Master thesis in Industrial Ecology

Developing a circularity self-assessment tool: *a case study for the Dutch plastics industry*

By Xander Arntzenius, 2020

Abstract – The European Commission published the “EU action plan for the Circular Economy” in 2015, the Dutch government strives for a circular Netherlands before the year 2050 (Rijksoverheid, 2016) and Rotterdam aims for circularity as the norm in 2030 (Rotterdam Circulair, 2018). To reach these goals, set by governmental organisations, change is required in all levels of society: individuals, municipalities, companies and other types of organisations. This master thesis focuses on the role of companies in the transition towards a circular economy. Companies often have limited insights in their circular performance. A current state analysis is needed to set realistic targets and keep track of the progress. Currently, there is a lack of workable tools that facilitate this analysis. For such a tool to contribute to the acceleration of the progress towards a circular economy, it is considered of great importance that it is easy in use and stimulates the user to action. This research developed a self-assessment rubric to create insights in the circular performance of an individual company. A case study was conducted for the Dutch plastics industry. The result was tested in cooperation with three companies and the results proved to generate relevant insights.

Keywords: Circular Economy – Circularity assessment – Assessment rubrics – Plastics industry

Developing a circularity self-assessment tool: *a case study for the Dutch plastics industry*

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In collaboration with

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Berenschot

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Preface and acknowledgements

Before you lies a string of words. Approximately 29.000. With some help here and there, I have put them in the right order and supported them with some tables and figures to make a comprehensive story out of it.

I would like to thank all the people that helped me put these words in the right order.

First of all, *Mark*, thank you for your guidance. Each meeting we had, and it were a lot, you gave me new energy and the confidence that was required to continue working on this project.

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Finally, my unofficial but harshest supervisor, *Lieke*. This thesis would have not existed if you hadn't helped me as well as you did.

This thesis is the final product of my years of studying in Delft. As a 17 year old boy I entered the student life in Delft and as a 25 year old boy I will say goodbye. My years in Delft have brought me experience, knowledge and discipline (at least some), but even more, it brought me friends, fun and memories. These experiences and friendships have taught me most, and therefore I thank everybody.

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1. Problem introduction

This chapter will describe the context of the project. This master thesis will focus on assessing circular economy practices within companies. This chapter will start with exploring some of the literature that is considered relevant basic knowledge of the topics that are included in this project. A general introduction is followed by brief literature studies concerning the *Circular Economy* and *Measuring circularity.* A *Knowledge gap* and *Research objective* will be described and this will result in the *Research questions* for this project. Finally, this chapter will be ended with a description of the *Scientific contribution, Societal relevance* and *Fit with Industrial Ecology program.*

1.1 Introduction

These days, in 2020, our global society is facing a variety of anthropogenic environmental challenges. Increased greenhouse gas (GHG) emissions and resource depletion are consequences of the linear economy, which has been the established norm since the Industrial Revolution. The linear economy is depicted as a take-make-dispose system by the Ellen MacArthur Foundation (2017). 'Take' refers to extracting finite resources from the earth's crust, 'make' represents (mass)production and 'dispose' is portrayed by landfills, plastic soup and waste incineration plants.

Research of experts shows that earth's finite resources cannot sustain the global society's level of 'welfare' at the rate we consume some of these elements nowadays (Gordon, Bertram, Graedel, 2005). Plastic debris has accumulated in the oceans (Wabnitz, Nichols, 2010) and is directly harming ocean wildlife (Sigler, 2014). Finite resources reoccur in our current energy system in the form of fossil fuels. Not only product manufacturing, but also energy production is mainly fed by non-renewable resources. All these perceptible changes or challenges show the need for a structural change in our society as it is today.

However, there is an alternative to the established linear economy: the Circular Economy (CE).The CE is a concept first mentioned in the 1980's (Bassi, Dias, 2019), but has gained a great deal of academic and practical interest over the last years. Due to this increasing interest, it has grown rich in a vast variety of definitions. The Ellen MacArthur Foundation (EMF, 2015, page 1) describes it as "an industrial economy that is restorative or regenerative by intention and design". Other elements that are often used when describing the CE are "closed cycles of material and energy flows" (Mathews, Tang, Tan, 2011, page 467; Geng, 2013, page 1526) and "decoupling economic growth from the consumption of finite resources (EMF, Granta-Design, 2015, page 7). Regardless of the variety of definitions, all definitions in some way address to the need to reduce material and energy extraction from the earth's crust.

The variety of definitions of this concept make it hard to work towards a CE in a concrete way. Different countries, industries, companies and processes *complicate the development of a standardized unit* to quantify the circularity of an economy, on micro, meso or macro scale. This makes it challenging for governments, municipalities, companies and other

types of organizations to benchmark their current status, identify key problems, set realistic goals and estimate the effects of measures. Governments have already started to set goals, but there is no method ready to measure the progress (Planbureau voor de Leefomgeving, 2018). Municipalities and companies have to work towards these goals, but may have different definitions of a Circular Economy (or no definition at all). Concluding: there is a need for structure.

1.2 Circular economy

In the problem introduction, several elements of definitions of the CE are mentioned. Some of these are formulated more general (“an industrial economy that is restorative or regenerative by intention and design”, EMF, 2015) while others make it more specific and measurable (“closed cycles of material and energy flows”, Mathews et al., 2011; Geng, 2013). In a research done by Elia, Gnoni and Tornese in 2015, the circular economy is divided in five phases, where changes can be made: material input, design, production, consumption and End-of-Life (EoL). These five phases refer to all different steps and actors in the value chain. In a linear economy, these are five consequential steps, where the material input and the EoL are not connected.

The circular economy connects the EoL products and materials phase, to the material input phase, in order to minimise the products and materials ending up as waste as well as the required feedstock for new production. A (theoretical) fully circular economy would use all EoL material as feedstock for new production (EMF, 2015).

The fact that there is little consensus on the exact definition of CE, does not mean there are no well-known theories and organisations. One of the best-known organisations that spreads the philosophy of the Circular Economy is the Ellen MacArthur Foundation. Their visualisation of CE, called the Butterfly Diagram, is a widely used infographic that explains their vision on a circular economy (Figure 1). This image presents material and product flows as two loops within the biosphere and the technosphere. The biological nutrients (such as food) that we use in society should be safely returned to the biosphere, whilst the technical nutrients (such as metals) should be used over and over again, while kept at their highest possible value. This value level is shown by the loops in the technosphere. A smaller loop is preferable (so maintenance rather than recycle), because it requires less energy and therefore keeps the technical nutrients at a higher level than in a larger loop (wherein there is extra energy required to retain the value of the product or material).

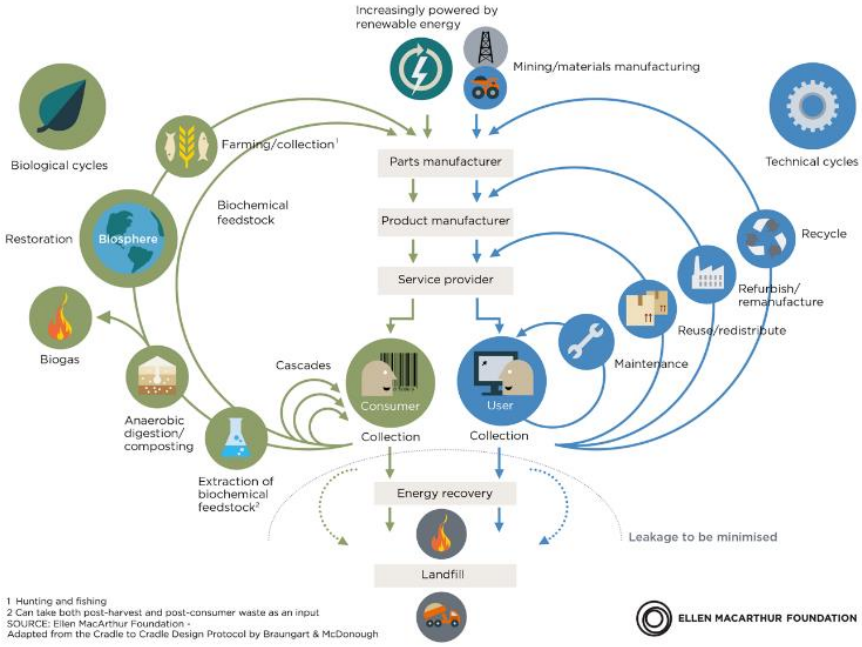

Figure 1 Circular Economy Butterfly Model by the Ellen MacArthur Foundation (2015)

Besides this diagram, the Ellen MacArthur Foundation describes four sources of value creation within the CE. These four elements are described in Figure 2. The power of *the inner circle* states that the negative externalities increase the larger the circle gets. This is also why a product or material should *circle longer* within the same cycle. Using a product longer before it enters a larger cycle reduces the need for new products or materials and thus for virgin material input. *Cascaded use across industries* gives a material the chance to be used in a new industry, losing some of its value, but still retaining a large share (in comparison to becoming waste). For example, garment that was used for clothing can later be used for furniture and finally end up in insulation material. Then finally, *pure/non-toxic/easier-to-separate inputs and designs* is required to gain the highest possible material and product value in all the circles described earlier. Mainly in post-consumer material flows there is a diverse mixture of material sorts. Pure, non-toxic, easy-to-separate materials increase the value of material flows after they have worked their way through as many cycles as possible. Together, these two images by EMF give a short insight in what the context of CE entails.

The Circular Economy already plays a role in governmental policy. The COP21, often referred to as the Paris Agreement, shows that the environmental challenges we face are challenges of global scale. 175 states, whereof 174 countries and the European Union, signed an agreement to take measures to keep the global average temperature rise well below 2,0 °C and preferably below 1,5°C (UNFCCC, 2016). This (practically) global agreement accelerated the authorities to incorporate environmental policies in their program. CE targets have been a substantial share of these policies. The European

Commission published the “EU action plan for the Circular Economy” in 2015 (European Commission), the Dutch government strives for a circular Netherlands before the year 2050 (Rijksoverheid, 2016) and Rotterdam aims for circularity as the norm in 2030 (Rotterdam Circulair, 2018). These governmental institutes have already started implementing measures contributing to reach CE targets: the Council of the European Union has adopted new rules to reduce plastic litter ending up in the ecosystem, specifically in marine environments (European Commission, 2018).

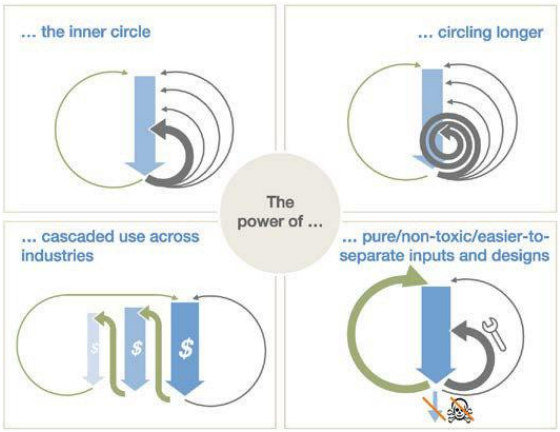

Figure 2 Sources of value creation by the Ellen MacArthur Foundation (2015)

The diagrams by EMF and the governmental plans concerning the Circular Economy give a brief insight in what the concept currently means, on a conceptual level, and what role it plays in policy making. It also explains that the topic is relevant and will only become more relevant, portrayed by the examples of the European, Dutch and Rotterdam governmental institutes.

1.3 Assessing circularity

On many different scales, governments have been setting targets that contribute to the transition towards a circular economy (local, regional, national and continental levels). To be able to monitor *effectiveness of governmental measures*, and to monitor *the progress towards these goals*, it is essential to be able to measure this abstract topic. The changes that contribute to CE will have to applied in all levels of society, and a large share of this change will have to come from business industries. The companies within these business industries will have to be guided by the governments to work towards these goals. Therefore, it is needed to provide these companies with the tools to assess and improve their circular performance. Currently, there is a lack of such a tool (Prieto-Sandoval, Jaca, Ormazabal, 2017).

A lot of different circularity indicators are existing based on various principles or frameworks. These indicators can be underlying of Life Cycle Analysis (LCA), MFA

(Material Flow Analysis), DfX (Design for X), I-O (Input-Output), etc (Sassanelli, Rosa, Rocca and Terzi, 2019). For example, the Dutch organisation Planbureau voor de Leefomgeving (PBL), based its analysis on the extensive R-ladder, existing of 10 steps to keep a product or material at its highest possible value (Potting, Hekkert, Worrel and Hanemaaijer, 2016). This list of 10 steps is composed by the following 10 words: refuse, rethink, reduce, reuse, repair, refurbish, re-manufacture, repurpose, recycle, recover. These words are strongly related to the sources of value creation as described before (by the Ellen MacArthur Foundation), the higher the word is on the list (e.g. refuse), the smaller the circle and the higher the retained value.

Besides the underlying theories, *existing indicators can be categorised in other ways.* The paper by Saidani (2019) tries to bring order in the chaos of the circularity indicators. They create a taxonomy based on ten criteria to classify the existing indicators into different categories (Saidani, Yannou, Leroy, Cluzel and Kendall, 2019). Indicators such as the ACT (Assessing Circular Trade-offs) (Circle Economy and PGGM, 2014), which should help to make circular decisions, the BCI (Building Circularity Indicators) (Verberne, 2016), which specifies the circularity of buildings, the IMCEE (Indicators for Material input for CE in Europe) (EEA, 2016), and many more similar indicators. In this study, they assess 55 different circularity indicators using 10 different criteria. These categories give a useful indication of what questions are important to ask when designing a framework like this. The 10 criteria that are used in this paper are: level of CE implementation, CE loops, performance, perspective, usages, transversality, dimension, units, format and sources. These criteria give interesting insights in what elements play a role in circularity assessment.

There are attempts by companies and other organisations to develop a holistic tool that assesses a company's circularity. The master thesis by Camacho Otero from Chalmers University (Gothenburg, 2015), analyses four circularity assessment tools. These are developed by Viktoria Swedish ICT, VBDO, Circle economy and the Ellen MacArthur foundation. A framework was developed to assess these tools on their completeness. Otero argues that the four tools that were assessed do not give a full review of the circularity of a company (Otero, 2015, *5. Conclusions*). The assessment frameworks are rather complementary than that one framework gives a complete overview. *Another tool* that was not considered by this study was developed by Hogeschool Windesheim (2018). It is an Excel tool and poses questions per category of circular business operations. These questions can then be answered by stating: 'never', 'almost never', 'sometimes', 'often' or 'always'. Although the tool is user friendly, the questions remain at a relatively superficial level and the potential answers ask for more context specific information.

To explore the available tools for circularity assessment by companies, a structured search for existing assessment tools online results was done. However, this delivered a meagre result. Searching for services of company circularity assessment online, using 'Circular economy assessment company' and 'Calculating circularity' presented 19 hits (see Appendix A). The search terms that were used can be found in the table in Appendix A. Scanning through the descriptive texts of these webpages, merely three assessment tools turned out to describe an actual assessment of the circularity of a company (marked in yellow in the table of Appendix A). All of the tools that were found, offered as services by

companies, were undisclosed tools and frameworks behind paywalls. Although this evidently gives no clear insight in what type of outlines these tools used, it does stress the lack of easily accessible tools for companies to use, experiment with and learn from.

Not only the content of such a tool would be important for the use of it. The success of such a tool would also lie in the use of it. This makes it important to identify the right empirical requirements of a circularity assessment tool.

These interesting cases and studies give a first insight in the dynamics of circularity assessment in the academic environment. Governments on every scale have large interest in circularity indicators and meso/macro level monitoring, whilst the change has to be implemented on a micro scale. For companies, there is not one dominant format to create insights in the company's circular performance, and to give suggestions to improve this. To summarize this section in bullets (per paragraph):

- Monitoring the progress towards a circular economy is of interest for many organisations, especially on company level
- Many different theories and principles can potentially underly assessment frameworks
- Examples for categorising circularity indicators are: level of CE implementation, CE loops, performance, etc.
- Examples of tools used for circularity assessment
- Search for assessment tools online

1.4 Knowledge gap

In the previous two sections, literature shows there is a lack of consensus on how to approach the Circular Economy. No single definition is adopted broadly, no indicator is used dominantly and no criteria are being used as a standard to assess circular performance. The knowledge gap is identified by the absence of the standardized assessment criteria for business operations. There is a lack of a structured set of criteria that entail all elements of a circular economy.

1.5 Research objective

As is pointed out in the previous section, the knowledge gap, there is a lack of a coherent set of criteria that is able to encompass the circular economy. There is an interest for monitoring the progress towards a circular economy from a higher governmental level, such as European, Dutch or provincial level. A generic method to measure circularity on company level can be developed using a set of criteria like described in the knowledge gap. This lack for a generic method to assess circularity on company level is also pointed out by the recent studies of Saidani et al. (2019), Moraga et al. (2019) and Sassanelli et al. (2019). As do several other papers confirm: there is a lack of a workable tool that could help an organisation create insights of their circular performance (Parchomenko, Nelen, Gillabel and Rechberger, 2018) and this is particularly on the micro level (individual company level) (Elia, Gnoni and Tornese, 2016).

A circular economy is a complex concept that will bring a lot of change to all parts and all levels of society. All different industries and company sizes will encounter the topic in a

different way and this creates the need for generic and flexible assessment tools that can be applied to all industries. From overarching perspective however, a certain similarity in structure would be very beneficial. The research objective is *developing a method to create a tool to assess the circular performance of an individual company*, that can be constructed for companies in different industries in a similar way.

The focus will be on companies that are not advanced yet in their circular performance. These are companies that are becoming increasingly aware of the environmental problems originating from product manufacturing and material consumption, the companies that lag behind in the transition towards a circular economy. The focus will mainly be on this group of companies, because stimulating these companies to start adopting circular practices in their business operations will gain the most improvement. Also, these companies can learn most from circular economy theory put into practice. This means the focus will be on the management of these companies, that give direction to the strategy of the company. The tool will be used in a board meeting with the management of the company, where the tool would facilitate a strategic session. Its purpose for exposing the current state of the circularity of the company, as well as providing the insights to improve this circular performance, makes the use of *self-assessment* function well in this context.

1.6 Research questions

In this paragraph, the previously described knowledge gap and research objective (Section 1.4 and 1.5, respectively) are rephrased into questions that will further guide the outlines of the research.

The global interest in circularity measurement, that assesses the circularity of an organisation, is clear. The absence of a standardized tool is also clear. An analysis of the required characteristics of such a tool has to lay the basis for the design of this methodology. After this, its validity should be verified by case studies in practice. To rephrase these needs in a research question:

How can the progress in the transition towards a Circular Economy of an individual company be assessed?

What can be noticed is that the question starting with ‘How’ will end up with a result that tells ‘the way to do something’. This means the main result of this research will be a method, that can be used to construct a tool that can be used to assess the circularity of a company.

Another noteworthy element is the ‘individual company’, which, as has been mentioned before, will put the focus on micro-level measurement.

The main research question will be answered by answering four sub questions that will split up the main research in smaller parts. These four questions are the following:

1. What are the empirical requirements for a framework to assess the progress in the transition towards a Circular Economy of an individual company?
2. What definitions of the Circular Economy exist and what definition will be used in this research?

3. What are the most important areas of action for circular business practices and levels of progress, to use as a base for the assessment framework?
4. How can the areas of action be translated into concrete criteria, and divided in different levels of progress, to assess the circularity of an individual company within a specific industry?

The approach and methodology on how to answer the main research question and the four sub questions will be explained in further detail in Chapter 2 – Methodology.

1.6.1 Scientific contribution

This research proposes a method that can be used to construct an assessment tool for different industries. Because of the empirical nature of the context of this research, there is an urge for a practical perspective, this is partially why a case study will be performed to validate the method. In this case study, the result of executing the process steps of the derived method, will be used to assess the circular performance of a company. This validates two things at the c. The research prior to the case study will rely on the available circular economy theory that can be found in literature, and companies will be involved to validate the accuracy of the translation in the empirical environment. This means that the main scientific contribution lies in summarizing and clustering the scientific knowledge on circularity and translate this into a practical approach.

1.6.2 Societal relevance

From a public perspective, there is strong interest in the Circular Economy. The targets that have been set are not without urgency. Many of the anthropogenic environmental problems as mentioned in the first paragraph of the introduction are strongly related with the current linear economic system. Climate change is acknowledged worldwide as a menace to our existence as it is today. Resource depletion and extremely rapid biodiversity loss are on the verge of becoming equally large global problems with equally large impact. The Circular Economy is a start to change the current status quo, in order to prevent these problems from radically changing the planet earth.

To meet targets and goals set by these governments, there is a need for more grip on the topic of the circular economy. Practically all products and materials that flow through our society are brought in society by companies. That is why the focus for this research will be on companies. This master thesis will present a method that could help accelerate the development of tools that could give this extra grip. With the focus on companies that are not implementing any circular business operations yet and might lack knowledge or insights in how they could contribute, much is to be gained in these first steps.

1.6.3 Fit with Industrial Ecology program

This topic and research objective neatly fit the characteristics of the Master Programme of Industrial Ecology. The Industrial Ecology Programme can be identified by a holistic approach of sustainability challenges in multi-actor sociotechnical environments. In more colloquial words, the study focuses on having sustainable development successfully

implemented in society. In this case, the project involves many different types of actors. Companies, governments and consumers all play their part and all have to collaborate towards a more sustainable society. The circular economy is a means to work towards a society that can continue in a way so that it can sustain itself for future generations to live in this same society.

2. Methodology

This chapter will describe the steps and methods that together will give shape to the research. The research approach will describe the approach that is dominant during the research. This will focus on what the role of Design Science in this project will be explained. In Section 1.5 – Research questions, the main research question is split up in four sub questions. This chapter will go more into depth in the coherence of these questions and how they together will collect the required knowledge to answer the main research question. Firstly, the research approach will be explained. Secondly, the course of the research will be explained with the use of a research flow diagram. Finally, the sub questions will be discussed more in depth.

2.1 Research approach

In Section 1.5, the Research objective was described. This states that this research will work towards a method to construct a tool to assess a company's circular performance. For this research objective, the appropriate approach will be described.

To develop a method like this, it requires a Design Science approach. "The objective of Design Science research is to develop technology based solutions to important and relevant business problems" (Hevner, March, Park, Ram, 2004, page 83). The process cycles that are involved in the field of design science research, also written by Hevner, include the Relevance cycle, the Rigor cycle and the Design cycle, see Figure 3. The cycles refer to the steps being iterative.

The Relevance cycle preserves the necessity and adequacy of the designed artefact. Also, this cycle focuses on the actual application environment. This environment is where the context, requirements, user group, etc. will interact with the tool to be developed. On the other side, there is the Rigor cycle. *The Rigor cycle* will include the scientific knowledge and theories that support the design. This is also where experiences, expertise knowledge and existing artefacts and processes are put under. In between the Relevance cycle and the Rigor cycle lies *the Design cycle*. This is the cycle where the design of the tool combines the actual environment and scientific foundation. This is an iterative process where the tool will be made, evaluated, adjusted and evaluated until it meets the requirements. The balance between constructing and evaluating the design tool is very important. A tool that is sufficiently supported by relevance from the environment, but not enough by the Rigor cycle, lacks a foundation and is therefore insufficient as a whole.

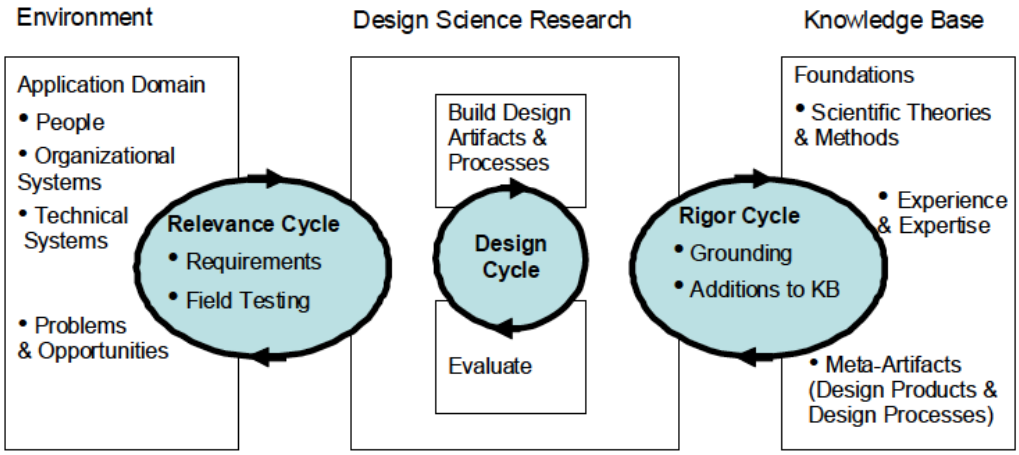

Figure 3 Three cycles of design science research by Hevner

The main objective of the research is to develop a method to construct a tool for companies in different industries in a similar way. Developing a method that has such a practical result as a product (an assessment tool for companies), but is supported by a scientifically supported structure, requires an iterative process. This complies with how Hevner (2014) described a design approach in his framework for design science. As described earlier, the three cycles should ensure the scientific support and empirical connection.

The Rigor cycle, the basis for the scientific support, will mainly be covered by literature. This is because theoretical support is required from verified sources. Scientific literature is a relatively reliable source for this. The Relevance cycle will mainly be covered by interviews. This is because the Relevance cycle is supposed to guarantee the practical relevance of what is derived from scientific literature. The interviews will be mainly with circular economy experts and industry experts. The Design cycle will require an accurate fusion of the information to be gathered from the other two cycles.

2.2 Research flow diagram

The research flow diagram, that can be found in Figure 4, is a visual representation of the way the research is structured. At the top right, a small legend explains what the colours and shapes in the Figure mean. The dark blue circle represents the answer to a sub question. Which sub question it answers is indicated in the top of the circle. Besides the blue circles, there are boxes in two colours, light blue and orange. The light blue boxes represent process steps that will support the answer to the sub questions. The orange boxes show the accompanied methodology to the corresponding process step.

As will be described in the next section, Section 2.3, and as can be seen in the research flow diagram, a case study will be carried out. Answering sub question 4 will be an iterative process in combination with performing the case study. The case study is used as both the validation of sub question 4 as part of the validation for the developed protocol. In the case study, the steps of the protocol will be followed, which will be composed in Chapter 6. This entails it will translate the generic framework, constructed in Chapter 5, to an industry specific assessment tool. These process steps of the case study (and thus, the protocol)

are displayed in a light orange box. This light orange box merely indicates that these steps together form a whole and are part of the validation process of sub question 4.

To make sure the research flow diagram is as clear as possible, some insights that have been gained during the research, in particular in the description of the process steps of the case study, have been used in the overview.

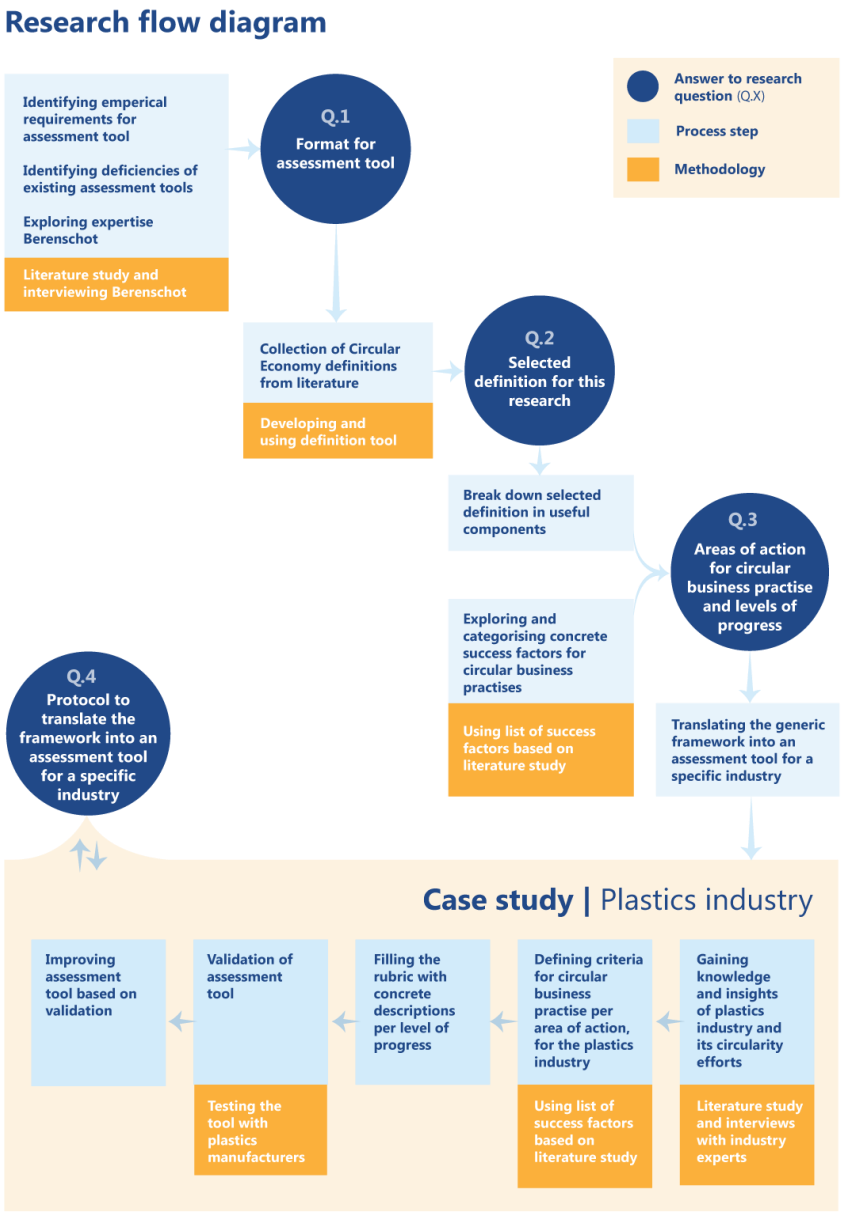

Figure 4 Research flow diagram

2.3 Research questions in depth

The main research question is divided up into four sub questions. Therefore, the research will be divided up in four Chapters, where every Chapter will discuss and answer one sub question. To answer the main research question, the different components are to be answered by these sub questions. To recapitulate, the main question to be answered is:

RQ: How can the progress in the transition towards a Circular Economy of an individual company be measured?

The first sub question will determine in what format the assessment tool will be developed. It will explore the important elements for a tool to be of added value for a company in an empirical environment and in what format it can be used best. The question therefore is:

Q1: What are the empirical requirements for a tool to assess the progress in the transition towards a Circular Economy of an individual company?

To answer this question, firstly, literature will be consulted. A brief introduction into the concept of the circular economy has been given in Section 1.2, however, this literature can be used to derive first requirements of the tool. Also, as has been referred to in Section 1.3, research has been done in reviewing assessment tools for company circularity ((Camacho Otero, 2017). From this type of literature, requirements for an assessment tool can be derived. Secondly, brief interviews can give insights into available and known formats for assessment. This can give more insight in the formats that are suitable for this type of assessment. The answer to this question will result in a format for an assessment methodology and other essential elements that will be taken into account in the rest of the project.

The second sub question will explore the field of the Circular Economy. As described in Section 1.2, there are many different definitions and there is a lack of consensus on these definitions. Therefore, this question will help to find the definition that will be used in the rest of this research:

Q2: What definitions of the Circular Economy exist and what definition is used in this research?

Answering this question starts by studying the literature for scientific definitions of the Circular Economy. To analyse the definition sample that will be collected, a tool will be constructed, that helps the user find a definition. Literature will be consulted to draft a list of dimensions. The user declares which of these dimensions should be included in the definition the user is looking for. It displays all the definitions that meet the requirements that were selected by the user. If multiple definitions meet the selected dimensions, the user analyses the resulting definitions and chooses the most suitable definition. If there are many definitions that meet the dimensions, the user can consider to add an extra dimension as a requirement. This way, the tool will help to select a definition that is suitable for the context of the research.

The third sub question will explore the empirical side of the Circular Economy theory. For this is where the generic assessment framework will be constructed. This will exist of two axes, the vertical and the horizontal axis, that will contain areas of action and levels of progress, respectively. Areas of action are types of activities a company could do to improve its circularity. They can be seen as categories of business practices. Levels of progress describe the extent to which companies have made progress or effort in these areas of action. The areas of action and levels of progress will be defined in this question.

Q3: What are the most important areas of action for circular business practices and levels of progress, to use as a base for the assessment framework?

This question will be answered by using the definition that will be the result of sub question 2. The definition will be broken down into relevant elements that the definition contains. These different elements will define the areas of action. To validate the accuracy of the elements that were derived from the definition, literature on success factors for circular business practices will be consulted as well. The levels of progress will be determined by literature. The result of this question will form the skeleton of the generic assessment tool to be used for the assessment of individual companies. This will be the same for different industries, since the definition that is used as a base is the same. If one would want to do this for a different purpose, another definition will have to be selected, and the methodology can be followed from there.

The fourth sub question will use the generic skeleton of the framework as a base to construct the assessment tool for any specific industry. This way, the generic framework can be used to develop a tool for all different types of industries. The areas of action from the generic framework will be specified in criteria that are specific per industry

Q4: How can the areas of action be translated into concrete criteria, and divided in different levels of progress, to assess the circularity of an individual company within a specific industry?

The fourth sub question, other than the previous three, starts with the word ‘How’. The answer to this question will be a method. Which means that the answer to this question is a protocol: a stepwise description of how the translation from the generic framework to the specific assessment tool can be done. This protocol will be constructed using elements from literature that has been reviewed earlier in the research. Also, interviews with industry and Circular Economy experts will help to shape the protocol. To help construct this protocol, a case study will be performed.

The case study will be the part where the protocol from sub question 4 will be developed and tested simultaneously. The protocol will be the process to transform the generic framework into an assessment tool for a specific industry, and describe the steps undertaken to do this along with the process. After testing the result of this process (the industry specific assessment tool), the protocol will be evaluated for its accuracy. The case study will be performed for the Dutch plastics industry. This is one of the industries pointed out as a priority by the Dutch government (Rijksoverheid, 2017). Besides this, recent European measures, concerning single-use plastics, are putting the industry under pressure (European Parliament, 2019). This makes the plastics industry an interesting

case. The result of this case study will be a circularity assessment tool for the Dutch plastics industry, as well as the evaluated protocol. In this process, expert interviews will help to collect the required information and insights in the plastics industry, to complete the specific assessment tool. To verify the relevance of the result, the completed assessment tool will be tested in practice with companies from the Dutch plastics industry. Three companies will participate in a session where the assessment tool will be tested, to measure the company's circular performance and discuss the results. This validation will be used to assess the first version of the design and subsequently improve the assessment tool.

3. Rubric format for circularity assessment

3.1 Introduction

In this chapter, the first sub question will be answered and the steps towards that answer will be explained. To answer the question, mainly literature and experience of consulted experts will provide the supporting information.

The format for the assessment framework will, for a large share, be dictated by empirical requirements. As the question is: *'What are the empirical requirements for a framework to assess the progress in the transition towards a Circular Economy of an individual company?'*.

As the final paragraph of Section 1.5 describes, the tool will be used in board meetings for companies that are not actively involved in improving the circular performance of a company, but are becoming increasingly aware of the necessity for change. The use of the *self-assessment tool* in this meeting would function as a current state analysis and provide insights in what could improve the circularity of the company.

3.2 Simplicity

As was described in Section 1.2, there is no established assessment framework available for circularity assessment on company level. Besides this, we have learned that the Circular Economy is a complex concept that entails more than increasing your company's recycling rate. The concept goes accompanied with a profound change in the way we manufacture products, operate businesses and consume products.

This means that all kinds of companies need to adapt to circular economy principles, therefore a method for assessing the circularity of a company, involves all types and all sizes of company. *This is why there is a clear need for a tool that is easy to use and is constructed in a way that it is approachable for all types of users*. SME owners come from all different levels of education and all different levels of experience with the Circular Economy. Also with little knowledge of the circular economy the tool should be clear and easy to use.

The research paper by Hopff, Nijhuis and Verhoef (2018, p. 15, *Conclusions*) presents one very clear conclusion in the effort of mapping out circular innovations in campus management, but stresses it as a general organisational challenge: *'One conclusion of this study is that the complexity must be reduced, especially in the initial phase, for the tactical and operational level.'* This statement is about the complexity of the circular economy as a concept. Nonetheless, this statement translates to the need of a simple tool as well. Also, it puts emphasis on the tactical and operational requirements. Describing the principles of a circular economy on an operational level is assumed to communicate the essences in a conceivable way.

Several required characteristics for a tool can be derived from this simplicity. The tool should be easy to use. Not only the use, but also the content in the tool is required to be easy to understand. Therefore, the used vocabulary should be not too complex. The tool should use texts and descriptions that the user can read and understand. Elements in the tool that are not self-explanatory, have to be explained at some point.

3.3 Flexibility

Besides simplicity, a tool also requires a certain level of flexibility. In the paper by EMF (2014), five principles are mentioned as the base for a CE: 1) design out waste, 2) build resilience through diversity, 3) rely on energy from renewable sources, 4) think in 'systems' and 5) waste is food. These fundamental elements of a circular economy show that a change is required in all different parts of business practices. From product design and product portfolio to responsible energy consumption, and from 'system thinking' in management decisions to closing the loops by applying circular thinking in the procurement. This means that in measuring all variant aspects of this concept, the data will present itself in qualitative and quantitative data forms. This creates the need for a flexible format for assessment, that is able to cope with measurable, but also unmeasurable values.

Additionally, in 2017, a conference paper by Camacho-Otero and Ordoñez was published that drafts an evaluation format for circular assessment tools. In the conclusions, it points out that a circularity assessment tool for company level measurement should entail elements like 'resource stewardship', 'management decision making', 'fostering engagement' and a 'focus on multiple scales' (Camacho-Otero et al., 2017, Section 5. Conclusions). This again shows the need to have a flexible format that can incorporate both quantitative and qualitative data easily.

Besides these aspects mentioned in the research, one of the main conclusions is that 'a significant challenge lies in how to incorporate context specificities into an assessment tool'. This inquires another form of flexibility from the assessment tool format. The endless variety of companies, in multiple axis (such as size, industry, motivation for sustainability, etc.) will ask for flexibility in interpretation, so that the user can weigh their own business practices, policy, decisions and innovation projects along a set out scale. An existing tool, designed by Ioannou, Hanekroot and Reijngoud, (2015, VBDO), seems to capture many elements that are labelled as essential by Camacho-Otero, however, the binary nature of the framework seems to miss out on the main conclusion mentioned earlier, where context specific elements should be captured in the tool.

3.4 Rubrics

A format that seems suitable for this context is the assessment rubrics. Interviews with industry experts (see Appendix B.1, B.2, B.3, Joost Krebbekx, Siem Haffmans and Jasper Klomps), have given new insights in common formats for assessment tools, that do incorporate the flexibility that has been defined in Section 3.2. Assessment rubrics are used more often to start a conversation in a very structured way. For this type of purpose they often make use of assessment rubrics, not unknown to myself (and my peer students from all over the world).

An assessment rubrics format uses important criteria that are put in a scheme on a vertical axis, with the score on the horizontal axis. The table is then filled with explanations on to what extent a person or company should meet the criterion to get a certain score. This is a method for assessing certain given criteria in a context, whereof the content or specific situation can vary in many ways. This is why it is often used to grade student projects, since these type of projects can vary in many ways (topic, data sources, methodology, supervisors, deliverable, etc.). To illustrate, an exam which has right and wrong answers can be judged on the answer, projects however, usually bring more challenges that are dependent on the specifications of the project. Therefore, a more qualitative assessment of the competences exposed during the project is required to reflect the quality of the work that has been presented. This variability in project context is comparable to the vast variety of companies (and their specifications) that can get in contact with an assessment tool like this, as was described in the prior Section, 3.3.

Additionally, research has showed that rubrics assessment improves the learning and planning processes of the assessed subjects. An assessment rubric shows what elements of the topic that is being assessed are important. In an educational environment, this has shown to reduce anxiety for students, improve their planning skills and improve the overall quality of deliverables (Pandero, 2013). The uncertainty of unknown subjects, such as the circular economy principles to many entrepreneurs, could be compared to the uncertainty that students experience when they are not aware of what elements are important for their personal assessment. The reduction of anxiety could therefor perhaps translate to reducing aversion for small and medium sized (SME) entrepreneurs that have no intrinsic affiliation with circular economy business practices within their company. However, this is an assumption and has not been supported by any source. This characteristic of the assessment format perfectly aligns with the intention of this research.

Finally, the method is easily adaptable. An extra criterion on the x-axis and on the y-axis can be implemented anytime during constructing or evaluating the rubric assessment form. This makes that this format for assessment is also conveniently usable for designing a generic framework skeleton, that can then be changed to the content that is specific for each industry.

3.5 Conclusion

In conclusion of this Chapter, the first sub question can be answered. The answer consists of two parts: the empirical requirements and the format in which the framework will be given shape. The user context of the presumed assessment tool requires two main empirical characteristics: simplicity and flexibility.

Simplicity – the tool requires a format that is understandable for users from all educational and expertise levels. This is expressed in an easy to use assessment format, an understandable vocabulary, readable and understandable text and clarifying explanations where necessary.

Flexibility – the tool is required to process data of variant nature. Both qualitative and quantitative data should be able to function as input for the assessment method, indicating a need for flexibility in this sense. Additionally, as literature (see Section 3.3) pointed out,

there is a need for flexibility to incorporate criteria that will give content for the industries specifically. Besides this, it requires adaptability to use a generic framework that can be adapted to any specific industry, whilst preserving the same skeleton. Finally, the format can be expanded or shortened at any moment in the development process.

Besides these two empirical requirements, valuable characteristics have been identified for assessment rubrics as an assessment format. This format has shown (in educational environment) to let the user learn better by creating an insightful overview of what the important aspects of the to be assessed topic is (Pandero, 2013). In this case (if applicable in this context, which has not been researched in the study by Pandero), that would increase the knowledge of assessed companies of circular economy business practices.

The assessment rubric can adopt the drafted requirements well. Since the format for assessment uses descriptive texts, it possible to *use easily understandable texts and an appropriate vocabulary*. More complicated terminology can be explained by supportive texts. The descriptive texts will contain elements that make it possible for the user to estimate their score clearly. *Besides these simplicity requirements*, qualitative and quantitative data sources can easily be included in the scoring. The tool can also easily be expanded or shortened. This makes assessment rubrics a suitable format.

4. Definition tool and chosen definition

Circularity cannot be measured if it is not defined. Although we have discussed the topic, being a core concept of this research, it has not explicitly been defined yet. The sub question that will be answered in this section is: *'What definitions of the Circular Economy exist and what definition is used in this research?'*.

4.1 Introduction

In this chapter, the process of constructing a tool that will help to select a suitable definition for the context of this research, will be explained. For this, several steps will be taken. Firstly, a sample of definitions will be collected from scientific sources. Afterwards, literature will be consulted to define important dimensions that are used to categorise definitions of the circular economy in other studies. Consequently, these definitions will be assessed for the drafted dimensions. Fourthly, dimensions that are important for the context of this research will be selected. To conclude this chapter, a definition will be selected to use in further steps of this study.

Many scientific studies that concern the CE, include the search for a proper definition to be used during their study. The definition tool that was developed in this chapter, can contribute to accelerating this process for many scientific studies to follow. This tool will be attached to the research paper as a separate Excel file.

4.2 Definitions

During a first round of literature review, both the content and purpose of the research were important. We were looking for meta-analyses, researching the concepts and definitions of the circular economy. This resulted in a small amount of useful studies, that can be found in Table 3. Especially the study by Kirchherr, Reike and Hekkert (2017) proved itself relevant to this type of literature study. It had done a lot of work that could be used and it gave new insights in how to approach a systematic literature review like this. The definitions that were collected in the study could be used and were only to be complemented by definitions published from 2018 till present.

Table 1 Selected results from first literature search with terms "circular economy definition"

Title	Authors
Conceptualizing the circular economy: An analysis of 114 definitions	Kirchherr, Reike en Hekkert (2017)
The circular economy and circular economic concepts—a literature analysis and redefinition	Geisendorf & Pietrulla (2018)

How do scholars approach the circular economy? A systematic literature review	Merli, Preziosi en Acampora (2017)
The circular economy umbrella: trends and gaps on integrating pathways	Homrich, Galvão, Gamboa Abadia en Carvalho (2017)
Towards a consensus on the circular economy	Prieto-Sandoval, Jaca en Ormazabal (2017)

To build on the work that had been done by Kirchherr et al., another round of literature searching proved indispensable. Since the research was published in 2017, and the amount of publications in the field of CE have not diminished, this round was needed to replenish the list of definitions, by including new definitions as they were published in the past two years. To collect a new sample of definitions, the scientific database 'Scopus' was consulted. Fifty results were found on with the search terms and limits as follows: *"Circular economy" AND definition, 2018-present, "circular economy" as keyword, English.* From these 50 results, 9 abstracts contained a definition. These could be added to the list of 114 from the previous research. After reviewing these 114 definitions, number 63 appeared to exist of two definitions, so we split these in two separate ones, ending up with 115 different definitions from the research by Kirchherr. Combining these 115 definitions with the 9 that were found in newly published papers, this amounts up to 124 definitions of the Circular Economy.

4.3 Dimensions

The total sample collection contains 124 definitions. To classify these, all are tested on certain dimensions. These dimensions were drafted from the studies mentioned in Table 1. In these studies, criteria are used to distinguish definitions and CE concepts from each other. Each study uses different criteria to categorise the different definitions and CE concepts. These are collected and compared, eventually to select relevant criteria to proceed with. Firstly, all the elements for categorisation used in the papers were collected. Then, they were compared to find recurring elements and their relevance was reviewed, to prevent irrelevant or overlapping dimensions. The overview of categories used in the reviewed papers and the way they were combined can be found in Appendix C.1.

The selected dimensions can be found in Table 2. After drafting a list of useful dimensions from literature, the definitions themselves pointed out which parts were left unaddressed to repeatedly. In other words, while assessing the definitions for the dimensions, insights of new relevant dimensions were gained and added to the list. This way, the list of dimensions was revised continuously. The first column of Table 2 shows the category of the dimensions, the second column shows the dimensions and the third column shows an example of when a dimension is marked as mentioned in the definition.

In the next sections, the drafted dimensions will be described one by one. The dimensions are explained in coherent sets of dimensions. To illustrate, Section 4.3.1, titled 'System perspective', will describe the dimensions system perspective, micro product-level, micro company-level, meso-level and macro-level.

Table 2 Dimensions used to classify the collected definitions

Category	Dimension	When does a criterium get a '1'?
System perspective	System perspective	" is understood as a system that is designed to"
	Micro product-level	" that takes the reusability of products and materials and"
	Micro company-level	"superior design of materials, products, systems and business models"
	Meso-level	" in a broader system encompassing industrial firms"
	Marcro-level	" redesigns industrial systems at the system level"
Motivations	Sustainable development	"to develop a sustainable, low carbon, resource efficient and competitive economy"
	Environment	"results into higher conservation of natural resources and "
	Economy	" that a healthy economy and environmental health can co-exist"
	Society	" bring great environmental, economic, and social benefits as"
Approach	Resource efficiency	" is meant to encourage resource-use efficiency and integrates"
	Renewable energy	" shifts towards the use of renewable energy, eliminates"
	Cleaner production	"eliminates the use of toxic chemicals"
	Industrial collaboration	" closed systems are the basis of so-called industrial symbiosis"
Perspective	Slowing the loop	" in which material flows keep circulating at a high rate"
	Closing the loop	"along with the notion of a closed-loop system"
	Narrowing the loop	"aiming to maximize resource efficiency"
Distinction	Distinction between cycles	"and return to the biosphere, and aims "
	Biological cycle	"distinguishes between technical and biological cycles"
	Technical cycle	"and technical nutrients (non-biological materials), which"
Enabler	Supply side	" deeply transforms production chains and "
	Demand side	"transformative economy redefining production and consumption patterns"
	Regulation and policy	"the high priority of waste recycling is supported by legislation, policies, and directives"
CE principles	Waste hierarchy	" as a way to obtain more value from resources while reducing material throughput."
	Reduce	"covering the activities of 'reduce, reuse, and recycle'"
	Reuse	"(CE) principles such as reuse and recycling"
	Recycle	" industrial substance reuse and recycling in regional level "
	ReSOLVE	-
	EMF definition reference	"a circular economy is restorative and regenerative by design"

4.3.1 System perspective

Not every definition used the same scale to describe the circular economy. Yes, all definitions describe an economy, which implies a system, but no, not all the definitions put the emphasis on the same scale. The definitions mention the scale when measures or goals are discussed, or important actors or required changes are described. In these parts of the definition, the system often (not always) is addressed to. Herein, the distinction was made between '*system perspective*', to check whether the definition approaches the CE as a system at all. The '*micro product-level*' and '*micro company-level*', those criteria were observed present when the definition described the role of incremental product improvement and the need for companies to change in daily operations and perhaps also business model, respectively. Then, '*meso-level*', is assessed present by words that describe a collective of organisations bound for any reason, like regional or sectoral connections. For example, descriptions entail keywords like 'Eco-Industrial Parks (EIP's)', 'throughout the value chain', 'within Dutch borders', etc. Then finally, '*macro-level*' zooms out even more to get to the scope of large countries, sectors or industries cross-border, groups of countries like the EU and also the global perspective is a macro-system.

4.3.2 Motivations

Usually, the CE is described as a means to a goal, meaning that the CE is not the goal itself. To work towards a circular economy, a definition can include different types of motivation. Three motivations reoccur in divergent ways, and are therefore used in the tool: sustainable development, environment, economy and society. One specific sentence that is often used says a CE is 'to decouple resource depletion from economic growth' (Liu, Li, Zuo, Zhang, & Wang (2009, p. 265); Beek, Heijden, Ridley, & Alteren (2016, p. 8); McKinsey & Company (2015); etc.). All the papers analysed from table 1 mentioned this category, but not all definitions mention all three elements of the Triple Bottom Line (Homrich et al. 2018), also known as People, Planet, Profit, or more recently, People, Planet, Prosperity. These three elements do not get an equal amount of stage time in the academic world. Environmental quality (52) and economic prosperity (48) both have a significant higher number of mentions than social equity (19), in the tested sample.

4.3.3 Approach

In this context, approach means 'solution approach'. This set of dimensions became clear because the definitions were mentioning these solutions alternately. The most used solutions, or measures, in the definitions for CE were: 'resource and energy efficiency', 'renewable energy', 'cleaner and purer production' and 'industrial collaboration', therefore, these dimensions are used in the definition tool. These solutions refer to corresponding problems, where also some overlap is noticeable. Resource and energy efficiency would be a solution to finite resource depletion. Renewable energy addresses mainly to GHG emissions, as does cleaner and purer production. Industrial collaboration finally, goes hand in hand with resource and energy efficiency.

4.3.4 Perspective

Within the papers listed in table 1, the perspective on the CE differed, regarding how circular the Circular Economy should be. Three types were defined and used in the tool: slowing the loop, closing the loop and narrowing the loop. Slowing the loop is practiced by extending the product's lifetime. Closing the loop refers to the post-use destination of a product or material, focussing on recycling. Narrowing the loop would be exercised by increased resource efficiency, resulting in a smaller (narrower) required input of raw materials. These keywords: 'slowing', 'closing' and 'narrowing' could be appointed to the three phases in a product life cycle as well. Narrowing, indicating material efficiency during production. Slowing, thus extending product lifetime, happens during the use-phase of the lifecycle. Finally closing the loop would align with the end-of-life protocol for products and materials that have lost their function.

4.3.5 Distinction

In the renowned Butterfly model, by the Ellen MacArthur Foundation (EMF), a distinction was made between biological and technical nutrients. Biological nutrients are biological elements that can be reabsorbed in the ecosystem, whilst technical nutrients will not be digested in nature. These nutrients move through the biosphere and technosphere, respectively.

4.3.6 Enabler

A definition often shows its perspective on where the change should happen to effectuate the transition towards a Circular Economy. Of all the definitions that mention, in direct or indirect ways, an enabler in the definition (72), the vast majority mentions a required change on the supply side (64 mentions). The demand side (20 mentions) and regulation and policy (12) were less appointed to. The supply side, in this context, refers to production. The companies that design and produce everything on the market, and not only products, but also services offered by the market. The demand side represents the consumers. Some definitions mention the required change in consumption pattern, but, as illustrated, significantly less than for the supply side. As for the regulation and policy, they stay out in the clear. Merely 12 definitions include, directly or indirectly, the role of the policy makers as an enabler.

4.3.7 CE principles

In the 'CE principles' dimension, a variety of commonly used terms that describe circular practices are collected. The set of 'reduce, reuse, recycle' is one that is often used to describe these CE practices. This sequence implicitly addresses to a certain waste hierarchy, since the sequence is never: recycle, reduce, reuse. It advocates the higher value maintained of reduce over reuse over recycle. Though, these terms were also used isolated from the others, where no specific waste hierarchy was mentioned, therefore, all three the terms were analysed separately. Waste hierarchy is also mentioned separate, since the use of only one of three terms does not imply a hierarchy. Also, 'ReSOLVE' was mentioned as a dimension. This is a bundle of six ways to implement circular practices, as

proposed by the EMF in 2015 in their publication ‘A toolkit for policymakers’. This dimension seemed interesting, because of its action oriented approach and simple way of communicating. However, none of the 124 definitions mentioned the ReSOLVE framework. Finally, it was noticed that the definition of the CE as compiled by the EMF, was referred to the most. The ‘ economy that is restorative and regenerative by intention and design’, drew attention and therefore was adopted as one of the dimensions. In the end, 20 definitions used direct citations of the EMF.

4.4 Classification tool

The tool was made in Microsoft Excel. Explanatory figures can be found in Appendix C2. The tool consists mainly of two tabs: Input & results and Definitions. The definitions tab is the database from where the input tab will collect the definitions. The definitions tab consists of a table containing the definitions (a total of 124), vertically structured, and the dimensions (a total of 28) horizontally structured. How these elements were collected was described in the previous Sections (4.1 - Definitions and 4.2 - Dimensions). The definitions were all assessed on the dimensions and when an element was recognized in the definition, this part in the text was coloured red (manually) and the corresponding dimension received a ‘1’ in the right cell. This is the backlog for the tool. If new definitions were to be imported, they can be added consecutive to the last current definition and it will be used in the classification as well.

The input tab shows the row: ‘input scenario’ in grey. This is where the user of the tool gives weight to the dimensions that are of his or her interest. If a dimension is required for the definition the user is looking for, the user puts a ‘1’ in the appropriate cell. On the right side of the scenario input, in yellow, the amount of definitions that meet the given requirements are given. These definitions are displayed beneath the scenario input row. Only the first 20 results are displayed, so if the results include more than 20 definitions, than the definitions tab can be used and filtered for all the 1’s in the column ‘Results scenario (AND)’. It is also possible to determine the amount of definitions that meet one of the given criteria. This way, for example, if one needs to know how many definitions address to either reduce, reuse or recycle, this number can be found by unhiding column ‘AG’.

4.5 Definition selection

For this research, one definition as a base for the assessment framework has to be chose. To select a definition that fits neatly into the context of this research, the dimensions that were drafted can be used. Since the context that is sketched is from the perspective of an individual company looking to improve their circular performance, there are some dimensions to be highlighted. First of all, the circular economy is reviewed as an system, where actors have influence on each other and eventually the system should, as a whole, become a circular one. This is why the system perspective criterium is considered as important. Also, the micro company-level is of our interest. This is because we look from the perspective of one company, one company that wants to improve their circular performance. Because of the system perspective, collaboration is required between actors within such a system, this is why the criterium industrial collaboration is considered as well. Besides that, in the Netherlands, we are eventually looking to fully close the loop, so this

dimension is selected as well. The change would in this case need to come from the supply side, because this is the side that represents market-driven change. Finally, to make sure the focus will be aligned with the levels of value preservation, the waste hierarchy dimension is also included in this selection. When selecting these six dimensions (system perspective, micro company-level, industrial collaboration, closing the loop, supply side, waste hierarchy), the definition tool gives only one result. This result is the following definition, published by Merli, Preziosi & Acampora in 2018 (p1. Abstract):

> *"Circular Economy (CE) aims to overcome the take-make-dispose linear pattern of production and consumption, proposing a circular system in which the value of products, materials and resources is maintained in the economy as long as possible … CE studies follow three main lines of action: the first aims to change the social and economic dynamics at macro and administrative level the second to support firms in circular processes implementation at micro level to spread new forms of consumption and product design the third, developed at meso level, discusses industrial symbiosis experiences. CE is associated with a variety of concepts, and waste management emerges as the most relevant sub-sector. CE is also strongly connected with the concept of sustainability, proposing ways to operationalize its implementation at the environmental and economic level, while scholars only marginally consider social and institutional implications. The most explored practices are those related to cleaner production, aiming at reducing environmental impact and waste production along the life cycle of a product, and optimizing the performance and efficiency of processes. Conversely, studies on CE may devote greater attention to strategies for social and institutional changes, able to transform the upstream process of production and consumption. Considering business model strategies, scholars mainly focus on studying closing material loops strategy, while slowing the loops, which requires a radical change of consumption and production patterns, is only marginally included with respect to CE implementation."*

4.6 Conclusion

To answer the sub question second sub question as it was formulated in Section 1.5: *'What definitions of the Circular Economy exist and what definition is used in this research?'*, a collection of 124 definitions was put together (mainly collected in earlier research by Kircherr et al.) and a definition tool was constructed. In this research, the tool was used to determine what definition is best appropriate for the context of this research. This functions as a base for the rest of the research.

From the 28 dimensions that were drafted in Section 4.3, 6 were reviewed as relevant for the decision in the definition that will be used for this research context. These 6 dimensions are the following:

1. system perspective,
2. micro company-level,
3. industrial collaboration,
4. closing the loop,
5. supply side and
6. waste hierarchy.

The collection of definitions, use of the definition tool and the 6 dimensions of interest, collected in Section 4.5, have together answered the second research question. The answer to this research question is the scientific definition of Merli et al. and can be found in the previous section The definition by Merli et al. contains 17 of the 28 elements that were drafted. The 6 required dimensions were described very concisely, as can be seen in the following parts:

1 & 6 "Circular Economy (CE) aims to overcome the take-make-dispose linear pattern of production and consumption, proposing a circular system in which the value of products, materials and resources is maintained in the economy as long as possible"

2 & 3 & 5 "CE studies follow three main lines of action: the first aims to change the social and economic dynamics at macro and administrative level the second to support firms in circular processes implementation at micro level to spread new forms of consumption and product design the third, developed at meso level, discusses industrial symbiosis experiences."

4 "The most explored practices are those related to cleaner production, aiming at reducing environmental impact and waste production along the life cycle of a product, and optimizing the performance and efficiency of processes."

5. Areas of action and levels of progress

This Chapter will show the development of the skeleton for the generic framework. This is the part where the definition for the Circular Economy, that has been selected previously, in Chapter 4, will be translated into a more practical version. The sub question that will provide us with these answers is: '*What are the most important areas of action for circular business practices and levels of progress, to use as a base for the assessment framework?'*.

5.1 Introduction

The business model canvas is a tool that helps to identify the divergent aspects of a company, in order to create overview of the important business processes. This method, developed by Osterwalder and Pigneur in 2010, shows clearly that companies have many activities they execute besides the core activities. Besides this, we know that improving the circular performance of a company's business practices requires changes in many different levels of the business operations. The different type of actions that are sought for whilst answering this sub question are called 'areas of action'. Within the assessment rubric, these will give body to the vertical axis.

These company areas of action will get more concrete content when translated to the assessment tool for a specific industry. The score however is part of the generic framework. This is what we will call the 'level of progress'. These words will describe the extent to which a company meets the one of the descriptions.

A thing to notice is that these areas of action will be dependent on the outcome of the selected definition. Which means that if one would run through this process again, with a different purpose or in a different context, the selected definition could differ from the definition selected currently. This would also mean the outcomes for the consecutive process steps could differ.

5.2 Selected definition

In Section 4.6, a definition was chosen, as a result of using the definition tool. This definition is reviewed in this section. Following, one can find the definition. Important elements that say something about circular business practices are marked grey.

"Circular Economy (CE) aims to overcome the take-make-dispose linear pattern of production and consumption, proposing a circular system in which the value of products, materials and resources is maintained in the economy as long as possible … CE studies follow three main lines of action: the first aims to change the social and economic dynamics at macro and administrative level, the second to support firms in circular processes

implementation at micro level to spread new forms of consumption and product design, the third, developed at meso level, discusses industrial symbiosis experiences. CE is associated with a variety of concepts, and waste management emerges as the most relevant sub-sector. CE is also strongly connected with the concept of sustainability, proposing ways to operationalize its implementation at the environmental and economic level, while scholars only marginally consider social and institutional implications. The most explored practices are those related to cleaner production, aiming at reducing environmental impact and waste production along the life cycle of a product, and optimizing the performance and efficiency of processes. Conversely, studies on CE may devote greater attention to strategies for social and institutional changes, able to transform the upstream process of production and consumption. Considering business model strategies, scholars mainly focus on studying closing material loops strategy, while slowing the loops, which requires a radical change of consumption and production patterns, is only marginally included with respect to CE implementation."

In order to be able to aggregate these terms later, the useful components of this definition are categorised in more general terms the components attribute to. This is done in the following table.

Table 3 Elements from the definition formulated into more general terms

1	**'production and consumption'**	**System perspective**
	This part of the sentence explains that a circular economy requires change at both the production and consumption side of the economic system. This means CE uses a system perspective.	
2	**'proposing a circular system'**	**System perspective**
	Extra emphasis on the system perspective is mentioned in these words.	
3	**'value of products, materials and resources is maintained in the economy as long as possible'**	**Preserving value**
	These words explain the need for preserving the value of the products, materials and resources that are circulating in the economy.	
4	**'change the social and economic dynamics at macro and administrative level'**	**Paradigm shift**
	A profound change in social and economic dynamics addresses to a shift in paradigm.	
5	**'circular processes implementation'**	**Business model, production and design**
	Supporting firms in circular processess indicates different ways where firms can implement circular thinking.	

6	**‘new forms of consumption and product design’**	**Business model and design**
	New forms of consumption can get shaped by new business models. Product design is generalised to design.	
7	**‘industrial symbiosis’**	**Collaboration**
	An industrial symbiosis is a form of collaboration and is therefore mentioned as the more general term: collaboration.	
8	**‘waste management’**	**Waste management**
	Waste management is considered as a general topic.	
9	**‘operationalize its implementation at the environmental and economic level’**	**Business model**
	Combining the environmental and economic perspective brings a company to a circular business model, therefore, business model is used as a more general term.	
10	**‘aiming at reducing environmental impact and waste production along the life cycle of a product’**	**System perspective**
	Along the life cycle refers to the system perspective.	
11	**‘optimizing the performance and efficiency of processes’**	**Production processes**
	This refers to the production processes.	
12	**‘business model strategies’**	**Business model**
	This has been mentioned before and is generalised as busines model.	
13	**‘closing material loops strategy'**	**Waste management**
	Closing loops refers to using waste as new input for production.	
14	**‘consumption and production patterns’**	**Business model**
	The addition of the word ‘patterns’ is important in this context. Through the word 'patterns' it refers to a business model that determines the ownership and consumption of products and materials.	

These elements (system perspective, preserving value, paradigm shift, business model, design, collaboration, waste management and optimizing production processes) will be used in the further analysis, that can be found in Section 5.3 and 5.4.

5.3 Exploring literature for success factors for circular business practises

The previous section has provided several insights in what exactly defines circular business practises. To elaborate further on this and to validate the elements derived from the definition, additional research was consulted. This literature can be found in an overview in Appendix D.1. In total, 11 scientific and non-scientific sources have provided a long list of criteria that were used to indicate the circularity in societal and business environments.

To illustrate, the thought process for one of these 11 sources will be explained in more detail. The following paper, by Geisendorf & Pietrulla (2018), is a paper that analyses the concept of CE and attempts to redefine the concept. During this analysis, 8 different types of criteria are used: 'efficiency in waste reduction', 'zero waste', 'technological/biological substances', 'product development', 'raw material sourcing', 'production processes', 'End-of-Life/disposal' and 'transportation'. Of these criteria, five were validated as useful and were put in a list of categorisation used in literature ('zero waste', 'product development', 'production processes', 'End-of-Life' and 'transportation'). This means that three elements have been left out of this list ('efficiency in waste reduction', 'technological/biological substances' and 'raw material sourcing'). This is mainly because these elements were either less relevant, or enclosed within one of the other elements. To illustrate, the CE works towards zero waste, making efficiency in waste reduction redundant. The division between technological and biological substances is considered not applicable for many companies, and additionally, the appropriate way to separate these different substances is enclosed within the 'End-of-Life'. Finally, raw material sourcing does not take place in a CE and the combination between circular product development and circular production processes entails the procurement of secondary sourced materials.

Similar to the analysis of the criteria used by Geisendorf & Pietrulla (2018), the ten remaining documents have been reviewed. The compilation of these criteria was put together in an overview that can be seen in Appendix D.2.

5.4 Combining the definition and literature analysis

The selected elements derived from the definition analysis and the full literature analysis have been merged into a list that can be found in Appendix D.3. This list contains 37 criteria, whereof many can be neglected because of strong overlap of content. More interesting is the aggregation of these elements. In the aggregation, the all the collected criteria have been arranged in such a way, that all of them are mentioned by overarching categories. This aggregation can be found in the Table 3.

Table 4 Areas of action aggregation

1	Policy and management	Securing goals
2	Design	Zero waste
		Product development
		End-of-Life/disposal
		Waste is designed out
		Prioritize regenerative resources
		Pure material flows
3	Cleaner and purer production	Energy demand
		Renewable energy
		Sustainable water use
		Production process
		All energy is based on renewable sources
		Transportation
		Water resources are extracted and cycled sustainably

		Preserving value
4	Business model innovations	Reverse cycle
		Set up global reverse networks for products and components
		Reorganize and streamline pure material flows
		Materials are cycled continuous at high value
		Business model
		Diversity builds strength
5	Knowledge & experience	Communication
		Innovation
		Diversity builds strength
6	System thinking	Synergies
		Industrial collaboration
		End-of-Life
		Network innovations
		System perspective
		Paradigm shift

The elements that were extracted from the definition recur in this list in the following ways: system perspective – system thinking, preserving value – both in design and business model, paradigm shift – system thinking, business model – business model, design - design, collaboration – system thinking, waste management – production and optimizing production processes – production.

The aggregation was performed by reviewing the full list of criteria and compiling it into sub sections. This process resulted in six areas of action that form the y-axis of the generic framework. Further on in the report, these areas of action will be displayed in figures to create an overview. In Figure 5, the corresponding icons can be found that will be used in these figures.

Figure 5 Icons used for the six areas of action

Figure 5 reveals part of the relation between the areas of action that Figure 6 displays more clearly. It can be seen that the dark blue circle in the centre represents the company that is to be assessed. Since it is still unclear in what industry this company is active, the light blue circles are general types of organisations that virtually every company interact with during their business operations (be it one type of actor more than the other), namely: suppliers, institutes and organisations, other companies, consumers, governments and suppliers. The company in dispute is part of a sociotechnical system that is filled with the type of actors as just described. The icons that we have seen in Figure 5 are placed within

this system. The dark blue ones that are located in the circle are part of internal business operations of the company, whilst in contrary, the orange squares are areas of action that concern interactions with the other actors in this system too. This is why the lines between the central and surrounding circles are coloured orange as well. Finally, there is a dependency implied by the use of the arrows starting at the policy icon.

Implementing a structured change in organisational decisions, usually lies within the management department, responsible for the policy making, this is the area that influences the other areas that are within the internal company business operations. It should be noted that the areas of action 'knowledge & experience' and 'system thinking' are influenced by policy as well, but other than the remaining four, they are also strongly dependent on other actors within the system.

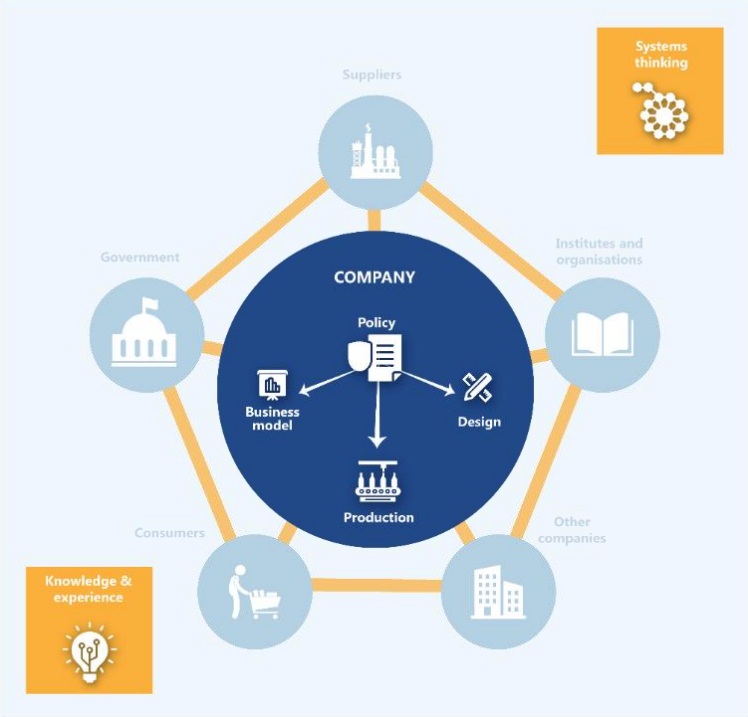

Figure 6 Coherence between the 6 areas of action

5.5 Levels of progress

In any assessment rubric, there is the requirement to have two axes that describe the framework. The construction of the vertical axis has been elaborated in Section 5.4, prior to this section. The horizontal axis describes the degree to what extent the user meets the description from the assessment tool. Theoretically speaking, the horizontal axis could be a number. This is how it is used in a student grading scheme. However, the strength of the method, as described in Section 3.2, is the ability to cope with qualitative and quantitative data in one framework. Besides this, it is also a requirement that the assessment tool is constructed in a way that context specific elements are communicated in such a way that the user can estimate their score based on descriptive elements, see Section 3.5.

The horizontal axis contains words that describe the level of progress of a company, containing the least circular business practise in for this factor, the most circular business practise, and several stages in between. This is determined subjectively per criterion. A scale containing five stages is able to capture the main differences in business practises, keeping the descriptions different enough to be able to make distinction, and say something about the level of progress at the same time. However, it can occur that, given a specific success factor, it is complicated to draft five distinctive levels of progress. In this case, which will be reviewed per situation, one of the levels of progress can remain unfilled and therefore non eligible.

Given the fact that even the least motivated companies (for circular business operations) are obliged to follow changes in national or industry specific regulations, the least active a company can be, is ‘reactive’. If one is more interested, motivated or more often confronted with circular business practices, but not implementing it on a regular basis, the company can be called ‘aware’. The next step would be for a company to systematically take circularity into account and be confronted with the topic on a frequent basis. The company might also have circularity included in a decision making process, or some other similar routine, though not as a priority yet. This level is called ‘systemic’. When a company is very pro-active in improving their circular business operations and is actively putting effort in this, this will be called ‘ambitious’. Finally, the front runners of the industry and companies that have successfully implemented circular business operations and participate (and lead) research and innovation projects are called ‘advanced’.

5.6 Conclusion

To conclude this chapter, the sub question will be answered in this paragraph. Sub question 3 is: *What are the most important areas of action for circular business practices and levels of progress, to use as a base for the assessment framework?.* In the previous two sections, the process of constructing the areas of action and the terms for the levels of progress have been described (Section 5.4 and 5.5, respectively). These axes together will describe the generic assessment framework skeleton. Beneath, in Figure 7, a visual representation of these axes can be viewed. This figure can be reviewed as the answer to the third sub question, since both components of the question are put in the scheme.

In further elaboration to the answer of sub question 3, displayed in Figure 7, the coherence between the areas of action (in the vertical axis), is mapped out in Figure 6, to be found in

Section 5.4. This mainly shows the difference between the areas ‘policy’, ‘design’, ‘production’ and ‘business model’, being internal areas, as opposed to the fourth and fifth, being ‘knowledge & experience’ and ‘system thinking’, respectively, concerning interaction with other actors in the sociotechnical system. Also, the first four areas have an extra relationship. The policy area influences the other three areas. The policy area is the starting point for many implementations within company change, this is why the arrows in the Figure are used.

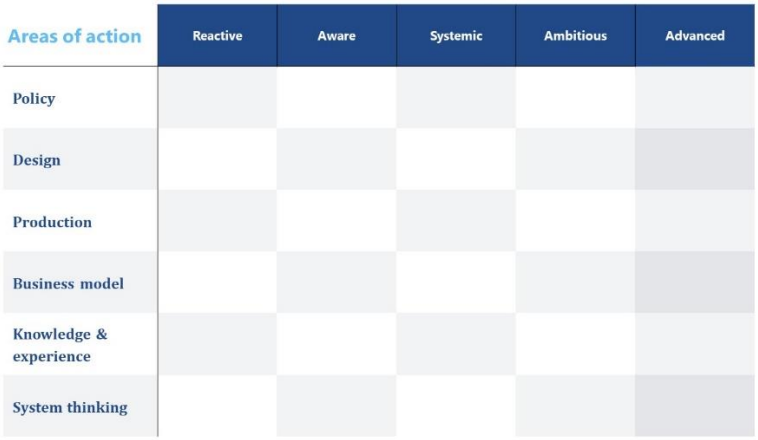

Figure 7 The skeleton for the generic assessment framework, composed by the areas of action on the vertical axis and the levels of progress on the horizontal axis

6. Criteria for circular business practise

In this chapter, the results will be of different nature than in the previous chapters. The result of this how question, namely: '*How can the areas of action be translated into concrete criteria, and divided in different levels of progress, to assess the circularity of an individual company within a specific industry?*', will entail a protocol. The answer will be elaborated on in Section 6.1 and Section 6.2, after which the protocol will be put to practise in the form of a case study in Chapter 7.

6.1 Introduction

The starting point for this section will be the result of the previous sub question, answered in Section 5.6. The generic assessment framework will be given concrete content for a specific industry. These protocol steps are elaborated further on in Section 6.2. However, the case study (Chapter 7) played an important role in the construction process of this protocol. The construction of the protocol occurred simultaneously with performing the case study. This means that to construct the protocol, steps were taken to translate the generic assessment framework into a specific assessment tool, and they were reviewed for elements in these steps that are important. These important elements are then described as detailed as possible in the process steps of the protocol. The result is that the construction of the protocol remains concise, but is clarified more elaborately in the explanation of the case study. In the conclusion of this chapter, a visual summary of the protocol steps will be shown.

6.2 Protocol steps

The step by step approach of the protocol requires effort and analytical skills of the user. However, the steps are intended to provide a clear structure and the case study functions as an example of the elaboration of these steps.

6.2.1 Choice for industry

In any situation where this assessment framework might be consulted, the context is different. This evidently influences the choice of industry. Usually it will be clear for the user what his or her own industry of interest is, but when this is not the case, it is advisable to focus on one of the industries labelled as a priority by the Dutch government (assuming the user or reader will use the research in a Dutch environment). In 2017, the national government, called the Rijksoverheid, has published an agreement, called the resource agreement ('Grondstoffenakkoord'). At that moment, it was signed by over 180 governmental, institutional and business organisations. Since then, this number has increased to over 300 signatories (Rijksoverheid, 2017). In this agreement, five industries were identified as priority sectors: biomass and food, plastics, manufacturing, construction and consumer goods.

When it is unclear what sector matches the research context best, it is advised to use one of these sectors. It can be noted that these sectors all have clear products as a result of the business of this industry, this makes that all these industries are highly relevant to assess. Besides this, the Dutch government has also explored the challenges and opportunities for these industries and collected these in documents called the 'transition agendas'.

6.2.2 Industry exploration

To be able to analyse circular business operations in a certain industry, an extensive analysis is required to gain insights in the specific barriers and opportunities for the selected industry. If the industry is one of the five priority sectors as defined by the Rijksoverheid, the transition agendas that were mentioned in the previous section can be consulted. These documents will provide clustered directions for development that directly contribute to the improved circularity of the corresponding industry. Further than this, other scientific, but also non-scientific publications, can help contribute to the understanding of the industry.

An information dense way to gain insights in the industry is by conducting interviews with people active in this industry. Arrange at least one interview with a person that has experience in a company that is active in the industry. Also arrange an interview with someone who has experience from an overarching organisation, such as a governmental department or a branch organisation. This is because experience from this type of organisation can have other kinds of insights and more information about the sector broad than for a specific company within this sector.

During the interviews, the areas of action give structure to what kind of information is required. Ask questions that expose concrete actions that can be undertaken to improve a company's circularity within these areas of action. In this context, concrete means that it gives insights on action level. The exploration therefor focuses mainly on two things: what *can be done* and what *is being done*. This sounds similar, however, the insights from these two perspectives help to construct different parts of the assessment rubric. What *can be done* helps to identify the criteria for circularity assessment. This will show what elements are important for circularity in the specific industry. What *is being done* helps to identify the standard of the industry. With respect to the defined criteria, it identifies which practices are considered as the minimum a company has to do and which is the maximum possible a company can do. It involves making a distinction between what the companies that lag behind do, and the frontrunners. This is to be able to describe the different levels of progress for the identified criteria.

Following are some examples that help to illustrate this difference:

A) A question that identifies the possibilities in the industry to become more circular is '*In what way can products be designed more circular in the plastics industry?*'. This question prompts for things that can be done to improve circularity.
B) A question that clarifies the standard of what is currently being done in the industry is '*How much of the products in the industry are produced with recycled material?'*. This will give insights in what is the minimum expected level of the companies in this industry and what is to be considered advanced.

A) Another example is a question that addresses to the production processes that occur in this industry, like '*What do the production processes look like and what resources are used in these production processes?*'. This creates insights in what resources are being used and can be reduced.
B) Among others, the answer to the previous question will explain that machines are used for the manufacturing process. To explore what is the standard for dealing with these machines, a question like '*How are production machines maintained and disposed of within the plastics industry?*'. This will explain what is the standard for the use of machinery within this industry.

To conclude, the areas of action (policy, design, production, business model, knowledge & experience and system thinking) are explored by acquiring knowledge of the possibilities and the standards of the industry. Once these insight have been gained, the following steps can be undertaken.

6.2.3 Define criteria

After the insights have been gained, these can be used to define the generic areas of action into concrete criteria for circular business practices. The insights that were derived from the interviews will function as the main input for the criteria selection. For this selection, the list that was drafted earlier, in Section 5.4, can be used. This list contains factors that contribute to the circularity of business practices, this means there is at least inspiration for relevant business operations to be gained, but even more likely, some elements would contribute to the content of the area of action. To illustrate, an example is distilled from the case study: the area of action 'policy' is split up in three criteria; 'definition and targets', 'implementation plan' and 'roles and responsibilities'.

Once all the information that was collected through the interviews of the industry exploration is included in the criteria that define the area of action, the concept version of the criteria will be complete. Later in the process, when the tool will be tested, it will show if there are redundant elements or lacking elements that need to be adopted in the criteria.

One or more interviews at this stage of the protocol will verify the relevance of all the criteria that were combined in this process step. To validate this, walk through the criteria that have been collected and discuss with an industry expert whether the criteria give a complete view of the important elements within that area of action. Also verify if any important element is missing.

6.2.4 Describe the levels of progress

To describe the criteria in a variant amount of stages (but mostly 5), indicators are required. These indicators function as subjects that describe whether the business operations of a company are considered circular within the criteria that is being described. To clarify this, the same example as used in the previous section, Section 6.2.3, will be used. The extent to which a company is progressed in the criterion 'definition and targets' can be concluded from aspects like: has a definition been defined and put in perspective, have key problems

in the industry been identified and prioritised, and finally, have targets been drafted and have they been related to the definition. These can then be combined in a description of how these indicators are met in the different levels of progress. To illustrate this, the scale of the first criterion from the case study is viewed in the following table (Table 4):

Table 5 Descriptions of the levels of progress for the 'definition & objectives' criterion.

Criterion	Definition & objectives
Indicator(s)	Defintion, role, key problems, ambitions, priorities, goals
Reactive	**Unclarities** remain about what a circular economy is and what the role of this company in a circular economy entails. There are **no ambitions** and priorities defined. Finally, the company has **not set goals** to work towards.
Aware	The company **has defined** the circular economy and what is means for the company itself. They **have set goals** but have **not specified** how it will contribute to a Circular Economy.
Systematic	The company **has defined** what the Circular Economy means for the **company** and the **industry** it applies to. There are **goals defined** and explained why these goals are important.
Ambitious	The company **has defined** what the Circular Economy means for the **company** and the **industry** it applies to. **Key problems** in the sector have been identified and **appropriate goals** have been set.
Advanced	The company has **clearly defined** what the Circular Economy entails for **this company** and how it involves the **sector**. **Ambitions** according to the impact of the company have been defined and **key problems** have been prioritised. Also, **specific goals** have been set that address to the key problems.

6.2.5 Validate constructed assessment tool

Finally, the result of the previous steps should be validated in one or more interviews with companies, where the constructed assessment tool will be put to practice. For this, a cooperative company in the right industry will have to be addressed to. Before the companies are selected to participate in this validation process step, one should draw out the relevant dimensions in which these companies can differ, and to what extent this has influence on the validation process. For instance, for the case study performed in Chapter 7, for the plastics industry, one main element was of importance, namely, the way in which the companies were involved in the design process of the plastics products. This has resulted in a sample of three companies that were involved in the design process of the products. One company was involved at the design for manufacturing process (optimising the design for the right production process), the second was involved at the design for manufacturing process and had an own product portfolio, and the final company only produced their own product portfolio.

After the sample collection, prepare the meeting. The sessions are evidently most fruitful when these can be held with a person from the company who knows about all aspects of the company. This is not specifically someone in a certain position, it can be someone from any position. The important thing is that someone knows about the strategy and the different facets of the company.

The purpose is to fill in the assessment tool as if it were the final version, record the meeting and make sure every criterion is discussed. Always ask for information supporting the company's choice for a level of progress. During the session, clarify uncertainties but note the uncertainties to clarify these in the improved version. Pay extra attention in the exclusiveness of the descriptions. This means that if it is hard to decide between two levels of progress, the distinction might not be clear enough. If it is difficult to formulate a clear distinction, perhaps 4 or 3 descriptions will better suit this criterion.

6.3 Conclusion

Following the steps as they have been explained in the previous section, one can use the generic framework as a starting point to explore a specific industry, identify the relevant aspects for a company within this industry and combine this in a holistic assessment tool.

To conclude, the protocol steps are put together in a concise form, and displayed in graphical representation that can be seen in Figure 8. The steps to be taken are the following:

Figure 8 Protocol steps for creating an industry specific assessment tool

These are explained more elaborately in the previous sections and will be clarified by the case study in the next chapter even more.

7. Case study

This following case study is a validation process step that serves multiple purposes. The process of constructing the industry specific assessment tool will validate and complement the protocol as described in the previous section. In the case study, interviews will be conducted that validate the relevance of the result of proposed protocol. Besides this, the interviews will also validate the relevance of the content of the generic assessment framework. This means the case study as presented in this section will review multiple elements, composed throughout the complete structure of this study.

Additionally, it is important to mention that the choice of industry in this case study is not relevant for the review of the protocol as presented in Section 6.2. This is merely a means to run through this process and review how well the steps are aligned and how they lead to a relevant result.

To conclude the introduction, a final remark is essential. The assessment tool will be developed for the Dutch industry, as will the interviews be conducted with Dutch companies. Therefore, the complete content of the assessment tool will be developed in Dutch as well.

7.1 Choice for the plastics industry

In this case study, the generic framework will be converted into a specific assessment tool for the Dutch plastics industry. As described in the protocol (Section 6.2), a choice was made between the 5 priority sectors that were defined by the Dutch government.

Besides this, the actuality of the plastics industry makes it interesting. Plastic debris is a very visible consequence of the regime of the linear economy and appeals to peoples imagination. A major contributor to this public interest is the plastic soup. This has resulted in concrete action undertaken by governmental institutions, for example, the approved ban on single-use plastics (European Parliament, 2019). This attention and, consequently to this, pressure, has resulted in an active movement towards more circular business operations in the plastics industry, which for a large share has remained shockingly unchanged for the past decades (De Ruijter, Appendix B.4)(Haffmans, Appendix B.2).

Paradoxically enough (given the fact that plastic debris is iconic for the consequences of a linear production chain), plastic materials are eminently suitable materials to construct a CE with. In other words: most plastics are 100% recyclable. This means that, at the rate we use materials currently to manufacture products, we could very well use plastics in a circular economy.

Within the plastics industry, the focus will be on the actors active in the core of the industry: the plastics manufacturers. As will become more clear in the next section, different types of actors are active in the industry, from mining resources till end-users. The core of the industry however lies within the plastics manufacturers: these are the companies that use

base material (usually granulate) to produce plastic parts, components, products or semi-finished products.

7.2 Exploration of the plastics industry

A large share of the companies that together form the plastics industry are associated with the branche organisation ‘Federatie NRK’. An interview with a board member of this organisation yielded a lot of information (Appendix B.4). This information has been united in a basic graphical representation of the plastics industry as a system. This infographic can be found in Figure 9. The central actor of the infographic is a plastics manufacturer. On the bottom left there is a small legend that explains the symbols used in the figure. The actors within the system are showed within a coloured circle, the colour of the circle says something about the actor role in the system. The dark blue colour shows companies that are involved in the production chain of the plastics industry. The yellow colour indicates these actors are involved in research and innovation that involves the plastics industry. The orange colour indicates that the actor is at the demand side of the company in dispute, so end-user or brand owner. And finally, the green colour is used for the actors that play a central role in closing the material loop.

In a linear plastics industry, where virgin material is used for production, the chain starts at the oil and gas mining companies, since this is the resource used to produce plastics. From there, large chemical companies process this raw material into plastics, which is then distributed over distributors and compounders. Common plastic (like PE and PP) are produced straight away and can therefore be sent to distributors directly, whilst the more specific plastics (think of additives, UV blockers, fire retardants, etc.) also pass through the compounders. A plastic manufacturer, the type of company the assessment tool is aimed for, uses process techniques, like high pressure injection moulding, to form the granulate in products, components, semi-finished products, etc.

These products (and components, etc.) have different destinations. They either go to a next stop in the assembly process, the brand owner, other companies (B2B, retail, etc.) or consumers. The End-of-Life products momentarily have two paths they can follow when they are disposed. They can end up in the regular waste streams and not be filtered out when waste is centrally separated, then it will end up in the incineration plant. If the plastic waste is properly disposed, in the plastics recycling containers, then it will go through a process of collecting and separating, after which it will be recycled and enters the industry again as a secondary sourced material.

Figure 9 A basic graphical representation of the Dutch plastics industry

The industry mainly consists of small and medium sized companies, this means the market is divided and not in hands of monopoly actors (De Ruijter, 2019). A great majority of the plastic manufacturing companies in the industry (almost all companies affiliated with the NRK), is involved in the design process of products, parts and components as well. Since brand owners, that make use of plastic manufacturing companies to produce their products, have knowledge on designing products at the user end, but not at the production end of the process. A lot of specific knowledge is required to design a product in such a way that it is the most suitable for the machinery that is used, this is a service that most of the manufacturing companies offer.

The transition agenda for plastics, as published by the Rijksoverheid in 2018, presents the four main directions for development that would contribute to the acceleration of the transition towards a circular plastics industry. These four directions consist of: prevention, increasing the supply and demand of renewable plastics, better material quality and strategic collaborations.

- Prevention – unnecessary material use and material leakage should be minimised and there should be strived for
- Increasing supply and demand of renewable plastics – there are several measures that can be undertaken to increase the attractiveness of renewable plastics, for example by increasing the price for disposing plastic waste
- Better material quality – installing a system that standardises quality grades of material, that ensure users of recycled plastics of the quality

- Strategic collaborations – a cooperative strategy for the industry as a system is crucial for success

7.3 Defining the concrete criteria per area of action

This section of the chapter will explain what criteria for circular business operations are used to assess the progress within the earlier defined areas of action.

Policy – this area of action exists of three components. First of all, the company's understanding of the topic should be explained. This is done by assessing the adopted definition and the way the definition is put to context of the circular economy in the industry. The feeling of the need for change has just started descending on some of the companies within the plastics industry (Haffmans, 2019). This means that the conceptual understanding and the role of the company are not necessarily clear. Yet, a complete understanding is the starting point for a structured way of innovating. Targets help to cut up the topic into smaller bits that can be worked towards to. An implementation plan defines the extent to which these targets are thought through and how they are going to be reached. Then, in order to make sure there is progress and continuous effort put into these circular plans, roles and responsibilities are discussed (Hopff et al., 2018, p. 15).

1. Definition and targets
2. Implementation plan
3. Roles and responsibilities

Design – many R's (reduce, reuse, recycle, and so forth, also mentioned in Section 1.3) have been identified and used in many different combinations to explain ways of keeping products and material circulating in society longer and at higher levels of value. Plastic materials have many degrees of form-freedom and are used to make products in all shapes, sizes and colours. In the design process, many measures can be taken to improve the circularity of the products (Haffmans, 2019). For example, less different materials in the product increase the recyclability. In the book 'product design in a circular economy', by Den Hollander, Bakker & Hultink, published in 2017, they split up the total amount of R's in two groups: design for product integrity and design for recycling. Design for product integrity was then, divided in design for long use, prolonged use and design for recovery. For the sake of consistency in this assessment tool, the ways of designing for a circular economy are split in the following sequence:

1. Design for long use
2. Design for prolonged use
3. Design for recovery
4. Design for recycling

Production – the production process is the area of action responsible for the most energy consumption. Most energy consumption of companies within the plastics industry is used in the production process (De Ruijter, 2019, Appendix B.4). Production, being the core business of the company, means that optimising these production processes has a significant impact on the business operations, and also means that optimisation is often worth the effort. Renewable energy as a criterion eliminates the need for fossil sources of

energy. Although water is a regenerative resource, it is possible to consume water at a faster rate than it runs through the hydrological cycle, causing draughts and water depletion. Water is used mostly for cooling the machines that are used for the production process, and there are several ways in which this water consumption can be reduced. Maintenance and reparations is focused on the machinery that the company uses, a stringent policy on maintenance and reparations prolongs the lifespan of machines and creates the opportunity for reuse. As is described in four directions of development by the Rijksoverheid (2018, see Section 7.2), criteria 4 and 5 directly address to the directions 'prevention' and 'increasing supply and demand', respectively. To conclude, subsequently to the first criterion, the elimination of fossil energy sources is stimulated by reducing the impact due to transportation.

1. Renewable energy
2. Sustainable water use
3. Maintenance and reparations
4. Material efficiency and waste handling
5. Procurement
6. Transportation

Business model - the World Economic Forum has published a document, that was made in cooperation with the Ellen MacArthur Foundation and McKinsey & Company (2014). In this paper, several solutions were presented as essential to establish global supply chain networks. One of which is to set up reverse networks for products and components. The business model area of action is linked to the design area of action, in the sense that it strives for similar goals, prolonging product life and recovering products, components and materials, but from a business model perspective instead of product design. This is what is reflected in the selected criteria: reverse logistics concerns recovery of EoL products, components and materials, repair service should prolong product lifetime and a smart product portfolio reduces the need for products, components or plastics in the first place.

1. Reverse logistics
2. Repair services
3. Product portfolio

Knowledge and experience – as is displayed in Figure 6, this area of action relies on collaboration and requires a system perspective. Therefore, it can be noticed that most of the criteria defined in this area of action involve other actors from the plastics industry as well. The first criterion is communication. This concerns the internal and external communication of a company about the CE topic. Innovation and exchange is also possible with and without the inclusion of external parties. Cooperation and exchange actively, and by definition, involves other actors. Education and training concerns the extent to which the company offers the possibilities towards their employees to learn more about the CE and CE business operations. Finally, information management facilitates many of the other criteria mentioned.

1. Communication
2. Innovation and research
3. Cooperation and exchange

4. Education and training
5. Information management

System thinking – in the paper by Hoffs et al. (2018), the need for a system perspective is underlined in the conclusions. Joint efforts and system innovations will stimulate the acceleration in the collective transition towards a circular economy. Synergies, linking projects and strategic partnerships are all criteria that are based on value creation through collaboration. The scope of a company considers the scope the company uses in its decisions and business practices. Finally, transparency helps to facilitate the research into an industry and helps to get to the core of key problems and obstacles.

1. Synergies
2. Linking projects
3. Strategic partnerships
4. Scope
5. Transparency

7.4 Compose descriptions per level of progress

To compose the descriptions of the levels of progress that divide the criteria that were drafted in Section 6.3.3, a combination of acquired insights and basic knowledge of circular economy practices was used. Criteria that have been compiled per area of action are at this stage to be divided into: reactive, aware, systemic, ambitious and advanced levels of meeting these criteria. Also, to describe the levels of progress, indicators for the criteria were put together. At this moment, the indicators are functioning as subjects to write about in the description. The way these stages were described was by starting at the 2 outer stages, so reactive and advanced. Starting at reactive, a text was composed describing the least active (reactive) way to handle the business operations concerning the criterion in dispute. After this, the most advanced way in which a company can meet the criterion was described. Then, using the subjects to write about, the levels of progress in between were described step by step. In the situation that it proved hard to make a distinction in these steps, an amount of 3 to 4 descriptions for the levels of progress could be, and has been, decided.

7.5 Assembling the findings into a specific assessment tool

The result of the assembled findings is a complete assessment tool. Since the content contains a lot of information and a lot of text, the result is attached in Appendix E.1 and E.2. The assessment tool consists of two components: the instruction & content booklet and the central fillable form. Since the intention of the assessment tool is in a board meeting of a company (see Section 1.5), and the tool is intended to retrieve a lot of information, it is important that the discussion takes place centrally. This is why the rating of the company will be done centrally. However, the information density of the rubric, containing all the different descriptions, makes it undesirable to have this displayed centrally as well. That is why the distinction between the two components has been made. To make the tool as user friendly and self-explanatory as possible, a user guide with introductory information on the Circular Economy is included. Additionally, an explanation for the relevance of all the criteria is included as well. Since the process of using the tool might raise questions,

remarks, interesting facts or other things to keep in mind, the booklet is equipped with planes for taking notes. As mentioned before, the full product is attached in Appendix E.1 and F2, however, the next figures (10 and 11) illustrate what the appearance of the tool looks like.

Management		Reactief	Bewust	Systematisch	Ambitieus	Vooruitstrevend	Onderbouwing
Definitie en doelstellingen	Hanteert het bedrijf een specifieke definitie voor de Circulaire Economie en hebben ze doelstellingen geformuleerd?	Het bedrijf heeft **niet duidelijk** in beeld wat een **Circulaire Economie** (CE) is en wat de rol van het bedrijf in een CE is. Er zijn **geen ambities** en **prioriteiten** opgesteld. Ook zijn er **geen doelstellingen** geformuleerd.	Het bedrijf heeft **wel gedefinieerd** wat de **CE betekent** voor het bedrijf zelf. Er zijn **doelstellingen** geformuleerd maar er is **niet omschreven** hoe dit **bijdraagt** aan een CE.	Het bedrijf heeft geformuleerd **wat** de **CE betekent** voor het **bedrijf** en voor de **sector** waarin het bedrijf zich bevindt. Er zijn **doelstellingen** geformuleerd en er is toegelicht op welke manier deze doelstellingen **bijdragen** aan een CE.	Het bedrijf heeft **omschreven** wat de **CE betekent** voor het bedrijf en voor de sector. **Kernproblemen** in de sector zijn **geïdentificeerd** en er zijn **doelstellingen geformuleerd** die duidelijk op deze kernproblemen aansluiten.	Het bedrijf heeft **duidelijk gedefinieerd** wat de Circulaire Economie inhoudt en wat het betekent voor het bedrijf en de sector. **Kernproblemen** zijn **geïdentificeerd** en **geprioriteerd**. Hier zijn **passende ambities** en **doelstellingen** bij geformuleerd.	
Implementatie plan	Zijn deze doelstellingen vertaald naar een implementatieplan?	Het bedrijf heeft **geen projecten** opgesteld om de circulariteit van het bedrijf te verbeteren. Er is **geen stimulans** van het **management** en er zijn **geen financiële middelen** beschikbaar voor het onderwerp Circulaire Economie.	Er zijn **ideëen voor projecten** en er is de **wil** om deze te starten, echter is er **geen of weinig budget** beschikbaar gesteld voor dergelijke projecten. Het heeft **geen prioriteit** boven algemene bedrijfsuitvoering, maar het staat op de agenda.	Er zijn **projecten opgesteld**. Tevens zijn er wat **financiële middelen** beschikbaar gesteld voor projecten. Er is ondersteuning vanuit het management, maar het heeft nog **geen prioriteit**. Dus: het staat op de agenda, maar **voortgang** gaat **langzaam**.	Projecten zijn **duidelijk gedefinieerd**. Het is duidelijk welke (financiële) **middelen vereist** zijn voor het project en deze zijn (grotendeels) **vrijgemaakt**. De projecten hebben **prioriteit** en beginnen **voortgang** te boeken. Er is nog **geen** (realistisch) plan voor het **monitoren** van de vooruitgang.	De **projecten** en **vereiste middelen** zijn **duidelijk gedefinieerd** en duidelijk **gelinked** aan de **ambities** van het bedrijf. Financiële en andere **middelen** zijn **vrijgemaakt** voor de projectgroepen. Er is een **realistisch plan** voor het objectief **monitoren** van de voortgang.	
Rollen en verantwoorde-lijkheden	Zijn de taken en verantwoordelijkheden verdeeld binnen de organisatie?	Er is **niemand** binnen het bedrijf **verantwoordelijk** gesteld voor projecten en het behalen van de ambities en doelstellingen van het bedrijf.	Er is **een verantwoordelijke** voor de Circulaire Economie projecten, maar het is nog niet duidelijk wie er aan de projecten mee gaan werken. Er is **geen structuur** voor **deadlines** en rapportage opgesteld.	Er is **een verantwoordelijke** voor de circulaire projecten van het bedrijf. Ook is het **per project** duidelijk wie er aan gaat werken en is er een **taakverdeling**. Er is nog **geen duidelijke structuur** voor deadlines en rapportage.	Er is **een verantwoordelijke** voor de circulaire projecten van het bedrijf. Er is een **duidelijke rolverdeling** binnen de **projecten** en de **deadlines** zijn vastgesteld.	Er is **een verantwoordelijke** voor het implementatieplan om de circulariteit te verbeteren. De projectteams hebben een **duidelijke rolverdeling**, ook zijn er **deadlines** gesteld. Er is een **duidelijke** aanpak voor de manier van **rapportage**.	

Figure 10 The policy area of action (management in Dutch) in final assessment tool for plastics industry

Figure 10 shows the page in the booklet that contains the rubrics information. Figure 11 shows the corresponding page with the explanation of the criteria. The text on both figures is written in Dutch.

Toelichting

Waarom dragen deze criteria bij aan een circulaire bedrijfsvoering?

Definitie en doelstelling
Een circulaire bedrijfsvoering begint door circulaire kenmerken op te nemen in je beleid. Om dit gestructureerd door te kunnen voeren in bedrijfsvoering en implementatie en projecten is het van belang om daarin een duidelijke definitie te hanteren en naar realistische doelstellingen toe te werken.

Implementatieplan
Een goed gestructureerd implementatieplan helpt om naar de geformuleerde doelstellingen toe te werken.

Rollen en verantwoordelijkheden
Door duidelijk rollen en verantwoordelijkheden te verdelen wordt er gewaarborgd dat een implementatieplan wordt gevolgd, voortgang wordt gemonitord en doelstellingen worden behaald of aangepast.

Ruimte voor
Aantekeningen

Berenschot

Figure 11 The corresponding page for the policy area of action, containing the explanation and panel for note-taking

7.5.1 Intentional use of tool

As described, it is desirable to have a central location to display the results of the assessment. Along the way, the facilitator of the process guides the company representatives through the areas of action and each criterion individually. As can be seen in Figure 12, the small version of the central fillable form, which can also be found in the appendix on a larger scale (Appendix E.2), the fillable form is empty. As the process progresses, the scores will be indicated with the use of post its (page marker format). This makes it possible to have discussion and change the attributed score easily.

To create an extra level of analysis, the post its used to score the criteria are used in three different colours: green, orange and red. These three different colours give the opportunity to rate the attributed score in another dimension. During the interviews, the colour indicated the difficulty level the company perceived to bring change into the criterion that was rated. Meaning, if a certain score is attributed, and the company would want to improve this, would this be straightforward (green), neutral (orange) or complex (red).

Finally, once all the criteria have been rated, the score can be displayed in the radar diagram at the bottom. Attributing scores (from 1 to 5) to the criteria and taking the average will make it possible to present the results in the form of this diagram.

Figure 12 The central fillable form

7.6 Validation of assessment tool

The circularity assessment tool as described in the previous sections has been tested in three validation sessions with companies. The focus of the tool is on Dutch plastics manufacturers. As described in the industry exploration, the companies active in this industry are relatively comparable in size. However, they do differ in the extent to which they are active in the design process of the final products. This is decisive for the sample collection. The sample collection for the validation sessions should include the different ways of contributing to this design process: full design responsibility or design for manufacturing. Because of these options, a selection of three companies was collected: a company fully focused on own products, one only contributing in design for manufacturing and a company delivering both services.

This sample collection existed of Ubbink BV, Espol Plastics and Hollarts Plastic Group. All three companies are plastics manufacturers in the Netherlands and are considered small to medium sized. All companies contribute to the design process in a different way. Ubbink BV is merely producing own products, Espol Plastics is merely producing commissioned by clients and Hollarts has several own products, but mostly produces for clients.

The interviews allowed for an extensive review of the assessment tool. All three participants cleared their schedule for over 2 hours so that there was enough time to discuss every aspect of the assessment tool elaborately. The interviews were recorded and used to work out the results in a structured way, after which conclusions could be drawn. These conclusions will be presented in the next section. A complete overview of the conclusions can be found in Appendix F.

7.7 Conclusion

The main conclusions of the validation sessions could be grouped in two categories: *use of the tool* and *relevance of the criteria.* These conclusions have been implemented in the final result of the assessment tool as presented in Section 7.5. To further explain the type of conclusions that were implemented according to the results of the user tests, some are explained. An extensive list of conclusions can be found in Appendix F.

Use of the tool

- A lot of relevant information came up for discussion and all three participants stated that there was no relevant information or activity from the company that was missed
- The session could be better structured with the guidance of the assessment booklet, therefore an instruction was included.
- Whilst the post-its give a clear summary of the session, an extra diagram (like a radar diagram) could help to conclude the session and create overview in one sight
- The coloured post-its gave an extra layer of depth in use of the tool. Different meanings of the colour have been tested. The most useful appeared to be to indicate the easiness of improving the business operations concerning a criterion. This helps to identify low hanging fruit.

Relevance of the criteria

- The relevance of the business model area of action is very dependent on the type of company. In this case: the business model criteria were less relevant for Espol Plastics and Hollarts Plastic Group (producing in commission) than for Ubbink (own product portfolio)
- A verbal explanation of the relevance of criteria can be supported by a written explanation in the assessment tool booklet
- For the transport criterion, it appeared to be difficult for companies to distinguish themselves with other means of transport than regular transportation, since the logistics are outsourced and there is no available alternative
- For the maintenance and reparations criterion, it appeared that it is the standard to have all the machines checked regularly and maintained very neatly, this makes the criterion not ambitious enough regarding circular performance

These conclusions have contributed to the final version of the circularity assessment tool as it is presented in Appendix E.1 and E.2.

8. Discussion

At some moments, this research was confronted with challenges and considerations that influence the results as they have been presented in the previous chapters. These points for discussion have been collected in this chapter, where one can read the most influential considerations and how they have potentially influenced the research.

8.1 Assessment/self-assessment

Some of the empirical requirements are originating from the fact that the tool will be designed as a self-assessment tool. For a long time during this research, it has been unclear whether the tool would be an assessment tool or a self-assessment tool. The decision does have some considerable consequences.

A self-assessment tool would emphasise the purpose for strategic course development. The focus would mainly be on creating insights for the company that uses the tool. A self-assessment tool provides an accessible way of creating awareness and introducing the user to the topic and the possibilities within the topic of the assessment.

An assessment tool would mean that an external party assesses the company. Since using the tool requires extensive knowledge about the company, the involvement of the assessed company will remain. The inclusion of an external party would increase the threshold for the assessment. This is often used in combination with certificates or benchmarking of the results.

Mainly because of the research objective, as described in Section 1.5, the decision has fallen on a self-assessment tool. The main reason is the accessibility of a self-assessment tool. The companies that are not actively involved yet in circular business operations can do the first exploration in this way, which gives them a first indication. This is approachable, since there are no costs attached and it can be used internally.

The stalling of this decision has had some other consequences for the research. For example: during the case study, the tool has been validated as an in-between version of a self-assessment/assessment tool. The session was prepared and guided, instead of self-explanatory. Therefor the focus of the validation sessions was less on the user experience than on the content of the tool.

8.2 Assessment rubrics

The format of assessment rubrics proved suitable for company level circularity measurement. However, other formats have come across as well. For example, the VBDO tool, which has been mentioned in Section 1.3. In this tool, statements are made and points are awarded it a company complies with the statement. Another example, the tool developed by Windesheim (mentioned in Section 1.3) poses questions. The user answers these questions stating ‘never’, ‘almost never’, ‘sometimes’, ‘often’ or ‘always’.

All three formats are able to cope with quantitative and qualitative data. However, there are some specific advantages of the rubrics format. The method described that the VBDO tool uses, the statements that award points, lacks a profound description of the content. It is a list of yes/no questions and does not deepen into criteria further. The other method, used by Windesheim, is comparable to assessment rubrics, however, there is a considerable difference. The strength of the rubrics lies within the descriptive texts. These texts create an image of the level of progress in the specific criterion, so the user can estimate the appropriate level of progress. These descriptive texts allow for the form freedom of describing each element separately.

Taking into consideration the amount of information that can be communicated through the use of assessment rubrics, the decision fell for this format of assessment.

8.3 Weighing factor

During the design phase, on multiple occasions, it has been considered to include a weighing factor for the calculation of the result. A weighing factor could introduce a distinction in the importance of the different areas of action, or specific criteria. This is something that could play an role when a similar assessment tool would be approached in a more quantitative manner. However, since the purpose of the tool is to stimulate a company that starts to improve their circularity, the weighing factor has not been included. This is mostly because the rubric format offers the opportunity to identify important elements in business operations to become circular. The insights gained and lessons learned from this format are more valuable than the exact number, therefore the weighing factor would distract from what the tool is designed to do for: exposing where the company can improve their circular performance.

Besides this, the addition of the weighing factor would emphasize too much on the result of a certain score. This emphasis would express that the tool is based on a quantitative analysis of some sorts, while a weighing factor would in fact be more of a randomly attributed value.

8.4 Subjective argumentation

Throughout the research, on multiple occasions, *the results have been subjected to personal interpretation of the researcher*. The clearest example, as was described in Section 4.7, lies in the difference in reviewing the circular economy definitions (for mentioned criteria) between this research, and the research performed by Kircherr et al. Some of the dimensions used in the tool developed in Chapter 4 have a direct overlap with the ones used in the research by Kircherr et al., ending up with a different result in counts. After analysing some of these deviations in results, there does not seem to be a consistent pattern recognised. To illustrate, for the dimension ‘system perspective’, this research found 57 results (only taking into account the 114 definitions that were used in Kircherr’s study as well), whilst the original study analysing these same 114 definitions ends with a mere 48 counts. On the other hand, when comparing the amount of definitions that count the ‘reuse’ dimension, the deviation leans the other way. Only 61 definitions in this research have been registered to mention the ‘reuse’ dimension, in contrary to 86 mentions by Kircherr. To improve the transparency of this thought process, the elements that were

recognized in this research have been marked red in the Excel file and examples have been illustrated in Table 2. However, no comparison could be made with the thought processes involved in the research by Kircherr et al., because these were not included in the publication. The deviation in the analysed definitions can result in a change in the further results along the process. The difference in recognizing the dimensions can result in a different definition for the same selected dimensions. Which could potentially lead to other areas of action for the generic framework. This could in turn lead to a different industry specific tool.

Besides this part of the report, personal interpretation of the researcher recurred in other parts. Aggregating the areas of action, finding words for the level of progress, selecting the criteria for circular business practices and describing the levels of progress content were all steps in this process where personal interpretation and experience have played part. In some ways, the consequences will be of minor impact, such as choice of words, others could have had a larger impact. Let me explain this briefly: if other terms for the different levels of progress would have been chosen, such as the following: *passive, conscious, consistent, proactive, progressive*, the impact would be minimal (assuming the description as presented in Section 5.5 would be comparable for these words). Whilst if the content descriptions of the levels of progress varies from the current version, the results could change as well. Some sorts of research inevitably go accompanied by subjective evaluation. This mainly has to do with the available time for the project. Progress had to be made and this asked for decisions to be made at some point, with the use of subjective arguments. It has been attempted to present these arguments as transparent as possible, however, if an abundance of time was available, the subjective decisive elements from this research could have been elaborated on further to demarcate these decisions as much as possible.

8.5 Subjectivity in use

Another element of the research that has an influence on the results is once more related to the included subjectivity of the assessment tool. A company that uses the tool can interpret some of the elements differently from how it was intended. Besides that, they can also have a distorted view of how their company is actually performing within certain of these criteria. These personal interpretations could lead to a distorted presentation of the results. In the worst case, a company does not feel the need to change any of their business operations, whilst actually lacking in their contribution to the shift towards a circular economy. These are relatively impactful consequences for the intended result of the tool. This subjectivity can be accounted for in different ways.

First of all, since it is used as a self-assessment tool, it is the purpose to identify areas where the company can improve. For now, the intended use is an internal purpose only, which makes that there is no benefit to be gained from greenwashing the results. This makes that the instruction could include a message stating the user should be as critical as possible. A critical attitude improves the results from the self-assessment tool and improves the

Secondly, to eliminate the subjectivity, an external party can be involved in the assessment process. Involvement of an external party would change the self-assessment format to a

regular assessment format. The assessor can than provide objectivity by not having a conflict of interest during the assessment of the company. The relation between the assessor and the company however is a delicate one. An external party can act as an auditor or an advisor and this influences the way a company would review the assessment.

8.6 Single validation protocol

The process steps of the protocol have been taken once. The result has been reviewed and conclusions have been drawn. However, this is merely one case study, performed by one person. Interesting results might arise when the same process steps are performed by another person. Will the same criteria, or approximately the same criteria be formulated and will the levels of progress will be described in the same way as has been done in this case? In case not, the protocol could be improved by providing more concrete steps. However, it is not the determined yet whether this is a hard requirement. Namely, if the same result of assessing can be met, using different criteria and using different descriptions, it is perhaps not required to have this reproducibility focused on ending up with the exact same assessment tool, as much as gaining the same insights and conclusions from the use of this assessment tool. Not only can it lead to interesting results to repeat the protocol for the same industry, validation of the process steps by applying it to another industry would lead to an equally relevant evaluation.

9. Conclusion

To finalise this research paper, the main research question will be answered. The answers to the sub questions have been explained in the previous chapters and can be found in the conclusions of Chapter 3, 4, 5 and 6. Using these conclusions, the main research question can be answered: '*How can the progress towards a circular economy of an individual company be measured?'*.

After answering the main research question, more general conclusions from the research will be described. After this, recommendations for further research and for use of the results of this research are made.

9.1 Answering the main research question

This research has used a design science approach to develop an assessment tool to measure the circular performance of a company. In this approach, different scientific and non-scientific literature, as well as industry experts (circular business experts and plastics industry experts), were consulted to gain insights in topics and find the answers to the sub questions. This is done according to the elements of design science as first published by Hevner in 2014. The approach is illustrated by three main cycles, the Rigor, Design and Relevance cycle. The Rigor cycle, existing of scientific support to secure the accuracy of the assessment tool, corresponds to the literature and the industry experts that were consulted. The Relevance cycle, preserving the practical relevance of the assessment tool, is embodied by the expert input and empirical validation process that involved interviews with companies. Finally, the Design cycle has mainly been given shape by the iterative steps of putting insights from both prior cycles together into the assessment tool, and testing this in a practical environment. Because of the empirical nature of the project, a practical perspective was useful during many moment in the process. To conclude this research paper, the main research question will be answered. This question reads as follows:

'*How can the progress towards a circular economy of an individual company be measured?'*

The scarce current offerings in circularity assessment services lack in usability, concreteness or completeness (see Section 1.3 and 1.4). The variety of types of companies present the need for a flexible and adjustable method to assess the circularity of a company. The complex matter and indicators that rely on both qualitative and quantitative terms amplify this requirement. Finally, considering the purpose of creating insights and stimulating companies to change their business operations into a more circular orientated perspective, has resulted in the decision to give shape to this circularity assessment tool in the form of an assessment rubric. This will allow us to describe complex matter, combine different types of data and stimulate the user to change, while learning about the possibilities.

To be able to measure the circular performance of a company, it is essential to clarify what exact definition of the Circular Economy is used in for this purpose. Since scientific literature provides us with many possible definitions, a selection tool was developed to help select the appropriate definition according to this research context. The tool uses dimensions that can be selected, to filter out definitions that do not mention this required dimension. For the selection of the definition, several dimensions were considered important to be addressed to. First of all, a Circular Economy is reviewed as an economic *system*, where actors have influence on each other and eventually the system should, as a whole, become a circular one. Besides this, the research context tells us it is required to have a clearly defined scale at which the Circular Economy should be implemented, therefore, the definition should include the elements that indicate the *micro scale* on *company level* is important. Because of the system perspective, collaboration is required between actors within such a system. This is why the criterium *industrial collaboration* is selected as well. Besides that, in the Netherlands, we are eventually looking to fully close the loop, so the dimension *closing the loop* is selected as well. The change would in this case need to come from the *supply side*, because this is the side that represents market-driven change. Finally, to make sure the focus will be distributed aligned with the levels of value preservation, the *waste hierarchy* dimension is also included in this selection. This has leaded to the selection of the definition as first stated by Merli, Preziosi & Acampora in 2018 (p1. Abstract).

This definition was analysed for the elements it contains, in order to extract the elements that dictate the requirements for circular business practices. Since the definition is on a somewhat higher abstraction level than business operations, the elements that could be extracted were complemented with more concrete literature on circular business operations. Combining these insights has resulted in 6 proposed areas of action, that form the start of a generic assessment framework to be used cross-industry. The areas of action defined in this process step are: 1) policy, 2) design, 3) production, 4) business model, 5) knowledge and experience 6) system thinking. The extent to which a company meets the criteria that will give body to these areas of action are called ‘levels of progress’. The different levels of progress are called: reactive, aware, systematic, ambitious and advanced.

In order to measure the progress towards a circular economy of an individual company, the generic assessment framework will need to be completed with industry specific criteria and descriptions of the levels of progress. Therefore thorough industry research needs to be executed in forms of interviews with industry experts and literature review. With the insights, criteria can be formed that align with the industry specific context. The industry specific criteria will be described in 3-5 levels of progress, where the company in dispute will score their own business operations, according to the best fitting description. This process has been elaborated in this study in the form of a case study for the Dutch plastics industry.

To conclude, this research put together all these insights and constructed an assessment rubric developed for the Dutch plastics industry. The full assessment rubric has been designed in the Dutch language and presented in Appendix E.1 and E.2. The intentional use is to be found in Section 7.4.

The validation sessions, as described in Section 7.6, describe the positive evaluation of the results of this assessment tool. The proposed tool was tested on 3 companies and gave indicative results in the progress of the company towards a circular plastics industry. All relevant information about and actions of the company were discussed in sessions of approximately 2 hours. These results created a clear overview of the level of progress of the company per business operation criterion. Therefore, the assessment tool has been evaluated as effective.

9.2 Research conclusions

In the problem introduction (Chapter 1), a lack of usable assessment tools for company circularity assessment is described. The complexity of a Circular Economy makes it hard to translate this topic into concrete business operations for all different industries. CE is a holistic concept that describes a whole economic system and the concrete circular business operations that can have a positive impact vary throughout different industries. Therefore, there is a necessity for an adaptive tool with a consistent structure that can be used cross-industry. Currently, targets on governmental levels play a large role in policy making. However, many companies continue with business as usual and are experiencing trouble with implementing circular business operations in their business. This research has delivered a set of products that can help solve this problem. It is consistent of three separate products: the definition tool, the protocol and the assessment tool. The conclusions will be split up regarding these three deliverables.

9.2.1 Definition tool

Many research studies that concern the circular economy include a clarification of the definition of a circular economy. During this research, a tool was developed that can structure and accelerate this process for scientific studies. First of all, a broad selection of definitions is collected and presented in a structured way, which can be easily updated. This collection on its own can help researchers in the start phase of a study. The dimensions that are used give insights in the different elements that (could) play a role in any definition and prompt the user to explore the relevant aspects in the specific research context. Also, the tool creates meta insight in the existing definitions. The count of dimensions from the definitions can be used to generate overview of the academic world regarding CE research as a whole. To illustrate: the results of the current sample of definitions tells us that 62 definitions include ‘recycling’, 59 include ‘reusing’, however, merely 36 defintions include ‘reducing’. Whilst in various models, like the butterfly model by EMF, reducing is considered to be the most impactful. This shows that the inclusion of reducing material use in scientific definitions, is inconsistent with how renowned experts describe the importance of it. This example shows the type of insights that the tool can contribute to.

9.2.2 Protocol

In Chapter 6, the construction of the protocol is described. The versatility of the concept has shown that it is complex to comprise in a single tool for all sectors. Therefore, this protocol describes how to construct an industry specific tool, using the generic assessment framework as a starting point. *The protocol can serve divergent types of organisations*. It can be used by companies that are interested in developing a circularity assessment tool serving their sector. It can be used by governmental organisations, that want to stimulate companies within a certain industry. Further, it can be used by advisory organisations that want to use the tool to help companies within an industry develop their circular performance.

The protocol has been formulated as concrete as possible. It describes what knowledge is needed and how the knowledge is translated to elements in the assessment tool. Despite this, *there is still a need for analytical and research skills* of the user. This is due to this complexity of the topic. The holistic nature of a circular economy means that all steps in the value chain have to be accounted for in an assessment format. This means that the assessment is dependent on a lot of specific elements from this industry. These industry specific dependencies are required to include in the assessment tool to make tool that uses comprehensible and concrete elements. This is why the industries have to be explored thoroughly.

9.2.3 Assessment tool

The result of the described process is the completed circularity assessment tool as presented in Section 7.5: a grading scheme for Dutch plastics manufacturers. In the first chapter, a lack of accessible assessment tools was described. Assessment services are hidden behind paywalls and companies that want to make a first inventory of the possibilities for their company have limited options to fall back on.

This project has resulted with a qualitative assessment tool that is constructed to help companies explore their current state circularity and most valuable first steps in improving the circularity. The tool is easy to use for every type of user and creates insights in what a circular economy is and what it means for a specific industry. This is different from the offer of tools that has been available previously. This tool uses a holistic approach of the circular economy topic, but allows for the complexities in specific industries to be included in the assessment as well.

9.2.4 Final conclusions

Using these different deliverables will help to accelerate the transition towards a circular economy on different levels. First of all, the definition tool can stimulate the research within the context of the circular economy. Secondly, the definition tool can help companies formulate their definition of a circular economy and improve and stimulate their comprehension of the topic. Thirdly, the protocol provides guidelines for organisations active in the field of circular economy to construct auxiliary tools to assess circularity on

company level. Finally, the tool that has been developed in the case study of this research has shown relevant insights are to be gained from using a tool like this.

Lacking to use the proposed elements can create a gap between governmental targets and circular economy practices in reality. It will not accelerate the transition because this economical shift will rely more on the frontrunners. The companies that lag behind will be offered less suitable tools to start improving their performance.

9.3 Recommendations

The recommendations will be separated in three parts: first, a short disclaimer to clarify what the tool does not do. Then, the recommendations for further research and the recommendations for users of the developed protocol and/or the developed tool will be explained.

9.3.1 Disclaimer: what does it not do

The circularity assessment tool has been used in three validation sessions. These sessions have shown the strengths of the tool. However, not only strengths arose. The tool is developed for a specific purpose, which also means that it is less useful for other things. The self-assessment tool as it is designed now helps to create insights for companies that start improving their circular business performance.

Currently, the tool does not actively help to formulate the most suitable strategic plans to improve the circular performance of a company. The descriptions of the level of progress do provide guidelines for what would be the most advanced way to fulfil a certain criterion. However, this does not actively steer a company in its specific case in any direction.

The tool does not offer a way of introducing a new criterion that can improve the circular business performance of a company. If a company has own ideas, for example at the business model area of action, that could contribute to circular business performance, it can be included digitally, but there is no option for it to take into account during an assessment session.

Moreover, the tool is currently not usable to use as an assessment tool that can benchmark companies at their performance. This is because it is given shape as a self-assessment tool. If the results of a self-assessment tool are not solemnly for internal use, there is incentive for the user to score higher. This will most-likely influence the results of the assessment..

9.3.2 Recommendations for further research

The insights that the assessment tool presents are considered valuable on its own. These insights help a company identify what are the main areas of action and criteria for circular business practices. It also gives an indication of types of action that could be undertaken or types of projects that could be initiated. *However, what would amplify the outcomes of the assessment* even more is a way to translate these results into a concrete plan of attack for a company to start improving the circularity of the business operations. This would

increase the value of this tool as it would lower the barrier even more to initiate implementation plans and change into the company structure.

For several purposes, it can be of added value to *use the assessment tool for benchmarking* of companies as well. This is something that can be implemented. For this to be included, the subjectivity has to be eliminated as well as possible. This can be done in several ways. One way to realise this is to make use of an auditor. If an experienced external party would be included in the assessment session, this partner can judge the score of a company, according to what the company can show the auditor during this session. This would not change much for the use of the tool, however, the company should in this case be able to convince an external partner of a certain level of progress.

Besides this, other research can contribute to the topic. During this research, it has been considered to introduce the requirements for transition dynamics into the assessment tool. The shift from a linear to a circular economy is a transition that requires certain elements. J. Wittmayer (2017) explores the concept of actor roles in sustainable transition management in a research paper called ‘Actor roles in transition management’. However, this does not yet give insights in concrete roles that can contribute to a successful sustainable transition. Further research to actor roles in circular transitions can help to have companies focus on transition elements that match their strengths. This way, an even more systematic approach can be implemented in circular transition theories and companies and other organisations can focus on their specific role in a transition.

9.3.3 Recommendations for use

As described earlier, the products of this master thesis can help the transition towards a circular economy on several levels. Their functions have been described in the conclusions in the previous section. This section aims more at the first recommendations to use these deliverables.

The assessment tool for the plastics industry is ready to be used. As described, the tool can be used by different organisations in different ways. For companies that want to use such a tool to advise companies within the plastics industry, I recommend to get to know the tool through 2 or 3 explorative sessions. The sessions that have been performed in this study were conducted to validate the content of the tool, not the full use experience of the tool. The sessions were conducted with one person, which seemed adequate. However, it is possible that 2 or more representatives of the company can improve the level of discussion or supportive arguments for a choice for a level of progress.

The protocol as it is described can be used to construct other assessment tools, for example the four sectors that were defined by the Rijksoverheid as priority sectors. For governmental organisations, it is recommended to construct and spread these self-assessment tools. The of spreading the tools widely are hard to estimate, but it is assumed that the tool would increase the awareness and knowledge of companies within these industries. The shift towards a circular economy may get a boost in the right direction.

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11. Appendices

A – Existing assessment tools

This appendix shows the desk research looking for available circularity assessment tools, it is referred to in Section 1.4, Knowledge gap.

	Bedrijf	Product	Omschrijving	Zoektermen
1	Circular IQ	Circular IQ tool	een software tool die helpt bij het verzamelen en inzichtelijk maken van data over producten en materialen	Circular Economy assessment company
2	Ecochain	Product footprint	tool die op product niveau env. footprint berekent	Meet circulariteit bedrijf
		Organization footprint	tool die op organisatie niveau env. footprint berekent	
		Value-chain footprint	tool die op waarde-keten niveau env. footprint berekent	
3	Circle Economy	Circle portfolio	Investeerders de kans geven om de circulariteit van hun portfolio te meten	Circular Economy assessment company
		Circle assessment	Meten van circulariteit en kansen identificeren om circulaire strategien toe te passen	
		Circle market	Tweedehands platform voor textiel	
		Circle fashion tool	Decision making tool om kledingproducenten 'closed-loop' options te laten verkennen	
		Circle lab	Online platform	
		Circle business case	Kansen bekijken voor circulaire business modellen in de waardeketen	
		Circle scan	Circulaire projecten verkennen	
		Circle workshops	Circulaire workshops om kansen te verkennen	
4	Ellen MacArthur Foundation	Circularity score	In ontwikkeling	Circular Economy assessment company
5	Optimal Planet	Optimal SCANS	Sustainability, Circularity Assessment & Normation System	Sustainability and circularity assessment
7	IDEAL&CO	Circularity calculator	Tool om circulariteit van een product te meten	Calculating circularity
8	Circula8	Circul8 products	Monitort de activiteiten van een Producer Responsibility Organisation (PRO)	Calculating circularity
		Circul8 waste	Supply chain benadering voor organisaties die in waste management werken	
		Circul8 materials	Verbind waste met bedrijven die het als material kunnen gebruiken	
9	Thinkstep	MCI, material circularity indicator	Circulariteit wordt opgemaakt door de circulariteit van de materialen die in de producten gebruikt worden	Circular assessment software
10	Copper8	Alliander dashboard	Methodiek en dashboard voor Alliander	Sustainability and circularity assessment

B – List of interviewees and topics of interviews

This appendix presents an overview of the people that have been interviewed during this master thesis.

Number	Name	Organisation	Topic	Section
1	Joost Krebbekx	Berenschot	Assessment format	3.4
2	Siem Haffmans	Partners for Innovation	Circular Economy assessment	3.4
3	Jasper Klomps	Ubbink	Circular Economy	3.4
4	Erik de Ruijter	NRK	Circular Economy within the Dutch plastics industry	7.1, 7.2 & 7.3
5	Jasper Klomps	Ubbink b.v.	Validation session assessment rubric	
6	Rene Veerman	Espol Plastics	Validation session assessment rubric	
7	Tjerk Holland	Hollarts Group	Validation session assessment rubric	
8	Martijn Kerssen	Oost NL	Circular Economy within the Dutch plastics industry	
9	Angelique Erkenbosch	Innovation Quarter	Assessment format	

C.1 – Dimensions for definition tool

This appendix contains the dimensions that were extrapolated from the research studies that were consulted. In total, 5 papers are reviewed in this table. The colours indicate the distinction between the information that was drawn from one paper, whereof the title is displayed in bold, top left of each colour box. Beneath it, there is a brief Dutch description. The second colon contains the author(s) and year of publication. Then, the amount of dimensions used and the classifications used within the dimension are shown.

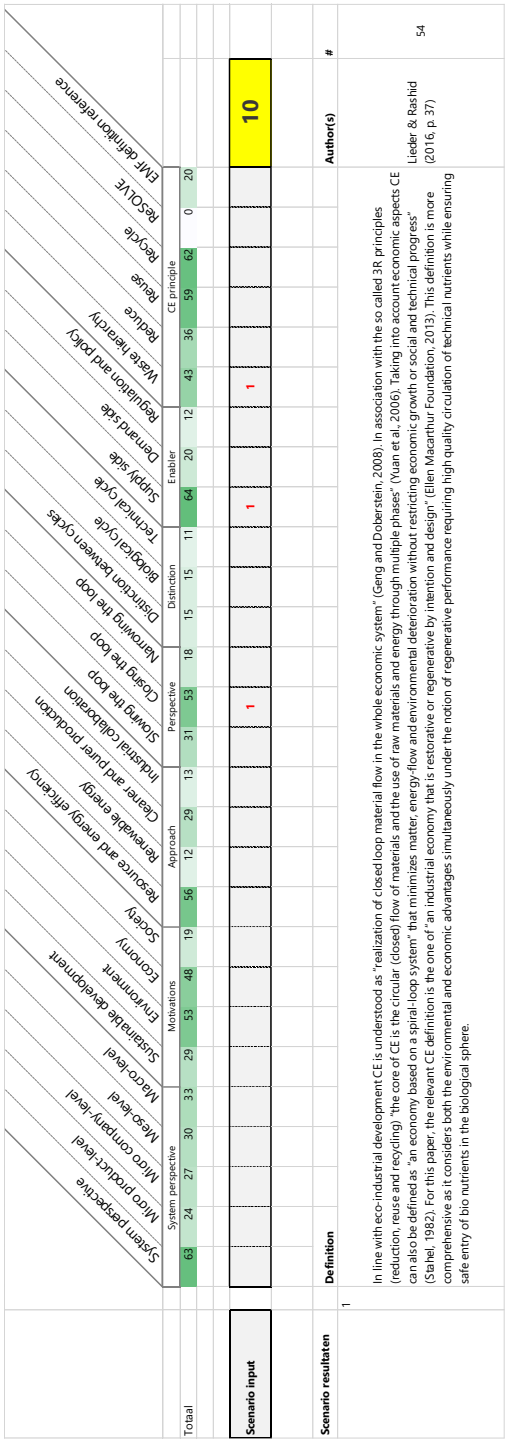
Title	Authors	#	Dimensions	Classifications
Conceptualizing the circular economy: An analysis of 114 definitions Dit is echt een literatuurstudie naar verschillende definities van de CE. Hier worden dimensies genoemd om een classificatie te maken van de verschillende definities die er bestaan.	Kirchherr, Reike en Hekkert (2017)	1	4R	Reduce Reuse Recycle Recover
		2	Waste hierarchy	
		3	Systems perspective	Micro Meso Macro
		4	Business models	
		5	Consumers	
		6	Sustainable development	Environmental quality Economic prosperity Social equity Future generation
The circular economy and circular economic concepts—a literature analysis and redefinition Deze studie beschrijft meer de oorsprong van verschillende concepten en definities van de CE. Hierin wordt beschreven dat een circulaire economie vorm kan krijgen in vele verschillende concepten, waarvan dé Circulaire Economie slechts een vorm is. Hierin worden onder anderen genoemd: Cradle-to-Cradle, Blue economy, Closed supply chains, Regenerative design, Natural capitalism, Industrial ecology, Biomimicry, Performance economy, etc.	Murray, Skene en Haynes (2015)	1	Motivations	Environment Profitability Social aspects
		2	Proposition for waste management	Efficiency and waste reduction Zero waste Distinction between biological and technical substances
		3	Guidelines and tools	Business model perspective Focus on operations Measurability Policy
		4	Economic sectors covered	Primary sector Secondary sector Tertiary sector
		5	Economic scope	Macro

				Meso Micro company level Micro product level
		6	Activities during life cycle stages	Product development Production processes Use End-of-life/disposal
How do scholars approach the circular economy? A systematic literature review Deze studie is specifiek gericht op het in kaart brengen van de universitaire studies die worden gedaan naar CE. Hierin wordt er in de dimensies dus ook gelet op wat voor type onderzoek er wordt gedaan.	Merli, Preziosi en Acampora (2017)	1	Research methodologies	Modelling Case study Theoretical and coceptual Review Survey
		2	Type of research	Economic model Policy Process engineering Business models and management Tools, models, framework, methods, for decision making
		3	Level of analysis	Micro Meso Macro Supply chain
		4	Keywords	Keywords families
		5	Sustainability	Economic Environmental Social
		6	Industries	Sector of activities
		7	Geographical focus	Specific geographicl areas object of the studies
		8	ReSOLVE framework	Regenerate Share Optimize Loops Virtualize Exchange
		9	Business models	Industrial symbiosis Extending resource value Access and performance model Encouraging sufficiency Classic long-life model Extending product value
The circular economy umbrella: trends and gaps on integrating pathways	Homrich, Galvão, Gamboa Abadia en Carvalho (2017)	1	Schools of thought of CE	Cradle-to-cradle Industrial ecology Biomimicry

Deze studie doet een complete analyse van het concept CE. Niet alleen de definitie wordt onderzocht, maar ook de belangrijke actoren en onderzoekers in het veld, belangrijk onderzoek dat is gedaan en topics die onderzocht worden.				Laws of ecology Performance economy Blue economy Regenerative design Permaculture Natural capitalism Industrial symbiosis
		2	Triple Bottom Line (TBL)	Environmental Economical Social
		3	CE approach	Slowing the loop Closing the loop Narrowing the loop
		4	Main issues	Symbiosis Transactional costs Externalities Partnership
Towards a consensus on the circular economy Deze studie doet een literatuurstudie naar CE met als doel de volgende 4 outputs: A knowlege map of the CE An analysis of the main notions of the concept An analysis of the main principles of the concept An analysis of the main determinants of the concept	Prieto-Sandoval, Jaca en Ormazabal (2017)	1	Different groups of CE	3 R's Sustainable design strategies (Nature Inspired Design)
		2	3 Tenets	Waste equals food Use current solar income Celebrate diversity
		3	CE determinants	Regulation and policy Supply side Demand side
		4	Definition should include this:	The recirculation of resources and energy, the minimization of resources demand, and the recovery of value from waste A multi-level approach Its importance as a path to achieve sustainable development Its close relationship with the way society innovates.

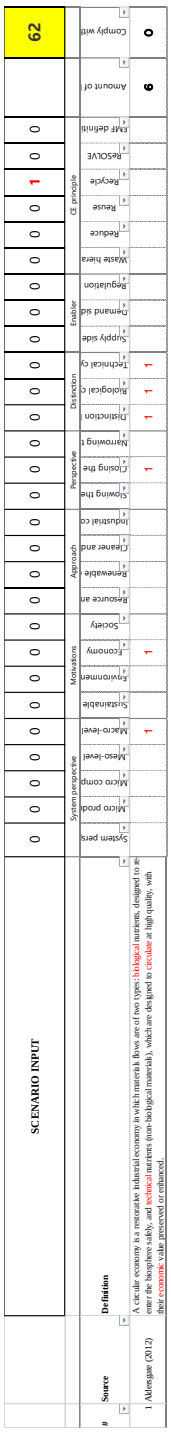
C.2 – Definition tool

The definition tool as an Excel file is attached to this research paper as a separate file. This appendix shows merely 2 images of the tool. The left one shows the 'Input & result' tab. To put up a dimension as a requirement, the user puts a '1' as an input for the corresponding grey cell. The number in the yellow cell communicates how many definitions meet all the given criteria and display these definitions and the corresponding author(s) (up to 20 definitions). The right image shows the back-end of the tool, the other tab which is called 'Definitions'. The row stating 'scenario input' copies the given input from the 'Input & results' tab. It displays all the definitions and the dimensions it contains. The elements from this definition that contain such a dimension are coloured red. Instructions can be found in the Excel file as well.



		System perspective						Motivations						Approach						Perspective						Distinction						Enabler						CE principle											
	Totaal	63	24	27	30	33	29	53	48	19	56	12	29	13	31	53	18	15	15	11	64	20	12	43	36	59	62	0	20																	
Scenario input																1					1			1																						
Scenario resultaten																1					1			1																						

#	Definition	Author(s)	#
1	In line with eco-industrial development CE is understood as "realization of closed loop material flow in the whole economic system" (Geng and Doberstein, 2008). In association with the so called 3R principles (reduction, reuse and recycling) "the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases" (Yuan et al, 2006). Taking into account economic aspects CE can also be defined as "an economy based on a spiral-loop system" that minimizes matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress" (Stahel, 1982). For this paper, the relevant CE definition is 'the one of "an industrial economy that is restorative or regenerative by intention and design" (Ellen Macarthur Foundation, 2013). This definition is more comprehensive as it considers both the environmental and economic advantages simultaneously under the notion of regenerative performance requiring high quality circulation of technical nutrients while ensuring safe entry of bio nutrients in the biological sphere.	Lieder & Rashid (2016, p. 37)	54



#	Source	Definition	SCENARIO INPUT	System perspective				Motivations						Approach						Perspective						Distinction						Enabler						CE principle											
			62	System pers	Micro prod	Micro comp	Meso-level	Macro-level	Sustainable	Environment	Economy	Society	Resource an	Renewable	Cleaner and	Industrial co	Slowing the	Closing the	Narrowing t	Distinction	Biological C	Technical cy	Supply side	Demand sid	Regulation	Waste hiera	Reduce	Reuse	Recycle	ReSOLVE	EMF definit	Amount of	Comply with
				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0		6	0
1	Ellenagain (2012)	A circular economy is a restorative industrial economy in which materials flows are of two types: biological nutrients, designed to re enter the biosphere safely, and technical nutrients (non-biological materials), which are designed to circulate at high quality, with their economic value preserved or enhanced.																																											

D.1 – Consulted literature for circular business practices

This appendix presents an overview of the specific literature that was consulted to explore the circular business practices. It is referred to in Section 5.3.

1	The circular economy and circular economic concepts—a literature analysis and redefinition	Geisendorf, S., & Pietrulla, F. (2018).
2	New dimensions for circularity on campus-framework for the application of circular principles in campus development	Hopff, Nijhuis en Verhoef (2019)
3	Developing a transition agenda towards a circular economy: the Dutch case of the province of Overijssel	De Bruijn en Entrop (2019)
4	Dimensions of literature review definition tool	Arntzenius (2020)
5	Elements from list of definitions from definition tool	Andersen (2007, p. 133)
		Bai, Qiao, Yao, Guo, & Xie (2014, p. 6)
		Bakker, Wang, Huisman, & den Hollander (2014, p. 11)
		Bocken, Olivetti, Cullen, Potting, & Lifset (2017, p. 476)
6	Making sense of the circular economy: the 7 key elements	Circle Economy: https://www.circle-economy.com/circular-economy/7-key-elements
7	Circular Economy toolkit	http://circulareconomytoolkit.org/Toolkit.html
8	Towards the Circular Economy: Accelerating the scale-up across global supply chains	World Economic Forum: Towards the Circular Economy
9	Metabolic 7 pillars of a circular economy	https://www.metabolic.nl/news/the-seven-pillars-of-the-circular-economy/
10	Circular product design	Den Hollander, M. C., Bakker, C. A., & Hultink, E. J. (2017)
11	Towards a consensus on the circular economy	Prieto-Sandoval*, Carmen Jaca, Marta Ormazabal (2018)

D.2 – Categorisation in literature

This appendix presents the categorisation as how it is described in Section 5.3. It presents the elements that were found from the literature as also displayed in Appendix D.1. Per source, success factors for circular business operations are summed up. The second colon contains an explanation of why the factor is taken into account (green) or not (white).

	Title of article or paper and factors from document	Author(s)
1	The circular economy and circular economic concepts—a literature analysis and redefinition	Murray, Skene en Haynes (2015)
	Efficiency in waste reduction	Eventually, waste should be eliminated
	Zero waste	Zero waste is reviewed as an important requirement for a CE
	Technological/biological substances	This distinction is not reviewed as an absolute requirement for a CE
	Product development	Inevitably, products need to be designed in a different way to reach a CE
	Raw material sourcing	Eventually, raw material sourcing should be eliminated
	Production processes	For plastics manufacturing companies this is an important element for improvement
	End-of-Life/disposal	End-of-Life of products needs to be changed
	Transportation	Transportation contributes to the life cycle impact (embodied energy) of products
2	New dimensions for circularity on campus-framework for the application of circular principles in campus development	Hopff, Nijhuis en Verhoef (2019)
	Systems thinking	Systems thinking is required, because a circularity can only be achieved in a system
	Synergy	Companies need to collaborate to improve systemic efficiency
	Knowledge & experience	Knowledge and experience needs to be gained and shared
	Policy & management	Improving the circular performance of a company starts with awareness and ambition of the company
	Securing goals	A company can actively focus on how to reach set targets
	Closing cycles	Closing cycles is strongly related to zero waste, but less specific
	Energy demand	Energy consumption is a part of circularity
	Space demand	Space demand is specific for the research of this paper
	Behaviour & habits	Also behaviour and habits are specific for this paper
3	Developing a transition agenda towards a circular economy: the Dutch case of the province of Overijssel	De Bruijn en Entrop (2019)
	Quoting the Ellen MacArthur Foundation, five principles of CE:	
	Waste is designed out	This says: zero waste and change in product design

	Diversity builds strength	Diverse roles have to be fulfilled to realise a sector transition
	Renewable energy	Again, renewable energy is part of e circular company
	Systems-thinking	A company needs to be seen as part of a system
	Prices reflect on real costs	This is important to have the economy become aligned with the environment
	Quoting the Ellen MacArthur Foundation, four building blocks of CE:	
	Circular product design & production	Products need to be designed in a different way and production needs to be optimized
	New business models	New business models can help to reduce the amount of products losing value
	Reverse cycle	A reverse cycle is a way to prevent waste from occuring
	Enablers & favourable system conditions: education, financing, collaborative platforms and a new economic framework	These are all means to an end
4	Dimensions of literature review definition tool	Arntzenius (2020)
	Resource & energy efficiency	In the end it there should be no new resources required
	Renewable energy	Companies should use renewable energy
	Cleaner & purer production	Purer to end up with easier recyclable End of Life products, cleaner to prevent emissions
	Industrial collaboration	Industrial collaboration is required to improve systemic efficiency
	Distinction between biological and technological cycle	This distinction is not reviewed as an absolute requirement for a CE
5	Elements from list of definitions from definition tool	
	Industrial symbiosis, resource minimisation, cleaner technologies	Andersen (2007, p. 133)
	Low carbon development, material reduction and circulation, pollution control and environmental management.	Bai, Qiao, Yao, Guo, & Xie (2014, p. 6)
	Waste equals food, nutrient management, circular products	Bakker, Wang, Huisman, & den Hollander (2014, p. 11)
	Leasing and product service systems	Bocken, Olivetti, Cullen, Potting, & Lifset (2017, p. 476)
	…	
6	Making sense of the circular economy: the 7 key elements	Circle economy
	Prioritise regenerative resources	…
	Preserve and extend what's already made	Equal to slowing the loop, cascading and maintaining value
	Use waste as a resource	Zero waste
	Rethink the business model	New business models can help to reduce the amount of products losing value
	Design for the future	Change the way products are designed
	Incorporate digital technology	Is not reviewed as an absolute requirement for the CE
	Collaborate to create joint value	Companies need to collaborate to improve systemic efficiency

D.3 – Full list of selected factors

In this appendix, the full list of factors that are used to aggregate the areas of action are displayed. These 37 factors are extrapolated from the definition and from the factors that were derived from the literature presented in Appendix D.2. This list is referred to in Section 5.4.

1	System perspective
2	Preserving value
3	Paradigm shift
4	Business model innovations
5	Design
6	Collaboration
7	Waste management
8	Optimizing production processes
9	Zero waste
10	Product development
11	Production processes
12	End-of-life/disposal
13	Transportation
14	Systems thinking
15	Synergy
16	Knowledge & experience
17	Policy and management
18	Securing goals
19	Communication
20	Energy demand
21	Waste is designed out
22	Diversity builds strength
23	Renewable energy
24	Systems thinking
25	Research and innovation
26	Reverse cycle
27	Renewable energy
28	Cleaner & purer production
29	Industrial collaboration
30	Industrial symbiosis, resource minimisation, cleaner technologies
31	Prioritise regenerative resources
32	Set up global reverse networks for products and components
33	Reorganize and streamline pure material flows
34	Materials are cycled at continuous high value
35	All energy is based on renewable sources
36	Water resources are extracted and cycled sustainably
37	Business model innovations

E.1 – Final assessment tool booklet

The booklet of the assessment tool is attached to this research paper as a separate PDF file. This appendix is referred to in Section 7.5, 7.7 and 9.1.

E.2 – Final assessment tool central form

The central form of the assessment tool is attached to this research paper as a separate PDF file. This appendix is referred to in Section 7.5, 7.7 and 9.1.

F – Conclusions from three validation sessions

This appendix contains the conclusions from the validation sessions that were conducted with three companies: Ubbink b.v., Espol Plastics and Hollarts Group.

Date: 6-1-2020

Interviewee: Jasper Klomps, from Ubbink b.v.

Conclusions

1. It took a long time, over 2 hours, however, it was the tool was thoroughly discussed.
2. This time, it has been discussed with two persons, however, the dynamics can be different if it were conducted with more people
3. A lot of relevant information turned up.
4. Self-reflection was very criticial. It was rather on the negative side than on the positive side.
5. Supporting information is automatically given, there is hardly need to prompt for this.
6. Steering from the assessment tool, in the form of written instructions is desirable.
7. Questions to introduce new topics are desirable as well.
8. The format of a booklet in useful and clear, however, creating overview of the results centrally seems desirable
9. Session asks for a way of presenting/communicating the results. This time, there was a relatively open ending.
10. Sometimes, criteria were not relevant. These criteria can be indicated: ‘not applicable’.
11. Additional value of the way the colours are used this time (2 left colons: red, middel colon: orange, 2 right colons: green) remains unclear.
12. Occasionally, there was a need for describing the relevance of a criterion. However, it could do no harm to describe the relevance of each criterion briefly.
13. One person was adequate to answer all the statements.
14. It is unclear whether there is a priority in the criteria, which ones would be more urgent than others.

Date: 13-1-2020

Interviewee: Rene Veerman

Conclusions:

1. It took about two hours, again, everything was thoroughly discussed. Duration was comfortable.
2. Introduction of the company did not bring all relevant information. Some steering in which basic information is of interest can help. However, if this would introduce a collaboration it is important to know the company.

3. Self-reflection was too positive. Some information can be interpreted optimistic too easily. It can be necessary to instruct the user to be critical towards the company in order to improve the results of the test.
4. A lot of relevant information came up.
5. SMEs do not have their policy formally on paper and in official documents. These criteria from the first area of action will not happen very quickly.
6. Supporting arguments for a choice of level of progress will come automatically, no need to prompt for this, however, this does not always have a very strong line of argumentation.
7. Function of colours was of additional value this time (red: not relevant for the company, orange: neutral, green: relevant for the company). However, it took a while to figure out it was not communicated clearly enough. The user thought it meant relevance for the company, whilst the intention was, the relevance for the circularity of the company.
8. A radar diagram provides a concise summary, however, the content behind the colours and criteria is very relevant, even for presenting a summary. However, both are useful.
9. Format of the booklet works well, centrally processing the results works well. Extra functionality of the colours also works well.
10. One person could adequately answer all the statements.
11. If the interviewee had the file digitally, he could use a beamer to discuss it centrally.
12. With this way of using the post its (not relevant: red, neutral: orange, relevant: green), the user would want to eliminate all the neutral elements by making them either relevant or not relevant.
13. For a small Enterprise that produces on commission, it is hard to actually experiment, especially with business models.
14. Textual changes are required for several criteria, for example for the transport criterion.
15. The difference between the design for extended use, and design for recovery, can be formulated clearer.
16. A description per criterion to describe the relevance for a circular performance is required.

Date: 15-01-2020

Interviewee: Tjerk Holland

Conclusions:

1. Some criteria were described too easily to score high, for example the maintenance of the machinery.
2. There was additional value in the use of the colours in this test (hard to change: red, neutral: orange, easy to change: green).

3. For the synergy criterion, it is important it concerns residual flows, not every kind of material, product or energy flow.
4. For strategical collaborations, it is important it does not concern collaborations with customers.
5. It is too easy to score good on the criterion of information management. Also, education and training is easily scored well on, if the user includes, for example, a training for an injection moulder on how to proper use a machine. The education and training however should be explicitly on circular economy practices.
6. Product portfolio may be better under the area of action ‘design’ than under ‘business model’.
7. Momentarily, it is very hard to distinguish yourself as a company to use sustainable transport. These logistics are often outsourced and there are few options to have this done sustainably.
8. The size of the company can be included somewhere in the tool, because it influences the results of the assessment of the company. For example in the policy area of action.

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