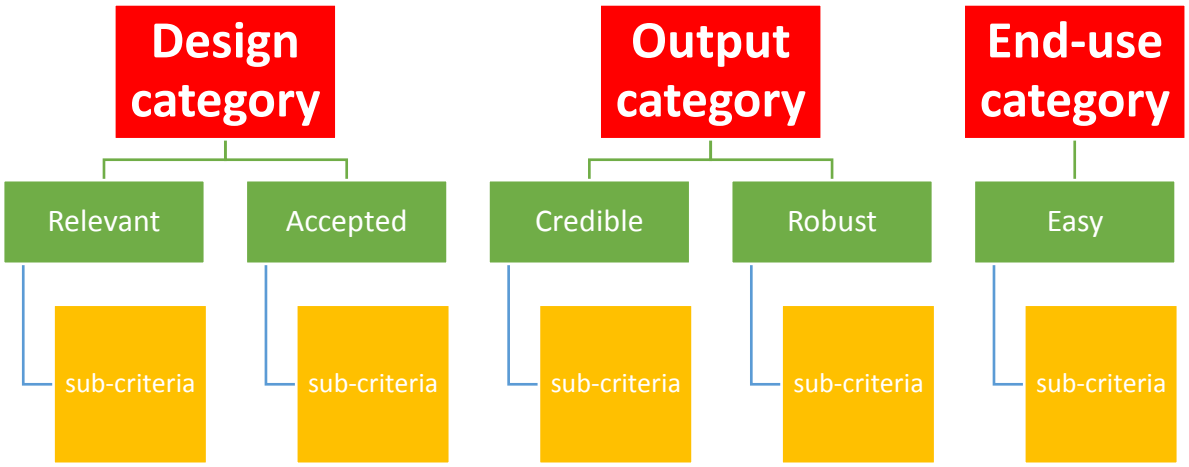


Figure 7 Indicator validation categories, criteria, and sub-criteria

2.3.1 Design category

This point of view entails the validation of the political relevance and the scientific quality of the construction or design of a given tool (Bockstaller & Girardin, 2003). These two aspects are consecutively described by the two criteria: 'Relevant' and 'Accepted'. Both criteria and their sub-criteria are discussed below.

A relevant indicator is adapted to local, regional, and/or national policy and concerns (European Commission, 2013). Böhringer & Jochem (2007) emphasize that political objectives should be derived from the indicators. Pinter (2006) agrees with this criterion by stating that indicators should be 'linked to specific policy and objectives'. Therefore, sub-criteria are listed in table 5 on the next page which describe (1) the possible purposes of using an indicator in policy and (2) the short-and long-term drivers that need to be addressed in circular regions. The purpose and role of indicators are previously discussed in paragraph 2.2.1. The short- and long term drivers are previously discussed in the Zero Waste framework (2.1.2). The indicator should address at least one purpose and one driver in order to be considered relevant.

The accepted criterion means 'accepted by the scientific community' and ensures that the indicator is scientifically sound designed. Böhringer and Jochem (2007) stress the importance of connecting indicators to the definitions of the measured concept. Furthermore, the indicators should represent holistic fields which increases the scientific validity of the overall measurement (Böhringer & Jochem, 2007; Shekhawat, 2016). To ensure the indicator is scientific, the sub-criteria represents the 7 key principles for CE which are discussed earlier in 2.1.1. An indicator should at least address one of these principles to be perceived scientific. An overview of the classification of these criteria and sub-criteria in the design category is provided on the next page in table 5.

Table 5 Classification of RACRE-criteria and sub-criteria in design category

	Design category	
RACRE-criteria	**Relevant**	**Accepted**
Main questions to be answered	1. What is the purpose of using indicators? 2. What drivers need to be addressed by the indicators?	1. How is CE defined? 2. What principles/aspects are relevant for the concept of CE?
Sub-criteria	Purpose and role of indicators: 2.2.1 Short- and long term drivers: 2.1.2	Key principles of CE: 2.1.1 1) Modular design 2) Zero waste 3) Renewable energy 4) think in systems 5) closing loops 6) shared value creation 7) new business models

2.3.2 Output category

The second point of view entails the validation of the operational aspects of the indicator (Bockstaller & Girardin, 2003; Cloquell-Ballester et al., 2006). This relates to the soundness of the indicator output which is described by two criteria: 'Credible' and 'Robust'. A credible indicator provides unambiguous results and is transparent about the measurement method (European Commission, 2013). A robust indicator is reliable and not easily manipulated (European Commission, 2013). Both criteria and their sub-criteria are discussed below.

In literature is described that a credible indicator should 'show trends' to provide acceptable and believable information (Donnelly et al., 2006). Furthermore, Shekhawat (2016) describes characteristics of a good indicator for the development of tourism indicators for SD and emphasizes that a credible indicator should be 'verifiable and replicable' and there should be some form of 'stakeholder involvement' incorporated in the selection process of indicators. There should also be 'transparency' in methodology and selection (Shekhawat, 2016). A main contribution to the indicator criteria specifically for CE is provided by Pinter (2006) who states that a credible indicator should provide unambiguous results and include stakeholders in the selection process. All these characteristics serve as sub-criteria for the 'credible' criterion and are summarized below in table 6.

According to literature, a robust indicator should be 'sensitive' i.e. can be used over time, and across space but only within the specific area (Donnelly et al., 2006). This is in accordance with Böhringer and Jochem (2007) who did an extensive survey on SD indices, and emphasize that data related to the indicators should be available for quantification of longer time horizons. The 'data should be reliable' and therefore consist of both qualitative as well as quantitative statistics which should not easily misrepresented/misinterpreted (Shekhawat, 2016). Also, data should be collected and/or reviewed by a third party statistical office (Shekhawat, 2016). Furthermore the indicator should be 'useable and easily interpreted' in order to avoid any misconceptions (Tan, Yeo, Ng, Tjandra, & Song, 2015). Pinter (2006) emphasizes that a robust indicator should be 'widely accepted in existing accounting frameworks'. Especially connecting indicators to commonly used underlying monitoring and information systems is of great importance as the role and functions of accounting systems and indicators are complementary (Pintér, 2006). 'Standardized indicators' help governments to monitor CE development consistently and compare it to that of others (Azapagic & Perdan, 2000). The abovementioned characteristics serve as sub-criteria for the 'robust' criterion and are summarized below in table 6.

Table 6 Classification of RACRE-criteria and sub-criteria in output category

	Output category	
RACRE-criteria	**Credible**	**Robust**
Main questions to be answered	1. How is the indicators' credibility guaranteed?	1. What determines the reliability and accuracy of an indicator?
Sub-criteria	• Unambiguous results • Show trends • Verifiable and replicable • Stakeholder involvement • Transparent	• Sensitive • Data is reliable through 3rd party verification • Useable and easily interpreted • Widely accepted in accounting frameworks

2.3.3 End-use category

The third point of view entails the validation of the usefulness of an indicator for the potential user (Bockstaller & Girardin, 2003; Cloquell-Ballester et al., 2006). This relates to the utility of the indicator in CE measurement and is described by the criterion 'easy'. An easy indicator is feasible to monitor in terms of effort and cost (European Commission, 2013).

In literature, many characteristics of an applicable indicator are described. It should also be applicable to the scope i.e. relevant to local and regional concerns (Tan et al., 2015). This means that an indicator should be 'understandable' i.e. simple to understand, use, and implement (Donnelly et al., 2006). Böhringer and Jochem (2007) emphasize that 'data should be available' against reasonable time and costs. This is in line with Shekhawat (2016) who states that data should be accessible and the collection should be 'technically feasible'. The abovementioned characteristics serve as sub-criteria for the 'easy' criterion and are summarized below in table 7.

Table 7 Classification of RACRE-criteria and sub-criteria in end-use category

	End-use category
RACRE-criteria	**Easy**
Main questions to be answered	1. What makes the indicator easy and useful to the final user?
Sub-criteria	• Applicable to scope • Data is available • Technically feasible

2.3.4 Validation framework and criteria

As described above, the design, output, and end-use categories are proposed to ensure the indicator is scientifically sound designed, provides relevant and reliable information, and is useful to the end users. The RACRE-criteria is classified in these categories to provide concrete sub-criteria to assess the indicators on a greater level of detail. This leads to a comprehensive list of SD and CE sub-criteria which is shown on the next page in table 8 which will be validated during the case study.

Table 8 Overview of RACRE-criteria and the sub-criteria from SD and CE literature

Points of view	Design		Output		End-use
RACRE	**Relevant**	**Accepted**	**Credible**	**Robust**	**Easy**
Sub-criteria from literature	**Purpose of indicators:** • Raise awareness • Measure progress • Inform decision-making **Short and long-term drivers addressed:** 1. Awareness, education & research 2. Sustainable consumption & behaviour 3. New infrastructure & systems thinking 4. Transformed industrial design 5. Zero depletion legislation & policies 6. Prevent, reuse, recycle of natural assets	**Principles that are addressed:** 1. Modular design 2. Zero waste 3. Renewable energy 4. think in systems 5. closing loops 6. shared value creation 7. new business models	• Unambiguous results • Show trends • Verifiable and replicable • Stakeholder involvement • Transparent	• Sensitive • Data is reliable through 3rd party verification • Useable and easily interpreted • Widely accepted in accounting frameworks	• Applicable to scope • Data is available • Technically feasible

3. Methods

This section describes the research methods i.e. research strategy and design, sampling, methods of data collection and analysis. Paragraph 3.1 describes the overall study step by step. The main objective of this thesis was to a describe a validation procedure of CE criteria according to the 3S method in the MRA. Therefore, the criteria in the validation framework described in table 8 in the previous section was validated according to the 3S method which is extensively described in paragraph 3.2. Additionally, to illustrate how these validated criteria can serve as an evaluation tool for existing CE indicators, a list of potential CE indicators was collected. This is described in paragraph 3.3. In the last paragraph 3.4 the credibility and reliability issues for this research are discussed.

3.1 Multi-method qualitative study

This research is of an exploratory nature as it attempted to develop a better understanding of how one can design a region-specific set of validated criteria. By means of a desk research, interviews with experts, and a focus group, a methodology was developed to validate key criteria for a specific region. With these key criteria, potential CE indicators can be evaluated and selected accordingly. The objectives of this method were to (1) develop a list of generic SD and CE criteria; (2) validate these criteria according to the 3S methodology for the MRA and present a list of specific criteria (3) present a methodology for evaluating existing CE indicators against the validated criteria. The process of validating criteria according to the 3S methodology (aim 2) is introduced as the '*3S validation of CE criteria framework'* and shown within the dotted lines in figure 8 below.

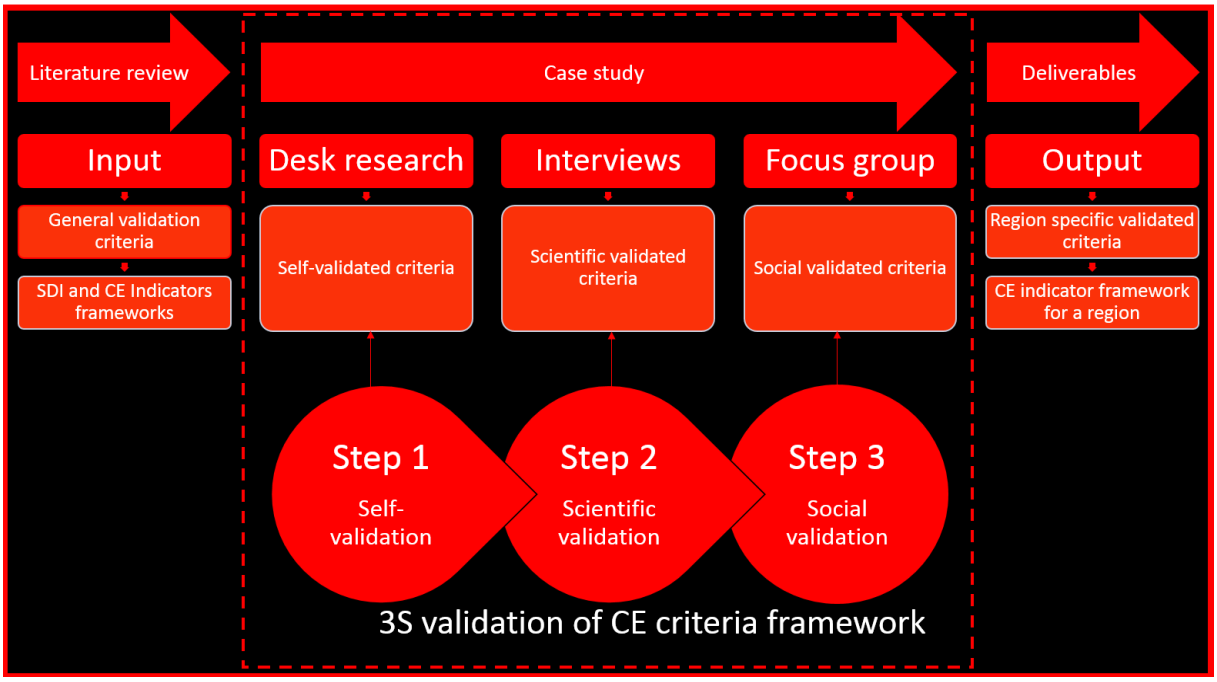


Figure 8: Research design of thesis and the 3S validation of criteria framework

The general orientation in this research is of inductive nature, since a qualitative research strategy was deployed. A case study design was chosen for the collection and analysis of data (Saunders, Lewis, & Thornhill, 2009). This was chosen because in any case, the methodology underlying indicator development should fit scientific standards, which implies a procedure of validation (Bockstaller & Girardin, 2003). However, the aim of this thesis was to validate MRA specific criteria for the selection of CE indicators to assist decision-makers in policymaking and setting goals. Therefore, the criteria should also incorporate social content (Bockstaller & Girardin, 2003). Thus, besides integrating independent experts' judgments, also a social validation stage including public participation was

incorporated in this research. Such a participative process is characterized by working with qualitative data and the use of a variety of methods to collect data such as expert panels and stakeholder meetings. This is done in order to establish different views of which validation criteria might be relevant in the context of the MRA (Saunders et al., 2009). A case study was chosen because it is an appropriate method for theory-building when understanding of the requirements of the CE indicator framework is weak (Stubbs & Cocklin, 2008). This research however is also characterized by some deductive elements as it involved a weaving back and forth between data and theory. This generic qualitative research strategy is often called '*iterative*' (Bryman, 2012). This is elaborated more extensively for the interviews in 3.2.2.1 sampling interviews and for the focus group in 3.2.3.1 Sampling focus group.

3.1.1 Case study: Metropole Region Amsterdam

A single case was chosen to gain a rich understanding of the context and processes regarding CE that are being enacted in the MRA. The MRA represents an unique case in the context of CE as this region provides major opportunities to move towards a CE (The Netherlands Circular Hotspot, 2016). Regional governments joined forces and spread their ambition to become a worldwide frontrunner in finding smart solutions for the limited availability of resources through the principles of CE. It's a comparatively densely populated area in which large amounts of resources circulate and in which many innovative and sustainable entrepreneurs are active. Furthermore, the region has a logistic network including a harbor, global airport Schiphol, and compact railways and roads. The region also offers a broad spectrum of economic activities and knowledge institutions, and several CE-related bottom-up initiatives are already present. In order to close material cycles and to achieve an international outstanding position as a circular resource hub in 2025 the following five strategies are deployed as shown in table 9 below (The Netherlands Circular Hotspot, 2016):

Table 9 Circular strategies Metropole Region Amsterdam

1. Map the main waste streams in the region and their potential to recycle or reuse
2. Identify opportunities to strengthen business development, employment and innovation focused on CE
3. Pursue those activities that fit in the strategy of the MRA as a circular resources hub
4. Set up online and offline communication that increases publicity and communication on the MRA as a circular resource hub
5. Strengthen the involvement and consciousness of citizens about the CE activities of their region

Overall, the MRA provides a unique case for observing and analyzing a phenomenon that few other regions have as the preconditions for making CE a success (i.e. energetic citizens, innovative entrepreneurs, advanced knowledge institutes, facilitating and stimulating governments. This makes the MRA an appropriate and interesting case in this research.

3.2 3S validation process of criteria

The main aim of this research was to validate criteria according to the 3S method for CE in the MRA. The data collection and analysis deployed here is described in 3.2.1, 3.2.2, 3.2.3. Due to the uniqueness of the case and the lack of knowledge on CE, an extensive evaluation took place in which several data collection techniques were deployed for the purpose of triangulation. Triangulation refers to the use of different sources of data and methodologies in one study, resulting in greater confidence in findings (Bryman, 2012; Saunders et al., 2009). This thorough evaluation was performed according to the 3S methodology which describes a validation process including three steps i.e. self-validation, scientific validation, social validation (Cloquell-Ballester et al., 2006). This validation process was characterized by three different data collection methods accordingly. First, the criteria found in literature were validated by executing a *desk research* i.e. self-validation, with the purpose of facilitating interpretation in the later stages. Second, adapted criteria from the desk research were validated by performing *interviews with expert's* i.e. scientific validation. Third, a *focus group* meeting was held to (1) ensure the criteria were validated through a participative process including key public stakeholders from the region and (2) establish a threshold what criteria to include in the final key criteria. This process is outlined in figure 9 below:

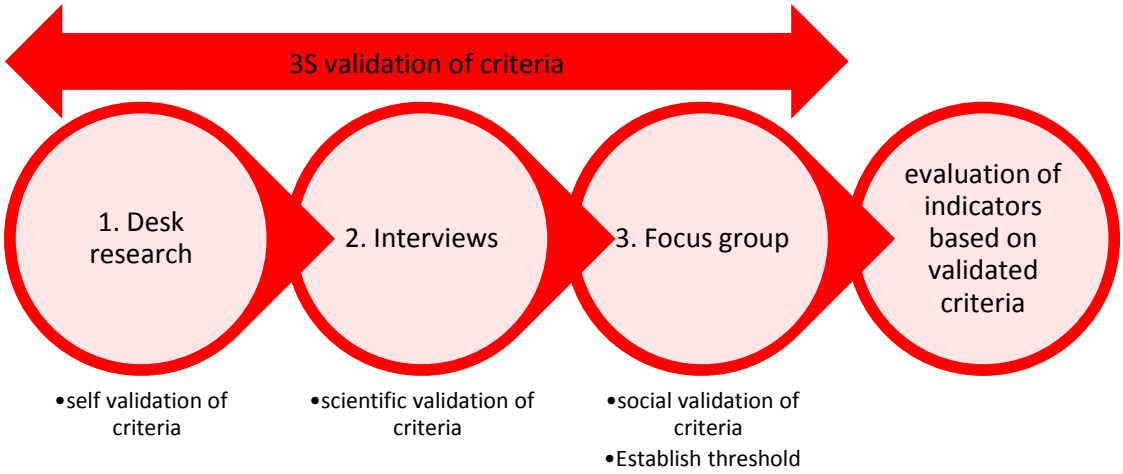


Figure 9 Multi-method approach to validate criteria for selecting CE indicators

In each phase, the criteria in the categories design, output, and end-use were validated as described below in table 10. Therefore, it was attempted to answer the *main questions* in each phase by means of evaluating the criteria and sub-criteria proposed in theory.

Table 10 Operationalization of RACRE-criteria for the design, output, and end-use categories

	Design category		**Output category**		**End-use category**
RACRE	**Relevant**	**Acceptable**	**Credible**	**Robust**	**Easy**
Main questions to be answered	1. What is the purpose of using indicators? 2. What drivers need to be addressed by the indicators?	1. How is CE defined? 2. What principles/aspects are relevant for the concept of CE?	1. How is the indicators' credibility guaranteed?	1. What determines the reliability and accuracy of an indicator?	1. What makes the indicator easy and useful to the final user?

Sub-criteria	See Table 5	See Table 5	See table 6	See table 6	See table 7

The aim of the desk research was twofold. On the one hand, the desk research was used to become more familiar with the regional CE objectives, targets, and strategies which facilitated the interpretation in the next two phases. On the other hand, the researcher answered the abovementioned questions in table 10 to provide context to the sub-criteria from literature. Then, the expert interviews were executed to discuss the sub-criteria found in the desk research. The aim of this phase was to provide the validation process with expert knowledge and experience. In sum, both the desk research as well as the expert interviews were used to examine whether or not the sub-criteria were relevant. Whenever one of the sub-criteria was described implicitly or explicitly in either the desk research or the interview, the sub-criteria was considered to be relevant. Whenever the sub-criteria was not described or mentioned at all, it was considered not to be relevant and not taken into consideration in the thesis.

The focus group was used to establish a threshold what criteria to include in the final list of key criteria (5.4.3). In the focus group the relative importance of each sub-criteria found in the desk research and the interviews was determined. Therefore, the participants were asked to fill in a form during the session to evaluate the importance of the sub-criteria on a 5-point Likert scale (1=not relevant, 5=very relevant). After filling in the form, each participant was asked to substantiate his/her choice which led to a fruitful discussion. In the next paragraphs, the data collection and analysis will be described for each step in the validation process.

3.2.1 Step 1: Desk Research

The aim of the desk research was to accomplish the first step of the 3S validation method: self-validation of the criteria for the MRA by means of reviewing documents. Data was gathered for the validation of MRA-specific criteria. Below is described how this data were managed, analyzed and interpreted during the research.

3.2.1.1 Sampling desk research

For the validation of MRA-specific criteria, secondary data from multiple sources was collected comprising of (Saunders et al., 2009): various publicly available official documents from European, national, or local governments (agenda's, ambition reports, programs, conventions). The sources that were used to gather these documents comprised of web-pages from official governmental and research organizations. The most important gateways to secondary data on European, national, and local level are shown in table 11 on the next page:

Table 11 Selected gateways to secondary data on the internet

Name	Internet address	Comment
Europa	http://europa.eu.int	Information published by the European Union including press releases, legislation, fact sheets. Available links to Eurostat Statistics.
Netherlands	http://rijksoverheid.nl	Information published by Dutch government about legislation, strategies, goals and targets concerning sustainability and circular economy
MRA	http://metropoolregioamsterdam.nl	Information about MRA about local economy, logistics, urban planning, sustainability, urbanization
Amsterdam	http://amsterdameconomicboard.com	Information about MRA and the city of Amsterdam about circular economy, digital connectivity, health and mobility, and talent for the future.

From this data, the criteria was evaluated which served the main aim of this thesis: *provide a set of MRA-specific criteria*.

To gather the sample, the following screening criteria were used for the selection of appropriate documents (table 12):

Table 12 Screening criteria for MRA-specific criteria validation

- **Relevant**: the information in the articles should comprise CE strategies involving the selection of goals, objectives, targets, features and resources. Furthermore, the publications should be published *in 2005 or later*
- **Applicable:** the information should cover European, national, regional and/or local strategies

A complete list of articles and publications can be found in appendix A. A full list of citations and references are available on request.

3.2.1.2 Qualitative content analysis of documents

The analysis of the data comprised a thorough evaluation of the documents. Therefore, a qualitative content analysis was deployed. This is the most prevalent approach to the qualitative analysis of documents and consisted of a search for key criteria for MRA indicators (Bryman, 2012). Therefore, each document was evaluated according to the validation framework shown in table 8 in paragraph 2.3.4. Furthermore, there was searched for regional CE targets, objectives, and strategies to become more familiar with the MRA case. This facilitated interpretation during the interviews and the focus group. The sub-criteria that were deemed relevant according to the desk research were filled in the framework which can be found in appendix B.

3.2.2 Step 2: Interviews

The second step of the 3S validation method comprised the scientific validation of the criteria for the MRA by means of conducting interviews. Semi-structured interviews were held with experts to ensure rigor and objectivity in the process of validating criteria. Therefore, the adapted validation criteria from the previous step (desk research) were evaluated by independent experts' judgements. Below is described how this data was managed, analyzed and interpreted during this phase.

3.2.2.1 Sampling interviews

For the interviews, a non-probability of sampling was used: Generic purposive sampling (Bryman, 2012). Generic purposive sampling is based on the 'generic inductive qualitative model' which can be described as relatively open-ended and emphasizes the generation of concepts and theories, while it does not necessarily entails the iterative style of grounded theory (Bryman, 2012). Sampling is conducted purposively but not necessarily with regard to the generation of theory and theoretical categories (Bryman, 2012). The goal of this type of sampling in this research was to sample participants in a strategic way, meaning that those sampled, are relevant to CE, indicators, and the MRA. Therefore, individuals were initially selected for the interviews because they were active in the MRA and they occupied a position which was relevant to CE and monitoring. The following criteria for choosing interviewees was considered as shown in table 13 below:

Table 13 Sample criteria for interviews

- Should have a function within the MRA which is directly related to CE
- Should have an academic background and an advanced level of knowledge on the CE
- Should be recommended by previous interviewees and open to an interview
- Should be stationed near Amsterdam and be available during the research

This resulted in a total of 7 interviews semi-structured (see Table 14 for details). Three interviews were held with governmental stakeholders that are involved with the topic of CE. This was done to give substance to the design criteria proposed in theory i.e. verify the CE goals, objectives and targets of the regional and local governments found in the desk research. An additional of four interviews were held with experts in the field of CE monitoring from different organizations. The interviews lasted between 30 and 60 minutes, were all done face-to-face, digitally recorded and backed up by note taking.

Table 14 Description of the interviewees

#	**Interviews**	
	Governmental experts **Position**	**Stakeholder**
1	CTO Project leader Circular Economy	Municipality of Amsterdam
2	CTO Project leader Circular Economy	Municipality of Amsterdam
3	Strategic Advisor	Amsterdam Economic Board
	Scientific experts	
4	Strategic Advisor	Waternet
5	Circular Developer/Project manager	Circle Economy
6	Program manager Circular Cities	Amsterdam Advanced Metropolitan Solutions (AMS)
7	Researcher Environmental Technology	Wageningen University

3.2.2.2 Thematic analysis

Semi-structured interviews were held with experts in the field of CE. All questionnaires started with introduction questions after which the main body consisted of questions structured according to the validation framework shown in table 8 in paragraph 2.3.4. During the interviews, indirect questions were asked regarding the sub-criteria from literature and the desk research. This enabled the interviewees to come up with sub-criteria which were perceived as relevant in his/her view. The semi-structured interview template can be found in appendix C.

Before the analysis of the interviews, all the recorded audio were transcribed. The transcripts were then analyzed by means of thematic analysis. Thematic analysis is one of the most common approaches to qualitative analysis according to Bryman (2012). To support this general strategy a coding framework based on the validation framework was used for ordering and synthesizing the data. The adapted validation framework consists of an index of categories, criteria, and sub-criteria, which are represented in the framework and closely resembles the SPSSS spreadsheets (Bryman, 2012). This adapted validation framework can be found in appendix D. During the analysis of the transcriptions, all irrelevant text (such as filler words) was removed. This enabled the researcher to structure and code the answers of the interviewees according to the categories, criteria, and sub-criteria in the framework. When searching for themes and criteria the researcher looked for the following phenomena according to Bryman (2012) as shown below in table 15:

Table 15 Defining a theme

➢ Repetitions ➢ Indigenous typologies or categories ➢ Metaphors or analogies ➢ Transitions	➢ Linguistic connectors ➢ Missing data ➢ Theory-related concepts ➢ Similarities and differences

The transcripts and an overview of all quotes of the interviewees are available upon request.

3.2.3 Step 3: Focus group

In the third and last step of the 3S validation process, social validation of the validation criteria for the MRA was guaranteed by organizing a focus group. Data was gathered from public stakeholders that were active in the MRA and engaged in CE practices. Therefore, sub-criteria from step 1 (desk research) and step 2 (interviews) were evaluated in this stakeholder meeting. The main purpose of this focus group was to asses and discuss the relative importance of each sub-criteria derived from the previous phases. This enabled the researcher to establish a threshold what sub-criteria to include in the final key criteria evaluation scheme. Below is described how the data was managed, analyzed and interpreted during this phase.

3.2.3.1 Sampling focus group

The sample for the interviews was used to suggest further relevant participants for the focus group. This sampling method is called 'snowball sampling' and it is quite common for this technique to be preceded by another form of purposive sampling (Bryman, 2012). Since a methodology was developed in this research for regional and local governments, the focus group aimed at interaction between key (governmental) stakeholders at these levels. Independent experts were included in both the interviews as well as the focus group to guarantee scientific validity and objectivity (Bryman, 2012; Cloquell-Ballester et al., 2006; Mascarenhas et al., 2010). Unlike with individual interviews, the researcher was also interested in how the local governmental officials and independent experts responded to each other's views. For the selection process of participants for the focus group, the aforementioned interview criteria were taken into account. However, the additional considerations in table 16 below were needed to be taken into account as this influenced the number of members in the focus group (Bryman, 2012; Cloquell-Ballester et al., 2006; Saunders et al., 2009):

➢ Typical group size is four to ten members ➢ A minimum of two experts and a maximum of eight experts ➢ Availability of experts ➢ Budget and time restrictions

Table 16 Additional considerations for the selection process of participants in focus group

This resulted in the following selection of key local stakeholders (see Table 17 for details). The stakeholders were provided with a digital hand-out days up front to give them some information about the purpose and the structure of the focus group. This hand-out was also printed for the session and can be found in appendix E. In this focus group meeting, the regional and local CE goals and objectives found in the desk research and interviews were discussed. Furthermore, the evaluation criteria was critically debated whereby the composition and structure of the focus group allowed for evaluation from multiple perspectives (i.e. governmental, business, research). The focus group lasted approximately 60 minutes and was digitally recorded. Since the researcher led the focus group, a fellow student was asked to take care for the note taking. This fellow student was carefully chosen since he was also engaged in the topic of CE which facilitated interpretation during the meeting.

Table 17 Details of the participants of the focus group

#	**Focus group**	
	Governmental actors	
	Position	**Stakeholder**
1	Strategic Advisor	Amsterdam Economic Board
2	Business Connector CE	Amsterdam Economic Board
3	Strategy and research assistant	Amsterdam Economic Board
4	CTO Project leader Circular Economy	Municipality of Amsterdam
	CE Expert	
5	Research Manager	Accenture
	Note taker	
6	MSc Sustainable Business and Innovation	Fellow student UU

3.2.3.2 Thematic analysis

In contrast with the expert interviews, it was chosen to directly present the sub-criteria during the focus group by means of a presentation and an evaluation form which was handed out. This evaluation form can be found in appendix F. In this way, the participants were given the opportunity to assess the relative importance of the sub-criteria on a 5-point Likert scale. Here, 0 represented an *irrelevant* sub-criteria whereas 4 represented a *very relevant* sub-criteria. After filling in the form, each participant was asked to substantiate his/her assessment during the meeting. Therefore, the participants were asked two questions regarding the relevancy of each-sub criteria for the three categories design, output, and end-use:

1. What sub-criteria have you considered not relevant at all for CE indicators in de MRA?
2. Can you arrange the sub-criteria from very relevant (score 4) to irrelevant (score 0)?

The relative importance of the sub-criteria was assessed as shown in table 18 below:

Table 18 The relative importance of each sub-criteria according to the focus group assessment

Assessment score	0-6 points	7-13 points	14-20 points
Relative importance of sub-criteria	Low relevancy	Medium relevancy	High relevancy
Included in the final key criteria?	No	Yes	Yes

The assessment consisted of a total of 5 participants. Thus, the total score for each sub-criteria varied between 0 (0, 0, 0, 0, 0) and 20 (4, 4, 4, 4, 4). Whenever a sub-criteria was scored zero up to and including six points, for instance three points (1, 0, 1, 0 , 1), the sub-criteria was given 'low relevancy'

and excluded from the key criteria list. Sub-criteria which were scored seven up to and including 13 were given 'medium relevancy' and included in the key criteria list. The same applied to the sub-criteria with 'high relevancy'. This resulted in a useful review of the sub-criteria from which the most important results are discussed in 4.3.

Furthermore, for the analysis of the focus group, the audio file was transcribed first. Then, also thematic analysis was used in the same way as for the interviews. Accordingly, to structure and code the results the adapted validation framework was used which can be found in appendix G. The transcripts and an overview of all quotes of the participants are available on request.

3.3 Screening and evaluation of indicators

In order to evaluate indicators against the validated criteria, a comprehensive list of indicator frameworks consisting of potential CE indicators is needed. Therefore, scientific articles and annual reports are collected. These potential indicator frameworks can serve as input for the evaluation of the indicators against the validated criteria. The actual evaluation of indicators against the validated criteria however, were outside the scope of this research. Nevertheless, the selection of these frameworks and related indicators can be used as input in other studies.

3.3.1 Sampling CE indicator frameworks

For the screening of CE indicator frameworks, scientific articles, CE assessments and annual reports were gathered. Therefore, sources that were used here comprised of Scopus, Google Scholar, and web-pages from research organizations.

The process of quantifying impacts starts with the question whether an indicator exists for measuring the impact (Cloquell-Ballester et al., 2006). The existence of such an indicator can be examined by screening literature of existing CE indicator frameworks (Cloquell-Ballester et al., 2006; Tan et al., 2015). In this research the initial screening criteria, adopted from Tan et al. (2015), were used to compose a first list of relevant articles as shown in table 19 below:

Table 19 Inclusion of articles in desk research

- **Relevant**: the indicators in the articles should directly be relevant to the topic of *measuring CE*. Furthermore the articles should be published *in 2005 or later*
- **Applicable:** the indicators in the articles should be applicable *at national, regional and/or local* and measure either the *environmental, social, and/*or *economic* dimension

Therefore, a search query was formulated to search in Scopus for articles that have potentially relevant and applicable indicators for the scope of this thesis:

TITLE-ABSTRACT-KEY((national OR regional OR local) AND (indicators OR assessment OR index) AND (sustainability OR circular economy OR eco-efficiency OR resource efficiency) AND (city OR cities OR urban) AND (water OR energy OR materials)) AND PUBYEAR> 2004

Short surveys, books, articles in press, book chapters, and conference reviews were excluded from the search as well as articles in the following irrelevant research areas: Pharmacology, Toxicology, and Pharmaceutics; Mathematics; Medicine. In total 48 documents were found from which 42 articles were accessible as shown in appendix H.

Besides scientific literature, also secondary sources were consulted to complement the relatively scarce literature on indicators for CE. These reports were obtained through web-pages of large global research organizations such as the World Resources Institute (WRI), European Environment Agency (EEA), United Nations Environment Program (UNEP), and others. In total 13 additional reports were added which is shown in appendix I.

In total, 55 documents and reports were found that consist of one or more potential CE indicators. These potential CE indicators can be evaluated according to the final key criteria proposed in 5.4.3.

3.4 Credibility of research findings

Validity and reliability are important criteria in establishing and assessing the quality of qualitative research (Bryman, 2012). Validity refers to whether you are observing, identifying or 'measuring' what you say you are and how well conclusions drawn from a particular study can be generalized to other social settings (Bryman, 2012). Reliability is fundamentally concerned with issues of consistency of measures (Bryman, 2012). This research may be prone to the following validity and reliability errors and biases as shown below in table 20 (Saunders et al., 2009):

Validity

- ***Internal validity:*** refers to whether there is a good match between what is observed during the desk research, interviews, and focus group, and the theoretical ideas that are developed. To enhance the level of congruence between what is observed and the theoretical ideas that are developed, triangulation of method and sources of data was applied.
- ***External validity:*** refers to the degree to which findings can be generalized across social settings. Since a single case study was deployed the generalizability of the case results are limited. However, a single case was chosen to gain a deep understanding of the context and processes regarding CE in the MRA.

Reliability

- ***Subject or participant error***: the limited time available for the interviews and the focus group may cause insufficient data.
- ***Subject or participant bias****:* the interviewees and participants of the focus group might have provided answers that are guided by the semi-structured questions or by the attitude of the interviewer/observer.
- ***Observer error:*** the use of semi-structured interviews and a focus group, conducted by only one interviewer/observer
- ***Observer bias:*** the shared concern of the researcher and the interviewees for Circular Economy and sustainability issues

Table 20 Validity and reliability issues

4. Results

This part explores the results of validating the criteria for each phase i.e. desk research, interviews and focus group. The overall goal of this validation is to test the proposed 3S methodology for the case of the MRA. Therefore, the criteria are explored chronologically in each phase for the MRA to identify what the exact content and importance of each sub-criteria is. In paragraph 4.1, the results of the validation of the sub-criteria in the desk research are described. In paragraph 4.2 is described which sub-criteria found in the desk research are also discussed during the expert interviews. Also, additional or missing sub-criteria could be discovered in this phase which is described in this paragraph. Paragraph 4.3 reveals the relative importance of the different sub-criteria according to the participants of the focus group. The aim of the focus group was to establish a threshold and determine what sub-criteria are particularly relevant for the MRA.

4.1 Desk research

The aim of the desk research is to evaluate what sub-criteria are described in public documents and reports. Therefore, the criteria categories 'design', 'output', and 'end-use' were analyzed by screening official document and reports from the European Union, the Dutch government, and the local government within the MRA as described in 3.2.1.1 Sampling desk research. An overview of the results for the MRA are shown in table 21 below and further elaborated in the coming paragraphs. A comprehensive overview including the EU and the Dutch government can be found in appendix J.

Table 21 Overview of the sub-criteria found in the desk research

MRA				
Design category		Output category		End-use category
Relevant for policy	**Accepted** by scientific community	**Credible**	**Robust**	**Easy**
Indicators purpose/objective: ✓ Raise awareness: *Encourage economic activity, Provide understanding/transparency, Indicators have the ability to attract talents, companies, and investors* ✓ Measure progress: *Enable benchmarking* ✓ Inform decision making: *Support political action, Target setting*	**CE principles described:** ○ ~~Modular design~~ ✓ Zero waste ○ ~~Renewable energy~~ ✓ think in systems ✓ closing loops ✓ shared value creation ✓ new business models	✓ Unambiguous results/Show trends/Provide early warnings ✓ Stakeholder involvement ✓ Verifiable and replicable/transparency in method (Eurostat, GRI, TSC, CBS)	✓ Sensitive/Annual data ✓ Data is reliable through 3rd party verification/Data collection through AMS data platform or individual MRA stakeholders ○ ~~Useable and easily interpreted~~ ✓ Widely accepted in accounting frameworks/ (internationally) standardized (MFA/MFM) accounting methods	✓ Applicable to scope: Simple to understand, use, and implement by addressing local streams and prioritized areas in MRA ✓ Data is available/Technically feasible through DANK atlas, CBS, AMS, TNO ✓ *Indicators allow for (inter)national benchmarking* ✓ *Complementary and integrated*
Short and long-term drivers addressed: ✓ Awareness, education & research ✓ Sustainable consumption & behaviour ✓ New infrastructure & systems thinking ✓ Transformed industrial design ✓ Zero depletion legislation & policies ✓ Prevent, reuse, recycle of natural assets				

The sub-criteria from literature that are found in the desk research are classified in the validation framework above. Some sub-criteria from literature are not found during the desk research and are strikethrough as can be observed in the above table 20. The sub-criteria in *italic* are added in the above table as they are found in the desk research but are not described in literature.

4.1.1 Design category

This part explores what policy *relevant* and *accepted* by scientific community sub-criteria are described by the EU, the Dutch government, and the MRA. For the policy *relevant* sub-criteria, the following main questions are answered:

1. What is the purpose of using indicators?
2. What short- and long term drivers need to be addressed by the indicators?

For the *accepted* by scientific community sub-criteria, the following main questions are answered:

1. How is circular economy defined?
2. What principles/aspects are important for the concept of CE?

These questions and their sub-criteria can be found table 5 paragraph 2.3.1.

4.1.1.1 Relevant for policy and accepted by scientific community

The European Commission (EC) has developed strategies to secure the supply of vital resources in the future. Already in 2008 the 'raw materials initiative' was deployed with the aim to secure worldwide access to natural resources. Later, a flagship initiative for a resource efficient Europe was launched to secure economic growth and employment. This EU action plan for CE was initiated which includes commitments on eco-design, the development of strategic approaches on plastics and chemicals and a major initiative to fund innovative projects under the umbrella of the EU's Horizon 2020 research program. This EU action plan fuels the transition to circular practices in different European regions. The strategies and objectives proposed by the EU are categorized in the Zero Waste framework as described in 2.1.2. The following short-and long term drivers are addressed with different programs which are shown in table 22 below:

Table 22 Short- and long-term drivers, strategies, and targets in the EU action plan

Zero Waste EU – Under Horizon 2020		
Long-term drivers	**Strategy/Program**	**Objectives targets**
1. Awareness, Education & research	Industry 2020 circular economy	➢ R&D funding of 650 million
2. Sustainable consumption & behavior	Product environmental footprint Green public procurement (GPP)	➢ EU prepares independent testing program to help identification of issue ➢ Initiate environmental product footprint pilot ➢ 50% Green public procurement in 2025
3. New infrastructure & systems thinking	GPP	➢ Develop new or revise existing GPP criteria ➢ Supporting higher uptake of GPP
Short-term drivers		
4. Transformed industrial design	Eco-design directive Quality standards	➢ promote the reparability, upgradability, durability, and recyclability of products ➢ Boosting markets for secondary raw materials

5. Zero Depletion legislation & policies	Energy labelling and ecolabel	➢ Innovation 'deals' ➢ Revise legislative proposals on waste ➢ Common rules on fertilizers ➢ Reduce landfill and tipping fees
6. Prevent, reuse, recycle of natural resource assets	From waste to resource	➢ a common EU target for recycling **municipal waste** of 65% by 2030 ➢ a common EU target for recycling **packaging waste** of 75% by 2030 ➢ boost reuse and recycling of **municipal waste** to a minimum of 70% by 2030 ➢ a binding **landfill** reduction target of 10% by 2030 ➢ **ban** the **landfilling** of recyclable plastics, metals, glass, thesis and cardboard, and biodegradable waste by 2025, and **eliminate landfill** by 2030 ➢ **Food waste** in manufacturing is reduced with at least 25% in 2025 ➢ increase **resource productivity** (RMC/GDP) by 15 % between 2014 and 2030 under a business as usual scenario

Awareness, education and research is stimulated by a major initiative to fund innovative projects in the Horizon 2020 research program. *Sustainable consumption and behavior* is promoted by advanced guidance on the legal requirements for reliability, accuracy, and clarity of 'green claims'. Furthermore, the EU is testing the Product Environmental Footprint to measure and communicate environmental performance of products. This driver as well as the *new infrastructure & systems thinking* driver are addressed by developing new, or revising old criteria, with special emphasis on aspects relevant to CE such as durability and reparability. Also, a quantitative target is defined of 50% Green Public Procurement (GPP) in 2025. The drivers *transformed industrial design* and *Zero depletion legislation and policies* are addressed by 'innovation deals' and the 'eco-design directive' which promote reparability, upgradeability, and recyclability through revised legislation and extra funding. Prioritized action areas for the *prevent, reuse, and recycle of natural assets* drivers are plastics, food waste, construction, critical raw materials, industrial and mining waste. The most important quantitative targets for this driver are shown in table 22 above.

Regarding the purpose and objective of CE indicators, the EU describe that indicators help to *measure progress* and help to *understand* how resource efficiency contributes to economic goals which supports *political action and setting targets*. Furthermore, indicators can help *harmonize understanding* of different stakeholders and it can provide *additional information* on the competitiveness of Europe. The principles of CE are addressed by indicators such as supply of key raw materials, repair and reuse, waste generation, trade in secondary raw materials, and the use of recycled materials in products. Furthermore, the wish to use complementary societal and economic progress indicators is expressed but this work is still in progress.

The Dutch government has recently published the 'mid-term Review – Green growth' in which issues regarding resource management are directly related to bio based- and circular economy. Therefore, the program 'from waste to resource' was initiated in 2014 to stimulate the transition to a CE. The objectives that are described in the policy program that address the following short-and long-term drivers are shown in table 23 below:

Table 23 Short- and long-term drivers, strategies, and targets for CE in the Netherlands

Zero Waste NL – From waste to resource		
Long-term drivers	**Strategy/Program**	**Objectives targets**
1. Awareness, Education & research	Research program 'from waste to resources'	➢ Stimulate knowledge sharing for CE models ➢ Governance systems and (inter)national knowledge sharing
2. Sustainable consumption & behavior	Green deal Retail Green deal bodemassen/duurzaam doen	➢ Promote circular consumption ➢ Improve waste collection
3. New infrastructure & systems thinking	Green deal procurement Green deal GFT Green deal NL	➢ Stimulate green public procurement ➢ Promote circular supply chains such as chemical leasing
Short-term drivers		➢
4. Transformed industrial design	Program circular design Program circular production	➢ Provide economic incentives and create circular business models by revolving MIA and VAMIL funds
5. Zero Depletion legislation & policies	Eco-design directive Eco innovation plan	➢ Adjust policy for waste to resource ➢ Connect national projects and policy with international programs ➢ Change legislation related to waste and food
6. Prevent, reuse, recycle of natural resource assets	From waste to resource	➢ Reduction of 50% of the **total waste generation** in 2025 compared to 2015 ➢ Recycling of 75% of total **municipal and retail- and service sector waste** in 2020 ➢ Maintain recovery rate of **construction waste** from 95% despite a substantial increase of construction waste (23 Mton in 2006 to 31 Mton in 2021). ➢ Maintain recovery rate of industrial waste from 90% despite a substantial increase of **industrial waste** (16 Mton in 2006 to 18 Mton in 2021). ➢ Banned landfill of **combustible waste**

The first driver is addressed by the design of new educational institutions for the program 'from waste to resource' which is connected to the Horizon 2020 research program. The research program is integrated in the Dutch Top Sector Policy, and aims to provide resources for knowledge dissemination between different research institutions in the country. The second and third driver are addressed by the various green deals which promote circular production and consumption and improve waste collection. GPP plays also a key role in the transition here as it public procurement accounts for a significant proportion of the Dutch consumption. The *transformed industrial design* driver is addressed by program circular design and circular production as these programs provide economic incentives for circular business models. Furthermore, this driver as well as the *Zero Depletion legislation & policies* driver are managed by adjusting policies and legislation related to organic wastes and providing

innovation and regional funds. Prioritized streams for the 6th driver according to the national waste plan are cardboard, textiles, building and construction waste, organic/food waste, aluminum, pvc, and bulky household waste.

Regarding the purpose and objective of CE indicators, the Ministry of Infrastructure and Environment emphasizes that indicators, monitoring methods and labelling can help to increase *transparency*. This helps consumers, companies, and policymakers to make informed decisions. Moreover, for policymakers, indicators enable to *benchmark* regions, *evaluate* policy, and *show progress* towards established targets and develop future *scenarios* accordingly.

The Metropole region of Amsterdam (MRA) is a metropolitan network of 32 municipalities which is economically the strongest region of The Netherlands, aiming at enhancing its international competitiveness in a sustainable way. In order to realize this vision, the MRA developed seven development paths to anticipate on challenges the region is facing the coming decades. One of the seven development paths is the stimulation of the transition towards a clean economy in which circular- and bio-based economy have priority on the agenda of the MRA. CE is defined as '*smart distribution of energy, water, resources and food in an economy where waste equals food and all energy is renewable'* (Metropoolregio Amsterdam, 2016, p.38). The program stimulates local collaboration between companies, civilians, and governments to accelerate the transition to more circular business models in the MRA. Meetings with stakeholders in the region resulted in potential pilot areas such as the Westas, Zaanstad, Gooi en Vechtstreek, Schiphol Trade Park, and Floriade Almere.

The Amsterdam Economic Board (AMECBoard) coordinates the collaboration and activities between the different municipalities, knowledge institutions and industry in the MRA. The AMECBoard developed five challenges: *Circular economy, digital connectivity, health, mobility, and talent for the future*. Within the challenge circular economy, the following short-and long term drivers are addressed with different programs as shown in table 24 below:

Table 24 Short- and long-term drivers, strategies, and targets for CE in the MRA

Zero Waste MRA – MRA as circular hub		
Long-term drivers	**Strategy/Program**	**Objectives targets**
1. Awareness, Education & research	MRA as circular hub Urban innovation program circular development	➢ Develop MRA-wide resources monitoring system (MRA-dashboard) ➢ Research in regional waste management solutions ➢ At least 10 education programs have incorporated CE in 2020
2. Sustainable consumption & behavior	Program circular procurement	➢ Provide temporary storage of construction waste and create online marketplace to sell this ➢ Program circular procurement is adopted by frontrunners in 2016 ➢ At least 20% circular procurement from municipalities in 2020
3. New infrastructure & systems thinking	Roadmap for circular districts	➢ Develop a plan with frontrunners in business to close cycles in the region ➢ At least 8 dedicated clusters of innovation created in the MRA in 2020 **Amsterdam** ➢ 400.000 sustainable dwellings in 2040
Short-term drivers		

4. Transformed industrial design	Bio based connections Living labs	➢ Create pilot areas such as Westas, Zaanstad, Gooi en Vechtstreek, Schiphol Trade Park, and Floriade Almere ➢ At least 50 initiatives of industry lead to new business models in 2020 ➢ at least 150 new start-ups from which 75 survive valley of death in 2020 ➢ 3600 jobs and 480 million Euros additional revenue in 2025
5. Zero Depletion legislation & policies	SER Free circular zones Amsterdam business program	➢ The development of a roadmap how to enable CE transition through adjusting legislation ➢ Alignment of national policy with local targets and objectives
6. Prevent, reuse, recycle of natural resource assets	Quick scan city circular Quick scan Buiksloterham Greendeal circular economy	➢ 400 Kton CO2 savings a year in 2040. ➢ Protocols on 8 priority resource streams put into practice in 2016 ➢ Protocols on 16 priority resource streams put into practice in 2020 **Amsterdam:** ➢ 30% of the fine household waste is separated in 2016 ➢ 65 % of the fine household waste is separated in 2020 ➢ 75% of the bulky household waste is separated in 2020

One of the main challenges for the AMECBoard is to stimulate the transition towards a circular region by creating synergies of activities and knowledge sharing between different stakeholders. This challenge is closely related to the first driver and addressed by the 'Urban innovation program Circular Development' (i.e. research in regional waste management solutions, an MRA wide resource monitoring system, integration of CE in at least 10 education programs in 2020). Sustainable consumption & behavior is stimulated through the circular procurement program. In 2016 the most ambitious municipalities of the MRA are expected to have adopted the program and in 2020 at least 20% of all municipalities are demanded to purchase circular products and services. By offering temporary storage locations of construction waste, the construction sector is encouraged to upgrade and recycle building waste. This strategy addresses the third driver by creating opportunities for business to close cycles locally. This is supported by the development of a roadmap for circular districts or 'hubs' which enhances cross-sectoral firm clustering. The programs Bio based connections and the 'living labs' encourage industry to transform the current industrial design by piloting new business models. Eventually, this should results in at least 50 initiatives from industry to create new business models and 150 new start-ups from which 75 pass the valley of death. These pilots should deliver 3600 new jobs and 480 million Euro additional revenue in 2025. The *Zero Depletion legislation & policies* driver is addressed by creating 'circular free zones' which reduce the legislative barriers for industry to trade secondary raw materials. National policy and objectives drafted by the Dutch Social Economic Council (SER) are integrated in the Amsterdam Business Program and aligned with local targets in the MRA. The AMECBoard identified the following resource streams with opportunity for CE practices: construction and demolition waste, bio-based plants, textiles, organic waste, phosphate, hydrogen, plastics, metals, mattresses, servers, and electronic waste. The city of Amsterdam, which is the pioneering city and flagship of the MRA, also established some ambitious objectives regarding CE based on the Europe 2020 and SDGs as can be observed in table 24. The quick scan 'Amsterdam Circular' revealed that especially the construction- and organic waste sectors provide a lot of opportunities for synergies between businesses.

According to the AMECBoard, the use of indicators has multiple purposes. One of the strategies of the AMECBoard consists of an MRA-wide economic oriented dashboard developed to *monitor* and *steer* the development of the MRA. Furthermore, the aim of the dashboard is linking CE to economic performance and provide information on indicators that can be influenced

with policy interventions. Also, the indicators should have the *potential to attract talents, companies and investors* to the region. Furthermore, the dashboard should provide information on: internal progress, external benchmarking, and long-term developments and opportunities.

Regarding the *accepted* by scientific community sub-criteria. Most of the 7 principles of CE are translated into practice. The zero waste principle for instance is addressed in multiple ways. Waste prevention strategies are executed for marine litter, construction and demolition wastes, food waste and hazardous waste. The systems thinking and closing loops principles are addressed by various strategies including optimization of circular chains and stimulation of pilot areas. Also adjustments and refinements are made regarding policies and legislation for CE. Green public procurement also fosters the consumption of durable and recyclable products, harnessing collaborative action by business and consumers. New business models are promoted by developing new economic incentives and initiating pilot areas such as the harbor of Amsterdam and area Buiksloterham. Furthermore, the development of high quality raw materials is promoted by funding and revised legislation on waste, food, and feed. Shared value creation is also recognized as an important principle which is evidenced by the use of complementary measures of societal and economic progress. The first principle 'modular design' and the third principle 'renewable energy' as main energy source are not described as an integral part of the (inter)national and regional CE development programs.

4.1.2 Output category

This part explores what *robustness* and *credibility* sub-criteria are described for the different implementation levels. For the *robustness* sub-criteria, the following main question is answered:

1. How is the indicators' credibility guaranteed?

For the *credibility* sub-criteria, the following main question is answered:

1. What determines the reliability and accuracy of an indicator?

These questions and their sub-criteria can be found table 6 paragraph 2.3.2.

4.1.2.1 Credibility and robustness

The EC state that there is a need for a set of key meaningful indicators that capture the main elements of CE. To improve the credibility of the indicator a range of thematic indicators including lead indicators such as resource productivity should be developed. The indicator framework should introduce an *early warning system* for monitoring compliance with targets. *Transparency in method* can be achieved by simplification and harmonization of definitions and calculation methods across Europe. This comprises amongst others clarifying and defining municipal landfill and packaging waste targets.

To ensure the indicators are robust, only four calculation methods are allowed to be used for the calculation of recycling targets. The data reliability is guaranteed by collection of *validated statistics* provided by Eurostat and the development of a *computerized data monitoring system with third-party verification*. Some issues that should be dealt with care is that some indicators measure resources by weight while the economic value, scarcity, and environmental impact is not only determined by weight.

The Dutch government state that credible indicators should bring *transparency* about the impact of economy on the natural capital. These impacts can only be understood when *definitions are clearly defined* and the lead indicators are *acknowledged by all relevant stakeholders up-front*. Furthermore, there should be *alignment* between international, national, and local *assessment methods* such as GRI, TSC, CBS and the recently developed True Price Platform.

The robustness of the indicators is influenced by the development of a *common accounting method* according to the System of Environmental-Economic Accounting (SEEA) which is currently initiated by CBS, RIVM, CPB, TNO, and PBL. The SEEA provides a coherent frameworks for integrating environmental and economic information. Data reliability is ensured by the revision of the availability, quality and use of data by the PBL. Furthermore the 'Digitale Atlas Natuurlijk Kapitaal' (DANK) is still under development which is producing a natural capital database based on GIS datasets. National and some local data is produced and updated regularly by the RIVM (National Institute for Health and Environment) and University Wageningen. CBS produces biannually statistics while the SEEA and the System of National Account (SNA) provide annual statistics.

The AMECBoard and the municipality of Amsterdam emphasize that the indicators developed should be *replicable* and *scalable*. The AMECBoard advocates the inclusion of an '*early warning system'* for the MRA scenario 2025. Furthermore, the indicators should be based on a *sound and transparent method*. Methods that are proposed in the Urban Pulse project, commissioned by the Municipality of Amsterdam, are MFA and GIS. This European based methodologies yield transparent, reliable data, and reliable outcomes of indicators. The sensitivity of the data differs per resource between daily to yearly statistics. The various existing indicator framework indicator reliability by integrating indicators from existing frameworks such as the local City circle scan and the national RACE indicators.

4.1.3 End-use category

This part explores how the *easy* sub-criteria i.e. easiness of use and the applicability of indicators differs for international, national, and regional governments. Therefore, the following main question is answered:

1. What makes the indicator easy and useful to the final user?

These questions and their sub-criteria can be found table 7 paragraph 2.3.3.

4.1.3.1 Easy to use

Indicators developed by the EC are applicable at European and National level. However, the EC emphasizes on the importance of *alignment* of European indicators with national and regional policy. The EC favors a *single entry point* for all waste data across the EU and make these statistics *consistent* with the requirements of EU legislation which enhances the technical feasibility of data collection. New developed indicators should accompanied by indicators from the *complementary* 'resource efficiency scoreboard', the 'raw materials scoreboard', and Europe 2020 indicators.

The Dutch government also advocates for the *alignment* of indicators on national and regional level while simultaneously addressing the Sustainable Development Goals (SDGs). *Data is available* for natural resources and their reductions and additions to stock, the economic importance of resources, prices, taxes, and subsidies to influence consumer and producer behavior, and eco-innovation and investments. *Data availability is limited* about technologies that lead to more efficient use of resources in production processes, quality labelling, and substitution of non-renewable technical materials with renewable biological sources. Currently, *no data is available* for the circularity of residuals and the measurement of circular business models. National data about carbon, water, and energy is available through multiregional input-output analysis (MRIO). In terms of regional data, the CBS publishes the 'regional accounts' which provide data for each COROP area. However, these data are very aggregated, and only in monetary terms. The indicators based on SEEA accounts allow for national and international *benchmarking*.

The AMECBoard and the municipality of Amsterdam initiated several programs to identify the resource streams and material flows in the region (i.e. Circle City Scan, Urban Pulse, and Circular Buiksloterham).

Although these programs have a regional focus, *alignment with national and international scope* is addressed. The European Horizon 2020 and the Raw Materials Initiative programs, but also the Dutch national Green Growth strategy provide a starting point for these regional initiatives. The MRA-dashboard should provide insights in the progress towards annual goals of the AMECBoard. Therefore the *scope of the indicators* should be national, regional, and city-level. Data is divided over a lot of local actors in the MRA among others AEB, Alliander, Waternet, Harbor of Amsterdam, TNO, etc. Currently, the Amsterdam Metropolitan Solutions (AMS) is developing an advanced data platform which integrates civic, governmental, and research data. This is executed in conjunction with the Comprehensive Knowledge Archive Network (CKAN) and the CitySDK Linked data platform. Until now, limited high-temporal resolution data is available for water and energy flows. The programs are looking for monitoring and measurement methods that overlap with national and international accounts. Such complementary methods provide *benchmarking* opportunities with other cities which is a main objective within the MRA.

4.2 Interviews

In this section the validation criteria that are discussed in the interviews are described. The aim of the expert interviews is to evaluate the sub-criteria derived from the desk research. Also, additional or missing sub-criteria are described in this phase. In 3.2.2.2 Thematic analysis is described how this data is gathered and analyzed. Table 25 below provides a short overview of the most important results.

Table 25 Overview of the sub-criteria according to the interviewees

Interviews (7)				
Design category		Output category		End-use category
Relevant for policy	**Accepted** by scientific community	**Credible**	**Robust**	**Easy**
Indicator purpose/objective: ✓ Raise awareness: Encourage economic activity, Provide understanding/transparency, ~~*Indicators have the ability to attract talents, companies, and investors*~~ ✓ Measure progress: Enable benchmarking, *Learning* ✓ Inform decision making: Support political action, Target setting, *Define system boundaries*	**CE principles described:** ~~o modular design~~ ✓ Zero waste ~~o renewable energy~~ ✓ think in systems ✓ closing loops ✓ shared value creation ✓ new business models • *no consensus about definition* • *Stakeholder engagement for defining CE*	✓ Unambiguous results/Show trends/Provide early warnings ✓ *Stakeholder engagement* ✓ Verifiable and replicable/Transparency in method (Eurostat, GRI, TSC, CBS)	✓ Sensitive/Annual data ✓ Data is reliable through 3rd party verification/*Data collection through Eurostat or 3rd party data verification* ~~o Useable and easily interpreted~~ ✓ Widely accepted in accounting frameworks/ *Based on existing indicator frameworks/ Clear definition of system boundaries* ○ ~~(internationally) standardized (MFA/MFM) accounting methods/~~	○ Applicable to scope: Simple to understand, use, and implement by addressing local streams and prioritized areas in MRA ○ Data is available/Technically feasible ~~o Indicators allow for (inter)national benchmarking~~ ○ Complementary and integrated
Short and long-term drivers addressed: • Awareness, education & research • Sustainable consumption & behaviour • New infrastructure & systems thinking • Transformed industrial design • Zero depletion legislation & policies • Prevent, reuse, recycle of natural assets				

The sub-criteria from the desk research that are discussed in the interviews are listed above in table 25. Some sub-criteria from the desk research are not discussed during the interviews and are strikethrough as can be observed above. The sub-criteria in *italic* are additional sub-criteria as they are discussed in the interviews while they are not found during the desk study.

4.2.1 Design category

This part explores what policy *relevant* and *accepted* by scientific community sub-criteria are mentioned by the interviewees. Therefore, the same main questions as described in the 4.1.1 Design category are answered.

4.2.1.1 Relevant for policy and accepted by scientific community

All the governmental officials acknowledge that some policy strategies and targets are deployed regarding CE in the MRA. Currently, strategies are adopted for organic waste and the construction waste sector. These strategies aim to among others develop new business models, increase and disseminate CE knowledge between institutions, and to reduce the dependency on resources in the MRA (interviewee 2, quote 6, personal communication, March 14, 2016). Various national and local agreements are signed such as 'circle city', 'circular buildings', 'circular procurement' to assemble the different initiatives and stimulate the transition to a more circular region (interviewee 3, quote 7, personal communication, March 15, 2016). According to interviewee expert 4, cities and regions are looking for assistance to really understand what steps they should be taken towards CE since '*local governments want to reduce their CO2 footprint, improve their resource utilization, reduce waste generation, and find new ways to cycle it within the city'* (quote 12, personal communication, April 8, 2016). One clear target is mentioned by multiple interviewees, i.e. 65 percent recycling of municipal waste in 2020 (interviewee 1, quote 4, personal communication, February 22, 2016; interviewee 3, quote 11, personal communication, March 15, 2016; interviewee 6, quote 5, personal communication, April 12, 2016). Furthermore, important themes for the MRA in the context of monitoring CE are climate, energy, resources, knowledge, mobility, health, financing, and food. The prioritized areas for CE are: textiles, construction waste, organic waste, plastics, incontinence materials, mattresses, metals, and waste water (interviewee 2, quote 27, personal communication, March 14, 2016; interviewee 4, quote 36, personal communication, March 17, 2016). According to interviewee 5, the construction sector and the organic waste sector have currently the most potential and priority in the MRA (interviewee 5, quote 54, personal communication, April 8, 2016). The interviewee argues that these streams are much localized and *'actually happen in the MRA as the materials are sourced here, and buildings are build and produced in the MRA'*. With textiles, metals, and E-waste, these chains are not local but global which makes it more difficult to influence with policy (interviewee 5, quote 56, personal communication, April 8, 2016). According to interviewee 3, the prioritized streams should be influenced by the following instruments/strategies: circular procurement, adjusted regulations, taxes, attractive financial arrangements, sharing knowledge (quote 35, personal communication, March 15, 2016). This is acknowledged by interviewee 5 who argues that *'contextual elements need to be incorporated as well such as policy, regulations, legal issues, and engagement of stakeholders'* (quote 61, personal communication, April 8, 2016). However, he also states that cities currently are focusing too much on regulation and should engage and collaborate more with citizens and business *'one thing we can see from Amsterdam and other progressive cities is that regulation is only part of the way. They also really try to collaborate and engage with citizens and businesses to make things happen. And often it's not about setting regulation, but it's just more giving people the freedom to explore different things.'* (quote 62, personal communication, April 8, 2016).The strategies that are described by the interviewees and address the short-and long-term drivers as shown in table 26 below:

Table 26 Short- and long-term drivers, strategies, and targets according to the interviewees

Zero Waste MRA		
Long-term drivers	**Strategy/Program**	**Objectives targets**
1. Awareness, Education & research		➢ Increase and disseminate CE knowledge between institutions ➢ Engagement with local stakeholders
2. Sustainable consumption & behavior	Program circular procurement	➢ Reduce CO2 footprint ➢ Reduce waste generation
3. New infrastructure & systems thinking	Circle city	➢ Reduce dependency on resources
Short-term drivers		
4. Transformed industrial design	Circular buildings	➢ Find new ways to cycle waste in cities
5. Zero Depletion legislation & policies		➢ Adjusted regulation, taxes, attractive financial arrangements
6. Prevent, reuse, recycle of natural resource assets	Quickscan city circular	➢ Improve resource utilization for construction waste, organic waste, plastics, incontinence materials, mattresses **Amsterdam:** ➢ 65 % of the fine household waste is separated in 2020

The purpose of using indicators for governments that are frequently named are to *measure progress, support political action, provide understanding and create transparency, benchmarking, and encouraging economic activity.* The element of *learning* and *defining system boundaries* are not described in the desk research but explicitly mentioned in a few interviews.

For the *accepted* by scientific community sub-criteria, most of all the seven principles for describing CE are mentioned as important aspects for measuring CE in the MRA region. Principle 2 'zero waste', principle 4 'systems thinking' and principle 5 'closing loops' are mentioned in essentially each interview. Interviewee 3 describes the 'shared value creation, while interviewee 2 stipulates the importance of measuring 'economic and non-economic impacts' (interviewee 2, quote 29, personal communication, March 14, 2016; interviewee 3, quote 30, personal communication, March 15, 2016; interviewee 4, quote 32, March 17, 2016; interviewee 5, quote 58, personal communication, April 8, 2016). Expected positive outcomes that the indicators should measure can be categorized in three dimensions i.e. economic, social and environmental impact. Environmental impacts that can be measured are mentioned such as: increased quality of materials/products, increased material, water, energy efficiency, reduction of wastes, and high quality recycling on local level (interviewee 2, quote 24, personal communication, March 14, 2016; interviewee 3, quote 30, personal communication, March 15, 2016; interviewee 4, quote 36, personal communication, March 17, 2016). Social impacts such as job creation, quality of life, increase of comfort, and improved knowledge/understanding of CE are mentioned as potential indicators (interviewee 3, quote 30, personal communication, March 15, 2016; interviewee 4, quote 33, personal communication, March 17, 2016; interviewee 5, quote 51, personal communication, April 8, 2016). The economic impacts that are mentioned are added value in GDP, generation of circular economic activities, and reduced costs (interviewee 2, quote 31, personal communication, March 14, 2016; interviewee 4, quote 36, personal communication, March 17, 2016). The remainder 3 principles are also recognized but to a lesser extent. However, interviewee 6 recognizes that the implementation and strategies on CE is still in its early stages and states that there

is still no consensus about what the definition of CE entails (quote 2, personal communication, April 12, 2016). Since it is still not clear what CE means in the context of cities and regions, 4 of all the interviewees emphasize that stakeholders need to be integrated during the indicator selection process to incorporate public participation to build consensus about how CE should be defined.

4.2.2 Output category

This part explores how the *robustness* and *credibility* sub-criteria are evaluated by the interviewees. Therefore, the same main questions as described in the 4.1.2 Output category are answered.

4.2.2.1 Credibility and robustness

The credibility of the indicators can be enhanced by *providing unambiguous results* which create transparency and visibility. According to interviewee 5, credibility can be improved by '*critically evaluating if the indicators measure what resonates with the city, and if not, how can they be modified or adapted to make it easier to understand*' (quote 40, personal communication, April 8, 2016). Interviewee 5 also emphasizes that one should combine new developed indicators with '*things that are already measured, to create a standard set of indicators'* (quote 41, personal communication, April 13, 2016). To create such a standardized set of indicators, a combination of standardized methodologies are used such as MFA to understand flows, and LCA to understand impacts. However, unlike with measuring sustainable development (SD) or environmental, social, and corporate governance (ESG), no ISO standards are established for CE yet. Interviewee 5 stresses the importance of an ISO standard for CE to increase indicators' credibility and robustness (quote 44, personal communication, April 8, 2016). Interviewee 7 emphasizes the necessity of an indicator to be '*easy to understand and to communicate'* and also argues that standardization of the calculation method will increase the credibility of the indicator (quote 13, personal communication, April 8, 2016). Although standardization of method can be an effective way of increasing the credibility and robustness of the indicators, interviewees 1 also argues that this can be a very time-consuming process (quote 14, personal communication, February 22, 2016).

Besides standardization of method and using a common accounting method, the robustness of an indicator is also influenced by proper definition of the system boundaries and different data collection methods (Interviewee 7, quote 16, personal communication, April 13, 2016). Interviewee 7 emphasizes that one *'needs to measure the right thing and it really depends on what you want to assess specifically because CE is a bit broad'.* Interviewee 6 acknowledges that consensus about CE indicators in an early stage can help to determine the system boundaries (quote 8, personal communication, 12 April, 2016). Data collection methods influence indicator robustness as *'currently there is a lot of freedom within methods how to get your data. You have different classes and create indices from that but it doesn't tell you precisely what data you can use. This gives you uncertainty from data, not from the method'* (interviewee 7, quote 15, personal communication, April 13, 206). The interviewees mention different data collection actors in the MRA who all have different ways of collecting data. However, some collective data collection initiatives are undertaken such as the collaboration '*clean* capital' between water company Waternet, waste company Afval-energiebedrijf (AEB), and the harbor of Amsterdam initiated by the Municipality of Amsterdam (interviewee 1, quote 15, personal communication, February 22, 2016). Three of the interviewees argue that *third party validation of data* is necessary to ensure indicators' robustness and reliability (interviewee 1, quote 16, personal communication, February 22, 2016; interviewee 2, quote 21, personal communication, March 14 , 2016; interviewee 3, quote 28, Personal Communication, March 15, 2016; interviewee 6, quote 17, personal communication, April 12, 2016).

4.2.3 End-use category

This part explores described what sub-criteria are important for assessing the practical usefulness of indicators according to the interviewees. Therefore, the same main question as described in the 4.1.3 End-use category are answered.

4.2.3.1 Easy to use

According to the interviewees, the applicability of the indicator is closely related to the purpose that indicators have for policymakers or scientists. Here, the governmental officials emphasize on the fact that indicators have to *support political action* and provide guidelines for *target setting* (interviewee 1, quote 18 , personal communication, February 22, 2016; interviewee 2, quote 8, personal communication, March 14, 2016; interviewee 3, quote 13, personal communication, March 15, 2016). However, the experts put more emphasis on that indicators can help *raise awareness for CE* and assist in *defining system boundaries* (interviewee 4, quote 14, personal communication, March 17, 2016; interviewee 5, quote 16, April 8, 2016; interviewee 6, quote 8, personal communication, April 12, 2016; interviewee 7, quote 3, personal communication, April 13, 2016). Geographically, it is important for policymakers that the *indicator measures prioritized areas* in the MRA and *can be influenced with political instruments* in the region accordingly (interviewee 1, quote 18, personal communication, February 22, 2016).

The feasibility of the indicator (i.e. associated costs and time to collect data) is perceived by essentially each interviewee as an very important sub-criteria for selecting indicators (interviewee 1, quote 23, personal communication, February 22, 2016; interviewee 3, quote 42, personal communication, March 15, 2016; interviewee 4; quote 41, personal communication, March 17, 2016; interviewee 5, quote 66, personal communication, April 8, 2016; interviewee 6, quote 21, personal communication, April 12, 2016). The interviewees state that a lot of data is available and accessible through companies such as the AEB, Waternet, Alliander, and the harbor of Amsterdam. Furthermore, research institutions gather data such as the Amsterdam Metropolitan Solutions (AMS), the bureau of research and statistics OIS, TNO, World Business Council of Sustainable Development (WBCSD) and the Green Cities UK.

The interviewees provide mixed results in relation to the 'complementarity' criteria. Some interviewees state that the suggested indicators should complement each other and new developed indicators should be based on existing frameworks/indicators (interviewee 4, quote 50, personal communication, March 17, 2016; interviewee 5, quote 68, personal communication, April 8, 2016). Interviewee 5 states that existing CE assessment on industry scale is recently used for regional CE assessment: *'How can you smartly combine what is already been measured, but it could also be new indicators with very specifically focused on circular business models, or things like the sharing economy.'* (quote 70, personal communication, April 8, 2016). Also, complementarity of indicators increases the likelihood that the indicators can be benchmarked nationally or internationally (interviewee 2, quote 32, personal communication, March 14, 2016). This increases indicators' reliability and usefulness significantly (interviewee 4, quote 48, personal communication, March 14, 2016). However, interviewee 1 emphasizes that common indicators based on a linear economy are unable to provide a reliable metric for measuring circular economy (quote 25, personal communication, February 22, 2016).

4.3 Focus group

This part explores the results from the focus group. The aim of this validation phase was to establish a threshold to determine what sub-criteria should be included in the final evaluation scheme. Therefore, the relative importance of each sub-criteria derived from the desk research and the interviews was evaluated with 5 participants. Each participant was asked two questions for each sub-criteria (yellow

box). The first question that was asked is*: 'Which sub-criteria is **not** relevant for measuring CE in the MRA?*'. The second question: *'Can you arrange the sub-criteria from most relevant to least relevant for measuring CE in the MRA?'*. A more detailed description of how the focus group was organized can be found in 3.2.3.2 Thematic analysis. Table 27 below provides a short overview of the most important results from the discussion. A more comprehensive analysis can be found in appendix J.

Table 27 Overview of the relative importance of each sub-criteria according to the focus group

Focus group				
Design category		Output category		End-use category
Relevant for policy	**Accepted** by scientific community	**Credible**	**Robust**	**Easy**
High relevancy: • Measure progress • Support political action • Encourage economic activity • Target setting • Benchmarking • Indicators have the ability to attract talent, companies, and investors	**High relevancy:** • modular design • zero waste • renewable energy • closing loops	**High relevancy:** • Transparency in method • unambiguous results	**High relevancy:** • Internationally standardized calculation method	**High relevancy:** • Applicable to scope: Simple to understand, use, and implement by addressing local streams and prioritized areas in MRA • Data availability and technical feasibility
Medium relevancy: • Provide understanding/transparency	**Medium relevancy:** • think in systems • new business models		**Medium relevancy:** • Data reliability • Sensitivity	**Medium relevancy:** • Complementary and integrated
Low relevancy: • Learning • Define system boundaries	**Low relevancy:** • shared value creation		**Low relevancy:** • Based on existing indicator frameworks	

All sub-criteria from the interviews and desk research are discussed during the focus and listed in the table above. It is shown in table how the relative importance of the different sub-criteria are scored during the focus group.

4.3.1 Design category

In this part is explored how the relative importance of the policy *relevance* and *accepted* by scientific community sub-criteria are perceived by the participants.

4.3.1.1 Relevant for policy and accepted by scientific community

In both validation criteria, no sub-criteria are labelled as 'irrelevant'. For the policy *relevant* criteria, the sub-criteria that have high relevancy according to the participants are *measure progress, support political action, encourage economic activity, benchmarking and target setting* (participant 1, quote 2, personal communication, May 25, 2016; participant 2, quote 1, personal communication, May 25, 2016; participant 4, quote 2 and 4, personal communication, May 25, 2016; participant 5, quote 5, personal communication, May 25, 2016). An example of supporting political action is provided by participant 2 who recognizes that indicators should *attract talent, companies, and investors* to the MRA (participant 2, quote 11, personal communication, May 25, 2016). Participant 5 summarizes that in policy one wants to achieve three purposes: achieve a goal, have influence on the means to achieve the goal, have impact on society, business, and nature. The sub-criteria provide *understanding/transparency for CE* is not mentioned explicitly in this phase and is categorized by the participants with *medium relevancy.* However, this sub-criterion is identified as important during the focus group in the end-use category and associated by the participant with the sub-criterion *applicable to scope. The* sub-criteria with *the least relevance* during the focus group include *learning* and *defining system boundaries*.

In the *accepted* by scientific community criteria, sub-criteria that are labelled with high relevancy are *modular design, zero waste, renewable energy, and closing loops.* Especially *zero waste* and *closing loops* is mentioned as *'essential for the measurement of CE'* by participant 1 and 5 (participant 1, quote 5, personal communication, May 25, 2016; participant 5, quote 7, personal communication, May 25, 2016). Participant 2 emphasizes on the importance of addressing efficient use of energy and water besides looking at material efficiency (quote 4, personal communication, May 25, 2016). The sub-criteria that are labelled with medium relevancy are *systems thinking* and *new business models*. Two participants emphasize that the latter are also important for *closing loops* and *creating economic activity* (participant 3, quote 6, personal communication, May 25, 2016, participant 5, quote 7, personal communication, May 25, 2016). The sub-criteria that is labelled with low relevancy for measuring CE is *shared value creation*. According to participant 1, 2 and 5, this sub-criteria is already integrated in the other principles of CE such as *new business models* and *modular design* (participant 2, quote 3, personal communication, May 25, 2016; participant 5, quote 7, personal communication, May 25, 2016). However, participant 4 argues that this should be an separate sub-criteria since it describes also non-economic impacts and value creation (participant 4, quote 5, personal communication, May 25, 2016).

4.3.2 Output category

In this part is explored how the relative importance of the *robustness and credibility* sub-criteria are perceived by the participants.

4.3.2.1 Credibility and robustness

In both the credibility and the robustness criteria, no sub-criteria are labelled as 'irrelevant'. Within the criteria credibility, the sub-criteria *unambiguous results* and *transparency in method* are both labelled with high relevancy. A sub-criterion that should be added here according to participant 2, 4, and 5 is *internationally standardized method* (participant 5, quote 10, personal communication, May 25, 2016). This sub-criterion however, is already categorized in the robustness criteria.

The participants labelled *internationally standardized method* as sub-criteria from robustness with high relevancy. According to participant 2 the MRA has the ambition to become an international frontrunner in CE which comprises the development of *'international standardized and accepted indicators'* (participant 2, quote 5, personal communication, May 25, 2016). However, participant 4 emphasizes that international standardization of methods can be a very time-consuming process (participant 4, quote 7, personal communication, May 25, 2016). The robustness is determined by to which extent the indicator is sensitive to changes and susceptible to manipulation. Participant 4 argues that there is a desire to have *'a dashboard with real-time indicators that can process weekly data to act on sudden changes'* (quote 8, personal communication, May 25, 2016). The sub-criteria *data reliability* and *sensitivity* are identified with medium relevancy. Although *data reliability* is perceived as an important criteria, the data does not necessarily have to be collected by a third party. However, the participants do think the data should be verified by a third party (participant 1, quote 6, personal communication, May 25, 2016). Overall, *sensitivity* of the indicator is indicated as case dependent. To which degree the data should be detailed and timely depends on the unit of measurement (participant 1, quote 6, personal communication, May 25, 2016; participant 4, quote 8, personal communication, May 25, 2016). Participant 5 emphasizes that the data should be *'as timely as necessary, and as detailed as necessary'* (participant 5, quote 14, personal communication, May 25, 2016). The sub-criterion *based on existing indicator frameworks* is perceived by the participants with the least relevance.

4.3.3 End-use category

In this part is explored how the relative importance of the *easy* sub-criteria are perceived by the participants.

4.3.3.1 Easy to use

Among the end-use validation criteria, no sub-criteria is identified as 'irrelevant'. Moreover, all the sub-criteria are labelled with high relevancy among others *simple to understand, applicable to scope, data is available, technical feasible, complementary and integrated*. The applicability of the indicator relates back to the discussion '*for what purpose do you want to use the indicator?'* says participant 1 (quote 9, personal communication, 25 May, 2016). Participant 1, 2, and 3 argue that MRA indicators are used to *support political action*, *provide understanding and transparency*, and *create awareness* (participant 1, quote 9, personal communication, 25 May, 2016; participant 2, quote 6, personal communication, 25 May, 2016; participant 5, quote 15, personal communication, 25 May, 2016). In this context, the MRA indicators should inform about prioritized areas such as the organic- and construction waste streams (participant 4, quote 1, personal communication, 25 May, 2016). Furthermore, participants 1, 4 and 5 emphasize that the indicator should describe areas that can be influenced with political instruments such as regulation, subsidies, taxes (quote 2, personal communication, 25 May, 2016; quote 3, personal communication, 25 May, 2016; quote 15, personal communication, 25 May, 2016). Another relevant sub-criterion addressed is that impact should be measured in the economic, social, and environmental domain (participant 2, quote 2 and 11, personal communication, 25 May, 2016; participant 4, quote 5 and 17, personal communication, 25 May, 2016; participant 5, quote 7 and 20, personal communication, 25 May, 2016).

The *data availability* and the *technical feasibility* of gathering this data is also associated with high relevancy according to most of the participants. Participant 1 emphasizes that although data availability is very relevant, the starting point of measuring should not be the data availability but more '*what you want to measure'* (quote 11, personal communication, 25 May, 2016). Participant 4 argues that a policymaker needs to balance between *´what do you want to know, and what data is available and accessible within a reasonable amount of time and effort?*' (quote 9, personal communication, 25 May, 2016). Overall, all participants acknowledge that *data availability* plays an essential role in the actual use of indicators.

The sub-criteria *complementary and integrated* is identified by some participants with low relevancy and by some participants with high relevancy. Although the former admits that connecting indicators to commonly used underlying monitoring and information systems can be of great value, it can also be a long and time-consuming process (participant 2, quote 6, personal communication, 25 May, 2016; participant 4, quote 11, personal communication, 25 May, 2016). Participant 5 argues that on the one hand, CE is such a new concept that it would be very hard to connect existing, linear-based indicators, to new developed CE indicators. However, on the other hand, when developing new indicators without connecting them to old ones it becomes hard to compare them with each other (participant 5, quote 18, personal communication, May 25, 2016).

5. Analysis

This part describes how differences and similarities in results from the desk research, the interviews, and the focus group can be explained by theory and the 3S method. The results are aggregated and discussed for each criteria category in paragraphs 5.1, 5.2, and 5.3 (i.e. design, output, end-use category). A visual representation of this step is provided below in figure 10. Paragraph 5.4 presents the method which is developed in the thesis. It describes three steps how generic criteria can be validated by means of stakeholder engagement leading to a final list of key-criteria. Then is described how this validated criteria can be used to select appropriate CE indicators accordingly.

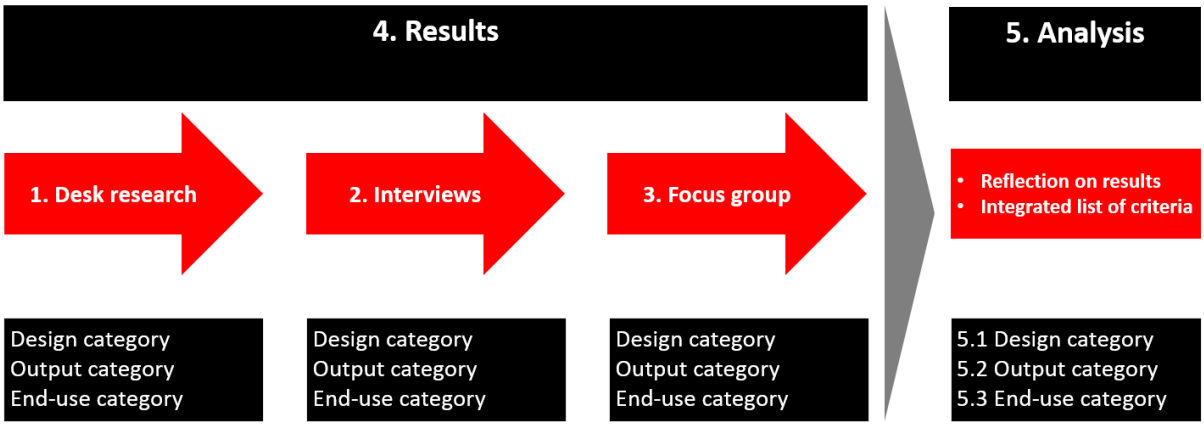


Figure 10 Process description of integration of criteria categories and sub-criteria

5.1 Design category

This section explores the differences and similarities in the three phases for the policy relevance and accepted by scientific community sub-criteria. Different purposes give different rise to different indicators. Therefore, one needs to clarify what the purpose is of the indicators used for the MRA which is described in the first part of 5.1.1. The second part of 5.1.1 describes the short- and long-term drivers that are addressed in the MRA. Paragraph 5.1.2 how CE is defined by different stakeholders and what principles aspects of CE are considered to be the most important for the MRA.

5.1.1 Policy relevance

The most important '*policy relevant*' sub-criteria that are discussed in each phase for MRA indicators are *raise awareness, measure progress,* and *inform decision-making.* These three sub-criteria are also described in theory as the main purposes of using indicators (Devine-Wright, 2005; Meadows, 1998; Veleva & Ellenbecker, 2001; Veleva et al., 2001). The results show that the first main purpose*, raising awareness*, can have different outcomes such as encouraging economic activity, providing understanding/transparency, attracting talent, companies, and investors. The second main purpose, *measure progress*, provides benchmarking opportunities. Benchmarking enables policymakers and business managers to identify local strengths and weaknesses, gain new ideas and benefit from a mutual learning process (Mascarenhas et al., 2010). The third main purpose, *inform decision-making*, is related to target setting and supporting political action. This is in line with literature of Veleva and Ellenbecker (2001) who emphasize that not every organization will have goals or targets for each aspect of CE. However, each organization needs to start with some goals/targets and while gaining experience, new goals will introduce additional indicators for CE. This relates to the aspect of learning, which is identified during the interviews but does not come back in the desk research and is given less priority during the focus group. It is therefore not included in the list of final sub-criteria. This is not completely in line with Veleva and Ellenbecker (2001) who state that using indicators promotes organizational learning. It is part of a feedback system in which measurements help policymakers to

decide whether they are on course or if corrective actions are needed (Veleva & Ellenbecker, 2001). Indicators can support political action, for instance by attracting talent, companies, and investors to the MRA, which is also a clear defined objective issued by the AMECBoard. This is consistent with literature of Pinter (2006) who argues that the indicators should be linked to specific policy and objectives which are relevant for the area. Defining system boundaries is mentioned as an important purpose of using indicators during the interviews. However, this is not described in the desk research and is given less priority during the focus group. It is therefore not included in the list of final sub-criteria. Nevertheless, Shekhawat (2016) states that *'indicators quantify change, identify processes and provide a framework for setting targets and monitoring performance'* (Shekhawat, 2016, p.271). In this respect, indicators do have a function of providing system boundaries. Overall, the results show that there is no clear consensus about the purpose of the indicators for the MRA. The desk research show that the indicators are particularly meant to provide background information for key policy decisions. This is confirmed during the interviews by some policymakers from the Municipality of Amsterdam and the MRA. However, the interviews with expert show that the purpose of indicators tend to be more focused on creating awareness, create a common understanding of CE, and educating the public. These results are in line with the 3S method, which emphasize that the self-validation (desk research) and social validation (focus group) phases support consensus building for policymaking whereas the scientific validation (interviews) provides independent experience and knowledge of the subject (Cloquell-Ballester et al., 2006). In this thesis, the desk research is primarily concerned with an analysis of reports and documents of governmental institutions which provides political credibility. The interviews however, incorporate also expert knowledge which is characterized by bringing scientific credibility to the criteria validation process (Cloquell-Ballester et al., 2006; Meadows, 1998).

Besides understanding what the exact purpose of using indicators is, one needs to know what exact policies and objectives should be addressed by the indicator. The Zero Waste framework of Zaman and Lehman (2013) is used to identify the most important strategies that address the short- and long-term drivers for a circular MRA.

The desk research reveals that a lot of strategies and programs are developed and deployed at different implementation levels. At European level, the 'Horizon 2020' program is initiated which addresses all the short- and long-term drivers in the ZW framework. From comprehensive research programs to improved waste collection methods, attractive financial arrangement for circular startups, and concrete waste reduction/recycling targets. The European program is aligned with Dutch policy which is illustrated by the extensive 'from waste to resource' program, which connects European targets with national and local goals. The prioritized resource streams are also aligned and comprise plastics, organic waste, construction waste, and critical raw materials. Current strategies and objectives in the MRA are in line with national policy as well, also addressing all short- and long-term drivers in the ZW framework. Each driver is represented by at least one quantitative target among others *knowledge dissemination, circular procurement, innovation cluster development, business model creation, new jobs and additional revenues, improved resource utilization.* However, these concrete targets are not recognized in both the interviews and the focus group. Only one concrete target regarding CE is recognized and mentioned in each phase i.e. separation of 65 % of household waste in 2020. Apparently, some targets are developed for the MRA while these strategies and objectives are not yet integrated into all relevant organizations. This could be explained by the relative small timeframe of publishing the targets and conducting the interviews and organizing the focus group. Another explanations could also be that the stakeholders were not informed at all about the strategies and objectives in the MRA. However, it is highly unlikely that not one stakeholder recognizes these targets while they are chosen based on their current role as policymaker in the MRA and their considerable level of knowledge on CE. The lack of awareness and the lack of information about these

targets and strategies in the MRA can be serious barriers for change. Lozano (2012) emphasizes that internally planned change offers the most proactive and less conflicting option for organizations to engage with changes such as the transition towards a circular MRA. Concerning the improved resource utilization, in total, 8 resource streams are prioritized in 2015 and another 16 in 2017. However, the interviews and focus group point out that currently the organic- and construction waste streams have the most potential and are prioritized. Overall, the desk research shows that the European objectives are aligned with Dutch national policy and with regional targets and objectives in the MRA. However, the interviews and the focus group point out that most European and National targets are not recognized by the stakeholders in the MRA. This points out inconsistencies between the strategic and operational activities in the MRA. This can be explained in two ways, either the strategies and targets are too complicated to bring into practice, or the organization is just not aware of them.

5.1.2 Accepted by scientific community

From none of the three phases becomes clear what the exact definition for a circular MRA is. According to the interviewees, the transition to a circular region is still in its early stages and there is no consensus about how CE is defined for the MRA. However, it does become clear what elements should be incorporated in the CE definition. From the 7 principles of CE, nearly all principles are identified as key sub-criteria in each phase which is in line with theory on CE (Ellen MacArthur Foundation, 2013; McDonough & Braungart, 2002; Stahel & Reday-Mulvay, 1981). The focus group reveals that the principles *modular design, zero waste, renewable energy, and closing loops* are scored with 'high relevancy' by the participants and are included in the list of key sub-criteria. The principles *systems thinking* and *new business model development* are scored with 'medium relevancy' and are included in the list of key-sub-criteria as well. This difference can be explained by the fact that the two sub-criteria are perceived by the participants as relatively hard to translate into practical indicators. In literature, a few scholars address this issue and emphasize that current linear based indicators mainly focus on individual parameters (Yong Geng, Sarkis, Ulgiati, & Zhang, 2013; Yong Geng, Zhang, Ulgiati, & Sarkis, 2010). These unidimensional indicators are less suitable to track the broad systemic aspects of CE. Therefore, Geng et al. (2013) propose emergy-based accounting, which is capable of capturing the diverse non-linear interactions between society and the natural system in which economy is embedded. This form of accounting is supported by many other authors as a tool to for environmental policy and resource management within the measurement of complex system dynamics (Brown & Buranakarn, 2003; Q. Huang, Zheng, & Hu, 2015; S. L. Huang, Lee, & Chen, 2006; Mori & Christodoulou, 2012; Zhang, Chen, & Heck, 2014; Zucaro, Ripa, Mellino, Ascione, & Ulgiati, 2014). The *shared value creation* sub-criteria (i.e. describing the impacts of CE strategies in social, economic, and environmental terms) is recognized by the interviewees as well as the participants of the focus group. However, in the focus group is also emphasized that *natural resource use for shared value creation* is not a relevant sub-criterion which seems to be a contradiction. This is caused by misinterpretation of the latter sub-criterion by the participants, which is proved by multiple question marks at this specific sub-criteria on the evaluation form (appendix F). Afterwards, multiple participants pointed out the lack of, and need for social and economic indicators. This is also recognized in CE literature where many scholars point out the lack of integration of economic, social, and ecological indicators (Geng et al., 2012; Ghisellini et al., 2015; Naustdalslid, 2014; Su et al., 2013). However, the assessment in the focus group pointed out that this principle is already integrated in the other sub-criteria and does not necessarily have to be a separate sub-criterion. It was therefore given 'low relevancy' during the focus group assessment. Therefore, it was decided to exclude this principle from the key sub-criteria list. Overall, clear (scientific) definitions are described for CE in the desk research, however, the interviews point out that there is still no consensus about how CE is defined for the MRA. In order to work with indicators and give meaning to CE, it's of great importance that a common vision is developed on what

circular economy means for the MRA. The interviews point out that stakeholder integration is prerequisite for this development which is recognized in various literature (Loorbach & Rotmans, 2006; Lozano, 2012; Mascarenhas et al., 2010) A combined vision and strategy of a variety of stakeholders in the area is required to foster the transition to a more circular MRA. This leads to the following key sub-criteria for the design category in the MRA (Table 28):

Table 28 Design validation criteria and the corresponding key sub-criteria

Design category	
Relevant for policy	**Accepted** by scientific community
Meets one the following purpose(s):	*Is connected to at least one of the following principles:*
1. Raise awareness a. Encourage economic activity b. Provide understanding in policy c. attract talent, companies, and investors	1. Modular design: flexible design of products and product chains enhances the resilience of systems which are central in a circular economy
2. Measure progress a. Enable benchmarking	2. Zero waste: design out of waste by reducing, reusing or recycling of technical and biological nutrients
3. Inform decision-making a. Stimulate target setting b. Support political action	3. Zero emission energy from renewable sources
Short and long-term drivers addressed: 1. Awareness, education & research (*knowledge dissemination)* 2. Sustainable consumption & behaviour (*circular procurement)* 3. New infrastructure & systems thinking (*innovation cluster development)* 4. Transformed industrial design *(business model creation, new jobs and additional revenues)* 5. Zero depletion legislation & policies *(free circular zones)* 6. Prevent, reuse, recycle of natural assets *(Target – 65% of the fine household waste is separated in 2020)*	4. Think in systems: the ability to understand how parts influence on another within a whole lies at the core of non-linear, feedback rich, circular systems 5. Value is created by closing loops: cross-chain and cross-sector collaborations lead to an increase of effectiveness of resource allocation and utilization 6. Creation of new business models: from `product ownership' to 'consumer as user' and performance-based payment models

5.2 Output category

This section explores the differences and similarities in the three phases for the credibility and robustness sub-criteria. The first paragraph, 5.2.1, explores how the indicators' credibility is guaranteed according to the MRA stakeholders and how this relates to theory and method. The second paragraph, 5.2.2, describes what robustness sub-criteria determines whether an indicator is accurate and reliable.

5.2.1 Credibility

In all three stages, credibility of indicators is enhanced whenever they provide *unambiguous results* and are capable of *identifying risks* relevant to the MRA future scenarios. This is in line with theory which describes that an indicator should be 'simple to understand' and 'easily interpreted' (Shekhawat, 2016). There is also consensus about the necessity of simplification and harmonization of definitions and calculation methods to increase *transparency in methods*. This also increases the replicability and scalability of the regional framework to other regions and nations. It is closely related to the *standardization of calculation methods internationally* which is emphasized in all phases as well. This is line with literature with Pinter (2006) who describes that connecting indicators to commonly used underlying monitoring systems is important since the role and functions of accounting systems and indicators are complementary. Furthermore, standardization of indicators helps governments and nations to monitor CE and compare it to that of other (Azapagic & Perdan, 2000). In summary, all the three phases show that unambiguous results and transparency in method prove to be key sub-criteria to enhance the credibility of an indicator.

5.2.2 Robustness

The most important sub-criterion in the 'robustness' criterion is the *standardization of calculation methods internationally* which is described above and scored 'high relevancy' during the focus group. Other sub-criteria that are also pointed out to be relevant in each phase are the *data reliability* and *sensitiveness*. These sub-criteria are identified in the focus group with 'medium relevancy' and are therefore included in the list of key sub-criteria. The lower relevancy of *sensitiveness* of data can be explained by the fact that the participants argue that the data should be as timely and detailed as necessary which varies for each indicator. In literature, this sub-criterion is described as an important requirements for indicators as indicators and the underlying data need to be able to quantify reliable data over longer time horizons (Böhringer & Jochem, 2007; Donnelly et al., 2006; Shekhawat, 2016). While *data reliability* is perceived as an important sub-criteria, it is also emphasized that 3rd party verification of data is not always feasible in terms of costs and time. This seems plausible for the MRA as Gustavson et al. (1999) recognized a trend that data reliability '*tended to degrade as the spatial unit became smaller, which reflects the fact that most information is, still, spatially aggregated to a high level before being disaggregated again to smaller units*' (Gustavson, Lonergan, & Ruitenbeek, 1999, p.123). This is confirmed by a recent study of the Dutch central bureau of statistics (CBS) who conclude that regional data in the Netherlands is still very aggregated, and mostly only in monetary terms available (CBS, 2015). The interviews show that 'robustness' of an indicator is also influenced by providing a *clear definition of system boundaries*. This sub-criteria however, was only recognized in one interview. According to the researcher, this is a matter of specificity as this sub-criterion can be perceived as an element of the 'credible' sub-criteria *transparency in method*. This explains why the sub-criterion is not mentioned explicitly in either the desk research or the focus group. Overall, the sub-criteria that are recognized by the different stakeholders in the three phases show a high level of congruence with literature. However, some differences can be observed between opinions of experts and policymakers. Whereas the experts elaborate extensively on the different aspects a robust indicator, the policymakers are less critical and more open to capture 'the bigger picture'. Nevertheless, they do recognize the importance of critically reflecting on the indicators' robustness. Table 29 below shows the most important key-sub criteria for the credibility and robustness criteria determined by the stakeholders.

Table 29 Output validation criteria and the corresponding key sub-criteria

Output category	
Credible	**Robust**
Meets the following requirements:	Meets the following requirements:
1. Provides unambiguous and clear results 1a) show trends 2a) provide early warnings	***1. based on one of the International standardized methods Eurostat, GRI, TSC, or CBS*** 1a) is not susceptible to manipulation
2. provides transparency in method 2a) clear definition of system boundaries	***2. Data reliability*** 2a) data is statistically validated by 3rd party
	3. Sensitiveness 3a) data is produced on a regular basis suitable to the unit of measurement

5.3 End-use category

This section explores the differences and similarities in the three phases for the easy criteria. It describes what sub-criteria are recognized by the different stakeholders to guarantee the final indicator is easy and useful to the end-user.

5.3.1 Easy

All the validation phases show that *applicability to scope*, *data availability, and technical feasibility* are perceived as the most important sub-criteria in the end-use validation category. During the focus group all these sub-criteria score 'high relevancy' and are included in the list of final key sub-criteria. The applicability to scope sub-criterion is supported by literature of Tan et al. (2015) who emphasize that indicators should be applicable to their geographical scope and represent key concerns of the studied region. A difference can be observed in the stakeholder's opinions concerning the data availability sub-criterion. Whereas the expert interviews point out that the starting point of measuring should always be what is intellectually interesting, the governmental actors need to balance between what is politically relevant and what data is available. This can also be observed in theory of Meadows (1998) who states that experts can develop indicators that carry no meaning outside the expert community, while non-experts tend to make the indicator practical and useable. This tradeoff is described by the technical feasibility sub-criterion and plays a key role is the assessment of indicators. According to Donnely et al. (2007) the data should be available, cost effective, and not technically complex. *Complementarity of the indicator* with other frameworks is identified in the focus group with 'medium relevancy' and included in the final list of key sub-criteria. The participants declare that complementarity of indicators requires standardization which can be a time-consuming and sometimes undesirable process. However, in both the desk research and during the interviews, complementarity of the indicator is discussed extensively as it provides benchmark opportunities. In literature is emphasized that each region should develop its individual set of indicators within a common structure in order to allow comparison across time and space, without ignoring the specific needs and situations of that region (Mascarenhas et al., 2010). In sum, there is consensus about what sub-criteria should be included in the list of key sub-criteria. In table 30 below these findings are summarized.

Table 30 End-use validation criteria and corresponding key sub-criteria

End-use category
Easy
Meets the following requirements:
1. Applicable to scope 1a) simple to understand 1b) addresses either water/energy/waste problems 1c) addresses the waste and/or organic waste sector
2. Data is available 2a) data can be retrieved at local stakeholder
3. Data is technical feasible 3a) can be collected cost effective 3b) is not technically complex
4. Complementary with other indicator frameworks 4a) allows for (inter)national benchmarking

5.4 Criteria validation and indicator selection method

The main goal of this thesis is to present a method which enables policymakers and researchers to select scientifically sound, politically relevant, and easy to use CE indicators for a region. In this section is explained what steps are taken in this research, and how others can use this step by step method to evaluate the appropriateness of CE indicators for other regions. Therefore, the aim of this proposed method is threefold. The first aim is to (1) review SD and CE criteria from literature. The second aim is to (2) validate these criteria by a participative process, the 3S method. The third aim is to (3) present a technique for evaluating existing CE indicators against the final set of validated criteria. These three steps are elaborated below. A process description of these steps is provided below in figure 11.

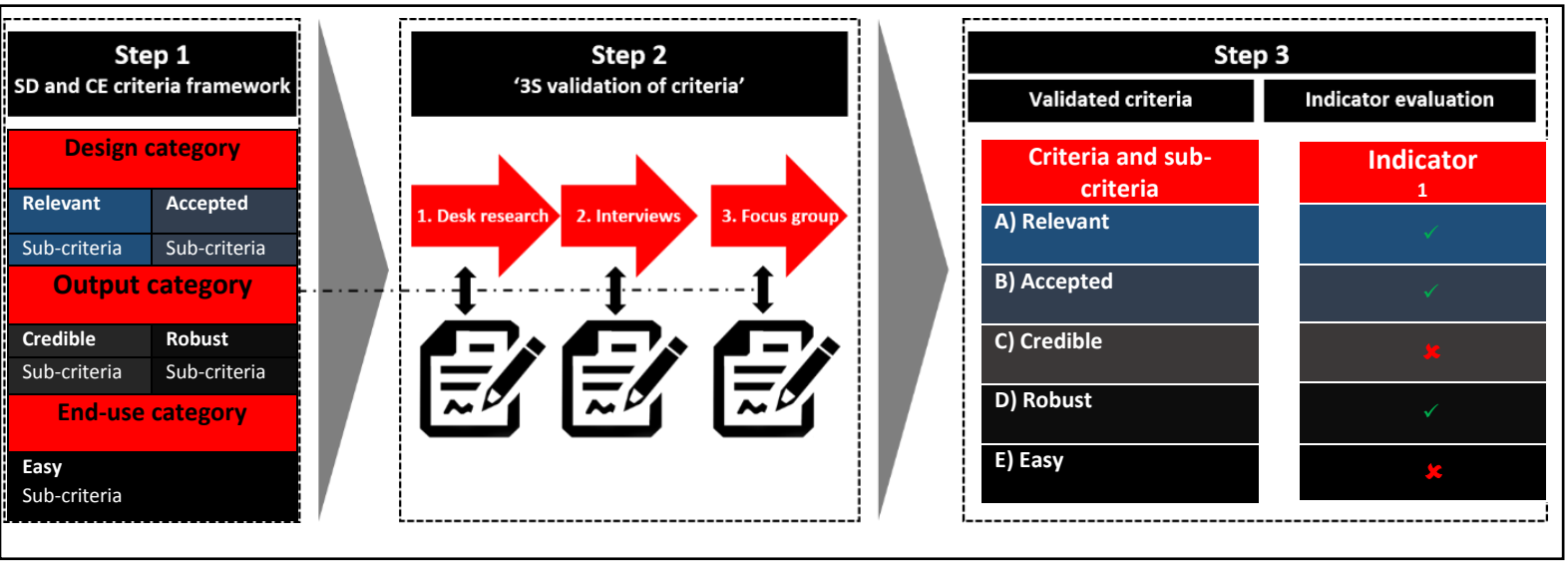


Figure 11 Flow diagram of research steps to select CE indicators for a region

5.4.1 Step 1: SD and CE criteria framework

Every indicator has its own specific requirement regarding its purpose, scope, and design. In other words, each region needs to develop its individual unique set of indicators according to a common method. Therefore, criteria are necessary to ensure the chosen indicator set of indicators are in line with these the unique characteristics of the region. Therefore, the first step of this method consists of a literature review of existing SD and CE indicator criteria. This review leads to a set of generic criteria from literature that need to be tailored to the specific needs and situation i.e. the intended purpose of the indicators. The generic criteria that are used and validated in this thesis can be found in 2.3.4. This is done by adapting the 3S method which is explained in the next step below.

5.4.2 Step 2: 3S validation of criteria

Stakeholder involvement in the conceptualization and design of indicators is crucial. Therefore, the second step consists of the validation of a set of generic criteria in three steps: self-validation, scientific validation, social validation. During this procedure the criteria overcome a systematic validation process and integrate regional views, values, concerns, and common goals of all stakeholders. This validation process leads to a final set of validated key criteria and sub-criteria. A comprehensive explanation of how the 3S method is used in this thesis can be found in 3.2. The list of key-criteria specific for the region can now be used to evaluate the appropriateness of existing indicators. This evaluation leads eventually to a set of sound indicators for the region. This evaluation process is described in the next step below.

5.4.3 Step 3: Evaluation of indicators against criteria

The third and last step consists of the evaluation of an indicator against the validated list of criteria. In this thesis, the desk research, the interviews, and the focus group have led to a final set of MRA validation criteria for the evaluation of indicators. Continuing evaluation of indicators against these criteria is an important basis for future quality assurance of the set. The list is comprehensive but not finite and may be adapted in the future. It can also be used in the future to decide whether new indicators can be added to the framework or existing ones deleted. In table 31 below the list of validation criteria specifically for the MRA is provided to help identify appropriate CE indicators for the region.

Table 31 Evaluation scheme with MRA-specific criteria for assessing indicators

Criteria and sub-criteria	
A) Relevant	
Meets one the following purpose(s):	**Indicator**
1. Raise awareness: a. Encourage economic activity b. Provide understanding in policy attract talent, companies, and investors	
2. Measure progress: a. Enable benchmarking	
3. Inform decision-making: a. Stimulate target setting b. Support political action	
Addresses one of the short and/or long-term drivers:	
1. Awareness, education & research (*knowledge dissemination)*	
2. Sustainable consumption & behaviour (*circular procurement)*	
3. New infrastructure & systems thinking (*innovation cluster development)*	
4. Transformed industrial design *(business model creation, new jobs and additional revenues)*	
5. Zero depletion legislation & policies *(free circular zones)*	
6. Prevent, reuse, recycle of natural assets *(Target – 65% of the fine household waste is separated in 2020)*	
B) Accepted	
Is connected to at least one of the following principles:	**Indicator**
1. Modular design	
2. Zero waste	
3. Zero emission energy	
4. Think in systems	
5. Value creation by closing loops	
6. Creation of new business models	
C) Credible	
Credibility is guaranteed by:	**Indicator**
1. Provides unambiguous and clear results *a.* show trends *b.* provide early warnings	

2. provides transparency in method a. clear definition of system boundaries	
D) Robust	
Robustness is guaranteed by:	**Indicator**
1. International standardized methods (Eurostat, GRI, TSC, or CBS) a. is not susceptible to manipulation	
2. Reliable data a. ta is statistically validated by 3rd party	
3. Sensitiveness of data a. data is produced on a regular basis according to the unit of measurement	
E) Easy	
Utility is guaranteed by:	**Indicator**
1. Applicable to scope a. simple to understand b. addresses either water/energy/waste problems c. addresses the waste and/or organic waste sector	
2. Data is available a. Data can be retrieved from local stakeholders	
3. Data is technical feasible a. cost effective b. not technically complex	
4. Complementary with other indicator frameworks	

In order to evaluate existing CE indicators with the validated criteria from above, a comprehensive list is needed of indicator frameworks consisting of potential CE indicators. The evaluation scheme is designed for indicator validation at individual level. Although the scheme allows for a qualitative judgement of criteria, the research choose deliberately not to score each category. The weighing of each criteria should be determined for each region specifically by means of a working group (Cloquell-Ballester et al., 2006). This working group consists of a multidisciplinary team with experts and non-experts and may vary, depending on the economic and temporary resources available (Cloquell-Ballester et al., 2006; Meadows, 1998). The list of indicators that can be reviewed for this thesis can be found in 3.3. The actual evaluation of indicators against the validated criteria is beyond the scope of this thesis. This is expected to be an interesting step for further research.

6. Discussion

Paragraph 6.1 describes the main strengths and weaknesses of the 3S method and how this can be improved in the future. Paragraph 6.2 describes the quality of the research and how the researcher attempted to reduce validity and reliability errors and biases. Furthermore, paragraph 6.3 provides recommendations for further research.

6.1 Reflection on method

Currently, there is little knowledge in science and practice about how to design scientifically and politically credible indicators for CE. To address this gap, the aim of this research was to describe a method which enables policymakers and researchers to develop a set of key-criteria which can be used for the selection of sound CE indicators. Therefore, different stakeholders were engaged according to the 3S method to bring scientific and political credibility to the criteria selection process. The 3S method proposes to perform both an individual and a group evaluation in the first validation step of criteria. Due to resource constraints (i.e. budget, time), the researcher executed an individual evaluation combined with three exploratory interviews. This may have influenced the results in the first validation step. However, these exploratory interviews proved to be a valuable addition to the desk research by providing some key insights in the latest CE developments in the MRA. Also, it facilitated interpretation during the interviews and focus group.

The second validation step, the scientific validation, was executed by performing interviews with both policymakers and experts from the MRA. These stakeholder were chosen based on their knowledge and experience on the subject and according to the sampling criteria described in table 13 in 3.2.2.1. The semi-structured interviews allowed new criteria to emerge for exploration and provided deeper insights about each sub-criteria. A main limitation of doing interviews is that relatively little interviews can be executed during the research. Furthermore, it was sometimes a challenge to question all criteria during the interviews. A possible way to overcome these issues in further research is to replace the interviews for a survey, in which relatively many experts can validate a certain amount of criteria. However, a survey does not provide the respondent the opportunity to elaborate further on certain criteria, in contrast with interviews.

The third validation step, the social validation, was performed by organizing a focus group to ensure the criteria were validated through a participative process. This step also included the establishment of a threshold what criteria to include in the final key-criteria list. The participants of this meeting were chosen based on their social position in society and basic knowledge of CE measurement. Furthermore, the researcher strived for a typical four to ten members, with a minimum of two and a maximum of eight experts (Cloquell-Ballester et al., 2006). Therefore, a total of 12 participants were invited to join the meeting which resulted in a focus group with five members including one expert. The relatively small number of participants could be explained by the high complexity of the subject (Saunders et al., 2009). The stakeholders were provided with a digital hand-out days up front to give them some information about the focus group. According to the participants, this enhanced the understanding of the purpose of the focus group significantly. The researcher attempted to balance the information provided up front by only sending information about the purpose and the structure of the focus group. The researcher acted as 'moderator' and facilitated the focus group with the purpose of keeping the group within boundaries of the topic discussed and encourage discussion. Observer biases and errors were reduced by digital recording the audio and asking a fellow student to take notes during the meeting. The focus group meeting led to a fruitful discussion of the different criteria and sub-criteria.

Overall, the analysis suggests that there is especially little consensus between the desk research and the interviews about the design category. It seems that there is no conformity about the purpose of using indicators in the MRA and how CE is defined for the region. Also inconsistencies seem to be in place between the strategic targets and day-to-day (operational) activities. Methodologically, these unconformities could be explained by the fact that the first two validation phases leave less room for discussion. The focus group enables the researcher to partially reach consensus about these inconsistencies. Although the focus group also shows that there is little consensus in the design category about the criteria, the focus group do leads to more conformity about the definition of CE and the most important purposes of using indicators in the MRA. Nevertheless, the researcher recognizes that organizing an additional focus group may have enhanced consensus building.

6.2 Validity and reliability issues

The quality of the results of the desk research, the interviews, and the focus group was subject to validity and reliability issues. The *internal validity* in this research refers to whether there is a good match between what is observed during the desk research, interviews, and focus group, and the theoretical ideas that are developed. To ensure a high level of congruence between the validation criteria and the observations, triangulation of methods and sources of data was used (Bryman, 2012; Saunders et al., 2009). In total three different methods were deployed and two different sources of data (conversations, documents) which resulted in greater confidence in findings. According to Saunders et al. (2009), in research in which a case study approach is used, it is desirable to triangulate multiple sources of data. In this research a single case was chosen to gain rich understanding of the context and processes regarding CE that are being enacted in the MRA. The MRA represented a unique case in the context of CE as this region provides major opportunities to move towards a CE. In this context, a case study approach seemed a worthwhile way of exploring existing theory on CE assessment criteria and indicators.

External validity refers to the degree to which findings can be generalized across social settings. The generalizability of the results from this single case study are limited because it concerned a relatively small sample. However, the purpose of this case study was not to produce a theory that is generalizable to all populations. The researcher was particularly interested in how current validation criteria in literature for CE indicator assessment differs for this particular research setting. The current lack of knowledge and research on the topic of validation criteria for CE indicator assessment at regional scale provided a rationale for this single case study. Moreover, the researcher proposed a method which can be deployed in any region to develop region-specific criteria. Therefore, other regions and cities in the Netherlands and abroad can take advantage of the method proposed in this research.

Reliability of the research is concerned with issues of consistency of measures (Bryman, 2012). According to Saunders et al. (2009), there may be four threats to reliability in social research: Observer error, observer bias, subject or participant error, subject or participant bias. Observer error and bias is concerned with the robustness of the collection of documents, the design of the semi-structured questionnaire, and the design of the focus group. Therefore, it was attempted to address the same themes and concepts in each phase and analyze the data with one coherent framework. Furthermore, data collection and analysis was conducted by only one interviewer/observer which reduced *the observer error*. *Observer bias* in this research is probably caused by the shared concern from the researcher, the interviewees, and the participants for CE and sustainability. This influenced the sampling strategy since snowball sampling was used during the interviews to select participants for the focus group. However, a main strength of this research is the execution of the '3S methodology' which comprises three complementary validation stages: self-validation, scientific validation, and social validation. Self-validation was performed to avoid conceptual inconsistencies as well as operational

mistakes. To guarantee reliability, quality, and objectivity of judgements, interviews were performed with scientists and experts in the field of CE and indicator assessment. Furthermore, public participants were included such as representatives from public administration, business owners, and other social agents in order to reach consensus in environmental and social impact assessment. As these three validation stages were complementary, the credibility of the validation criteria increased as they overcame the different stages.

In order to reduce the chance of *subject or participant error*, the interviewees were informed days up front about the duration of the interview in order to let them reserve enough time in their schedule. This enabled the interviewees to elaborate more extensively on some interview questions. Also, the researcher endeavored to plan the interviews and the focus group in a short time period to limit this error. It was attempted to keep *subject or participant bias* as low as possible by asking open questions about each theme first. In this way, the answers provided by the participants and interviewees were the least guided by the semi-structured interviews.

6.3 Suggestions for further research

It is beyond the scope of this research to do an extensive evaluation of potential CE indicators for the MRA. The main objective of this research was to develop a methodology which describes how to tailor criteria to the unique characteristics of a region and select a set of CE indicators according to these specific criteria. Therefore, this research extends current theoretical insights by providing a step by step approach including stakeholder participation to assess the correct performance of CE indicators for a specific region. Furthermore, this also contributes to theory as regional adoption and measurement of CE practices requires further investigation according to Ghisellini et al. (2015). The current lack of knowledge and awareness of European producers and consumers can be enhanced by providing transparency through the use of CE indicators (Ghisellini et al., 2015). At macro level, CE indicators can serve as a tool to evaluate the legislation and awareness of cities, regions and nations which provides feedback information to policymakers about the soundness of the policies so far (Ghisellini et al., 2015). By not only evaluating the environmental and economic aspects, the researcher attempted to suggest a more systematic evaluation that integrates indicators of environmental, economic, and social development. This is not addressed in previous CE assessment literature (Geng et al., 2012; Zhijun & Nailing, 2007).

A suggestion for further research is to develop a comprehensive CE indicator framework for the MRA according to this research. Furthermore, the proposed method could be used for other case studies as well which can be a useful tool for researchers and policymakers to develop a CE indicator framework. This can result in the development of various CE indicator frameworks for multiple regions which provides insights about the CE transition of cities and regions. This also enables benchmarking opportunities and learning through the exchange of best practices between cities and regions.

7. Conclusion

Over the last decade, Circular Economy (CE) is receiving increased attention worldwide as a way to decouple economic growth and prosperity from the linear consumption and production of finite resources. Cities and urban areas are a growing source of energy and material consumption due to worldwide urbanization and are increasingly recognized by policymakers as an arena to significantly reduce negative impacts on society and nature. Clearly, tools and methodologies are needed to measure the environmental, social, and economic impacts of established objectives and targets in cities and regions. However, currently there is a lack of knowledge on how to design a CE indicator framework which is scientifically sound designed, provides relevant information according to the purpose and scope, and is easy to use in practice. This thesis is aimed at providing a step by step method for a rigorous validation process of region specific criteria which guarantees the selected indicators are scientific, relevant, and useful. Therefore, the main question that is answered in this thesis is: '*How can a set of scientifically sound, politically relevant, and practical indicators be developed for the purpose of measuring CE for a region?*

A set of validated indicators for the purpose of measuring CE in a region can be developed in the following steps:

1. *Perform a literature review of existing SD and CE criteria to establish a list of generic criteria*
2. *Validate generic criteria according to the proposed 3S method for the specific region*
    a. *Self-validation/desk research*
    b. *Scientific validation/expert interviews*
    c. *Social validation/focus group*
3. *Design evaluation scheme with region-specific criteria for single indicator evaluation*
4. *Evaluate existing CE indicators according to the region-specific criteria*

The researcher proposes a unique approach in the field of CE assessment by adopting the 3S methodology (i.e. self-validation, scientific validation, and social validation) and tailors the generic SD and CE criteria to the specific needs and situation of the Metropole Region of Amsterdam (MRA). The results from the 3S validation method show that there is little consensus about the sub-criteria in the 'relevant to policy' criteria. An indicator is considered relevant whenever it; *encourages economic activity, provides understanding, attracts talent companies and investors, enables benchmarking, stimulates target setting, and supports political action*. The indicators should address one of the following short-and long-term drivers in the region; *knowledge dissemination, circular procurement, innovation cluster development, new business model creation, and improved resource utilization*. The sub-criteria of the 'accepted by scientific community' criteria more show conformity as the indicators should at least incorporate one of the following sub-criteria; *modular design of products, zero waste, zero emissions energy, the systems thinking, closing loops, and creation of new business models*. However, there is no consensus between the stakeholders about how CE is defined for the MRA. The sub-criteria from the criteria 'credible', 'robust', 'easy', do show conformity among the stakeholders. An indicator is considered to be credible whenever it provides *unambiguous results, show trends, provides early warnings, and provides transparency of methods*. The indicator is viewed as robust when it is *based on an international standardized method*, its data *is statistically validated* by a 3rd party, and its data is *produced on a regular basis*. The indicator is considered to be 'easy' when it's *simple to understand,* its data *is available* and can be collected at *reasonable costs* and *time*, and it's *complementary* with other indicator frameworks.

Methodologically, the results imply that a comprehensive and detailed self-validation phase helps to become familiar with the CE objectives, targets, and strategies which facilitates interpretation during the scientific- and social validation phases. Furthermore, incorporation of independent experts' judgements through the use of in depth interviews can help to bring scientific credibility to the indicator selection process. The results from the desk research and the interviews show that the various stakeholders engaged in the process hold different preferences and values regarding the purpose of indicators. However, the focus group shows that consensus can be built among stakeholders regarding the opinions and perceptions of the purpose of the indicators individually, and the framework as a whole. Up to now, CE assessment was only validated from a scientific point of view through the incorporation of experts in the indicator selection process. However, this method also includes a social validation phase in the decision process which improves the public participation process and supports consensus building. Also, by integrating public stakeholders in the process through a focus group, a better understanding of policy relevant criteria is obtained. The feasibility of the method in terms of time and costs has shown to be acceptable and can be enhanced by replacing the in-depth interviews for focus group(s). The indicator evaluation against the specific criteria is designed for indicator validation on an individual level. However, with the appropriate adjustments and modifications, this step can be deployed on framework level as well.

7.1 Advice to business

The method developed in this thesis offers an opportunity for planners, policymakers, and researchers to identify key criteria for a regional CE indicator framework; thus providing a first step to develop a scientific, relevant, and useful set of CE indicators for a region. In section 5.4, this step by step approach is described in detail. Building on this method, the following recommendations are made:

- Select a small working group with experts and non-experts for the literature review
  - Develop framework with generic criteria
- Perform 3S method on generic criteria
  - Clarify purpose of the indicator set by doing interviews with non-experts and experts
  - Identify common vision and shared values by means of a focus group
  - Provide a list with tailored criteria by means of a focus group
- Review existing models and indicator frameworks
  - Evaluate existing indicators against tailored criteria by means of a survey

8. Reference list

Andersen, M. S. (2006). An introductory note on the environmental economics of the circular economy. *Sustainability Science*, *2*(1), 133–140.

Azapagic, A., & Perdan, S. (2000). Indicators of sustainable development for industry: a general framework. *Trans IChemE*, *78*(July), 243–261.

Bockstaller, C., & Girardin, P. (2003). How to validate environmental indicators. *Agricultural Systems*, *76*(2), 639–653.

Böhringer, C., & Jochem, P. E. P. (2007). Measuring the immeasurable — A survey of sustainability indices. *Ecological Economics*, *63*(1), 1–8.

Bringezu, S., Schütz, H., & Moll, S. (2003). Rationale for and Interpretation of Economy-Wide Materials Flow Analysis and Derived Indicators. *Journal of Industrial Ecology*, *7*(2), 43–64.

Brown, M. T., & Buranakarn, V. (2003). Emergy indices and ratios for sustainable material cycles and recycle options. *Resources, Conservation and Recycling*, *38*(1), 1–22.

Bryman, A. (2012). *Social Research Methods* (Fourth). New York: Oxford University Press Inc.

CBS. (2015). *Expanding the Material Flow Monitor*. Den Haag.

Circle Economy. (2014). Multidisciplinary coalition transforms the Netherlands into a global circular hotspot. Retrieved December 1, 2015, from http://www.circle-economy.com/news/multidisciplinary-coalition-transforms-netherlands-global-circular-hotspot/

Circle Economy, TNO, & Fabric. (2015). *Amsterdam Circulair: Een visie en routekaart voor de stad en regio*. *Policy document*. Amsterdam.

Cloquell-Ballester, V. A., Cloquell-Ballester, V. A., Monterde-Díaz, R., & Santamarina-Siurana, M. C. (2006). Indicators validation for the improvement of environmental and social impact quantitative assessment. *Environmental Impact Assessment Review*, *26*(1), 79–105.

Cramer, P. J. (2014). Moving Towards a Circular Economy in the Netherlands : Challenges and Directions, 1–9.

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, *8*(2), 125–139.

Dietz, S., & Neumayer, E. (2007). Weak and strong sustainability in the SEEA: Concepts and measurement. *Ecological Economics*, *61*(4), 617–626.

Donnelly, A., Jones, M., O'Mahony, T., & Byrne, G. (2006). Decision-support framework for establishing objectives, targets and indicators for use in strategic environmental assessment, Impact Assessment and Project Appraisal. *Environmental Impact Assessment Review*, *24*(2), 151–157.

Donnelly, A., Jones, M., O'Mahony, T., & Byrne, G. (2007). Selecting environmental indicator for use in strategic environmental assessment. *Environmental Impact Assessment Review*, *27*(2), 161–175.

Ellen MacArthur Foundation. (2013). Towards the Circular Economy: Economyc and business rationale for accelerated transition. *Journal of Industrial Ecology*, *1*(1), 4–8.

Erkman, S. (1997). Industrial ecology: an historical view. *Journal of Cleaner Production*, *5*(1-2), 1–10.

European Commission. (2013). *Resource Efficiency Indicators*. Bristol.

Fischer-Kowalski, M., Krausmann, F., Giljum, S., Lutter, S., Mayer, A., Bringezu, S., … Weisz, H. (2011). Methodology and indicators of economy-wide material flow accounting: State of the art and reliability across sources. *Journal of Industrial Ecology*, *15*(6), 855–876.

Geng, Fu, J., Sarkis, J., & Xue, B. (2012). Towards a national circular economy indicator system in China: An evaluation and critical analysis. *Journal of Cleaner Production*, *23*(1), 216–224.

Geng, Zhu, Q., Doberstein, B., & Fujita, T. (2009). Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China. *Waste Management*, *29*(2), 996–1002.

Geng, Y., & Doberstein, B. (2008). Developing the circular economy in China: Challenges and opportunities for achieving "leapfrog development." *International Journal of Sustainable Development & World Ecology*, *15*(9), 231–239.

Geng, Y., Sarkis, J., Ulgiati, S., & Zhang, P. (2013). Measuring China's Circular economy. *American Assocation for the Advancement of Science*, *339*(3), 1526–1527.

Geng, Y., Zhang, P., Ulgiati, S., & Sarkis, J. (2010). Emergy analysis of an industrial park: The case of Dalian, China. *Science of the Total Environment*, *408*(22), 5273–5283.

Georgiadis, P., & Besiou, M. (2008). Sustainability in electrical and electronic equipment closed-loop supply chains: A System Dynamics approach. *Journal of Cleaner Production*, *16*(15), 1665–1678.

Ghisellini, P., Cialani, C., & Ulgiati, S. (2015). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production*, 1–22.

Gudmundsson, H. (2003). Making concepts matter: sustainable mobility and indicator systems in transport policy. *International Social Science Journal*, *55*(176), 199–217.

Gustavson, K. R., Lonergan, S. C., & Ruitenbeek, H. J. (1999). Selection and modeling of sustainable development indicators: a case study of the Fraser River Basin, British Columbia. *Ecological Economics*, *28*(1), 117–132.

Huang, Q., Zheng, X., & Hu, Y. (2015). Analysis of Land-Use Emergy Indicators Based on Urban Metabolism: A Case Study for Beijing. *Sustainability*, *7*(6), 7473–7491.

Huang, S. L., Lee, C. L., & Chen, C. W. (2006). Socioeconomic metabolism in Taiwan: Emergy synthesis versus material flow analysis. *Resources, Conservation and Recycling*, *48*(2), 166–196.

Jackson, L. E., Kurtz, J. C., & Fisher, W. S. (2000). *Evaluation Guidelines for Ecological Indicators*. Durham.

Jackson, T. (2014). *Prosperity Without Growth* (Vol. 40). Earthscan.

Kennedy, C., Cuddihy, J., & Engel-yan, J. (2007). The Changing Metabolism of Cities. *Journal of Industrial Ecology*, *11*(2), 44.

Li, H., Bao, W., Xiu, C., Zhang, Y., & Xu, H. (2010). Energy conservation and circular economy in China's process industries. *Energy*, *35*(11), 4273–4281.

Loorbach, D., & Rotmans, J. (2006). Managing Transitions for Sustainable Development. *Understanding Industrial Transformation - Views from Different Disciplines.*, 226.

Lozano, R. (2008). Envisioning sustainability three-dimensionally. *Journal of Cleaner Production*, *16*(17), 1838–1846.

Lozano, R. (2012). Addressing Stakeholders and Better Contributing to Sustainability through Game Theory. *The Journal of Corporate Citizenship*, *43*(0), 44–62.

Lyle, J. T. (1994). *Regenerative Design for Sustainable Development*. New York: Wiley.

Mascarenhas, A., Coelho, P., Subtil, E., & Ramos, T. B. (2010). The role of common local indicators in regional sustainability assessment. *Ecological Indicators*, *10*(3), 646–656.

McDonough, W., & Braungart, M. (2002). *Cradle-to-cradle, remaking the way we make things* (1st ed.). New York: North Point Press.

Meadows, D. (1998). *Indicators and Information Systems for Sustainable Development*.

Metropole Region Amsterdam. (2016). *Ruimtelijk-Economische Actie - Agenda 2016 - 2020*. Amsterdam.

Mori, K., & Christodoulou, A. (2012). Review of sustainability indices and indicators: Towards a new City

Sustainability Index (CSI). *Environmental Impact Assessment Review*, *32*(1), 94–106.

Moriguchi, Y. (2007). Material flow indicators to measure progress toward a sound material-cycle society. *Journal of Material Cycles and Waste Management*, *9*(2), 112–120.

Naustdalslid, J. (2014). Circular economy in China – the environmental dimension of the harmonious society. *International Journal of Sustainable Development & World Ecology*, *21*(4), 303–313.

Ness, D. (2008). Sustainable urban infrastructure in China: Towards a Factor 10 improvement in resource productivity through integrated infrastructure systems. *International Journal of Sustainable Development & World Ecology*, *15*(November), 337–344.

Pintér, L. (2006). Circular Economy in China: Moving from Rhetoric to Implementation. *Journal of Chemical Information and Modeling*, *53*(May), 160.

Prabhu, R., Colfer, C.J.P. and Dudley, R. G. (1999). *Guidelines for Developing, Testing and Selecting Criteria and Indicators for Sustainable Forest Management*. *Management*. Jakarta: Center for International Forestry Research.

Preston, F. (2012). A Global Redesign? Shaping the Circular Economy. *Energy, Environment and Resource Governance*, (March).

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students* (Fifth). Essex: Pearson Education.

Shekhawat, R. S. (2016). Tourism Indicators: Tool for Sustainable Development. In N. Ruparel & V. Modi (Eds.), *Management and Research Practices in Emerging Markets* (pp. 267–275). Gujarat: Books India Publication.

Spiller, M., & Agudelo-Vera, C. M. (2011). *Mapping diversity of urban metabolic functions – a planning approach for more resilient cities*. *5th AESOP Young Academics Network Meeting 2011, 15-18 February 2011, Delft, the Netherlands*. Wageningen.

Stahel. (2014). Reuse is the key to the Circular Economy. Retrieved February 18, 2016, from https://ec.europa.eu/environment/ecoap/about-eco-innovation/experts-interviews/reuse-is-the-key-to-the-circular-economy_en

Stahel, & Reday-Mulvay. (1981). *Jobs for Tomorrow: the Potential for Substituting Manpower for Energy*. New York: Vantage Press.

Stubbs, W., & Cocklin, C. (2008). An ecological modernist interpretation of sustainability: The Case of Interface Inc. *Business Strategy and the Environment*, *17*(8), 512–523.

Su, B., Heshmati, A., Geng, Y., & Yu, X. (2013). A review of the circular economy in China: Moving from rhetoric to implementation. *Journal of Cleaner Production*, *42*, 215–227.

Tan, H. X., Yeo, Z., Ng, R., Tjandra, T. B., & Song, B. (2015). A Sustainability Indicator Framework for Singapore Small and Medium-Sized Manufacturing Enterprises. *Procedia CIRP*, *29*, 132–137.

The Netherlands Circular Hotspot. (2016). The case of the Metropole Region Amsterdam. Retrieved February 29, 2016, from http://www.netherlandscircularhotspot.nl/metropole-region-of-amsterdam.html

UNEP. (2011). *Decoupling Natural Resource Use and Environmental Impacts from Economic Growth*.

Veleva, & Ellenbecker, M. (2001). *Indicators of sustainable production: Framework and methodology*. *Journal of Cleaner Production* (Vol. 9).

Veleva, Hart, M., Greiner, T., & Crumbley, C. (2001). Indicators of sustainable production. *Journal of Cleaner Production*, *9*(5), 447–452.

WCED. (1987). *Our common future*. New York: Oxford University Press Inc.

World Resources Institute. (2005). *Material flows accounts: a tool for making environmental policy*. Washington, DC.

Yong, R. (2007). The circular economy in China. *Journal of Material Cycles and Waste Management*, *9*(2), 121–129.

Young, S. T., & Dhanda, K. K. (2013). *Sustainability: Essentials for Business*. Sage Publications.

Zaman, A. U. (2015). A comprehensive review of the development of zero waste management: Lessons learned and guidelines. *Journal of Cleaner Production*, *91*, 12–25.

Zaman, A. U., & Lehmann, S. (2013). The zero waste index: a performance measurement tool for waste management systems in a "zero waste city." *Journal of Cleaner Production*, *50*, 123–132.

Zhang, Z., Chen, X., & Heck, P. (2014). Emergy-Based Regional Socio-Economic Metabolism Analysis: An Application of Data Envelopment Analysis and Decomposition Analysis. *Sustainability*, *6*(12), 8618–8638.

Zhijun, F., & Nailing, Y. (2007). Putting a circular economy into practice in China. *Sustainability Science*, *2*(1), 95–101.

Zucaro, A., Ripa, M., Mellino, S., Ascione, M., & Ulgiati, S. (2014). Urban resource use and environmental performance indicators. An application of decomposition analysis. *Ecological Indicators*, *47*, 16–25.

9. Appendices

Appendix A – Articles and publications used in desk research

Europe		
Organisation	**Name**	**Year**
European Commission	*Analysis associated with the Roadmap to a Resource Efficient Europe Part I.*	2011
European Commission	*Towards a circular economy: A zero waste programme for Europe.*	2014
European Commission	*Circular Economy - Clear targets and Tools for better Waste Management.*	2015a
European Commission	*Circular economy: Closing the loop. From waste to resource.*	2015b
European Commission	*Closing the loop - An EU action plan for the Circular Economy.*	2015c
European Union	*Mainstream competitiveness - the circular economy package.*	2016
Netherlands		
CBS	*Expanding the Material Flow Monitor.*	2015
Dutch Government	*Van Afval naar Grondstof.*	2014
Dutch Ministry of Economic Affairs	*Green Deal: Nederland hotspot voor Circulaire Economie.*	2013
Dutch Ministry of Infrastructure and Environment	*Landelijk afvalbeheerplan 2009-2021 Naar een materiaalketenbeleid.*	2014
MRA		
AEB	*Metropoolregio Amsterdam: Wonen, werken, wereldplek.*	2014
AMS	*URBAN PULSE Understanding resource flows and dynamics in Amsterdam.*	2015
Circle Economy, TNO, & Fabric	*Amsterdam Circulair: Een visie en routekaart voor de stad en regio.*	2015
Dutch Ministry of Economic Affairs	*Green Deal: Nederland hotspot voor Circulaire Economie.*	2013
Metabolic, Studioninedots, & DELVA	*Een Living Lab voor Transitioning circulaire gebiedsontwikkeling: Circulair Buiksloterham*	2015
Metropole Region Amsterdam	*Ruimtelijk-Economische Actie - Agenda 2016 - 2020.*	2016
Municipality of Amsterdam	*De Circulaire Metropool: Amsterdam 2014-2018.*	2014
Municipality of Amsterdam	*Duurzaam Amsterdam.*	2015

Appendix B – Content analysis framework

Scope		
	Design category	
	Relevant for policy (see comprehensive table above)	**Accepted** by scientific community
	Objectives, targets, and strategies	*Connection to the principles of CE*
Article 1		
Article 2		

Scope						
	Output category					
	Credible		**Robust**			
	Unambigious (Parameters and results are clearly defined)	*Transparency in method* (Calculation is standardized and transparent)	*Defensible theory* (Based on a common accounting method)	*Data reliability* (Collected by statistical office, statistically validated)	*Sensitive* (Produced on a regular basis, data density is high)	*Indicator reliability* (Based on a coherent framework, Informs about what is meant to be measured)
Article 1						
Article 2						

Scope				
	End-use category			
	Easy			
	Applicable to scope	*Data is available*	*Technical feasible* (Data collection is relatively easy, associated costs with data collection are acceptable)	*Complementary and integrated* (Monitored and analyzed in relation to other dimensions, Indicator allows for benchmarking)
Article 1				
Article 2				

Appendix C – Semi-structured interview template

Introductory questions

Name	
Organisation	
Date	
What is your function/role?	
How long are you working here in this role?	

Design category

1. What is the role of X in Amsterdam concerning Circular Economy?
2. What definition has X developed to define CE in Amsterdam?
    a. Characteristics: Materials, water, energy etc
    b. Aspects People/planet/profit
3. Are there specific theme's/programmes developed by X?
    a. Which themes specific on indicators?
4. Are there specific targets/objectives formulated for circular economy in Amsterdam (by the government, or by X)?
    a. If yes, which objectives and targets are formulated?
    b. By who?
    c. If not, why not and are there plans to formulate objectives?
5. Are you involved in formulating these objectives/targets? Is the government involved by defining objectives/targets for CE?
    a. If yes, which ones?
    b. If not, why not?
6. What is the purpose of using indicators for CE in the region of Amsterdam? (awareness, measure progress, inform decision-making, benchmarking, learning, inclusion of stakeholders)
7. What is the role of X concerning CE indicators in Amsterdam?
8. Can you tell me more about the City circle scan?
    a. What is it?
    b. Why is it developed?
    c. For who?
9. Why did you choose for these waste streams?
10. Can you tell me more about the potential and priority of other waste streams?
    a. demolition waste (bouwafval)
    b. vegetable-, fruit- and garden (groente en fruit afval)
    c. textiles
    d. metals

e. incontinence materials f. plastics; g. electronic and electric waste
11. Are there targets/objectives for these waste streams formulated? a. qualitative or quantitative?
12. Are there indicators developed for monitoring these objectives/targets? a. Welke?
13. Does any of these indicators overlap with one of the following principles of CE? a. 3R principle (reduce, reuse, recycle) b. Zero emission (use of sustainable energy) c. Creating shared value/planet/profit
14. Are these indicators input or output related indicators? (consumption or production cycle indicators)
15. Wordt er gekeken naar de consumptie van materiaal, water, en energie of naar de productie van vervuild water, afval, en emissies?
16. Is the indicator easy to understand and to communicate? a. How did you manage to develop an indicator that is easy to understand and to communicate?
17. Can you tell me more about the 'circulaire indicatoren framework' developed in collaboration with TNO
18. How are the ecological impact indicators related to CE?
19. How did you measure circular services in amsterdam as a percentage of gross added value?
20. On what level are these indicators measured? a. Locally b. Regionaal c. National
Output category
21. Is there a standardized way of developing these indicators?
22. Is there a standardized way of measuring? a. If yes, which one? b. If not, how do you measure?
23. What aspects of CE should be described by the indicators?

24. Are there criteria used to assess the appropriateness of an indicator or a set of indicators? (relevance, completeness, availability, measurability, reliability, familiarity, non-redundancy)
25. Are these criteria discussed with different stakeholders?
26. Are these criteria validated by an independent organisation?

End-use category

27. How are possible indicators chosen to be definitive indicators? In other words, what criteria decides whether an potential indicator is chosen to be the final indicator?
28. What is the influence of data availability in choosing indicators?
29. Do you also look for/learn from indicators that are used in other countries?
30. Are the objectives/targets that X defined for the region of amsterdam adjusted in time?
31. At what timeframe? (annually, biannually)

Additional questions

32. Do you know stakeholders that would be interesting to interview concerning my thesis? a. especially interested in data availability of different waste streams b. or experts in the field of developing indicators

Appendix D – Thematic analysis framework interviews

Governmental officials	Design category			
	Relevant for policy		**Accepted** by scientific community	
	Objectives, targets, and strategies		*Connection to the principles of CE*	
Interviewee 1				
Interviewee 2				

Governmental officials	Output category					
	Credible		**Robust**			
	Unambiguous	*Transparency in method*	*Defensible theory*	*Data reliability*	*Sensitive*	*Indicator reliability*

	(Parameters and results are clearly defined)		(Calculation is standardized and transparent)		(Based on a common accounting method)		(Collected by statistical office, statistically validated)		(Produced on a regular basis, data density is high)		(Based on a coherent framework, Informs about what is meant to be measured)	
Interviewee 1												
Interviewee 2												

EU								
Governmental officials	End-use							
	Easy							
	Applicable to scope		*Data is available*		*Technical feasible* (Data collection is relatively easy, associated costs with data collection are acceptable)		*Complementary and integrated* (Monitored and analyzed in relation to other dimensions, Indicator allows for benchmarking)	
Interviewee 1								
Interviewee 2								

Miscellaneous		
Governmental officials		
	Quote	*sentences*
Interviewee 1		
Interviewee 2		

Appendix E – Focus group digital hand-out

Page 1

Focus groep hand-out

Welkom bij deze focus groep!

Hartelijke dank voor uw komst. Het komende uur gaan we **criteria** valideren voor het kiezen van Circulaire Economie (CE) indicatoren binnen de Metropool Regio Amsterdam (MRA).

In deze hand-out vind u:

(1) agenda;

(2) het **doel** van de focus group;

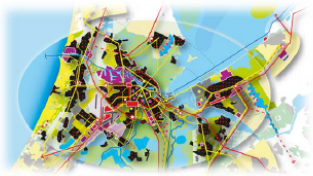
(3) de **opzet** van de discussie;

Agenda

1. **Introductie (5 min)**
   - 1.1. Huishoudelijke mededelingen
   - 1.2. Achtergrond
   - 1.3. Doel van de focus groep
2. **Discussie (45 min)**
   - 2.1. Design criteria
   - 2.2. Output criteria
   - 2.3. Gebruikscriteria
3. **Wrap up (5 min)**
4. **Afsluiting (5 min)**

Valideren van criteria voor de MRA

Datum: 25-05-2016, 15:00-16:00
Locatie:
Amsterdam Economic Board
Jodenbreestraat 25
Amsterdam



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page 2

Lijst met aanwezigen		
Discussieleden		
Naam	Functie	Organisatie
Dominique van Ratingen	Programma Manager Circulaire Economie	Amsterdam Economic Board
Edwin Oskam	Strategisch adviseur, coordinator Boardthema's	Amsterdam Economic Board
Mirko van Vliet	Junior Strategisch adviseur	Amsterdam Economic Board
Marjolein Brasz	Business Connector Circulaire Economie	Amsterdam Economic Board
Sladjana Mijatovic	Programmamanager Stedelijke Innovatie	Gemeente Amsterdam
Sytze Dijkstra	Onderzoeksmanager	Accenture Strategy
Moderator		
Erik Wisse	Onderzoeksstagaire Circulaire Economie	Accenture Strategy
Notulist		
Maurits van Riemsdijk	Onderzoeksstagaire Circulaire Economie	Schuttelaar & Partners
Timekeeper		
Mirko van Vliet	Junior Strategisch adviseur	Amsterdam Economic Board

1.1 Huishoudelijke mededelingen

- De focus group wordt **opgenomen** met een mobiele telefoon voor onderzoeksdoeleinden
- Ten behoeve van de onderzoeksresultaten graag elkaar rustig uit laten praten.
- Er wordt een aantal **foto's** genomen voor in het thesis verslag en de presentatie
- Uw gegevens worden zonder uw uitdrukkelijke toestemming **niet** verstrekt aan derden

1.2 Achtergrond

De MRA is de sterkste regio van Nederland. De wereldwijde concurrentie tussen stedelijke regio's neemt toe en binnen de MRA zijn alle ingrediënten aanwezig om deze strijd aan te gaan. De partijen in de MRA zetten in op een slimme en innovatieve metropool, waarin het delen van **kennis** centraal staat.

De Amsterdam Economic Board (AMECBoard) werkt hierin aan een intensieve samenwerking tussen kennisinstellingen, bedrijven en overheden. Binnen het AMECBoard duurzaamheidsbeleid geldt Circulaire Economie (CE) als een belangrijke challenge.

De ambitie is om in internationaal opzicht de leider te worden in het vinden van innovatieve oplossingen om de druk op grondstoffen te verlagen. Ook de Gemeente Amsterdam zet in haar duurzaamheidsagenda vol in op de CE als pijler binnen het duurzaamheidsbeleid.

Het **monitoren** van de voortgang van de activiteiten en resultaten neemt hierbij een centrale plek in binnen de organisaties. Een integraal dashboard moet transparantie en inzicht bieden over de prestaties van de MRA, de challenges, clusters en projecten.

Dit onderzoek richt zich op het ontwikkelen van een **indicatoren** raamwerk voor het meten van CE op regionale schaal. Het doel van het onderzoek is:

(1) het ontwikkelen van een uitgebreide lijst van bestaande **indicatoren** die relevant zijn voor het meten van CE in een regio;

(2) het ontwikkelen van (validatie) **criteria** specifiek voor de MRA;

(3) een **methodiek** presenteren om een set indicatoren te evalueren en te selecteren op basis van de MRA-specifieke criteria.

1.3 Doel Focus Groep

Het doel van deze focus groep draagt bij aan het 2e onderzoeksdoel: *het ontwikkelen van validatie criteria specifiek voor de MRA*. Tijdens de discussie worden de criteria voorgelegd en geëvalueerd in de context van Circulaire Economie in de MRA.

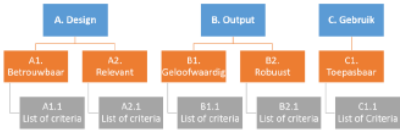
2. Opzet discussie

Gedurende deze sessie worden er 3 categorieën criteria geëvalueerd (zie figuur 1), namelijk **design, output, en gebruiks-criteria.** De categorieën bestaan uit 1 of meerdere subcategorieën (A1, A2, B1, B2, C1). Bij elke subcategorie hoort een lijst met criteria (A1.1, A2.1, B1.1, B2.1, C1.1).

Voor elke lijst met criteria bespreken we de volgende vragen:

- Welke van deze criteria zijn **niet** relevant voor het meten van Circulaire Economie binnen de MRA?
- Kun je de criteria rangschikken van **meest** relevant tot **minst** relevant?
- Welke criteria ontbreken er?

Figuur 1



Dank voor uw komst!

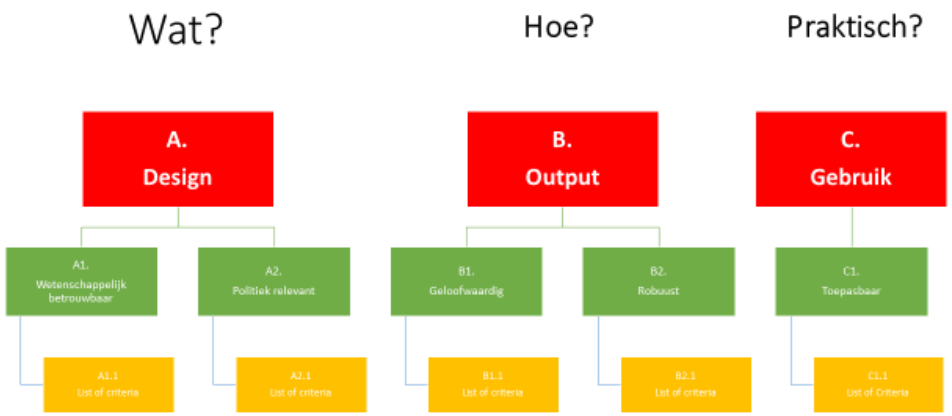
Hartelijke dank voor uw komst! Indien gewenst ontvangt u een digitale versie van het focus groep verslag. Daarnaast is het ook mogelijk eind juni het eindverslag op te vragen.

Contactgegevens

Erik Wisse
Onderzoeksstagair CE
Accenture Strategy

06-54947567
erik.wisse@accenture.com

Appendix F – Evaluation form focus group



1) Welke van deze criteria zijn **niet** van relevant voor het meten van Circulaire Economie binnen de MRA?
2) Kun je de criteria rangschikken van **meest** relevant tot **minst** relevant?

A. Design: Wat?	
A1. Wetenschappelijk betrouwbaar	**Score**
1) Indicator beschrijft afval=grondstof d.m.v. weigeren, reduceren, hergebruiken, repareren, renoveren, recyclen	
2) Indicator beschrijft tenminste 1 van de volgende dimensies: People, Planet, Profit	
3) Indicator beschrijft productie- en/of consumptie van energie/water/grondstoffen/afval/emissies	
4) Indicator beschrijft productie- en/of consumptie van duurzame energie	
5) Indicator beschrijft het sluiten van kringlopen (organische en anorganische stoffen)	
6) Indicator beschrijft modulair/flexibel design	
7) Indicator beschrijft nieuwe business modellen	

0 = niet relevant **1** = weinig relevant **2**= gemiddeld relevant **3**= relevant **4**= zeer relevant

1) Welke van deze criteria zijn **niet** van relevant voor het meten van Circulaire Economie binnen de MRA?
2) Kun je de criteria rangschikken van **meest** relevant tot **minst** relevant?

A. Design: Wat willen we meten?	
A2. Politiek relevant	**Score**
1) Indicator is **representatief** voor de MRA	
2) Indicator is **in lijn** met **Europese** doelstellingen	
3) Indicator is **in lijn** met **nationale** doelstellingen	
4) Indicator is **in lijn** met **regionale** doelstellingen	
5) Indicator is **in lijn** met lokale doelstellingen	
6) Indicator beschrijft tenminste één van de **prioritaire ketens** binnen de MRA	
7) Indicator heeft de **potentie** te kunnen worden **beïnvloed** d.m.v. **beleid** (aanbesteden, regelgeving, belasting, financiering)	
8) Indicator heeft de **potentie** om de **markt te beïnvloeden**	

0 = niet relevant **1** = weinig relevant **2**= gemiddeld relevant **3**= relevant **4**= zeer relevant

1) Welke van deze criteria zijn **niet** van relevant voor het meten van Circulaire Economie binnen de MRA?

2) Kun je de criteria rangschikken van **meest** relevant tot **minst** relevant?

B. Output: Hoe?			
B1. Geloofwaardig	**Score**	**B2. Robuust**	**Score**
1) Indicator heeft **duidelijk** omschreven **parameters**		1) Indicator is gebaseerd op een **internationaal geaccepteerde** methode	
2) Indicator heeft een **gestandaardiseerde** meetmethode (transparant)		2) Indicator data wordt verzameld door een **onafhankelijk** bureau	
3) Indicator is algemeen **geaccepteerd** door/**herkenbaar** voor stakeholders		3) Data van de indicator is **actueel**	
4) Indicator uitkomsten zijn **begrijpelijk** en **communiceerbaar**		4) Data van de indicator is **gedetailleerd**	
5) Indicator heeft **duidelijk** omschreven **resultaten**		5) Indicator is **gevoelig** voor **veranderingen**	
		6) Indicator is **ongevoelig** voor **manipulatie**	
		7) Indicator geeft **consistente** informatie over de **voortgang** van CE in de MRA	

0 = niet relevant **1** = weinig relevant **2**= gemiddeld relevant **3**= relevant **4**= zeer relevant

1) Welke van deze criteria zijn **niet** relevant voor het meten van Circulaire Economie binnen de MRA?

2) Kun je de criteria rangschikken van **meest** relevant tot **minst** relevant?

C. Praktisch?	
C1. Toepasbaar	**Score**
1) Indicator is **toepasbaar** op MRA niveau	
2) Indicator **data** is **beschikbaar**	
3) Indicator **data** is **beschikbaar** tegen **aanvaardbare inspanning**	
4) Indicator **data** is **beschikbaar** tegen **aanvaardbare kosten**	
5) Indicator is **complementair** aan overige indicatoren	
6) Indicator **resultaten** kunnen worden **vergeleken** met andere regio's (Nationaal/Internationaal)	
7) Indicator is **toegankelijk** voor een leek	

0 = niet relevant **1** = weinig relevant **2**= gemiddeld relevant **3**= relevant **4**= zeer relevant

Appendix G – Thematic analysis framework focus group

MRA members	Design category			
	Relevant for policy		**Accepted** by scientific community	
	Objectives, targets, and strategies		*Connection to the principles of CE*	
Participant 1				
Participant 2				
Participant 3				
Participant 4				
Expert				
Participant 5				

MRA members	Output category											
	Credible				**Robust**							
	Unambiguous (Parameters and results are clearly defined)		*Transparency in method* (Calculation is standardized and transparent)		*Defensible theory* (Based on a common accounting method)		*Data reliability* (Collected by statistical office, statistically validated)		*Sensitive* (Produced on a regular basis, data density is high)		*Indicator reliability* (Based on a coherent framework, Informs about what is meant to be measured)	
Participant 1												
Participant 2												
Participant 3												
Participant 4												
Expert												
Participant 5												

MRA members	End-use							
	Easy							
	Applicable to scope		*Data is available*		*Technical feasible* (Data collection is relatively easy, associated costs with data collection are acceptable)		*Complementary and integrated* (Monitored and analyzed in relation to other dimensions, Indicator allows for benchmarking)	
Participant 1								
Participant 2								
Participant 3								
Participant 4								
Expert								
Participant 5								

Miscellaneous		
Governmental officials		
	Quote	*sentences*
Participant 1		
Participant 2		

Appendix H – Sample of CE indicator frameworks from scientific literature

	Author	Title	Scope	Focus	Year	Source
Available	Van Leeuwen and Sjerps	The City Blueprint of Amsterdam: an assessment of integrated water resources management in the capital of the Netherlands	regional	water	2015	Thesis
Available	Di Maio and Rem	A Robust Indicator for Promoting Circular Economy through Recycling	Company/ product level	Environmental	2015	Thesis
Available	Park and Chertow	Establishing and testing the "reuse potential" indicator for managing wastes as resources	Product	Environmental and economic dimension	2014	Thesis
Available	Zaman and Lehman	The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city'	regional	Resources	2013	Thesis
Available	Su et al.	A review of the circular economy in China: Moving from rhetoric to implementation	regional	Environmental and economic dimension	2013	Thesis
Available	Mattila	Input-output analysis of the networks of production, consumption and environmental destruction in Finland	European/ national	Environmental and economic dimension	2013	Thesis
Available	Bastein et al.	Opportunities for a Circular Economy in the Netherlands	national	Environmental and economic dimension	2013	Thesis
Available	Wilson et al.	Comparative analysis of solid waste management in 20 cities	regional	Environmental, social and economic dimension	2012	Thesis
Available	Geng et al.	Towards a national circular economy indicator system in China: An evaluation and critical analysis	national/regional	Environmental and economic dimension	2012	Thesis
Available	Mori and Christodoulou	Review of sustainability indices and indicators: Towards a new City Sustainability Index (CSI)	European/ national/regional	Environmental, social and economic dimension	2012	Thesis
Available	Moldan et al.	How to understand and measure environmental sustainability: Indicators and targets	European/ national	Environmental, social and economic dimension	2012	Thesis
Available	Hoornweg and Perinaz Bhada-Tata	What a waste: A Global Review of Solid Waste Management	Global/national/regional	Environmental and economic dimension	2012	Thesis
Available	Geng et al.	A Review of the Circular Economy in China: Moving from Rhetoric to Implementation	National/Regional	Environmental	2012	Thesis
Available	Li et al.	Energy conservation and circular economy in China's process industries	regional	Environmental, social and economic dimension	2010	Thesis
Available	Geng et al.	Implementing China's circular economy concept at the regional level: A review of progress in Dalian, China	regional	Environmental and economic dimension	2009	Thesis
Available	Singh et al.	An overview of sustainability assessment methodologies	Global/national/regional	Environmental, social and economic dimension	2009	Thesis
Available	Li et al.	Measurement indicators and an evaluation approach for assessing urban sustainable development: A case study for China's Jining City	Regional	Environmental, social and economic dimension	2009	Thesis
Available	Geng et al.	Evaluating the applicability of the Chinese eco-industrial park standard in two industrial zones	regional	Environmental, social and economic dimension	2008	Thesis
Available	Sendra et al.	Material flow analysis adapted to an industrial area	regional	environmental	2007	Thesis
Available	Moriguchi	Material flow indicators to measure progress toward a sound material-cycle society	National	environmental	2007	Thesis

Available	Zhijun and Nailing	Putting a circular economy into practice in China	National	Environmental, social and economic dimension	2007	Thesis
Available	Böhringer and Jochem	Measuring the immeasurable — A survey of sustainability indices	global/national/regional	Environmental, social and economic dimension	2007	Thesis
Available	Huan et al.	Socioeconomic metabolism in Taiwan: Emergy synthesis versus material flow analysis	National	environmental	2006	Thesis
Available	Pinter	Circular Economy in China: Moving from Rhetoric to Implementation			2006	Thesis
Available	Sun et al.	Sustainability assessment of regional water resources under the DPSIR framework	regional	Environmental , social and economic dimension (water)	2016	Thesis
Unavailable	Xiong et al.	Research on the spatial patterns of ecological and economic sustainable development capacities in the Xinjiang Region	regional	Environmental and economic dimension	2015	Thesis
Available	Shu-hua Ma et al.	Mode of circular economy in China's iron and steel industry: A case study in Wu'an city	regional		2014	Thesis
Available	Prata et al.	Moving Towards The Sustainable City: The Role Of Electric Vehicles, Renewable Energy And Energy Efficiency	regional	Environmental, social and economic dimensions	2013	Thesis
Available	Zucaro et al.	Urban resource use and environmental performance indicators. An application of decomposition analysis	regional	Environmental, social and economic dimensions	2014	Thesis
Unavailable	Zhang and Zheng	From system to landscape: The other orientation of regional material flow analysis			2014	
Available	Cook et al.	Evaluation of alternative water sources for commercial buildings: A case study in Brisbane, Australia	Buildings		2014	Thesis
Available	Feiock et al.	The Integrated City Sustainability Database			2014	Thesis
Unavailable	Wu	Analysis of water sustainable utilization in changsha city based on water footprint theory				Thesis
Available	Zhang et al.	Emergy evaluation of an integrated livestock wastewater treatment system	local		2014	Thesis
Available	Zhang et al.	Emergy-based regional socio-economic metabolism analysis: An application of data envelopment analysis and decomposition analysis	Regional	Environmental	2014	Thesis
Available	Marull et al.	Emerging megaregions: A new spatial scale to explore urban sustainability	Regional	PPP	2013	Thesis
Unavailable	Ramos et al.	Water supply sustainability indicators for the southern California-Baja California area	regional	PPP (water)		
Available	Moga and Puskas	Energy management in buildings obtained through multi-criteria assessment system	Buildings		2013	Thesis
Available	Suhaida et al.	Green buildings in Malaysia towards greener environment: Challenges for policy makers			2013	Thesis
Unavailable	Sheldon and Zik	Water scarcity: An energy problem			2012	Thesis
Available	Mcintyre	Community-scale assessment of rooftop-mounted solar energy potential with meteorological, atlas, and GIS data: A case study of Guelph, Ontario (Canada)		Energy	2012	Thesis
Available	Ni et al.	Scenario analysis for sustainable development of Chongming Island: Water resources sustainability	regional	Environmental (water)	2012	Thesis
Available	Al Sabbagh et al.	Resource management performance in Bahrain: A systematic analysis of municipal waste management, secondary material flows and organizational aspects	regional	Environmental (resources/waste)	2012	Thesis
Unavailable	Shi et al.	An approach for analyzing resources metabolism of industrial ecosystems	regional	Environmental (resources/waste)	2012	Thesis
Available	Echenique et al.	Growing cities sustainably		PPP	2012	Thesis
Available	Ziolkowska and Ziolkowski	Product generational dematerialization indicator: A case of crude oil in the global economy	nationa/regional/local		2011	
Available	Zhang et al.	Comparative analysis of socio-economic and environmental performances for Chinese EIPs: case studies in Baotou, Suzhou, and Shanghai	regional	PPP	2009	Thesis
Available	I-Cheng Chang	Using a Set of Strategic Indicator Systems as a Decision-making Support Implement for Establishing a Recycling-oriented Society	National/regional	Environmental (resources/waste)	2005	Thesis

Appendix I – Sample of CE indicator frameworks from grey literature

Author/Organization	Title	Scope	Focus	year	Source
Arcadis	Sustainable Cities Index	national/regional	Environmental, social and economic dimension	2015	Report
Van Gansewinkel	National Waste Report: Waardevol	National/regional	environmental	2015	Report
European Environment Agency	Environmental Indicators Report 2014 - Environmental Impacts of Production-consumption systems in Europe	European/national	Environmental indicators	2014	Report
World Resources Institute	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities	European/national	Environmental and economic dimension	2014	Report
PWC	Amsterdam: A city of opportunity	Regional	Environmental, social and economic dimension	2014	Report
European Environment Agency	Towards a green economy in Europe - EU environmental policy targets and objectives 2010-2050	European/national	Environmental and economic dimension	2013	Report
IMSA	Unleashing the Power of the circular economy	Global/national/regional	Environmental, social and economic dimension	2013	Report
European Commission	Resource Efficiency Indicators	European/national/regional	Environmental, social and economic dimension	2013	Report
Siemens	European Green City Index: Amsterdam	regional	Environmental and economic dimension	2011	Report
UNEP	Decoupling Natural Resource Use and Environmental Impacts from Economic Growth	Global/national/regional	Environmental, social and economic dimension	2011	Report
SERI	Establishing Environmental Sustainability Thresholds and Indicators	Global/national/regional	environmental	2010	Report
Siemens	European Green City Index: Assessing the environmental impact of Europe's major cities	regional	Environmental, social and economic dimension	2009	Report
World Resources Institute	Material flows accounts: a tool for making environmental policy	Global/national/regional	environmental	2005	Report

Appendix J – Detailed results from desk research of EU and Netherlands

European Union

Design category		Output category		End-use category
Relevant for policy	**Accepted** by scientific community	**Credible**	**Robust**	**Easy**
Indicators purpose: ✓ Measure progress ✓ Support political action ✓ Target setting ✓ Provide understanding/transparency **Short and long-term drivers addressed:** ✓ Awareness, education & research ✓ Sustainable consumption & behaviour ✓ New infrastructure & systems thinking ✓ Transformed industrial design ✓ Zero depletion legislation & policies ✓ Prevent, reuse, recycle of natural assets	**CE principles described:** ~~o Modular design~~ ✓ Zero waste ✓ think in systems ✓ closing loops ✓ shared value creation ~~o new business models~~	✓ Provide early warnings ✓ Transparency of method (Eurostat) • *Set of thematic indicators* • *Include lead indicators*	✓ Data collection through Eurostat or 3rd party data verification ✓ Annual data • *Based on existing indicator frameworks*	• *European and/or national sco* • *Data is available through Euro* • *Indicators are complemen with Raw Materials Scoreb and Resource Effici Scoreboard* • *Framework is in line with SDG*

Netherlands

Design category		Output category		End-use category
Relevant for policy	**Accepted** by scientific community	**Credible**	**Robust**	**Easy**
Indicators purpose: ✓ Measure progress ✓ Support political action ✓ Target setting ✓ Provide understanding/transparency • *Enable benchmarking* • *Support scenario planning* **Short and long-term drivers addressed:** ✓ Awareness, education & research ✓ Sustainable consumption & behaviour ✓ New infrastructure & systems thinking ✓ Transformed industrial design ✓ Zero depletion legislation & policies ✓ Prevent, reuse, recycle of natural assets	**CE principles described:** • *Modular design* ✓ Zero waste ✓ think in systems ✓ closing loops ✓ shared value creation • *new business models*	✓ Provide early warnings ✓ Transparency of method (Eurostat, GRI, TSC, CBS)	✓ Data collection through Eurostat or 3rd party data verification • *Standardized (MFA/MFM) accounting methods* • *Integration with MFM based frameworks* • *Annual and biannual data*	• *National and regional level sc* • *Data is available through D atlas, CBS, RWS-tool* • *Indicators allow for (inter)nati benchmarking* ✓ Framework is in line with SDG