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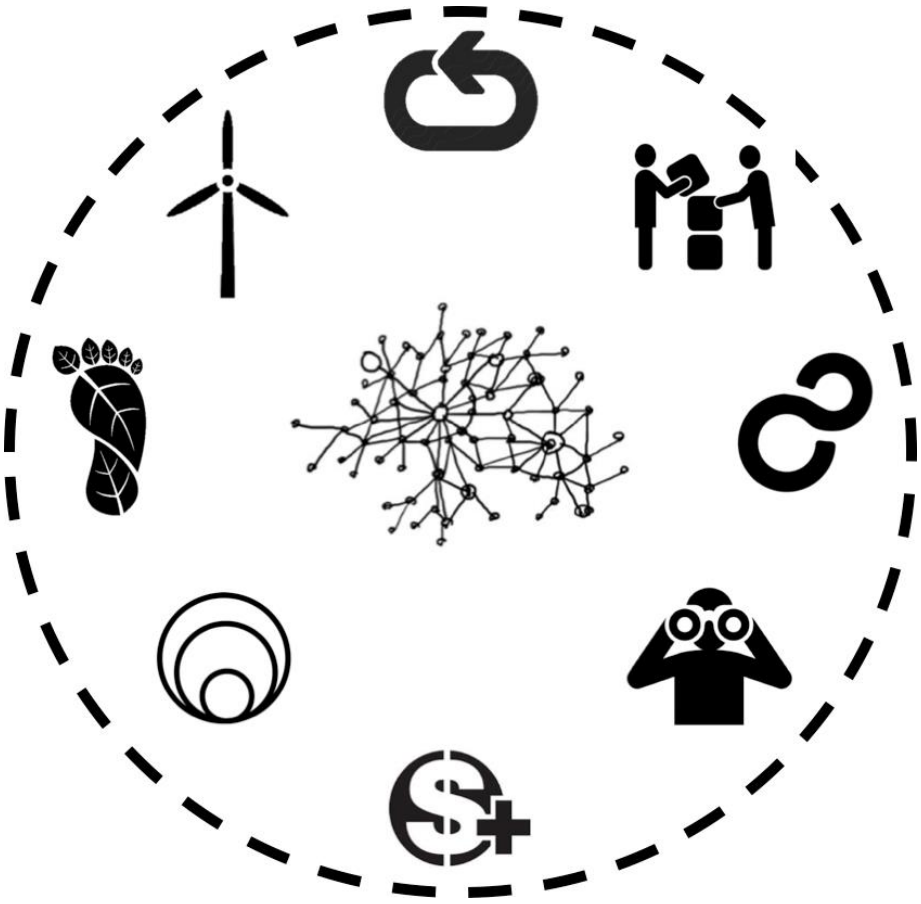

Circularity assessment for companies: elements for a general framework

Challenge Lab 2015: Sustainable urban development

Master's Thesis in the Erasmus Mundus Master's Programme in Industrial Ecology

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Cover:
[The principles of a circular economy, own illustration]

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Abstract

Circularity assessment for companies: elements for a general framework

Challenge Lab 2015: Sustainable Urban Development

Sustainable urban development was defined as the challenge to be addressed by the students of the 2015 version of the Challenge Lab and as the framework under which research questions would be derived. The Challenge Lab is a neutral arena where students become change agents and address complex problems from a systems' perspective. By applying the back-casting methodology, students identify leverage points to intervene the system and contribute to its transition towards sustainability. In the case of this specific master thesis, and as a result of such process, resource efficiency was identified as such leverage point and circular economy as a suitable strategy to address it. In order to successfully transition towards a circular economy, different actors have underlined circularity measurement as a key step and some initiatives have already been developed. After reviewing these proposals, it was evident the lack of agreement about the main elements such assessment should have if it were going to help to adequately transform the economic system towards circularity. In this sense, this study aimed at building a general framework based on expert contributions that could be used to evaluate circularity assessment proposals, in terms of their alignment with fundamental aspects of circularity. From an expert perspective a circularity assessment has to include several aspects if it is going to contribute to a transition towards circularity. First, it should contribute to improve resource stewardship, should serve as a managerial decision-making and foster engagement. In addition to this, kind of assessment needs to integrate the multiple scales at which the company has influence and not just focus on one. Then, it has into account different aspects that define circularity and finally, it requires following the circular economy principles if it will transparently inform decision-making. Based on these elements, the existing initiatives were evaluated and it was found that none of them are 100% aligned with the expert proposals leaving room for improvement and collaboration.

Keywords: circularity assessment, circular economy, back-casting, sustainable urban development, transformative sustainability education

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Table of contents

List of tables

List of figures

List of Appendices

1 Introduction

Achieving sustainability is a complex challenge that requires specific capabilities and skills, not only academic but also personal. These capabilities include understanding complex systems, assessing potential for transformation and devising effective ways to realize that potential. On a personal level, leaders and sustainability professionals require openness and personal drive to motivate people to embark in such journey. The Challenge Lab (C-Lab), as an innovative education tool, aims at developing both sets of skills in students at Chalmers. This is achieved by providing a setting for interaction among different stakeholders that share a vision for sustainability and help participating students become change agents that effectively contribute to the transition towards a sustainable future.

In 2015 the C-Lab ran for the second time and focused on the topic of sustainable urban development. Following the C-Lab proposal, the back-casting method (Holmberg, 1998) was used to identify research questions for the master theses. This process required several steps before coming up with a particular problem and question. First, the definition of a vision and set of criteria for sustainable urban development; second, the identification of leverage points and current situation and the identification of the gap between the vision and today's situation; third, the design of solutions and finally, the development paths for achieving such sustainability vision. This particular master thesis presents the results from the process regarding the leverage point "Resource Efficiency" focusing on circular economy as a solution and particularly on the question of how to best assess circularity of companies as a key actor for the transformation towards a circular economy.

Part of being a C-Lab change agent is to adequately formulate a problem in order to find the right solution. Usually decision-makers rush into pushing solutions without considering all the aspects that need to be taken into account to assess if such proposal is sustainable or not. The C-Lab stresses the importance of developing skills to use tools that allow such 'slow' identification, which is at the base of systems' thinking. In opposition to this, the usual way master students develop their thesis projects is by taking a research problem or question already defined and given by an outsider. The Challenge Lab defies that approach and allows students to take the time to come up with the right question and then follow the right steps to answer it. This is a novel approach to education that aims at preparing transition leaders of tomorrow.

This document summarizes the results of the research process, which was divided in two phases. Phase 1 describes the process to find the research questions and phase 2 presents the process to answer them.

1.1 Aim and objective

The aim of this thesis is to contribute to increasing sustainability of cities by providing elements to improve resource efficiency. This is achieved by offering elements for a more complete understanding of circularity at the company as a key strategy for resource efficiency. By evaluating existing efforts to assess circularity for companies proposed by **Stakeholders**[1] under the light of **Experts'**[2] contributions, this research wants to provide guidance on how to strengthen such proposals based on robust scientific contributions from the founding disciplines of circular economy and other expert sources. This results in a stronger proposal for assessing circularity at the company level.

1.2 Scope and limitations

This thesis is circumscribed to the contributions of a limited number of experts in terms of interviews and literature resources. Consequently, it is by no means and exhaustive compilation of every pertinent work and opinion on the matter. The perspectives and suggestions are only representative of the participants in the study as presented in the appendices of this document. The conclusions only apply to the proposals evaluated as they were defined at the moment of this research.

The scope of this research is circularity assessment at the company level. There have been efforts to assess circularity at the national and global level as well as the product level that are partially mentioned here but not included in the process. In geographical terms, it is limited to efforts developed in Europe.

1.3 Research questions

As a result of the phase 1 of the Challenge Lab master thesis, the following research question was defined:

- ***RQ1: How can current proposals for circularity assessment for companies be improved?***
    - RQ 1.1: What key elements are required to assess circularity of companies from an expert perspective?
    - R.Q 1.2: What elements have been considered by the existing circularity assessment proposals?
    - R.Q 1.3: What gaps exist between what experts recommend and stakeholders propose regarding circularity assessment for companies?

[1] Stakeholder sources (Stakeholders) include the reports or documents outlining their circularity assessment initiatives and interviews with people responsible for its development in each organization.

[2] Expert sources (Experts) were defined as scientific and non-scientific literature as well as individuals working on the topic of circular economy or related issues such as recycling, life cycle assessment or in companies involved in initiatives that could be identified as part of a circular approach given that peer reviewed publications on the topic are still few while reports have been published at a very fast rate in the last two years

2 Phase 1: The Challenge Lab

In this section, the phase 1 of the C-Lab is presented, including an explanation of the educational approach, the methods, the process and the results of this first phase.

2.1 The educational approach

Transition towards sustainability is a complex process that entails transformation at many levels. This kind of processes requires specific skills, tools and knowledge in order to successfully achieve the goal. Piasecki (2000) has proposed a set of nine skills that environmental leaders should have in order to achieve the environmental goals of their organizations: a) focus on what works, b) understand the relevance of collaboration, c) embrace uncertainty and risk, d) be sensitive towards others, e) capacity to listen, f) build on other's shoulders, g) know how to communicate aspirations to their teams and h) are dead serious about it. The main result of developing skills for transformation is change in itself; therefore, agents involved in such process are what are known as change agents.

In addition to this, Hesselbarth & Schaltegger (2014) have identified competences linked to sustainability change agents in corporate environments that have been acquired during higher education. These competences include skills, attitudes and knowledge such as a) strategic competence, b) systems-thinking competence, c) anticipation competence, d) normative competence and e) interpersonal competence. These translate into knowledge about environmental, economic and social aspects, tools such as assessments and certification schemes, strategy creation and the basic academic skills. As a result, the authors argue, conventional education is not adequate for educating change agents and needs to be complemented by new approaches.

An example of such new approach is known as transformative sustainability learning. On the one hand, Sipos, Battisti, & Grimm (2008) define it as an "emergent" property of educational approaches that combine three elements: cognitive, psychomotor and affective learning domains with the aim of altering behavior in such a way that contributes to sustainability. On the other, Holmberg (2014) defines it as a collaboration strategy among different societal actors for transitioning towards sustainability in which students are defined as the 'bonding-agent'.

By combining these two approaches, elements to achieve transformative sustainability learning and to develop the skills identified by researchers can be outlined:

- This type of education aims at changing society by transforming individuals and by educating change agents. They could bring their competences to different levels where sustainability transitions need to occur such as the government, companies or communities.

- Such transformation is not achieved by focusing on transmitting knowledge from one source (teachers) to the other (students) but by affecting different realms that affect behavior: the head, the hands and the heart of students. This results from providing knowledge, solving problems and addressing inner values that would allow such change agents to understand, believe and practice sustainability.
- Transformative sustainability learning requires cooperation and collaboration between different stakeholders in order to bring in different perspectives but also to develop the ability to trust.

In sum, transformative sustainability learning challenges the usual approach to education and combines a series of elements that allow individuals to become change agents in a larger community and lead the transformation towards sustainability.

2.2 The Challenge Lab: an example at work

This type of education has been introduced at Chalmers University of Technology in order to complete the structure required for helping the university transition towards sustainability. Through the creation of the C-Lab, these elements have been implemented in order to consolidate a process that started 30 years ago (Holmberg, 2014). For 2015 and based on the lessons learned from the first edition of the course, the process was divided in two moments, a *leadership course* that helped introduce to students the tools required for the process and helped them practice the application of such tools in real cases; and the master thesis of which this report is a result. In the following section the structure of the C-Lab is introduced with a short explanation of its elements.

The C-Lab is a "student-driven transition arena" where students become change agents in the pursuit of a sustainable future (Holmberg, 2014) by driving transformation processes in their own environments given their specific positions and character (Hesselbarth & Schaltegger, 2014). In order to become change agents, students require specific skills and tools that are key for driving transition processes, such as the ones defined by Piasecki (2000) including aspirational motivation, complex thinking, collaboration, sensitivity towards people's values and courage, among others.

2.2.1 The process

The preparation course for the 2015 C-Lab was launched in the fall semester of 2014 with the participation of approximately 30 students from almost 20 different countries and 15 different programs throughout Chalmers. In this version of the course people from different countries worked together for 8 weeks on the different tasks assigned by the team and interacted with a wide rage of stakeholders from the region. Students with economics, engineering, design and environmental sciences backgrounds were part of the course and learned about topics such as dialogue, back-casting, value driven leadership and

design thinking. As a result this first stage of the process specific perspectives, ideas and inputs for addressing the particular challenge of the course, sustainable campus development, were defined.

2.2.2 The Challenge Lab method

The educational approach of the preparation course for the C-Lab has three basic elements. The first element refers to the method to address the sustainability challenge: back-casting. The second element concerns the perspectives under which, this method is presented: the outside-in and the inside-out perspectives. The third element, relates to the three ways of learning that were implemented during the course: theory, case study and personal reflection (Holmberg & Andersson, 2014). All these different elements contributed to the final outcome of the course and to the preparation of the master thesis students that continued in the second stage of the process in the spring semester of 2015.

Planning for transitions: the back-casting method

As mentioned earlier, the main method used in the C-Lab to address sustainability transitions is back-casting, a framework for strategic planning developed by Holmberg (1998; 2014). The author argues that this method offers a set of advantages when dealing with tasks such as the ones imposed by our current global crisis:

- It allows dealing with complex problems that are caused mainly by lock-ins and externalities.
- It helps liberating decision makers from available solutions today, allowing them to be creative and unrestricted. This is due to the fact that the starting point of the process is the future situation and a vision of what criteria has to be fulfilled, not the current situation.
- It is a method that decouples short-term problems from long-term vision.

These advantages can be only realized if the adequate steps are followed in a transparent way.

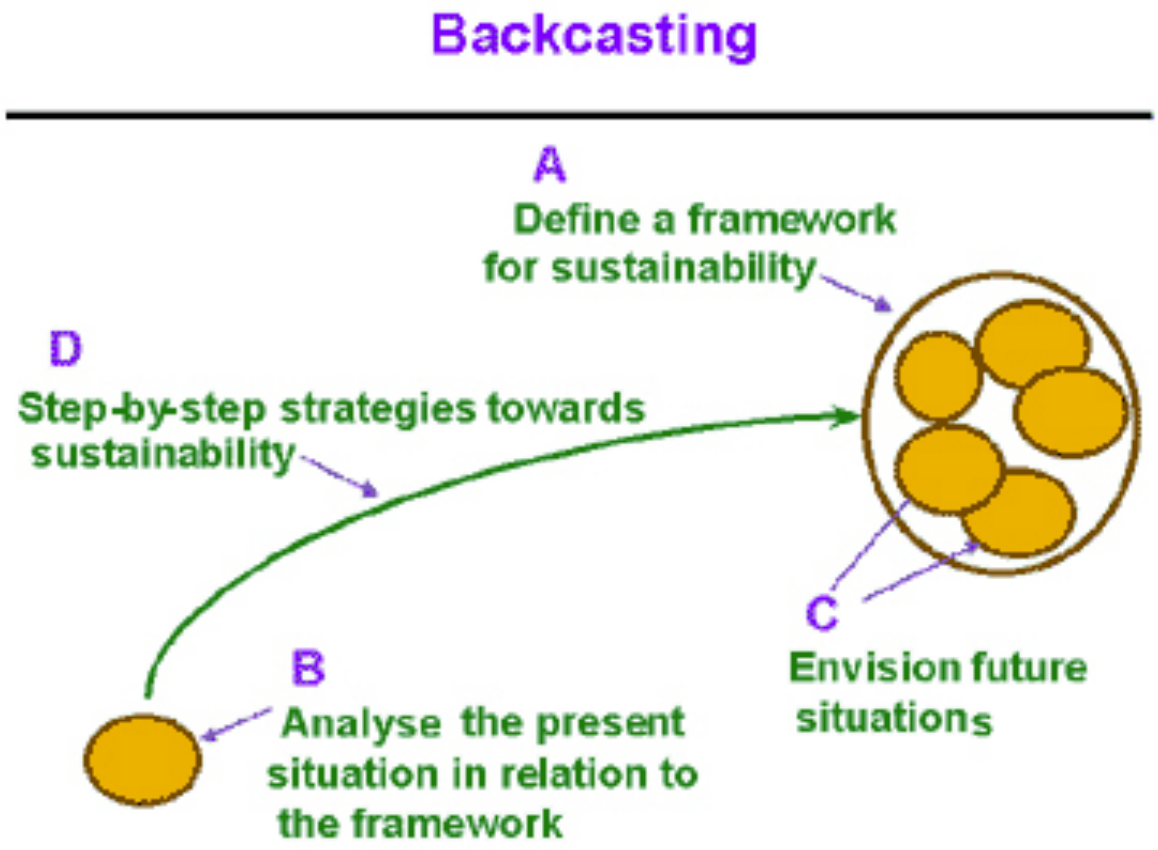

Figure 1 The Back-casting method. (Holmberg, , 1998)

The first step of the back-casting methodology as illustrated in Figure 1 is to define a set of conditions that the future situation needs to fulfill. In this sense, the author stresses the need to define such criteria in terms of the desired situation instead of the current situation. In addition to this, criteria have to be as far upstream in the causal chain as possible so they are unavoidable.

The second step for the back-casting process is to assess the current situation and the trends of different aspects, against the conditions defined in the first step. However it is absolutely relevant to take into account the complexity of the system, and find what Meadows (1997) called leverage points. They are defined, as those elements of the system that are interconnected in such a way that by intervening them, results are greater than expected.

The third step of the method is to identify solutions to close the gap between the trends/current situation and the sustainability conditions defined for the system. At this point creativity and design thinking as well as deep understanding of what Geels (2005) has called the Multi Level Perspective (MLP) are key skills to be used. It is key to assure that the

ideas that are proposed comply with the conditions of the system and of the envisioned future.

Finally, a development path that will bring society to sustainability has to be created. This includes strategies and actions that will allow for the solutions to happen. In this step time is considered and the steps that are require to implement the solutions are defined. In sum, this framework provides a systematic approach to identify areas of action from a future-based perspective, develop solutions that address complex problems and create a strategy to implement such solutions.

The triple approach: hands, head and heart

During the two stages of the C-Lab, the preparation course and the master thesis, each of the steps in the method were addressed from what Sipos, Battisti, & Grimm (2008) called the 'head-hands-heart' framework. The *'head'* is addressed through the outside-in perspective and the theory aspects of the methodology. The basic concepts of back-casting such as sustainability conditions, trends analysis and systems dynamics alongside with tools for developing solutions such as design thinking were presented by the facilitators. The participants in the C-Lab master thesis applied this knowledge to the topic 'Sustainable urban development' where they addressed the '*hand*'. Finally, exercises regarding personal development and stakeholder management were also implemented in order to involve the *'heart'* of the participants and were addressed by personal reflection tasks. Such exercises included Value Based, self-leadership tools and stakeholder dialogue tools.

A holistic perspective: outside-in and inside out

As mentioned before, the C-Lab used a two-perspective approach to apply back-casting and to develop skills among their participants. The first perspective, outside in, was related to the tools to understand and deal with exterior requirements for the transition including systems thinking, transition management and design thinking (Geels, 2005; Haraldsson, 2004; Lawson, 1997; Söderberg, 2014). The second perspective, inside-out, aimed at allowing participants understand their own values, strengths and motivations for embarking in a transformation process as well as providing them with tools to understand different stakeholders perspectives and to motivate them (Holmberg & Andersson, 2014). Addressing the process from these two perspectives allows participants to have a holistic view of the challenge and address it in such way.

Outside-in perspective

Systems thinking

Systems' thinking was the first tool presented during the C-Lab as a resource to be used when analyzing the challenge and the current situation. As Haraldsson (2004) describes it,

systems' thinking is a science to understand how complex systems behave. There are two domains within systems thinking, on one hand is systems analysis, which deals with how a system is organized in components and relations and on the other is systems dynamics that deals with the actual behavior of the systems in time. Since the C-lab deals with sustainability challenges at different levels, systems' thinking is required to develop an adequate understanding of the current situation.

Within the topic of systems' thinking, the Closed Loop Diagram (CLD) instrument was introduced to map the different problems to be addressed in the C-Lab. CLD helps identify key variables and relationships between them in order to understand the behavior. To create a CLD the following elements have to be defined:

- The problem.
- The question that would be answered by the diagram.
- The relevant variables according to their role.

Once these elements are defined, the diagram can be visualized. These steps require the input from a diverse group of stakeholders since they are absolutely crucial to an adequate systemic understanding (Haraldsson, 2004). If the right structure is defined and the key elements identified and manipulated, changes in the behavior of the system would be closer to the desired ones (Meadows, 1997).

Transitions management and social practice dynamics

Changing a system requires additional understanding of how the system is organized in different levels. Transition management as Geels (2005) defines it is the discipline that aims at understanding this process of change in larger systems. It entails reflection, innovation and the collective formulation of goals and strategies. It is also about social innovation which includes change of actors, structures and culture at the technological, institutional, regulatory, behavioral, economic and even spatial levels. Some characteristics of this process include top down approach, the ability to anticipate, it is an integral process, adaptive, experimental and happens at multiple levels.

MLP is a key concept in transition management and systems innovation. It refers to the different levels of human systems: niche, regimes and landscapes. The niche level refers to product arrangements that are protected at which new ideas are born; the regime level refers to the set of different rules that define socio-technical systems. The highest level is the landscape that is perceived as exogenous and can't be influenced. These different levels require different strategies in order to promote innovation and change, and transition management serves as the tool to drive such processes through stages such as pre-development, take off, break through and stabilization (Geels, 2005). Understanding

how transitions happen, what elements they need and where they happen are key elements for the definition of the development plan within the back casting method.

Another relevant perspective that deals with the dynamics of society is presented by Shove, Pantzar, & Watson (2012). They focus on how practices change and provide elements for policy and decision makers to drive such change. This approach suggests that practices are made of elements and connections that interact. The elements are of three types, *materials, competence or knowledge and meanings* and by interacting through enactment they result in particular practices. If sustainability is understood as a practice then affecting these elements and how people enact the practice should be a key objective of transition management. Although this approach was not explored directly during the first phase of the C-Lab, it provides supporting elements for the present study.

Design thinking

Design thinking is the process of thought that designers undergo when defining design problems and creating design solutions to such problems and is used in the C-Lab to create solutions to close the gap. Following Lawson (1997) design thinking is a combination of reasoning and imaging processes that result in what is known as creative problem solving. This process has basic steps: the assimilation step, the general study, the development stage and finally the communication step. The author indicates that these steps are interconnected and do not happen in a unique sequence but rather are iterative in nature. Some other characteristics of the design thinking process include its prescriptive nature in terms of providing an opinion through the solutions created, its orientation towards action rather than just reason and the vulnerability of its results, among others.

Designers have to be aware that usually the type of problem they want to solve is full of uncertainty and changes over time. Additionally, such problems cannot be defined objectively since they respond to different perspectives and involve different actors. However, it is usual that such problems can be understood in a hierarchy, i.e. in an arrangement that provides information about the priorities. Having this in mind, the solutions designers have to develop are multiple and never a single one. In this sense, one solution is never the optimal one since it always misses a perspective; however they have to be holistic responses to avoid bias or creating bigger problems that the one solving. Finally, although a solution is never complete and might not satisfy all stakeholders' demands, it always teaches something to the designer (Lawson, 1997).

Inside-out perspective

The second perspective used to apply the back-casting methodology was the inside out perspective. This approach has two components, self-leadership and stakeholder dialogue. These tools were used to develop specific skills in the participants to better equip them to

be part of the transition and bring others on board. These topics were addressed through workshops facilitated by external experts.

Having an inside-out perspective is supported by research conducted on the area of motivation as a driver for performance and engagement (Ryan & Deci (2000), Manz & Sims (1986) in Stewart, Courtrigth, & Manz (2011)). Following Ryan & Deci (2000) motivation can be intrinsic or extrinsic, the former referring to an internal driving force to perform an action. Such type of motivation depends on three factors: competence, autonomy and relatedness. All of them have to be present in any environment in order to allow individuals to develop motivation and subsequent engagement. Their definition of such elements is:

- Competence relates to the level of knowledge and skills regarding a specific topic.
- Autonomy is defined as the feeling of freedom when performing a task.
- Relatedness refers to the kind and level of connection with peers or authority figures and their support.

Self-leadership and stakeholder dialogue tools

As part of the C-Lab preparation course and master thesis methodology, activities such as self-discovery of values and strengths were implemented to enhance these three aspects in all participants. For self-discovery a test was applied by an external consultant whose result was a hierarchy of strengths and values that were part of each student personality. These were shared with other participants in order to get and provide feedback and build bonds. Knowing one's values and strengths allows for reflection on what role can one play in transition processes and look for the more adequate place in the process.

Another important aspect for successfully addressing transition is the ability to motivate others to engage and this was developed using dialogue tools. Following Isaacs (1993) dialogue is an approach to deal with complex problems that cannot be solved by individuals and require the participation of many different stakeholders as is the case for sustainability challenges. During both the C-lab preparation course and master thesis, participants and stakeholders used these tools to implement in order to establish a dialogue and motivate engagement.

2.3 Results from phase 1 of the Challenge Lab

During the C-Lab master thesis the topic proposed was sustainable urban development understood as the process by which urban centers progress in time. The natural focus was the city of Gothenburg as it is the environment for the 2015 C-lab however the resulting proposals from applying the back-casting method did not have to be restricted to this geographic area.

Figure 2 Change agents in the Challenge Lab 2015. Source: The Challenge Lab

In the following paragraphs the results for each step of the back-casting method applied to the C-Lab 2015 topic are presented as a framework for the problem and research question formulation of this thesis.

2.3.1 Step 1: Sustainability criteria for urban development

As a result of applying the first step of the back-casting methodology a set of criteria was agreed among the different participants in the C-Lab for four main dimensions: environment, economy, societal and wellbeing as presented in Table 1.

Table 1 Sustainability criteria for urban development. Challenge Lab 2015

Dimension	Criteria	Source
Environmental	Not to increase the concentration of substances from the lithosphere in the ecosphere.	(Holmberg, Robert, & Eriksson, 1996)
	Not to increase concentration of human made substances in the ecosphere.	
	Not systematically deteriorate the resource base; such as fresh water, fertile land, and biodiversity through manipulation,	

	mismanagement, or over-exploitation.	
Economic	The economic system enables us to meet the other criteria efficiently and effectively. The economic system should be influenced by the other dimensions (society, well-being, nature) and not the other way around.	(Pisano, 2012) (Sen, 1999) (Sen, 1980) (Simmie & Martin, 2010)
	The economic system is resilient in a way that it functions as a buffer against destructive disturbances, such as environmental catastrophes or economic mismanagement.	
	Enable further use of resources and avoid dissipative use of materials.	
	The economic system has an inherent mechanism of maintaining and serving societal infrastructure and institutions that permits human well-being to be met over time.	
Societal	Societal institutions are built on transparency, accountability, and mutual trust. They enable the well-being of the individuals in society.	(United Nations, 1948) (United Nations, 1976)
	The societal system is an instrument for individuals to live together within the other criteria.	
Wellbeing	Everyone has basic needs fulfilled such as food, water, health, energy, shelter, and safety.	(Cruz, Stahel, & Max-Neef, 2009) (Rawls, 1999) (OECD, 2013)
	Human life includes affection, understanding, morality, participation, leisure, *empowerment*, creation, identity, and knowledge.	

	Each person has an equal right to the most extensive basic freedom compatible with a similar freedom for others. This includes freedom of opinion and assembly, expression, conscience, and choice - without deliberately harming others.	
	Social and economic inequalities are not justified unless they are to the greatest benefit to the least-advantaged members of society.	

2.3.2 Step 2: Current situation and trends regarding urban development

As part of the back-casting methodology, the current situation and trends related to the specific topic were identified in order to find the gaps between them and the criteria for sustainability that has been developed (Holmberg, 1998). It also helps to identify leverage points where one can intervene the system in order to induce transformation. The funnel metaphor (Holmberg, 1998) indicates that there are two main trends regarding society and resources: an increasing one that includes population and demand and a reducing one related to resources and assimilative capacity due to the violation of sustainability conditions (Robert, Daly, Hawken, & Holmberg, 1997). In this sense, different aspects related to urban development were analyzed and trends were described.

On one hand there are decreasing trends for nature's assimilation capacity, productive land area, material resources and water. Examples of this situation are illustrated by Rockstrom, et al (2009) through the concept of planetary boundaries where aspects like climate change, ocean acidification, chemical pollution and atmospheric aerosol pollution express the reduction of the biosphere assimilative capacity. On the other hand, population, energy and resource demand are increasing putting even more pressure over resources. Regarding population, the UNFPA (2015) provides input for four basic trends including the demographic dividend, ageing, urbanization and migration.

As a result of the analysis of the current situation, different leverage points were identified within the group of change agents and aided by the coordinating team. These key areas included: energy, build environment, resource use, water and citizen participation. These aspects were defined as intervention points in the urban system in order to achieve a sustainable future. Once they were identified, the participants chose their area of interest according to their background and interest in a special session lead by John Holmberg.

Under the built environment leverage point, resource efficiency was identified as a key aspect that needed to be addressed if sustainability criteria were to be met. As an example of its relevance, the city of Gothenburg in partnership with academia and the private sector created the project Johanneberg District Factor 10 which aims at "the decoupling of natural resources use (energy and materials) from economic growth (Resource decoupling) and second, the decoupling of economic growth and increased human wellbeing from the environmental impacts (Impact decoupling)" (Castello AB; City of Gothenburg;, N.D., p. 2).

2.3.3 Step 3: Addressing resource efficiency

After selecting the leverage point associated with resource efficiency, a literature review and further interviews were conducted in order to identify a relevant solution. The concept of circular economy was identified as a solution proposed by different stakeholders to address this leverage point.

Defining Circular Economy

In recent years, different actors have addressed the resource efficiency question and proposed the idea of circular economy as a strategy to partially fulfill the criteria for a sustainable future defined in step 1 (Accenture Strategy (2014), Bechtel, Bojko, & Völkel (2013), European Commission (2014), Lögfren & Enocson (2014), Friends of Europe (2014), World Economic Forum (2012)). According to these sources, a circular economy is:

> "a generic term for an industrial economy that is, by design or intention, restorative and in which material flows are of two types, biological nutrients, designed to re-enter the biosphere safely, and technical nutrients, which are designed to circulate at high quality without entering the biosphere" (Roos, 2014, p. 254).

On the other hand, Joustra, de Jong, & Engelaer (2013) define it as:

> "an industrial system that […] replaces the 'end-of-life' or cradle to grave concepts with restoration, incorporates and promotes the use of renewable energy, eliminates the use of toxic chemicals (which impair re-use), and aims toward the elimination of waste through the superior design of materials, products, systems, and business models".

These definitions are derived from the contributions of different schools of thought such as Industrial Ecology, Cradle to Cradle, the Natural Step and Biomimmicry.

In 2013 the Ellen Macarthur, Foundation suggested five basic principles that drive the circular economy:

- **Principle 1**: "to design out waste" which means that industries have to consider waste prevention from the early stages of product development process.
- **Principle 2:** to "build resilience through diversity" by fostering a balancing relationship between efficiency and resilience as exhibited by natural systems.
- **Principle 3:** to "rely on energy from renewable sources" that doesn't exceed the planet's assimilative capacity.
- **Principle 4:** to "think in systems" as the decision-making overall approach.
- **Principle 5:** unavoidable waste needs to be treated as an input rather than a by-product.

In addition to these theoretical contributions, consulting companies such as Accenture and McKinsey also provide their own definition of circular economy affirming that it is a way of rethinking an organization's value proposition. This new approach requires growth being decoupled from resource use and environmental impacts and disruptive technologies and new business models support its establishment (Accenture Strategy, 2014, p. 4). In summary, *a circular economy is a model that requires economic activities to be restorative and decoupled from resource use and environmental impact while they keep delivering value to society.*

Circularity strategies

Under this framework, these actors have also defined different circular 'strategies' or business models. For example, and according with Accenture's report (Accenture Strategy, 2014) the new business models that will provide companies with a 'circular' advantage are five: Product Service Systems, product life extension, resource recovery, circular supplies and sharing platforms. Some of the relevant features of such business models include modularity, remanufacturing, renting, upcycling, urban mining and increased intensity of use. The main value drivers for these new business models include lasting resources, liquid markets, long life cycles and linked value chains each with a different contribution to market value. According to their analysis, lasting resources would contribute with 40%, followed by long life cycles contributing with 30%, linked value chains with 20% and lastly, liquid markets with 10%.

Based on this new approach, a circular company can be defined as one that creates value by implementing a circular value chain. To this respect Roos (2014, p. 257) provides a list of elements that constitute such a process:

- Minimization of inputs per unit of product,
- Maximization of process efficiency,
- Use of waste or by-products
- Creation of profit from such flows

On the other hand, Mentink (2014, p. 24) presents a definition of a circular business model as "the rationale of how an organization creates, delivers and captures value with and within closed material loops". Consequently, a circular company can be considered as one that creates value through circular business models, i.e. with or within closed material loops. On a more business driven side of the balance, Accenture Strategy (2014, p. 4) defines circular companies, as the organizations that "concentrate on rethinking products and services from the bottom up to "future proof" their operations to prepare for inevitable resource constraints – all the way through to the customer value proposition." If these three definitions were to be combined, a circular company is one that acknowledges the material restrictions of its environment and develops business models that deliver value through closed material loops.

Other approaches to Circular Economy

China is also a prominent example of how circular economy can be defined and implemented from a governmental perspective. This approach defines three different levels: micro or firm level, meso or industrial park level and macro or regional level at which Circular Economy can be implemented (Geng, Fu, Sarkis, & Xue, 2012). This model is based on reducing, reusing and recycling as strategies to face increasing pressures over the environment coming from a rapid economic growth. At the company level, the circular economy model entails the implementation of cleaner production methodologies that reduce the impact of the production activities on the environment, which include updating technology, more efficient resource use and reduced pollution (Yuan, Bi, & Moriguichi , 2006). The approach to a circular economy from the Chinese perspective is based on the need to increase resource productivity and eco-efficiency, which is targeted to the production phase of the value chain.

In general, circular economy could be considered as a strategy that complies with the sustainability criteria defined in the first step. On one hand it considers the sustainability conditions developed by Holmberg, Eriksson, & Robert (1996); it aims at putting the economic system within its ecological boundaries; it requires increased transparency from economic institutions such as companies and it wants human needs to be fulfilled without compromising the environment's ability to support us. However, it is important to recognize that the societal and well-being components are not explicitly addressed by the early proposals of circular economy and need to be addressed if circular economy is to contribute to a sustainable future.

2.3.4 Step 4: How to achieve circularity

The last step of the back-casting method consists of defining the development path for implementing the solution identified in the previous step in such a way that complies with the principles identified in step 1. Since the solution selected for the resource efficiency challenge in the built environment was the transition towards a circular economy, this

master thesis focuses on one of the fist steps identified by IMSA and Circle Economy (2013) as key to accelerate the process: circularity assessment. According to this report:

> "For the circular economy to become a success, a simple measure of achievement will be needed, as a first step towards fully integrated reporting (see step 10). This allows organisations (companies, harbours, governments, investors) to give incentives to their (chain) partners to become more circular, e.g. in procurement processes. In addition, governments can support front- running companies with tax [58] or subsidies measures based on the index. It will also provide first insights in true value creation throughout the value chain". (IMSA; Circle Economy;, 2013, p. 19)

Following this, attempts to define circularity assessment have been recently proposed from three main perspectives: private, academic and governmental.

- Private sector initiatives: Ellen MacArthur Foundation in UK, the Circle Economy and the VBDO in the Netherlands, and the Viktoria Swedish ICT has pioneered efforts in Sweden that focus on the company level.
- Academia: Haas, Krausmann, Wiedenhofer, & Heinz (2015) who assess the circularity of economic systems.
- Public sector: the Chinese government has been active in promoting the development of circular economy indicators at multiple levels (Geng, Fu, Sarkis, & Xue, 2012).

After reviewing these initiatives, it is evident the lack of agreement on the definition of circularity, the strategies to achieve it and the framework to assess it. Therefore, in order to contribute to the reduction of such disagreement, to help create a common language regarding the definition of circularity, its criteria and assessment approach, and to secure that the circular economy strategy complies with the criteria defined aboved, this master thesis focused on finding a common base to assess sustainability, evaluating existing efforts and offering guidance for improving them.

Based on this aim, the research questions of this master thesis are:

- ***RQ1: How can current proposals for circularity assessment for companies be improved?***
    - RQ 1.1: What key elements are required to assess circularity of companies from an expert perspective?
    - R.Q 1.2: What elements have been considered by the existing circularity assessment proposals?

- R.Q 1.3: What gaps exist between what experts recommend and stakeholders propose regarding circularity assessment for companies?

In the following section the research methods, the results and discussions of this process are presented.

3 Phase 2: Circularity assessment as a tool for transitioning towards sustainability

3.1 Background

Circularity assessment is a fairly new term that started to be used by organizations promoting the circular economy but that has not been properly defined yet in the scientific literature. However, some initiatives exist regarding measuring of circularity including indicators for evaluating the circular economy program in China (Geng, Fu, Sarkis, & Xue, 2012); or proposals at a smaller scale to assess how close a company is to circularity based on externality analysis (Andersen, 2006) and the most recent initiative to measure how circular is the global economy using material flow developed by Haas, Krausmann, Wiedenhofer, & Heinz (2015). These initiatives are isolated and there is little work on such a topic especially at the company level.

As mentioned earlier a circular company can be considered as one that acknowledges the material restrictions of its environment and develops business models that deliver value through closed material loops. Therefore, a circular assessment for companies should allow establishing if a company falls into this description or not. However this is not an easy task and this thesis aims at developing a more detailed definition of this topic based on the contributions of experts and stakeholders already developing such tool for decision-making. This phase of the C-Lab is used to answer the research questions defined in phase 1 and it is divided in several sections, methodology, results, discussion about the findings and the conclusions reached.

3.2 Methodology

Given the type of questions defined, the approach selected to analyze the data collected is based on a hermeneutics inquiry (Kinsella, 2006). As this author explains, a hermeneutical approach to research comprises five basic elements:

> "(a) seeks understanding rather than explanation; (b) acknowledges the situated location of interpretation; (c) recognizes the role of language and historicity in interpretation; (d) views inquiry as conversation; and (e) is comfortable with ambiguity." (Kinsella, 2006, p. 3).

This is the framework under which the information collected was analyzed and results were achieved. Having in mind what the aim of the present research is, the type of

information available, the diversity of the phenomenon to be studied and its contemporary character, it was concluded that this would be the more appropriate approach.

3.2.1 Methods for data collection

Data collection was conducted through literature review and qualitative interviews. The process started with the identification of a core set of individuals, organizations and literature based on their work on circular economy or topics related. The group of people to be interviewed expanded using the snowballing method.

The expert literature was used mainly to identify the principles behind the concept of circularity, while the interviews were used to define other elements relevant for a circularity assessment. The stakeholder literature and interviews were both used to derive the information on the categories defined in advance[3]. These categories were used as concepts to group the information collected and were defined as follows:

- **Purpose** is defined here as the aim that a circularity assessment has, what is the objective after implementing it.
- **Scale** refers to the system level at which the assessment is addressed;
- **Criteria** refer to the different features that are actually evaluated by the assessment in terms of criteria that would make a company circular;
- **Principles** implicitly followed by each proposal are listed.

Qualitative interviewing

Interviews have been used for many decades in social sciences as a tool to answer questions related to a variety of topics, from marketing to health issues. However, the approach to this method has changed over the years as researchers have identified different aspects relevant to the information that can be collected. For this specific research qualitative interviewing has been used as one of the methods to collect information and has been conducted following the principles proposed by Seale (2004).

The definition of the topics to be addressed and the questions to be asked through interviews was done based on different elements:

- The type of actor to be interviewed (Expert or Stakeholder),
- Their area of work,
- The sector they belong to
- Their previous work on the topic.

In this sense, comparable actors shared the same questions with the aim of allowing for patterns, similarities and shared meanings to emerge if that was the case.

[3] These categories were defined using a affinity analysis given that they were present in all proposals. Other aspects such as indicators, target and approach were mentioned in some of the proposals so they were not included since information was incomplete.

However, given the nature of the method, additional topics and questions were asked and in some cases completely different questions were asked. The initial set of questions was sent to the interviewees in advance so they could prepare their answers and if possible the interviews were recorded. When this was not possible, the researcher took notes that were later included in the systematization matrix alongside the notes from the recordings. As a result a file with the different responses was created in order to be used during the analysis phase of the process.

In Table 2 the main characteristics of the expert interviewees are presented. Most of the participants come from academia, while only 1 representative from the government and research institutes were interviewed. Geographically, the majority of interviewees come from Sweden but contributions from Netherlands and Austria were included. The stakeholders came from Sweden, UK and the Netherlands and all can be considered as private non-for profit organizations that in some cases, UK and the Netherlands, were associated with a consultancy firm.

Table 2 Experts interviews

Sector	Interviews	Contact	Recorded	% of interviewed
Government	1	3	0	6%
Institute	1	5	0	6%
Private	7	14	5	41%
University	7	16	6	47%
Total general	**16**	**38**	**11**	100%
Country	**Interviews**	**Contact**	**Recorded**	**% of interviewed**
Austria	1	2	2	12%
Netherlands	1	3	0	6%
Sweden	14	32	9	82%
Total general	**16**	**37**	**11**	100%

The interview was divided in three main sections: and introduction where the researcher introduced herself and the aim of the research and the specific interview, followed by the questions and a wrap-up section. The information collected was then summarized and entered in a matrix that was used later for the data analysis. In the case of the stakeholders similar format was used.

For the interviews, four sets of questions were asked depending on the level of familiarity with the idea of circular economy and circularity assessment of the expert. This was assessed based on the background information available for each expert selected.

The first group of questions addressed six topics: a) the purpose of a circularity assessment, b) the scale at which it would be relevant, c) the aspects that had to be included in the assessment, d) the challenges to conducting such assessment and e) a question regarding

how circularity could be integrated into sustainability assessment initiatives. The second set of question set covered a definition of circularity, tools to assess level of circularity, the relevant scale and the aspects. The third set included questions regarding the importance of having such tool, a circularity assessment in the transition towards a circular economy, the aspects and what processes would need to be assessed, were asked to institutions working on recycling. Finally, a fourth set of questions included the definition of circularity from a company perspective, challenges to implement a circular approach in the company and strategies to do so.

Literature Review

Parallel to the interviews a literature review was conducted in order to identify the principles of circularity and the other categories (principles, purpose, scale, aspects). Again this review was divided into circularity assessment proposals developed by the Stakeholders and literature from Expert sources connected to the topic of circular economy and founding disciplines. The founding disciplines selected for the expert literature review were Industrial Ecology, Cradle-to-Cradle and socio-ecological conditions developed by Holmberg, Robert, & Eriksson (1996) as it has been suggested by the Ellen Macarthur Foundation (2013). In total 15 expert sources were reviewed, 7 of which can be considered not scientific and 8 were peer-reviewed publications.

The experts' literature review focused on two sets of documents. On one hand reports on circular economy were reviewed. These included the initial reports developed by McKinsey for the Ellen Macarthur Foundation (Ellen Macarthur, Foundation;, 2013), reports from other consulting firms (Accenture Strategy, 2014), non-governmental organizations (Friends of Europe, 2014) (Preston, 2012) and governmental proposals (Port of Rotterdam; Rabobank;, n.d.). On the other, key peer-reviewed articles from the guiding schools of thought were also included in the process. Founding texts from Industrial Ecology, Cradle to Cradle and the principles for sustainability were reviewed. Based on this review an affinity analysis was also conducted and a group of principles was proposed.

The undergoing efforts to define circularity metrics, indicators and assessment tools were analyzed using the four documents provided by the Stakeholders already developing such efforts. The information gathered from the literature review was organized using mind maps and affinity analysis.

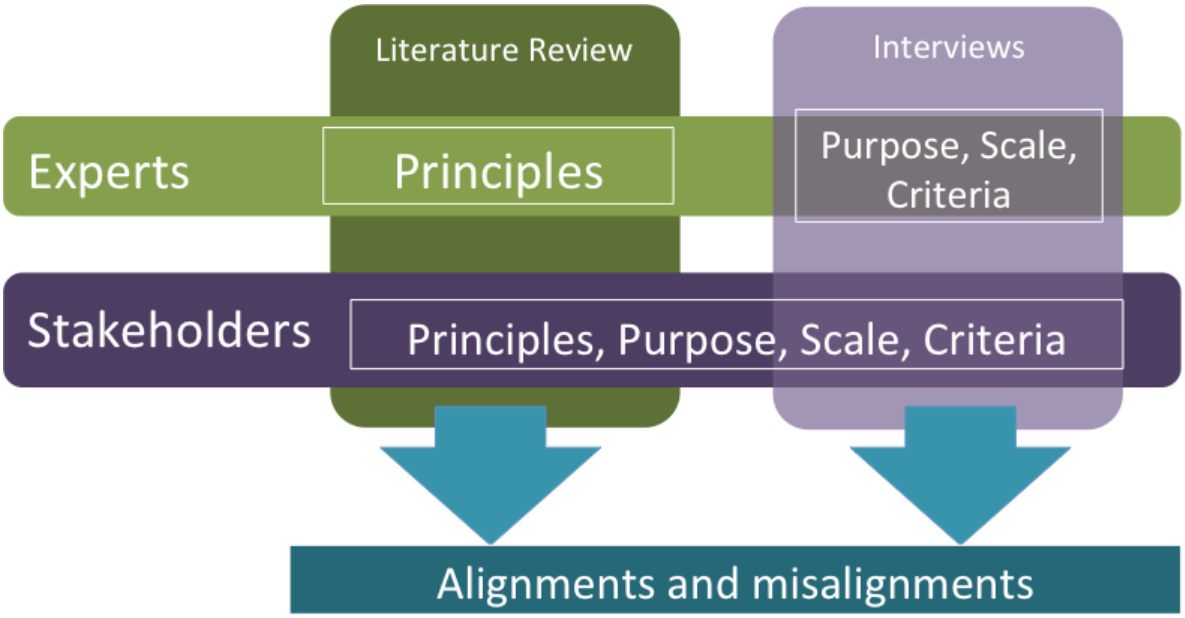

Figure 3 Method applied for information collection and analysis

3.2.2 Methods for data analysis

In order to analyze the data collected, the information from stakeholders was organized following the categories defined at the beginning of the process: purpose, scale, criteria and principles. The information from expert sources was organized also under these categories. Then this information was analyzed in order to answer the following questions:

- What elements are similar between different sources,
- What is the common denominator,
- How relevant is that element.

As a result of this analysis, a framework or benchmark was proposed and then, the information collected from the stakeholders was compared with this framework in order to find alignments and misalignments.

3.2.3 A suggestion for prioritizing criteria

Finally, it is also important to have guidance on how to define what elements should be considered more relevant and Meadows (1997, pp. 1-2) provides some elements for making such decision. She proposes nine levels for intervention in a system that would have different implications to how the system behaves. If the economy is the system that should be intervened with the objective of transforming it, an assessment of such process should be organized following that structure and the criteria should be defined in terms of

the different levels from the most simple to the most complex which results in smaller or bigger changes to the system:

1) Numbers (subsidies, taxes, standards)
2) Material stocks and flows
3) Regulating negative feedback loops
4) Driving positive feedback loops
5) Information flows
6) The rules of the system (incentives, punishment, constraints)
7) The power of self-organization
8) The goals of the system
9) The mindset or paradigm out of which the goals, rules, feedback structure arise

Therefore, in order to assess how much a company is contributing to circularity, the relevant aspects should be organized following this hierarchy. If a company were taking actions to reduce waste from their value chain this approach would have a smaller impact on how much they are contributing to circularity than a company that is "embedding" the concept into their strategy and business model. Following this input, each of the initiatives was also analyzed using this hierarchy to see how far upstream is their approach and how effective would it be in changing the system.

3.3 Results

In this section, the results from the analysis and interpretation of the data collected are presented.

3.3.1 Experts input analysis

Purpose

From an academic perspective, two aspects are relevant when discussing the purpose of a circularity assessment: it should contribute to closing the material loops and keep resources for future generations. However it was also mentioned that it is not possible or adequate to talk about circularity assessment of companies since companies can't be 100% circular and they shouldn't be. On the other hand, the consultancy firm addressed indicated that a circularity assessment should allow companies to understand what natural resources they depend on and what internal opportunities they have from waste streams. Other actors not directly related to circularity mentioned that this kind of assessment could be key for specific economic actors to make decisions that would encourage strategies towards circularity and communicate the importance of the transition. In sum three elements are key: *resource stewardship, management tool for decision-making and engagement tool.*

Scale

The suggestions here are quite varied depending on the type of organization consulted. For academic experts the value chain was suggested as the most adequate level, taking into account the need for having a life cycle perspective. However product offerings and components were also mentioned in one case, but another source indicated that the smaller relevant scale for assessing circularity was the company and not the product if a systems perspective was to be considered. In the case of the consulting firm different scales were proposed: life cycle, value chain, the business model and the product. Other actors did not mention this aspect in their answers. In sum, circularity assessment is a multi-scale tool that needs to address *the component level, the product level, the value chain, the business model and the company as a whole*.

Criteria

The experts consulted also provided input about what are relevant aspects to be assessed when evaluating circularity of a company. The experts from academia mentioned recycling, refurbishment, closing loops in a strict sense, reuse, smartness, energy use, costs, dependency on future materials, ability to retain value and waste reduction. Other expert mentioned that these aspects are not general but depend on the product offerings. From the perspective of consultants, the relevant aspects are the number of times the product is used, renewability, the origin of inputs, type of business model, material intensity and waste generation.

Institutes working on compatible topics suggested aspects such as recycling, repairing and remanufacturing; value proposition, remanufacturing, leasing, renewability and hazardousness. For private companies the main aspects are recyclability and reusability. Based on these contributions a set of 20 criteria was deducted as presented in Table 3.

Table 3 Criteria by principle and scale suggested by the experts.

Criteria	Description
Number of times the product is used	How many times the product is used per unit of time.
Recycling	How much of the value proposition is derived from recycled materials.
Refurbishment	How much of the value proposition is derived from refurbished products.
Remanufacturing	How much of the value proposition is derived from remanufacturing processes.
Renewability	How much of the energy input/material inputs come from renewable resources.

Repairing	How much of the value proposition is derived from repairing processes.
Reusability	How much of the value proposition comes from reused materials, components, products.
Waste generation	How much waste is generated to deliver a unit of value.
Waste reduction	How much waste is reduced as a result of the value proposition.
Origin of inputs	How much of the value proposition comes from different types of input materials: raw, recycled, reused.
Dependency on future materials	How much the value creation process of a company depends on materials that are going to be needed in the future.
Costs	How much do costs increase by implementing circularity.
Retain value	How much of the value proposition returns to the company in a certain period of time.
Smartness	How tight do the materials, components and products of a company circulate?
Hazardousness	How much of the material inputs used for a valued proposition is toxic.
Energy use	How much energy is used to deliver the value proposition.
Material intensity	How much material input is required to deliver the value proposition.
Efficient use	How efficient is the use of materials, components and products for delivering value.
Circulating of materials	How much does the company contribute to a closed circulation of materials at the society level.
Type of business models	How much of the value creation comes from circular business models.

Principles

Reports and non-scientific proposals

The Ellen Macarthur Foundation reports on circular economy provided a set of principles based on the contributions of different disciplines and schools of thought that they considered provide the basis for this approach. According to their report from 2013, (Ellen Macarthur, Foundation;, 2013) these include Regenerative Design started by professor John T. Lyle, the Performance Economy proposed by professor Walter Stahel, the Cradle-to-Cradle approach by William McDonough and Michael Braungart, Industrial Ecology and Biomimicry. Based on these contributions the Foundation proposed a set of principles to guide the implementation of the circular economy.

After the publication of such report, other initiatives have come later on to elaborate on the idea of circular economy and they offer principles as well. For example, Preston (2012) provides a review of what the circular economy transition entails by providing a definition of it, the requirements for such process, barriers and how to measure progress. Although the report doesn't give an explicit set of principles, two have been deducted: renewable and efficient energy and resource closed loop (pp. 3-4). The author mentions two additional elements that will be required if a transition towards a circular economy is going to happen: a positive impact economy on environment and society and collaborative economic activities.

Additional to this, in 2014 Accenture presented a report on what the circular economy entails for business (Accenture Strategy, 2014). As part of the definition of the circular advantage, some principles were identified:

- Growth is decoupled from scarce resources
- Companies focus on rethinking products to reduce waste
- Companies get involve in after-sales stages of the supply chain
- Value proposition is no longer associated with the physical product.

At a more regional level, Friends of Europe published a document where different actors at the Union level identified key elements related to the Circular Economy. From their contributions four principles were identified (Friends of Europe, 2014):

- A circular economy is regenerative
- It optimizes biological and technical flows
- It takes care of the manufactured capital
- Balances efficiency and effectiveness

Locally, in the Netherlands, the Port of Rotterdam also identified the opportunities a circular economy approach offers to the city and in collaboration with Rabobank, developed a report were other set of principles was presented (Port of Rotterdam; Rabobank;, n.d.). The principles include:

- Minimization of the use of inputs and elimination of waste and pollution
- Maximization of the value created at each stage
- Management of flows of bio-based resources from and back into the biosphere
- Recovery and retention flows of non-renewable resources in closed loops
- Establishment of mutually beneficial relationships between companies within each circular chain

These principles come from the conceptual framework that sustains the circular economy proposal.

Scientific proposals

Although these contributions have been very popular among different stakeholders and has gained momentum with both the private sector and governments, its scientific basis is still under construction. For example, if a concerned citizen would like to look for a peer-reviewed publication providing the foundations to the concept of circular economy as presented by the Foundation that is not yet available. As Haas, Krausmann, Wiedenhofer, & Heinz (2015) expressed in his recent article about the circularity of the global economy:

> "A critical examination of the literature on the circular economy reveals a lack of precise definitions and criteria for assessing measures to improve the circularity of the economy".

In this scenario it seems adequate to contribute to the discussion with a detailed review of the relevant contributions from the scientific literature to the principles that support the idea of a circular economy. In this sense, the contributions of three main scientific sources of circular economy are presented and described: industrial ecology, cradle to cradle and the sustainability conditions developed by (Holmberg, Robert, & Eriksson 1996).

Resulting from this analysis, the following categories of principles are proposed:

Table 4 Principles of circularity proposed by the expert literature.

 1. Closing the material loops	**"Closing the material loops"** refers to the need to close the material loops by decoupling growth from materials, transforming waste into valuable streams and managing non-renewable material flows in such a way that do not leak.
 2. Systems thinking	**"Systems thinking"** refers to the need of understanding the economy as a system within other systems and consequently of acknowledging the complexity that entails. This principle requires that any circularity effort iincorporates a systems approach.
 3. Resilient system	**"Resilient system"** establishes the need to consider both efficiency and resilience as goals of the economic system, in order to achieve effectively its ultimate aim of satisfying human needs sustainably.
 4. Maximize value	**"Maximize value"** deals with the need of the economic system to maximize returns from all types of capitals (natural, financial, human, social, etc.)
 8. Collaboration	**"Collaboration"** refers to the need of a new approach to interaction between economic agents based on cooperation rather than competition in order to maximize all types of values.
 5. Renewable energy sources	**"Renewable energy sources"** addresses the need to rely on renewable energy sources including labor for all economic processes.
 7. Positive footprint	**"Positive footprint"** calls for the aspirational aspect of the economic system in terms of being capable of restore and regenerate what is depleted by the system instead of only mitigating.
 6. Strong sustainability	**"Strong sustainability"** it requires economic agents to acknowledge sustainability from a top-down perspective where economy depends on society, which in turns depends on the environment instead of a bottom-up perspective where all dimensions are equally relevant.
 9. Future based orientation	**"Future based orientation"** which refers to the need of conducting analysis that look into the future and provide solutions that are free from lock-in and path dependence effects.

3.3.2 Stakeholder proposals analysis

Given the attractiveness of the circular economy idea for different sectors in society and suggestions from policy makers, researches and other stakeholders (IMSA; Circle Economy;, 2013), different initiatives to assess circularity have been developed in the last two years:

- **Circle Economy** is a foundation established to accelerate the transition towards circular economy in the Netherlands by supporting different stakeholders mainly private companies (Circle Economy & PGGM, 2015).
- **VBDO** is the association of investors for sustainable development in the Netherlands as well and they work with public listed companies to assure they are committed to implement sustainability and in 2015 their work is focusing on circularity (VBDO, 2015).
- **The Ellen MacArthur Foundation** is the pioneer in promoting the topic both at the national and global levels (Ellen MacArthur Foundation; Granta Design;, 2015).
- **Viktoria Swedish ICT** is an organization that works with the private sector to promote sustainable business models using research driven innovation (Viktoria Swedish ICT, 2015).

These proposals have different approaches, as well as levels of development, targets and goals but all have the aim of assessing circularity at the company level. In the following paragraphs the key elements defined in the methodology section will be described for each stakeholder. These will then be used in the data analysis to compare these results with the experts input to find alignments and misalignments.

Purpose

The purpose of the Viktoria Swedish ICT's circularity indicator project is to help companies' progress along a path towards CE. According to Viktoria ICT Sweden (2015) it could be used mainly internally to focus business strategies, calculating potential cost savings, as well as to benchmark and compare companies and products to encourage race to the top. It will also help quantify costs of different degrees of circularity.

In the case of VBDO, their assessment aims at measuring to what extent a company is taking concrete steps towards a circular business (VBDO;, n.d.).

For Circle Economy and PGGM, a circularity assessment tool should allow stakeholders evaluate organizations based on how well they are upholding circular economy principles and implementing their policies and intentions to move towards a circular economy (Circle Economy & PGGM, 2015).

Finally, the Ellen MacArthur Foundation claims that a circularity index should measure how well a product or company performs in the context of a circular economy in order to help

companies design more circular products, compare different products for internal reporting or procurement purposes, or to compare departments/companies (Ellen MacArthur Foundation; Granta Design;, 2015).

In sum, these proposals all aim to provide a way for companies to evaluate and measure the actions they are taking towards a circular economy and their performance and progress regarding that task.

Scale

Although this is not explicitly mentioned in the documents reviewed, during the interviews with the stakeholders the question regarding what would be a relevant scale for a circularity assessment was raised. Three out of the four proposals recognized the system level as a relevant scale for the assessment even though they were targeting the company.

Viktoria ICT's proposal focuses on the value-chain scale rather than the organization level.

VBDO and Circle Economy work at the organization level.

The Ellen MacArthur Foundation, they mentioned that although the systems thinking is at the base of the circular economy, their tool focuses on the product level but could be expanded to the company level by adding up the different results for products sets.

As it can be seen, there is no common ground between the different proposals as what is the relevant scale at which circularity assessment should be conducted.

Criteria

A third element that was identified from the different proposals was the different criteria to be considered when assessing circularity of a company. After reviewing and compiling the different aspects, it is evident the diversity of elements that are considered by the different organizations.

Viktoria Swedish ICT from Sweden considers three aspects: value retention, use of recirculated materials and product offering looping. The first aspect refers to how the business model allows the company to keep the value of the product instead of transferring it to consumers; the second element measures the amount of materials used as inputs that have been recirculated and finally, the last element refers to the cycling of the product offering, how tight and how many times the set of functionalities goes through the system.

VBDO (n.d.) proposal is divided in five aspects: strategic level and the governance approach: here they assess how 'embedded' circular thinking is in the strategy, the long-term strategy, targets and accountability. The second aspect, implementation, refers to

what extent the activities conducted by the company, such as product design, sourcing/procurement and revenue generation, follow circularity principles which are expressed in different metrics. Third, this tool considers the type of business models the company has, as well as the budget and the partnerships. Finally, this circularity assessment also considers if companies communicate to different stakeholders and engage them with topics related to circular economy. For each aspect, the tool establishes a yes/no question to define compliance with the criteria proposed.

In the Circle Economy proposal (Circle Economy & PGGM, 2015) four aspects were identified: first materials, energy and labor which evaluated in terms of renewability, recyclability, criticality, geopolitical risk, locality and competition. These aspects are defined by Circle Economy as the inputs used in the production process of the company. The second aspect related to the company's activities, is assessed in terms of how smart and efficient they are as well as their contribution to implementing modularity, extension of product life, degradability, and reduction of hazardousness.

The company's activities are understood here as all the processes that contribute to delivering value to the customers but in this specific report only design is addressed. Moreover, the organization's practices are evaluated in terms of transparency, collaboration and integrity. Practices are not an explicit aspect in the report but were identified here as a key element regarding how the organization should 'behave' as a whole. Finally, the impact of the company at the planetary level is assessed in terms of how much its activities contribute to surpass the planet's boundaries related to water, atmosphere and society.

The Ellen MacArthur Foundation (Ellen MacArthur Foundation; Granta Design;, 2015) considers three basic aspects that should be further complemented by additional indicators developed by other organizations. The main three aspects they suggest are inputs, use and end of life. Regarding inputs they want to know if they are reused, recycled or virgin; regarding use they suggest this should address intensity and length; finally, end of life scenarios identify if the product is reused, recycled or landfilled.

For the complementary indicators they suggest energy use, CO2, water use, cost, price variation and toxicity. They characterize these aspects as "the restorative part of the flow", the "linear part of the flow" and the "utility". The circularity assessment they propose also considers risk, impact and profitability aspects. In terms of risks, the assessment considers scarcity and toxicity while the impact aspects are mainly related to energy and water. Finally, the profitability is linked to the kind of business model the company could implement to become more circular. The methodology as it is presented does not provide information about complementary indicators for the company level although it makes some suggestions related to existing methods such as GRI (Ellen MacArthur Foundation; Granta Design;, 2015, p. 44).

Principles

A key element of circularity assessment is the definition of circularity in itself, which is mostly based on the Circular Economy principles. In this section the principles behind each proposal were identified based on the documents and the interviews. Using the classification from the expert input analysis, evidence for each principle was searched for in each proposal. As a result the following principles are considered by all of the studied proposals:

Table 5 Principles present in the stakeholder proposals

 1. Closing the material loops	**"Closing the material loops"** refers to the need to close the material loops by decoupling growth from materials, transforming waste into valuable streams and managing non-renewable material flows in such a way that do not leak.
 2. Systems thinking	**"Systems thinking"** refers to the need of understanding the economy as a system within other systems and consequently of acknowledging the complexity that entails. This principle requires that any circularity effort iincorporates a systems approach.
 3. Resilient system	**"Resilient system"** establishes the need to consider both efficiency and resilience as goals of the economic system, in order to achieve effectively its ultimate aim of satisfying human needs sustainably.
 4. Maximize value	**"Maximize value"** deals with the need of the economic system to maximize returns from all types of capitals (natural, financial, human, social, etc.)
 8. Collaboration	**"Collaboration"** refers to the need of a new approach to interaction between economic agents based on cooperation rather than competition in order to maximize all types of values.
 5. Renewable energy sources	**"Renewable energy sources"** addresses the need to rely on renewable energy sources including labor for all economic processes.
 7. Positive footprint	**"Positive footprint"** calls for the aspirational aspect of the economic system in terms of being capable of restore and regenerate what is depleted by the system instead of only mitigating.
 6. Strong sustainability	**"Strong sustainability"** it requires economic agents to acknowledge sustainability from a top-down perspective where economy depends on society, which in turns depends on the environment instead of a bottom-up perspective where all dimensions are equally relevant.

3.3.3 Gap analysis

The gap analysis is based on the framework developed following the experts' input and comparing each of the proposals with it. In order to do so, the number of elements from

the benchmark contained in a particular proposal was calculated in order to assess their alignment or misalignment. In this section the results from such analysis are presented.

Viktoria Swedish ICT

Viktoria Swedish ICT proposal is focused on how the business model of a company translates into circularity. Their approach compared to what the literature and experts suggested, is presented in Table 6. From the comparative analysis, it is concluded that several elements are not explicitly considered in this proposal. In terms of the purpose of the assessment, this approach does not provide insights on what resources the company is relying on and how they are contributing to their preservation for future generations. Regarding the scale, this project is not considering explicitly to conduct assessments at the company level or from a lifecycle perspective although it may be derived from their approach. As mentioned earlier they are focused on the product level and the business model but they do consider how the products loop, which entails a lifecycle perspective. Finally they do take into consideration most of the principles suggested by the literature and the experts, excluding "Systems thinking", "Resilient system", "Strong sustainability" and "Future-based orientation".

Table 6 Gap analysis for Viktoria Swedish ICT

VIKTORIA SWEDISH ICT ANALYSIS							
Component	**Experts input**						
Purpose	closing the material loops	keep resources for future generations		to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Scale	the value chain	product offerings and components	company	life cycle		business model	
Aspects	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
Principles	Closing the material loops						
	Systems thinking						
	Resilient system						
	Maximize value						
	Collaboration						
	Renewable energy sources						
	Strong sustainability						
	Positive footprint						
	Future- based orientation						

Viktoria Swedish ICT addresses higher levels of the hierarchy by considering if the company is retaining value since this implies a change in their business model which is the same case when they considered product looping. However there are no other elements to assess other high-level aspects of the process such as goals or mindsets that would imply a more decisive turn towards circularity.

VBDO

In Table 7 the results from the gap analysis for VBDO are presented. In terms of what the purpose of a circularity assessment should be, three elements are missing: how the results from the assessment contribute to keep natural resources for future generations, how they help the company understand what are the key natural resources they depend on and how it helps them identify opportunities from waste generation. Regarding the aspects that are relevant for assessing circularity, some that are not explicitly consider include energy use, costs, origin of the material resources and circularity strategies such as remanufacturing and repairing. In terms of principles, four are missing or are not explicitly mentioned in the document or by the interviewees: systems thinking, resilient system, strong sustainability and future based orientation. As it can be concluded, this proposal is missing approximately half of the elements suggested by the expert literature and interviews.

Table 7 Gap analysis for VBDO

VBDO ANALYSIS							
Component	**Experts input**						
Purpose	closing the material loops	keep resources for future generations		to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Scale	the value chain	product offerings and components	company	life cycle		business model	
Aspects	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
Principles	Closing the material loops						
	Systems thinking						
	Resilient system						
	Maximize value						
	Collaboration						
	Renewable energy sources						
	Strong sustainability						
	Positive footprint						
	Future- based orientation						

This proposal is the only one that assesses companies at the highest levels according to the (Meadows, 1997) hierarchy as it includes strategy, governance, communication and innovation, on top of the material/energy level. As a result, this assessment is taking into account how much the initiatives might be effectively contributing to a broader transformation of the economic system. Examples of indications of such levels include the embeddedness of circular thinking, implementation of circular business models, communication and engagement of stakeholders, among others.

Circle Economy

Based on their report (Circle Economy & PGGM, 2015) and comparing it with the proposal derived from expert sources, Table 8 was originated. In green are the elements that were identified in the stakeholder's proposal, in orange the ones that can be derived from the text but are not explicitly indicated and in red are the ones that were not identify in the document or the interview. As it can be concluded, most of the elements suggested by expert sources are present in this proposal and since it has been already described, here the focus is in the elements that are not present.

According with the analysis conducted here, there are few elements that are not present in this proposal, particularly in two areas: principles and criteria. On one hand, there are two principles that are not considered: collaboration and future based orientation. In terms of criteria, two aspects are also missing: circularity strategies such as reuse, remanufacturing and repairing and the costs dimension. Although it is possible to identify in the document and through the interviews references to the value chain and activities that involve collaboration, this is not an explicitly principle guiding the definition of the framework. On the other hand, the future based orientation approach is not completely absent of the proposal since intergenerational aspects are considered in the indicator proposals as well as the risk perspective.

Table 8 Gap analysis for Circle Economy

CIRCLE ECONOMY ANALYSIS							
Component	**Experts input**						
Purpose	closing the material loops	keep resources for future generations		to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Scale	the value chain	product offerings and components	company	life cycle		business model	
Aspects	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
Principles	Closing the material loops						
	Systems thinking						
	Resilient system						
	Maximize value						
	Collaboration						
	Renewable energy sources						
	Strong sustainability						
	Positive footprint						
	Future- based orientation						

From an intervention perspective and using the hierarchy suggested by (Meadows, 1997) this proposal does not address the higher levels of the hierarchy, leaving the assessment at information flows level, which could be considered quite high. In summary, Circle Economy's proposal explicitly contains most of the elements suggested both by the

literature and the experts in terms of elements, principles and criteria while only few are not mentioned although some references exists.

Ellen Macarthur Foundation

The EMF proposal to assess circularity appears to be the one that is the farthest from what the expert literature and interviews provided as key components of such proposal as it is shown in Table 9. In terms of principles, although the Foundation has defined circular economy following the schools of thought used here, for this specific project they decided to not apply most of them given the complexity of the process. As mentioned in their report:

> "While a circular economy is about systems thinking, the combination of design and business models and the effective flows and feedback loops, the creation of an analytical methodology and tool requires a more narrowly defined scope. […] Given this scope, it is evident that improving the MCI of a product or a company will not necessarily translate as an improvement of the circularity of the whole system." (Ellen MacArthur Foundation; Granta Design;, 2015, p. 9).

As a result this proposal is based only on the "Closing the loops" principle and does not incorporate the others.

In addition to this, the scale of the indicators is constrained to the product level and leveled up to the company level through a simple addition procedure. However, it incorporates a value chain perspective to some extent as it considers the use of the products and not only sourcing, manufacturing and end of life. Regarding the aspects considered in order to assess circularity, the proposal only considers partially the suggestions by the literature and the experts leaving outside aspects such as remanufacturing, refurbishment, renewability and how smart the materials and energy are used. Finally, although the purpose of this methodology is quite ambitious ranging from internal strategic decisions to comparisons, it is highlighted that it might not contribute to close the loops in the company level and as mentioned before either at the system level.

Table 9 Gap analysis for Ellen Macarthur Foundation

ELLEN MACARTHUR FOUNDATION							
Component	**Experts input**						
Purpose	closing the material loops	keep resources for future generations		to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Scale	the value chain	product offerings and components	company	life cycle		business model	
Aspects	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
Principles	Closing the material loops						
	Systems thinking						
	Resilient system						
	Maximize value						
	Collaboration						
	Renewable energy sources						
	Strong sustainability						
	Positive footprint						
	Future- based orientation						

This proposal is constrained to the lower levels of the system intervention hierarchy and does not assess the company in terms of higher leverage points. In their assumptions they state that more circular products are the result of changes in the mindset and business models but this might not be straightforward. In this sense the Material Circularity Indicator does not provide input to assess if a company is contributing to radical changes in the economic system, as it is required by their concept of Circular Economy but just focuses on measuring numbers, the lower element in the Meadows hierarchy.

Basic alignments and misalignments

Here, a summary of the main agreements and disagreements between proposals and between the proposals and the experts' input is presented.

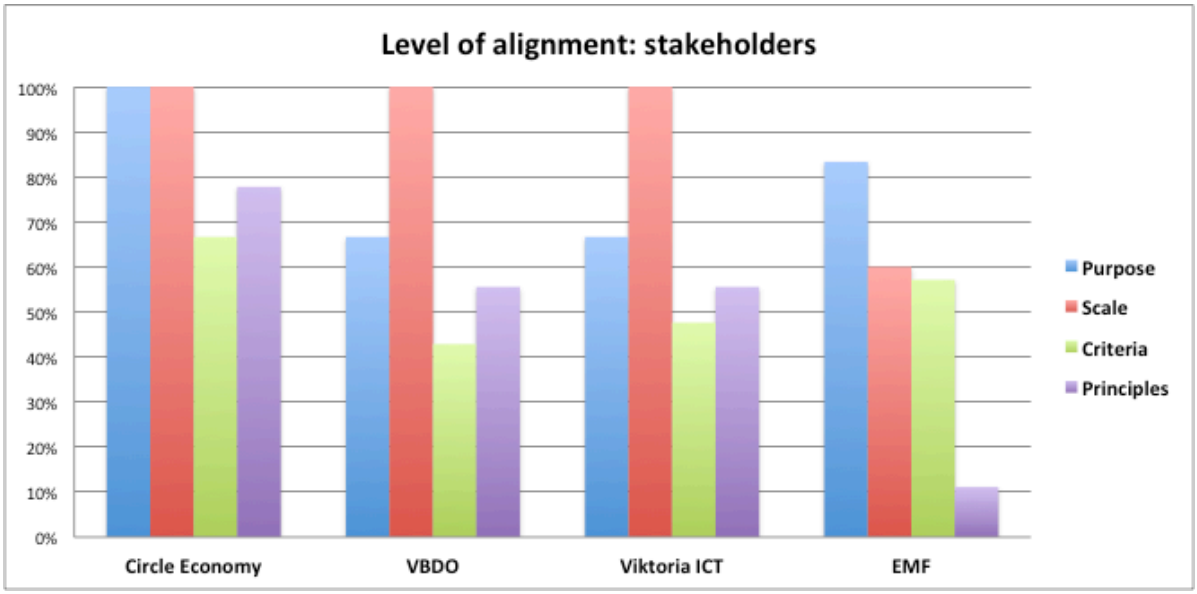

Figure 4 Comparison between stakeholders by category.

As it can be appreciated in Figure 4, in terms of purpose, only the proposal from Circle Economy considers all the elements provided by the literature and the interviews. “Keep resources for future generations” is the least considered purpose among the stakeholders. In addition to this, there seems to be disagreements regarding the role of a circularity assessment in helping companies understand what natural resources they depend on. In contrast, an agreement about the objective of such assessment in terms of facilitating decisions that would encourage strategies towards circularity can be identified. Other aspects that have also been considered, either explicitly or implicitly by all stakeholders as key purposes for a circularity assessment are: “closing the material loops”, “to communicate the importance of the transition” and “to identify internal opportunities from waste streams”. In general all the stakeholders considered share the purpose for a circularity assessment and more importantly, they seem to generally agree with the expert sources.

Regarding the scale at which the assessment should be implemented, only the Ellen MacArthur Foundation does not include the business model and lifecycle perspectives while all other proposals have a multi-level approach, which was strongly suggested by the expert sources. It is important to highlight that the product/offerings perspective is the strongest one, with all stakeholders agreeing that this level has to be included in the assessment, while the lifecycle perspective was not so strongly advocated for. When focusing on the product level, what is relevant for circularity is how the product is made and not how the product is used which requires a functional perspective rather than a physical one, which is the one considered here.

In Figure 5 the different criteria considered by the stakeholders' proposals are considered. In the case of waste reduction, value retention, recycling and closing material loops, all proposals included them while, energy use, dependency on future materials and strategies for closing the material loops are the less included.

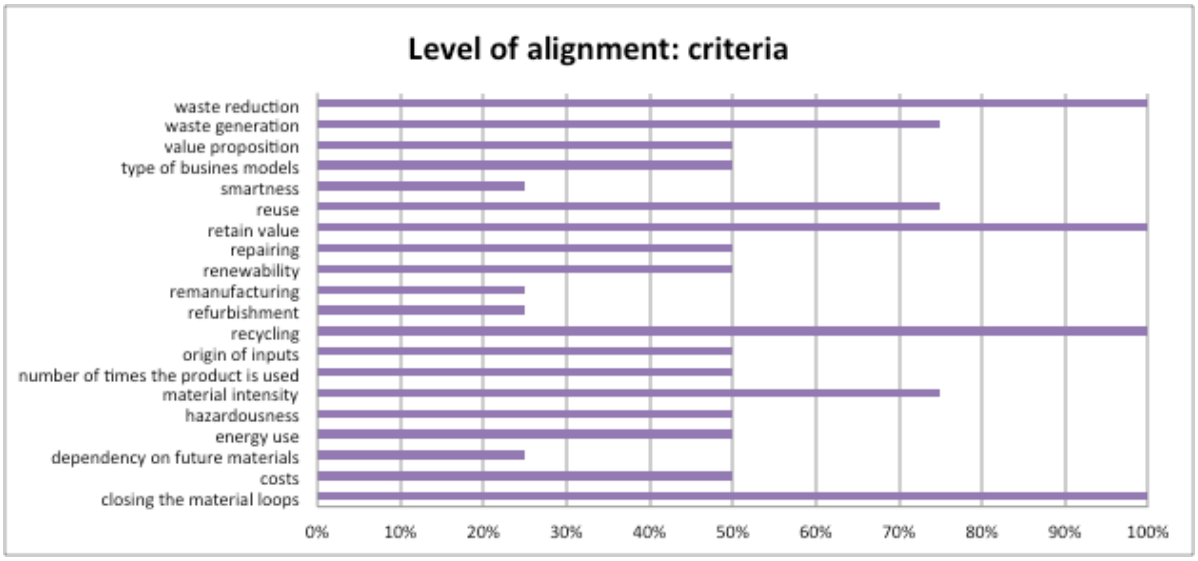

Figure 5 Criteria considered by different stakeholders' proposals.

Another element considered in this analysis was the principles under which each proposal was developed. The first conclusion that can be reached here is that none of the proposals considered all the principles identified from expert literature and interviews. Moreover, anyone of the proposals took into account the principle named here "Future-based orientation" but all other principles are in one or more proposal. After this principle, the two less considered were "Strong sustainability" and "Collaboration" which were only mentioned in one proposal each. The principle for which there is the highest level of agreement to take it into account, is "Closing the material loops" while the least agreement is connected to the principles "Systems thinking", "Resilient system" and "Positive footprint".

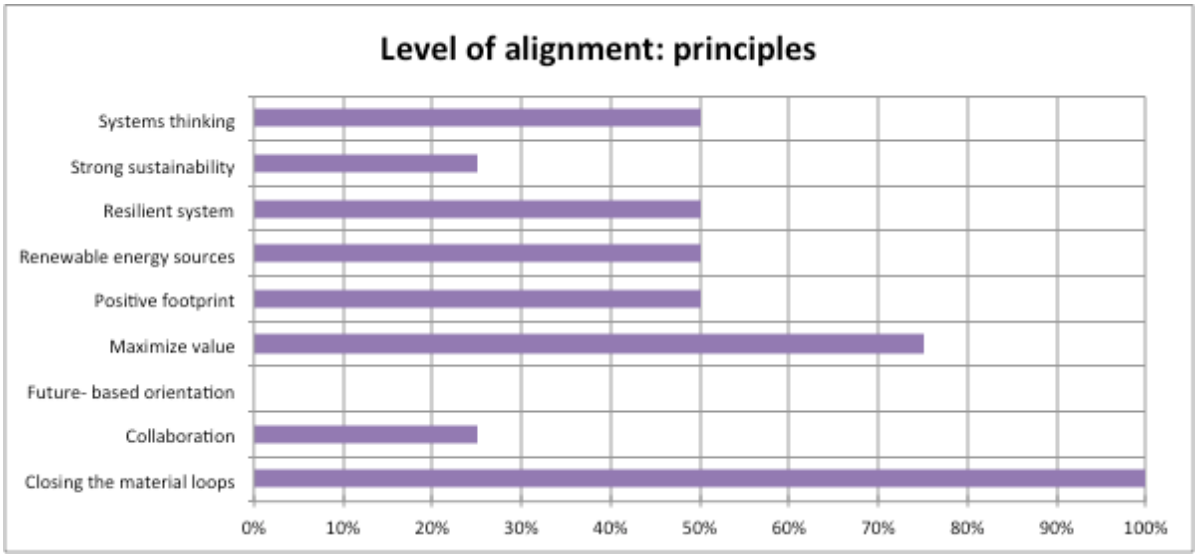

Figure 6 Principles considered by the different stakeholders' proposals

Finally, there is a balanced approach to the different elements proposed by Meadows. The different stakeholders have different perspectives on what are the elements that are relevant to evaluate circularity from a company perspective, some of them focusing on low priority ones such as numbers and others focusing on more relevant yet more complex aspects such as mindsets and system goals.

Concluding, although the proposals from stakeholders are different among them, they could be considered as being complementary under the perspective of expert sources. None of them comprises all the elements provided by the literature and the interviews but if added, these elements are all present.

3.4 Discussion

In this section two basic elements are discussed, the influence of the methodological approach to the results and important findings that were not explored in detail here and would offer opportunities for further inquiry.

3.4.1 Methods

Although the methodological approach selected recognizes the situated character of a qualitative inquiry such as this it is still important for the reader to be aware of some of the implications of this to the results. The results presented in this report are dependent on the selection of the expert sources both in terms of literature and experts. The framework proposed here is based mainly on the definitions developed by consulting firms that have taken up the concept of circular economy, which results in a particular perspective on it.

Their perspective is motivated by the need to expand their business and create opportunities to do so. There is lack of input from civil society organizations and other relevant actors from the economic system that would complement this view. This was counter balanced by introducing specific elements from scientific literature in order to have a wider understanding of the elements that could compose a circularity assessment. However there is still need to introduce elements from other stakeholders to the discussion of what circularity entails at the company level. Concluding, the framework suggested here and the recommendations for existing circularity assessment are specific to the type of expert sources consulted both in terms of literature and interviews.

3.4.2 Neutrality of sources

While the results depend on the type of sources consulted, it also important to recognize the fact that the interviewees and the interviewer are not neutral to the topic. In this particular case, individuals working on sustainability issues or sympathetic to sustainability were the main source of information, resulting in a favorable view of circularity. Although a sector bias was tried to be minimized by choosing individuals from different sectors most of them had some experience and were involved in sustainability initiatives that clearly influence their perspective. Some times this influence was on the positive side, advocating for circularity and some others it was on the negative one, indicating that circularity was just a marketing initiative. It is also important to recognize that the background of the interviewer also affects the interpretation of the input given by the different sources. In sum, given the qualitative nature of research methods, the information and results in this report are shaped by both the interviewees' context and the interviewer background, making it necessary to be aware of this influence and read the results and conclusions under this light.

The information collection was also affected by the definition of the questions asked to the interviewees. Such definition was guided by the research questions but was also intended to take into account the differences between stakeholders, their background and affiliation. However, an aspect that was raised during the interviews and that was not considered at the planning was the level of understanding of what a circularity assessment is. In this sense, some interviewees manifested that those were not the right questions to ask but this was more due to their lack of familiarity with the topic of circularity assessment and circular economy than the questions in itself. Once the questions were rephrased and the concept of circularity assessment was explained, the input was given. As a consequence such input was not specifically considering circularity assessment tools but rather a fuzzier concept of how to evaluate the role of companies in a circular economy. As a result, the definition of the questions to be asked also affected the contribution received and therefore, the results obtained.

Once the information was gathered in the form of recorded interviews or notes from the literature review, the systematization of it was an interpretation in itself affecting the final result. Although the contribution from the different actors were first registered as accurate as possible, in order to organize the information, and given the fact that the questions were phrased in order to make it easier for the interviewee to provide input, such results went through a process of interpretation that not only contains the perspective of the person interviewed or the document reviewed but also the understanding of the researcher. This research has been more a process of interpreting what the sources of information provided rather than just registering them so they could be understandable and useful for answering the research questions.

With information organized, the data analysis was done following a set of guiding questions related to the research questions and to suggestions from the literature about qualitative research. These questions are not neutral either and define a path that results in specific findings. Questions such as what elements are shared among sources, or what elements are missing where key to building the resulting framework and understanding the alignments and misalignments between the framework and the existing proposals, but other questions could have resulted in other conclusions. Such questions have to be defined under the guidance of the main research questions if meaningful contributions are needed. Resulting from this, the results obtained were dependent again on the analyzing questions posed rather than just the perspectives of the different experts.

3.4.3 Opportunities for further research: scale

Focusing more in the results obtained, an interesting outcome is the disagreement between sources about the relevant scale for a circularity assessment. Such discrepancy among interviewees might be due to the diverse nature of backgrounds among them and the fact that the idea of a circularity assessment is still very new. Since there were input from academics, non-academic researchers and consultants and from a variety of areas, the scale at which they work is different and integration efforts are not evident.

On the other hand, none of them have had worked specifically on circular economy and haven't had time to reflect on the topic as much as the Stakeholders have, allowing little room for consideration of such aspects as relevant scale. However, the difference in approach might be suggestive of the definition of circular economy: a complex and multi-scale concept of the economy anchored on a wider range of principles than the traditional definition of economy. In this sense, the result is that sources agree to disagree on the suggestion that circularity happens on just one scale highlighting the complexity of such phenomenon.

3.4.4 Opportunities for further research: what to evaluate

Another element relevant to the definition of circularity assessment is the understanding of assessment in itself. Although throughout the text the concepts of assessment, measurement and evaluation were used indistinctly which might be inaccurate and could explain some of the difference between proposals. For example, Viktoria Swedish ICT and the EMF proposals aimed at measuring circularity in terms of having a number that could express how circular a product/company is while Circle Economy and VBDO wanted to assess the contribution of a company to the circularity of the system. In this sense, measuring and assessing seem to be two different parts of an evaluation process that happen at different scales and might use different criteria, which can explain why the different proposals seem to be more complementary than competing.

3.4.5 Opportunities for further research: relationship with other tools

In this line, different Experts raised the question about the relationship of circularity assessment and tools such as Life Cycle Assessment or Material Flows Analysis. This was slightly mentioned by the stakeholders in two contradictory senses: on the one hand, the Ellen MacArthur Foundation and Viktoria Swedish ICT proposed that their circularity measurement can be part of Life Cycle Assessment. And Circle Economy and VBDO expressed that these tools can in turn, be part of the circularity assessment. In sum, if circularity assessment is understood as only concerning circulation of materials, it will be part of more broader tools and if it is defined as more than just materials, for example organizational aspects, it will use these tools for its own evaluating process.

3.4.6 Opportunities for further research: principles and criteria

One element that was not included in the process was the definition of what a principle is and how it is related to the criteria. This was taken from the literature but during the data collection and analysis it appeared to be a necessary to provide an introduction of what criteria was to the experts and stakeholders. Although the literature clearly defines the principles behind circularity how they result in criteria was not straightforward. This was evident when attempting to assign criteria to the suggested principles as it was difficult to find a proper matching and finally this step was not considered. As a result, what was identified was a gap between what the expert literature suggests as principles and what the experts consulted consider as relevant aspects that was not further explored here.

Although it has been said that something that cannot be measured cannot be managed, the concept of measuring needs to be challenged in a scenario of increased complexity and the “system intervention hierarchy” proposed by (Meadows, 1997) could be used as an indicator of how well an assessment is at addressing such complexity. None of the proposals studied here have this approach and it could be an interesting addition to the process but further investigation is needed. This approach would encourage developing a

hierarchy that would allow decision-makers to evaluate how effective an initiative is in terms of addressing the complexity of a system, which is an element lacking in the proposals analyzed. By recognizing the importance of where systems interventions are made, complexity can start to be operationalized.

3.4.7 Opportunities for further research: situated assessment

Finally, a key aspect brought up by academics is the role of context in assessment process but this was not introduced in the framework as it was only mentioned once, but it would be important to address it. This aspect is also mentioned for sustainability assessment as a key aspect to take into account when conducting such analysis, what is the role of site-specific conditions. In the literature this is referred as situational indicators, however, experts not only mentioned this but also specificities about the company's offering as key aspects to consider in a circularity assessment. The challenge here lies on how to incorporate context specificities into an assessment tool.

In sum, the framework suggested here and the recommendations for existing circularity assessment are specific to the type of expert sources consulted both in terms of literature and interviews. Moreover, both the interviewees' context and the interviewer background shape the information and results in this report, making it necessary to recognize this influence and to read the results and conclusions under this light. In addition to this the definition of the questions to be asked also affected the contribution received and therefore, the results obtained. In this sense, this research has been more a process of interpreting what the sources of information provided rather than just registering them so they could be understandable and useful for answering the research questions. Another key element was the questions that guided the analysis process in itself yielding the categories and basic elements of the suggested framework.

3.4.8 Opportunities for further research: concluding remarks

Taking into account the above mention elements several particularly interesting findings were identified. First, circularity can't happen just at one scale mirroring the complexity of this phenomenon; second, Stakeholder proposals are different and rather complementary, which could be explained by their different aims at measuring and assessing circularity. Third, a gap was identified between what the expert literature suggests as principles and what the experts consulted consider as relevant aspects but this was not further explored. Finally, an important challenge lies on how to incorporate context specificities into an assessment tool. These findings offer opportunities for further research if the issue of circularity assessment is to be explored and strengthened.

4 Conclusions

Achieving sustainable urban development requires transformation in many different areas or leverage points. One of such leverage points is built environment and specifically, resource use. Following the back-casting method developed by (Holmberg, Backcasting: A natural step in operationalising sustainable development, 1998) a set of criteria to define solutions to such challenges were defined in the Challenge Lab[4]. Then the current situation was analyzed using systems thinking in terms of its compliance with such criteria and then solutions in the form of projects were studied. As a result of this process circular economy and more specifically, circularity assessment was defined as the object of this research work. In particular, the aim of this inquiry was to establish the fundamental elements of a circularity assessment framework that effectively contributes to improving resource efficiency and achieving sustainability of cities.

In order to do so, a framework was structured based on experts input from literature sources and interviews. Perspectives from academia, private sector, government and civil society were combined in order to identify the purpose, scale, criteria and principles that should guide a circularity assessment. This framework was used to evaluate existing efforts for developing tools to assess circularity at the company level and identify alignments and misalignments. In total 15 articles and reports were reviewed and 20 experts interviewed while 4 proposals were assessed using similarity analysis under an interpretative inquiry approach.

Resulting from this process a general framework is proposed and suggestions for improvement were developed. Such framework has four basic elements, a purpose for circularity assessment; the relevant scales at which it should be implemented; the criteria that allow to define if a company is circular or not; and finally, what principles need to support the assessment.

In terms of the purpose, a circularity assessment assists companies in addressing their role in society as resource stewards, in making management decisions and in engaging with a wider audience. Regarding scale, circularity does not happen only within the boundaries of the company, it is a property of the broader system in which the company is embedded. In this sense circularity assessment has to be multi-scale and have a life cycle approach. Circularity is about reducing resource use and environmental negative impacts and creating

[4] The Challenge Lab is an innovative approach developed at Chalmers University of Technologies to sustainability education. There, master student develop their thesis using a 'heads, hand, heart' approach to discover the right questions and to use the right tools to answer them. Refer to Chapter 2 for details.

value as much as making our economic system resilient and future proved while delivering wellbeing.

Existing efforts to assess circularity consider these aspects partially; in some cases like for the Circle Economy and VBDO proposals, they are closer to the framework proposed here than the proposals suggested by the Ellen Macarthur Foundation and Viktoria Swedish ICT. The first group has a more comprehensive approach to the assessment while the other two, are more focused on the measuring of circularity. In this sense, it is concluded that the different proposals are complementary and elements of all could be combined to have an integral proposal that follows closer the suggestions made by the experts.

In sum the main contribution of the circular economy is the systems' approach to understanding the economy, which in turn requires a change in mindset by key actors in society. However this is only achieved if the operationalization of the idea follows the principles proposed as a result of decades of systems thinking and sustainability work. If tools to assess sustainability perpetuate a narrow-minded approach to reality and do not develop novel tools to incorporate it, quick fixes would result in unsustainable solutions for the different challenges that a circular economy approach wants to tackle. It is not enough to just mention the principles and acknowledge them but it is mandatory to translate them into practices.

Circularity, as any social phenomenon, is not a technical fix or a management solution; it is a complex approach that requires a complex understanding and complex solutions. In this sense, a circularity assessment requires collaboration between experts in both realms, and additionally, it demands integrating approaches from other sectors of society, like consumers, civil society and unions. Current proposals come from either technical or management experts, and some input from a narrow definition of civil society has been incorporated by some organizations but this needs to be further extended / taken further if complexity is to be addressed.

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6 Appendices

Appendix 1 List of experts

ID	Name	Last name	Organization	Area of research	Country	Sector	Status	Interview
1	Cony	Bakker	TU Delft	Circular economy	Netherlands	University	Contacted no answer	
2	Jaco	Quist	TU Delft	Sustainable innova	Netherlands	University	Contacted, no interest	
4	Thomas	Nilsson	MISTRA	Circular economy	Sweden	Government	Contacted, input given	Mar-18
5	Karin	Bradley	KTH	Sharing economy	Sweden	University	Contacted, waiting for answer	
6	Matthias	Lindhal	Linköping University	Functional sales	Sweden	University	Contacted, input given	Apr-07
7	Joachim	Krook	Linköping University	Urban mining	Sweden	University	Contacted, waiting for answer	
8	Sara	Palander	Swedish Center for Life Cycle Center	Lifecycle thinking	Sweden	Institute	Contacted, input given	Apr-28
9	Jonas	Norrman	GAME	Circular economy	Sweden	Institute	Contacted, waiting for answer	
10	Anna	Kjellberg	Ekocentrum	Communications	Sweden	Institute	Contacted, waiting for answer	
11	Nancy	Bocken	TU Delft	Circular business n	Netherlands	University	Contacted, input given	
12	Johan	Sidemark	Cradlenet	Circular economy	Sweden	Private	Contacted, no interest	
13	Tobias	Jansson	Circular Economy SE	Circular economy	Sweden	Private	Contacted, no interest	
14	Carina	Sundqvist	Inspirationsbyran	Circular economy	Sweden	Private	Contacted, waiting for answer	
15	Lina	Svensberg	Circular Economy SE	Circular economy	Sweden	Private	Contacted, no interest	
16	Leonardo	Rosado	Chalmers University of Technology	Urban metabolism	Sweden	University	Contacted, input given	Mar-23
17	Thomas	Lindhvqist	Lund University	Extended producer	Sweden	University	Contacted, no interest	
18	Johan	Felix	Chalmers Industriteknik	Recycling	Sweden	Institute	Contacted, input given	Mar-27
19	Mats	Torring	Stena Recycling	Recycling	Sweden	Private	Contacted, waiting for answer	
20	David	Schelin	Ragnsells	Recycling	Sweden	Private	Contacted, input given	
21	Mohamed	Taherzadeh	University of Boras	Resource recovery	Sweden	University	Contacted, waiting for answer	
22	Linda	Eliasson	Borås waste management	Recycling	Sweden	Government	Contacted, waiting for answerr	
23	Marcus	Wendin	Miljo Giraff	Circular assessme	Sweden	Private	Contacted, input given	Mar-27
24	Ulli	Gelbman	University of Graz	Recycling	Austria	University	Contacted, input given	Mar-24
25	Sverker	Molander	Chalmers University of Technology	Assessment	Sweden	University	Meeting set up	Apr-13
26	Lars	Tolgen	Ragnsells	Recycling	Sweden	Private	Contacted, input given	Mar-18
27	Ann-Charlotte	Mellquist	Cradlenet	Circular economy	Sweden	Private	Contacted, input given	Apr-01
28	Emma	Petersson	Terra Institute	Circular economy	Sweden	Private	Contacted, input given	Apr-15
29	Lars	Wiklund	Eskilstuna	Circular economy	Sweden	Government	Not contacted	
30	Caroline	Petersson	Camino Magasin	Circular economy	Sweden	Private	Not contacted	
31	Magnus	Wiberg	Uniforms for the Dedicated	Recycling	Sweden	Private	Contacted, input given	Mar-27
32	Oksana	Mont	Lund University	Functional sales	Sweden	University	Contacted, waiting for answer	
33	Mike	Lind	Uniforms for the Dedicated	Circular business n	Sweden	Private	Contacted, input given	Apr-10
34	Anne-Marie	Tillman	Chalmers University of Technology	Assessment	Sweden	University	Contacted, input given	Apr-13
35	Willi	Haas	Alpen Adria Universitaet	Circular assessme	Austria	University	Contacted, waiting for answer	
36	Kiki	Bauman	Chalmers University of Technology	Assessment	Sweden	University	Contacted, input given	May-04
37	Nathalie	Chalmers	World Economic Forum	Circular economy	Global	Institute	Contacted, waiting for answer	
38	Klas	Hallberg	Azko Nobel	Circular economy	Netherlands	Private	Contacted, input given	May-08
39	Tomas	Rydberg	IVL	Circular economy	Sweden	Institute	Contacted, input given	May-08

Appendix 2 List of stakeholders

ID	Name	Last name	Organization	Area of research	Country	Sector	Status	Interview	Questions	Recorded
1	Shyaam	Raukman	Circle Economy	Circular assessment	Netherlands	Private	Contacted, input given	Mar-02	Complete set	No
2	Steven	Sarasini	Viktoria	Circular assessment	Sweden	Institute	Contacted, input given	Mar-20	Complete set	No
3	Annemieke	Reijngoud	VBDO	Circular assessment	Netherlands	Private	Contacted, input given	Mar-16	Complete set	No
4	Marc	De Wit	Circle Economy	Circular assessment	Netherlands	Private	Contacted, input given	Mar-04	Partial set	No
5	Sven	Hermann	Ellen Macarthur Foundation	Circular assessment	UK	Institute	Contacted, input given	Mar-20	Complete set	No
6	Thomas	Nyrstrom	Viktoria	Circular business models	Sweden	Institute	Meeting set up	Mar-20	Complete set	No

Appendix 3 Summary of stakeholders proposals.

Dimension	Circle Economy	VBDO	EMF	Viktoria ICT
Purpose	To evaluate organisations based on how well they are upholding circular economy principles and implementing their policies and intentions to move towards a circular economy.	To measure to what extent a company is taking concrete steps towards a circular business.	To develop a methodoloty measures how well a product or company performs in the context of a circular economy in order to help companies design more circular products, compare different products for internal reporting or procurement purposes, or to compare departments/companies.	To help companies progress along a path towards CE. It could be used mainly internally to focus business strategies, calculating potential cost savings. It can be used to benchmark and compare companies and products to encourage race to the top. It will also quantify costs of different degrees of circularity.
Scale	Organization/system	Organization/system	Product	Value chain/ systemic level
Aspects	Materials, energy and labor: Renewability, recyclability, criticality, geopolitical risk, locality, competition.	Strategy and governance: wich includes how circular thinking is embedded in the strategy, the long-term strategy, targets and accountability.	Inputs: virgin, re-used or recycled	Value retention
	Activities: smart, efficiency, modular, extended lifetime, degradability, hazardousness, preventiveness.	Implementation: revenues from circular products and services, product design and procurement.	Use: length and intensity	Use of recirculated materials
	Practices: transparency, collaboration, integrity	Innovation: circular business models, innovation budget and strategic partnerships.	End-of-life: landfill, re-use, recycle	Product offering looping
	Impact: global impact on land, water, atmosphere and society	Communication and engagement regarding circular economy customer, stakeholders, raising awareness	Complementary indicators for assessment: Energy use, CO2, water use, cost, price variation, toxicity,	
Scope	Sourcing and procurement, product design and business models, waste management, governance, and environmental impact.	Governance, product design, sourcing and procurement and business models.	Sourcing, manufacturing, use, disposal.	Assess individual product offerings and BM over single or multiple lifecycles
Approach	Risk assessment, high in the causal chain	Comparision, incentivize, competition, race to the top, top down, meeting criteria.	Internal assessment, opportunities for transition, effectiveness	Affect decision making, quantify impacts, identify barriers/ Benchmark, compare
Indicators	Set of indicators (Units of service for normailzation)	Score (categories have same weight)	Material Circularity (Kg)	Circularity Indicator ($)
Principles	All materials are cycled infinitely	All materials are cycled infinitely	using feedstock from reused or recycled sources	Minimisation of waste in products and product systems
	All energy is derived from renewable or otherwise sustainable sources	All energy is derived from renewable or otherwise sustainable sources	reusing components or recycling materials after the use of the product	Consideration of the business ecosystem, effective collection and cycling systems and transparency
	Human activities support ecosystems and the rebuilding of natural capital	Human activities support ecosystems and the rebuilding of natural capital	keeping products in use longer (e.g., by reuse/redistribution)	Maximization of flexibility
	Resources are used to generate value (financial and other forms)	Resources are used to generate value (financial and other forms)	making more intensive use of products (e.g. via service or performance models)	Solar income
	Human activities support human health and happiness	Human activities support human health and happiness		Minimisation of total energy content of goods and services
	Human activities support a healthy and cohesive society and culture	Human activities support a healthy and cohesive society and culture		Retain value
Company level principles	serve as a conscious steward of resources and the biosphere by recognizing and acting within key planetary limits			
	not act in a way that removes resources from functional availability for future use			
	not exceed a “fair share” of resources or the right to pollute considering inter-generational, inter-species, and inter-cultural equity			
	use resources efficiently, making use of material and energetic conservation and cascading			
	use resources in a way that produces a range of values including and beyond financial value, and avoiding inappropriate allocation of scarce or impactful materials to frivolous functions			

Appendix 4 Alignment and misalignments analysis of stakeholder proposals: purpose

	Purpose					
Circle Economy	closing the material loops	keep resources for future generations	to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
VBDO	closing the material loops	keep resources for future generations	to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Viktoria ICT	closing the material loops	keep resources for future generations	to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
EMF	closing the material loops	keep resources for future generations	to know what natural resources they depend on	to identify internal opportunities they have from waste streams	to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition

Appendix 5 Alignment and misalignments analysis of stakeholder proposals: scale

	Scale				
Circle Economy	the value chain	product offerings and components	company	life cycle	business model
VBDO	the value chain	product offerings and components	company	life cycle	business model
Viktoria	the value chain	product offerings and components	company	life cycle	business model
EMF	the value chain	product offerings and components	company	life cycle	business model

Appendix 6 Alignment and misalignments analysis of stakeholder proposals: criteria

	Criteria						
Circle Economy	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
VBDO	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness
Viktoria	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material	retain value	reuse	origin of inputs		remanufacturing	hazardousness
EFM	recycling	smartness	waste reduction	number of times the product is used	waste generation	material intensity	type of busines models
	refurbishment	energy use	costs	renewability	dependency on future materials	repairing	value proposition
	closing the material loops	retain value	reuse	origin of inputs		remanufacturing	hazardousness

Appendix 7 Alignment and misalignments analysis of stakeholder proposals: principles

Principles			
Circle Economy	**VBDO**	**Viktoria**	**EMF**
Closing the material loops	Closing the material loops	Closing the material loops	Closing the material loops
Systems thinking	Systems thinking	Systems thinking	Systems thinking
Resilient system	Resilient system	Resilient system	Resilient system
Maximize value	Maximize value	Maximize value	Maximize value
Collaboration	Collaboration	Collaboration	Collaboration
Renewable energy sources	Renewable energy sources	Renewable energy sources	Renewable energy sources
Strong sustainability	Strong sustainability	Strong sustainability	Strong sustainability
Positive footprint	Positive footprint	Positive footprint	Positive footprint
Future- based orientation	Future- based orientation	Future- based orientation	Future- based orientation

Appendix 8 Similarity analysis of expert scientific literature review

Authors	Principles								
Graedel (2002)	Non human natural ecosystems are models for industrial activity in terms of cycling, community and diversity	Human technological activity is placed in a broader ecosystems context	Systems perspectives for environmental analysis and decision making	Exante environmental considerations	Businesses as policy makers rather than takers	Dematerialization	Forward-looking analysis		
Garner and Keolian (1995)	Systems view of interactions between industrial systems and ecosystems	Future oriented	Cyclic processes instead of linear	Reduce environmental burden of industrial system	Multidisciplinary approach	Equilibrium oriented			
Frosch (1992)	Integrate material and energy wastes into the production process	Avoid central planning or top down approach	Have a robust, flexible system	Systems thinking					
Gallopoulos (2006)	Manufacturing processess are part of a larger whole	Systems approach to for analysing and designing manufacturing processes	Reduce generation of waste and materials						
McDonough(1992)	Insist on rights of humanity and nature to co-exist	Recognize interdependence.	Respect relationships between spirit and matter.	Accept responsibility for the consequences of design	Create safe objects of long-term value.	Eliminate the concept of waste.	Rely on natural energy flows.	Understand the limitations of design.	Seek constant improvement by the sharing of knowledge.
Cradle 2 Cradle	Eliminate the concept of waste	Eco-efficient energy production	Treating Clean Water as a Valuable Resource and Fundamental Human Right	Positive Support for Social Systems					
Sustainable Principles	No systematic accumulation of non-renewable substances	No systematic accumulation of human-made substances	Not to systematically reduce physical conditions of the ecosphere	Efficient and just use of resources for satisfying human needs					
Description	**Closing the material loops**	**Collaboration**	**Resilient system**	**Renewable energy sources**	**Systems thinking**	**Maximize value**	**Positive footprint**	**Strong sustainability**	**Future oriented**

Appendix 9 Similarity analysis for expert non-scientific literature

ID	Author	Country	Institution	Type	Principles				
3	**Accenture (2014)**	Global	Accenture	Consulting	Growth is decoupled from scarce resources	Companies focus on rethinking products to reduce waste.	Companies get involve in after-sales stages of the supply chain.		
2	**Ellen Macarthur Foundation (2013)**	UK	Ellen Macarthur Foundation / McKinsey	Foundation/ Consulting	Design out waste	Build resilience through diversity	Rely on energy from renewable sources	Think in systems	Waste is food
4	**Port of Rotterdam and Rabobank (n.d.)**	Netherlands	Rotterdam/Rabobank	Government /Private	Minimise the use of inputs and eliminate waste and pollution.	Maximise the value created at each stage.	Manage flows of bio-based resources from and back into the biosphere, and recover and retain flows of non-renewable resources in closed loops.	Establish mutually beneficial relationships between companies within each circular chain.	
4	**Webster (2013)**	UK	Ellen Macarthur Foundation	Foundation	Circular economy is about systems, not components.	There must be a balance between efficiency and effectiveness (resilience).	Promote positive spirals of change.	Cascading products.	
1	**Preston (2012)**	UK	Chatham House	Think tank	Renewable energy and efficiency	Resource loop is closed	Positive impact on the environment and society	Collaborative consumption and production	
5	**Various authors (2014)**	Europe	Friends of Europe	Think tank	A CE is regenerative	Optimisation of biological and technical flows	Caring for manufactured capital	Balancing efficiency and effectiveness	
7	**IMSA 2013**	Netherlands	Circle Economy	Think tank	Restorative by design	Closed material loops	Waste is minimised	Cascading products.	Resilience by diversity
Description			**Systems thinking**	**Renewable energy**	Closing material loops	Maximize value	Resilient system	Positive footprint	Collaboration

Appendix 10 Summary of expert interviews

Dimension	Academia			Consultancies				Others	
Component	**Experts input**								
Purpose	closing the material loops	keep resources for future generations		to know what natural resources they depend on	to identify internal opportunities they have from waste streams			to make decisions that would encourage strategies towards circularity	to communicate the importance of the transition
Scale	the value chain	product offerings and components	company	life cycle	the value chain	business model	product	none	
Aspects	recycling	smartness		number of times the product is used		waste generation		recycling	leasing
	refurbishment	energy use		renewability				repairing	value proposition
	closing the material loops	retain value		origin of inputs				remanufacturing	hazardousness
	reuse	dependency on future materials		type of busines models				resuability	
	costs	waste reduction		material intensity				renewability	