Making Sense of Circular Economy

How Practitioners Interpret and Use the Idea of Resource Life-Extension

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Abstract

Calls have been voiced to change economic and industrial systems such that they align with sustainable development. One concept, circular economy, has emerged recently as a way to rethink waste and resource management. Within this research circular economy is defined as an umbrella concept that centres on the phenomenon of assessing a collection of resource life-extending strategies. This research explored how practitioners interpret the circular economy concept and how this influenced the enactment of waste and resource management, by use of a tool termed the Circularity Compass that was constructed for this purpose. A qualitative case study approach was followed, where 15 participants were interviewed, covering 23 innovation projects for 19 focal companies. The following seven insights stand out. Participants considered 1) materials and products and in particular parts or modules as playing important roles in establishing what resource life-extending strategies are possible; 2) other flows besides those directly related to the manufacturing of a product, such as material flows co-used with the product as well as energy and information flows, and frequently directed their attention at the infrastructure that facilitates these flows; 3) those strategies that allow for the flexible use of product capacity as valid interpretations of what constitutes a resource life-extending strategy; 4) resource life-extending strategies in sets of two or more, where they were frequently thought of as intimately related to each other; 5) addressing one or more barriers seen as inhibiting appropriate waste and resource management directly, whilst other barriers were subject to assumptions not further explored, or not acted upon in a number of cases; 6) various resource life-extending strategies as possibilities of a proposed intervention, without the need to completely resolve targeted routes; and, lastly, 7) participants experienced difficulties progressing the proposed solutions due to an inability to generate financial and political support.
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<td>WaRM</td>
<td>Waste and Resource Management</td>
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<tr>
<td>RLES(s)</td>
<td>Resource Life-Extending Strategy (or strategies)</td>
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<tr>
<td>MFA</td>
<td>Material Flow Analysis</td>
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<td>LCA</td>
<td>Life-Cycle Assessment</td>
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<td>CAF(s)</td>
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<td>VP</td>
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<td>EoL</td>
<td>End-of-Life</td>
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<td>Energy-in-use</td>
<td>The energy consumed by a product whilst it is being used</td>
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<td>CAD design</td>
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**Circularity**
- A technical term referring to the magnitude or the proportion of flows with a circular character

**Meaning work**
- The process by which our interpretation of the world is established, maintained and challenged
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1. **Introduction**

**Sustainability and circular economy**

This chapter outlines the sustainability challenge that lies before humankind and describes the manner in which this challenge is linked with the treatment of waste and the use of resources. As a result of the scale, complexity and immediacy of the sustainability challenge, calls have been voiced to change economic and industrial systems and associated practices dealing with waste and resources such that they align with sustainable development. One concept in particular, circular economy, has emerged recently as a way to rethink waste and resource management. The circular economy concept suggests that waste and resource management can be aligned with sustainable development by extending the productive life of resources through keeping them in productive ‘loops’ or ‘cycles.’ However, this concept is still developing and a plurality of interpretations currently exists. As such, early adopters of the concept have to establish their own (working) definition or interpretation within the context of their respective innovation projects. It is not self-evident that these interpretations have to be aligned with sustainable development, since reuse and recycling are not new strategies. Consequently, it is difficult to understand what knowledge and support could be offered to aid the implementation of circular economy strategies such that they are aligned with sustainable development. For this reason, this research seeks to understand how practitioners interpret circular economy and explores the concept’s potential for changing waste and resource management.

1.1. **Sustainability and circular economy**

This section offers an explanation for why the circular economy concept has risen to prominence. This is achieved by first outlining the magnitude and complexity of the sustainability challenge, which highlights the need for sustainable resource management, and linking this with the possibility of extending resource productivity as advocated by circular economy.

1.1.1. Human well-being under pressure

Human well-being has – and always will have – material components: nourishment sustains us, houses shelter us, and to remain in good health a clean environment is a prerequisite. In addition to this, we want to experience belonging, which can be symbolically expressed through the goods and services we consume. Goods and services can furthermore fulfil a desire for pleasurable and new experiences. Unfortunately, the material components that are so crucial to our well-being are under pressure.

Firstly, human activities have generated and continue to generate substantial amounts of waste. This waste, or material-in-the-wrong-place, has a plurality of negative effects. This can be in the form of emissions that have been shown to lead to climate change (IPCC 2014), which can disrupt markets and cause volatility in supply chains (McKinsey 2011). Emissions and other forms of pollution furthermore threaten ecosystems, diminishing their capacity to sustain biodiversity (Reid and Swiderska 2008) and provide ecosystem services (Defra 2014). In addition to this, emissions and particulates have been shown to negatively affect human health (Kampa and
Castanas 2008). Thus, in order to reduce value loss and destruction that is the result of the generation of these wastes, its generation and treatment needs to be rethought.

Secondly, population growth leads to pressure to generate more value from resources as more people means that a larger amount of basic needs have to be satisfied. Moreover, as populations become more affluent there is a further demand for goods and services associated with a more developed status, such as transport and electronic devices. At the same time, degrading ore qualities and the mounting energy intensiveness of mining and farming resources causes physical scarcity (PBL 2011). This is aggravated by resource nationalism practiced by countries implementing protectionist bans or taxes, limiting export (Stevens ET AL 2015). The question of how to increase the value extracted from resources has thus become a pressing one.

1.1.2. Sustainable resource management
To meet the demands of reducing waste and increasing value extraction it has been suggested that waste and resource management (WaRM) is adapted or changed such that it becomes aligned with sustainable development. This type of development ensures that economies can flourish, that societies experience stability and well being, and that the natural environment continues to be capable of providing ecosystem services whilst sustaining a wide diversity of species (Elkington 1994). This call for change has sounded consistently over recent decades, as illustrated by such seminal documents as Limits to growth (Meadows ET AL 1972), the Brundtland report Our Common Future (WCED 1987), Agenda 21 (UNCED 1992) and the climate change reports by the IPCC (e.g. IPCC 2014).

However, what material reality can and should underpin such development – referred to as sustainable materials or resource management (EPA 2009) – is much debated. Examples of concepts that have attempted to provide theoretical underpinning as well as practical support to guide sustainable development are industrial ecology (Forsch and Gallopoulos 1989), sustainable consumption and production (Tukker 2008), eco-design (Stevels 2007) and zero waste (Krausz 2012). However, definitive answers on what sustainable resource management entails have not yet emerged.

What seems certain is that sustainable materials management is a challenge of tremendous scale. An important measure used to indicate the scale of the problem is the expected increase in resource efficiency or productivity that is required: estimates range from a factor four (Weiszacker ET AL 1998) to a factor of 10 (RMI 2010). The Rathenau Institute (1996, in: Brezet and Rocha 2001) even suggests that the required change might lie between a factor 10 and 20. In short: incidental incremental change will not achieve sustainable materials management.

That sustainable materials management is also a complex problem is illustrated by the concept of the energy-water-food nexus (Kearins ET AL 2016). Other more expansive versions of the nexus concept also include materials (McKinsey 2011) or minerals (PBL 2011), whilst others more narrowly look at minerals and energy (Giurco ET AL 2014) or food and water interactions (Brears 2015). Regardless of the scope with which the nexus concept is applied, it describes the interrelated nature of resources where one resource can be an input in the production of another or can function as a substitute for it. For instance: energy is required in the production and delivery food. At the same time, certain agricultural crops can be used in the production of energy. These relationships are the reason that resource issues are often complex and interrelated.
Due to the scale and complexity of sustainable resource management, the kind of change that it requires can be described as systemic or radical change (e.g. Seebode et al 2012, Adams et al 2012). It can even be described as requiring a transition: a change that involves a wide variety of areas ranging from technology, business and industry, legislative and governing bodies as well as the daily practices of individuals (e.g. Elzen and Wieczorek 2005, Elzen et al 2012). As such, sustainable resource management can be said to be one of the major challenges of our time.

1.1.3. From linear to circular: extending the life of resources and systems thinking

As a result of promotional efforts by the Ellen MacArthur Foundation (EMF 2013) and the World Economic Forum (WEF 2014), the circular economy concept has attracted attention as a way to rethink WaRM and achieve sustainable resource management (Tennant 2013). This concept is based on the observation that current resource use can be seen as largely linear. That is: the industrial system is dominated by a take-make-use-dispose paradigm, where resources are mined or harvested, turned into products, used for a while and then discarded to end up in landfill or to dissipate into the environment. Studies such as by Haas and colleagues (Haas et al 2015) and TNO (2013) confirm these observations. Typically, this linear process is completed before the capacity of resources to generate value is exhausted or it unfolds in a manner that generates value loss or destruction. Put simply, resources prematurely reach their end-of-life and can thus no longer generate something for which there is a need or demand. Instead, not seldom they end up as materials-in-the-wrong-place, generating the associated negative effects.

Circular economy, in contrast, suggests that by extending the productive life of resources value extraction opportunities can be increased and instances of value loss or destruction reduced or omitted. Preserving or recovering resources for use in subsequent productive ‘loops’ or ‘cycles’ operationalizes the concept. Examples of strategies that can achieve this are reuse, recycling, cascades and redistribution or co-use. For this reasons, these strategies are henceforth designated as resource life-extending strategies (RLEs): the transformation of a resource that increases the intensity with which it is used over a given period. Such transformations can affect a resource’s location, the physical state or form of it or both. Resource, in this context, can refer to materials, products or energy.

RLEs are thought to generate such economic benefits as increased profitability and economic resilience (e.g. Greyson 2007, EMF 2013, Rutqvist and Lacy 2015), but also societal benefits such as job creation and better health (e.g. Stahel 2006, Pauli 2010). Moreover, they are attributed with the capacity to reduce and even restore damage afflicted to the environment (e.g. Cooper 1994, Murray et al 2015).

Apart from value optimization through the application of RLEs, BSI (2016) and EMF (2013) include systems thinking, innovation, collaboration and stewardship of human and natural capital as principals of circular economy. Systems thinking, in particular, is highlighted as a characteristic that makes the concept suitable for addressing the magnitude and complexity of sustainable resource management (Yuan et al 2006), as it allows for a better understanding of how, where and to what purpose resources are used in value chains. As such, it shifts the focus away from individual actors to the relationships that exist between them.

At the moment there is considerable momentum behind circular economy: apart from a wide variety of local projects in cities such as in London, New York, Rio de Janeiro and Amsterdam (EMF 2016a), the concept is also seeing national and supranational adoption. China, for example,
is advancing the concept through its Circular Economy Promotion Law (Sakai et al. 2011) and the EU is likewise developing policy guidelines in the form of an action plan for stimulating the implementation of strategies associated with the circular economy (EC 2014, 2015). Furthermore, the first circular economy indicators (EMF and Granta 2015) and standards (BSI 2016) have been put forward. Moreover, recent years have seen an increased number of academic publications related to the concept (Lieder and Rashid 2015).

1.2. Going circular?

1.2.1. One term, many interpretations
At present, the circular economy concept carries a diffuse meaning: a multitude of interpretations regarding what a circular economy could or should look like have been proposed. Moreover, theoretical clarity with regards to how loops or cycles are defined is absent and uncertainty exists as to what RLESs are within the concept’s scope. These points are illustrated by Fig. 1.01, which presents an overview of selected interpretations of what WaRM strategies are appropriate according to different actors, such as seminal thinkers, think tanks, advisory and legislative institutions, academics and businesses. The frameworks included in this overview have been selected for their use of ‘loops’ or ‘cycles,’ which means that they can be taken as different interpretations of circular economy. Contrasting and comparing the respective loops and cycles included in the frameworks reveals that they not only differ in the included RLES types, but that frameworks furthermore include different numbers of RLESs, as well as conceptualise the relationships between the included RLESs differently.

1.2.2. The problem: potential for change uncertain
The diffuse nature of the concept means that practitioners who use it to guide innovation and experimentation have to establish their own (working) definition or interpretation as thought to apply to the context of their respective innovation projects. Despite the association of the concept with systemic change and transitions, however, it is not self-evident that these interpretations need to be different from business-as-usual and in line with principles of sustainable resource management (Blomsma 2015b): RLESs, after all, have been in use since mid-19th century on an industrial scale and long before that in households and cottage industries (Strasser 1999, O’Brien 2008). Seen in this light, circular economy is not a radical or even a “really new” idea (Garcia and Calantone 2002) and can thus also be regarded as a continuation of business-as-usual practices. This latter interpretation is unlikely to result in significant changes in WaRM within the required time-frame for sustainable development, which means that the potential the circular economy concept holds to align WaRM with sustainable resource management is uncertain.

Given these uncertainties, it is difficult to understand what knowledge and support could be offered to aid experimentation with circular economy strategies such that their implementation is aligned with sustainable development. To enable this, one needs to know how practitioners interpret and use the circular economy concept and in what manner they enact it. At present, however, the understanding of this is limited.
Overview of selected WaRM frameworks (edited for fit only)

Seminal thinkers/ frameworks

Think tanks

Legislative & advisory

Academia

Business

Fig. 1.01 This overview contains the conceptual diagrams of WaRM frameworks in which 'loops' or 'cycles' play an important role. The included frameworks are selected to illustrate the variety of actors that engage with the circular economy concept as well as the variety of interpretations of the concept put forward by these actors. Some images were minimally edited to fit lay-out.
1.3. Aim, research questions and structure of this thesis

1.3.1. Aim and research questions
In order to be able to point to directions for further knowledge development as well as the creation of practical tools that can support experimentation with circular economy such that sustainable WaRM becomes more attainable, it thus needs to be understood how practitioners in a business environment imbue circular economy with meaning, render it actionable and how this affects WaRM in their respective contexts. For this reasons, the research question this research sets out to explore is:

*How is circular economy interpreted and enacted by practitioners and how does this influence the enactment of waste and resource management practices?*

This question can be split into the following sub-questions:

- What aspects of WaRM are important to practitioners in establishing an interpretation of the circular economy concept and how are these aspects imbued with meaning and made coherent and actionable?
- How does the meaning attributed to circular economy unfold as innovation projects progress?
- How does application of circular economy thinking influence the enactment of WaRM practices?

1.3.2. Structure of this thesis
This thesis consists of four parts: see also Fig. 1.02. *Part I - Literature Review* covers Chapters 02 to 05 and is dedicated to bringing together relevant aspects of the emerging field of circular economy. The featured analysis of the presented material facilitates the construction of the Circularity Compass: an analytical framework that is used in the empirical part of this research to capture salient distinctions in the meaning attributed to the circular economy concept. The development of the Circularity Compass is a necessary step in this research as there is no clear research tradition to build on for determining how practitioners interpret and use the circular economy concept. After all, much of the knowledge related to circular economy was developed in largely separate disciplines and concerns specific aspects of the concept, rather than the overarching concept. It is therefore not self-evident what theoretical perspective to adopt when researching the concept itself. For this reason, the literature review has a distinct analytical character as opposed to being purely descriptive.

Chapter 02 makes the first step towards the Circularity Compass by identifying meaning work as the appropriate theoretical grounding for this research. Meaning work, as used here, refers to the process through which interpretations of the world are established, maintained and challenged. Through means of a historical narrative, the WaRM discourse is characterized as a process that establishes, maintains and challenges what constitutes appropriate WaRM practices. The emergence of the circular economy concept is identified as an outcome of this process, as well as a possible catalyst for progressing it. Through this, the phenomenon of interest in this research is better understood as circular economy related meaning work.

Next, Chapter 03 explores what this positioning implies by reviewing two major research traditions into meaning work, frame analysis and sensemaking. This elucidates that meaning work serves to create recipes for action by establishing coherence, addressing uncertainty and
determining a course of action. What aspects are relevant in creating action recipes in the context of WaRM is further explored in Chapters 04 and 05. Chapter 04 reviews and analyses eight selected WaRM frameworks by conceptualising them as collective action frames (CAFs) and reviewing their proposed solutions through the lens of institutional logics. This brings to the fore that the definitions of what constitutes a waste and what a resource need to be captured clearly and consistently. To this purpose Chapter 05 examines relevant debates in the WaRM discourse relating to these two aspects. Together, Chapters 04 and 05 deliver the three key ingredients used in the creation of the Circularity Compass: the CAF functions of purpose and mechanism, prevention, perpetuation and proaction; the concept of resource states; and a typology for classifying different types of waste.

These ingredients are used to synthesize the Circularity Compass in Chapter 06. Next, Chapter 07 explains how the Circularity Compass was used in the empirical part of this research by revisiting meaning work and its three main implications for the research design. Firstly, meaning work is contextual, implying that it has to be studied in a real-life context. Thus chosen were 15 participants partaking in innovation projects inspired by the circular economy concept, spanning 23 innovation projects for 19 companies. A second implication is that a single observation or snapshot of the meaning attributed to the concept would not suffice, as meanings are subject to change. Consequently, interviews were conducted in three phases: when the projects were ongoing or were due to commence, on average seven months after the first interview and on average 28 months after the first interview. Lastly, meaning work poses that action and cognition exist in a recursive relationship. This implies that not only the established interpretation, but also the manner in which it is acted upon is part of the meaning attributed to the circular economy concept. This requires examining the aspects of the proposed solutions that were actively explored or acted upon as well as those aspects that received relatively little attention and to tracking the overall status of the innovation projects over the period covered in this research. Chapters 06 and 07 thus make up Part II – Research Methodology.

Part III – Results covers Chapters 08 to 10, where the results of the interviews of each phase are compiled and discussed. The case mappings of each case accompanying these chapters can be found in Appendix 03 Case Mappings Using the Circularity Compass.

Finally, Part IV - Discussion, conclusion and reflection synthesises the results and discusses the implications as well as recommendations for future work. The following seven insights stand out: participants considered 1) the particles, parts and products states as playing important roles in circular economy related meaning work; 2) other flows besides those directly related to the manufacturing of a product, such as material flows co-used with the product as well as energy and information flows, and frequently directed their attention to the infrastructure required in facilitating these flows; 3) those strategies that allow for the flexible use of product capacity as valid interpretations of what constitutes a RLES; 4) RLESs in sets of two or more, where they were frequently thought of as intimately related to each other; 5) addressing one or more barriers seen as inhibiting appropriate waste and resource management directly, whilst other barriers were subject to assumptions not further explored, or not acted upon; 6) various RLESs as possible outcomes of a proposed intervention, without the need to completely resolve targeted routes; and, lastly, 7) the majority of participants experienced difficulties progressing the proposed solutions due to an inability to generate financial and political support. Part IV concludes by a reflecting of the meaning work approach and a personal reflection on the research process.
Fig 1.02 This overview depicts how the different thesis chapters relate to each other. Particular emphasis is on the role of chapters 03, 04 and 05 and how these feed into subsequent chapters in the literature review as well as the research methodology. Depicted also is the origin of the main building blocks of the Circularity Compass and where other supporting concepts feature.
PART I

Literature review
2. The circular economy concept

The concept’s emergence from and role in the waste and resource discourse

This chapter serves to establish a theoretical framework suitable for this research. The first step is to determine that circular economy is an ‘umbrella concept.’ This conceptualisation allows for an historic review that anchors circular economy in the broader WaRM discourse (Blomsma and Brennan forthcoming). That is: circular economy is part of an on-going process that attempts to establish what are appropriate WaRM practices. Specifically, the emergence of the circular economy concept within the WaRM discourse is identified as both an outcome of this process, as well as a possible catalyst for progressing it further by highlighting something previously unseen or underexposed: namely, the capacity of a collection of strategies to extend resource life and the potential this harbours for increased value extraction and the reduction of value loss and destruction. This chapter is organized as follows. First, the ‘umbrella concept’ framework by Hirsch and Levin (1999) is introduced and it is shown that circular economy meets the definition of an umbrella concept. Next, a historical review is performed that provides insight into the knowledge gap circular economy attempts to fill and where the concept sits in its developmental trajectory. This chapter concludes with an analysis that clarifies that the emergence of the circular economy concept can be regarded as an expression of ‘meaning work’: the process by which our understanding of the world is established, maintained and challenged. This implies that meaning work is an appropriate theoretical framework for this thesis.

2.1. Circular economy as an umbrella concept

The circular economy concept, through its association with systemic change and transitions, affects many areas relating to waste and resource management: sourcing, design, technology, manufacturing, business models, legislative and governing systems as well as the daily practices of individuals. These areas are traditionally studied in different fields and disciplines, and typically use their respective research traditions and theoretical frameworks. It is therefore not immediately obvious what perspective to adopt when researching the phenomenon of circular economy and its use in practitioner-led innovation. For this reasons this chapter examines the nature and function of the circular economy concept, in order to establish what theoretical framework is appropriate for the purposes of this thesis. As a starting point, a working definition of ‘circular economy’ is required. For this, the umbrella concept framework by Hirsch and Levin (1999) is used.

2.1.1. Umbrella concepts: an introduction

Umbrella concepts are broad ideas or concepts “used loosely to encompass and account for a set of diverse phenomena” (Hirsch and Levin 1999:200). That is: pre-existing concepts previously unrelated or related in a different manner are grouped or see their relationship redefined by inclusion in a broader and overarching concept that is the umbrella concept. In this manner umbrella concepts focus the attention on a particular shared quality or characteristic of the concepts it encompasses. This act is analogous to changing the signal-to-noise ratio such that a particular signal – a particular phenomenon in the case of umbrella concepts – becomes clearer.
Hirsch and Levin (1999) pose that umbrella concepts tend to surface in fields or disciplines that lack guiding theories or a clear development paradigm. In other words: umbrella concepts surface in situations where there is a knowledge gap. In such situations, an umbrella concept can function as a catalyst by creating improved cognitive clarity as well as political validity around a phenomenon. Umbrella concepts achieve this in the following manner. When umbrella concepts are articulated they highlight a particular shared characteristic of a group of pre-existing concepts, which separates these characteristics from other characteristics. This simplifies and unifies what was previously messy and unrelated, providing a measure of cognitive clarity. Moreover, it establishes that there are links between the pre-existing concepts that merit clarification or further investigation. This creates a metaphysical space where it is considered a valid endeavour to explore these links.

Through this newly created clarity and validity new lines of investigation and even new fields are established, allowing for new discourses to take place. It is in this manner that umbrella concepts enable the creation of new knowledge, and, if successful, fill the knowledge gap that was the reason for their emergence. Although an umbrella concept can cause temporary disruption in a field, it ultimately strengthens it by what is learned from its associated investigations (Hirsch and Levin 1999).

When an umbrella concept has been formulated it predictably evolves along a trajectory that starts with emerging excitement. This phase is characterised by enthusiasm, or, the colloquial ‘buzz’ around a concept. After this an umbrella concept typically sees its validity challenged as attempts at operationalizing it surface definitional issues and a lack of tools and methods for applying it. After a phase of further theoretical development where these problems are addressed, the umbrella concept in question either coheres, collapses or persists as a contention (Hirsch and Levin 1999). As such, umbrella concepts cannot be seen as static intellectual containers and the status of any particular umbrella concept – how rigorous or coherent it is considered to be – varies depending on where it sits in this developmental trajectory.  

2.1.2. Circular economy as an umbrella concept: RLESs as the core of circular economy
There is ample ground to apply the umbrella concept framework to circular economy. Examining a selection of WaRM frameworks more closely makes this apparent: to this purpose Fig. 1.01 is included in Fig. 2.01 in altered form. In this version the original branding and layout is removed from the frameworks and they are redrawn using a uniform visual language, whilst the original strategies and their relationships are preserved (see also: Blomsma and Brennan forthcoming). The most notable changes include the addition of icons to designate similar strategies and the introduction of a colour scheme to indicate whether or not a framework distinguishes between biological and non-biological or technological cycles.

Fig. 2.01 illustrates more clearly that circularity frameworks include different numbers as well as different types of WaRM strategies. Although preventative strategies also feature, the included strategies overwhelmingly aim to extend resource life. What also stands out from Fig. 2.01 is the preoccupation of these frameworks with organizing the relationship between included strategies. For example: some strategies are assigned a hierarchical relationship implying preferential application of some strategies before others (Stahel 2006, DotE 1995), whilst others are presented as equally important (Braungart and McDonough 2002). In other frameworks strategies are presented as differing in the quantity of resources that can be rerouted through them (Green Alliance 2014, Ricoh 1994), whilst other diagrams do not distinguish between
capacity levels (EMF 2013). Moreover, some strategies are presented as capable of fulfilling different roles (EPA 1993, Ricoh 1994, Stahel 2006).

Circular economy can thus be said to revolve around assessing and organizing a collection of strategies with the capacity to extend resource life, where the assessment frequently extends to other types of WaRM strategies such as prevention. Considering RLESs as the pre-existing concepts that circular economy groups and the appropriate use of these strategies as the phenomenon that it attempts to account for, it is apparent that circular economy fits the definition of an umbrella concept. RLESs and determining their appropriate use can thus be considered the core of the circular economy concept. Circular economy as-an-umbrella-concept will be the working definition of circular economy used throughout this research.

The capacity of the circular economy concept to bind a RLES to it, however, is not absolute. This is evident from the difference that exists between the strategies included in the frameworks in Fig. 2.01, which indicates that the precise constitution of the set of strategies associated with the circular economy is diffuse and contested. As such, some RLESs are more strongly associated with the circular economy concept than others. This diffuseness is in line with the loose binding of concepts that umbrella concepts provide (Hirsch and Levin 1999).

Considering circular economy as an umbrella concept is in line with other definitions of the concept. CIRAIG (2015), for instance, refers to the concept as a “conceptual umbrella” (ibid:xi). Cooper, likewise, designates it as a “general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes” (Cooper 1999a and b, in: Murray ET AL (2015)). The conceptualisation of circular economy as-an-umbrella concept furthermore implies that the frameworks presented in Fig. 2.01 are but different interpretations of what a circular economy could or should look like. None, however, can be said to represent ‘the’ circular economy as circular economy as-an-umbrella-concept is merely the notion that RLESs represent an important source for value creation and a means to reduce or eliminate particular forms of value destruction. If one is to understand this contribution of circular economy to the WaRM discourse, it is necessary to understand the knowledge gap it attempts to fill and where it sits in its developmental trajectory.

2.2. Understanding the role of the circular economy and its state of development

2.2.1. Method of historical narrative

This section traces circular economy’s development from its constituent concepts – the RLESs – from mid-19th century to the present. It builds on earlier work: Blomsma (2015b), Brennan ET AL (2015) and Blomsma and Brennan (forthcoming). The historic narrative starts well before the term ‘circular economy’ became widely adopted in its current form and meaning, largely but not exclusively the contribution of promotional efforts of both the Ellen MacArthur Foundation (EMF 2013) and the World Economic Form (WEF 2014). Instead, as the starting point ca. mid-19th century is chosen, at what is termed the second industrial revolution, as this is the first time that RLESs were applied on an industrial scale. This era sees the increasing application of new technologies, such as electricity, and chemical as well as engineering expertise is increasingly applied (Huber 2004, Boons 2008). At the same time, industry was more frequently organized in central hubs, which were better connected through railroads. This sparked many new innovations as well as the generation of previously unseen quantities and types of materials.
Fig. 2.01 Depicted here are the WaRM frameworks also depicted in Fig 1.01, redrawn using a uniform visual language. This brings to the fore more clearly the variety in type and number of included strategies, as well as the different relationships that are thought to exist between these strategies.

From: Blomsma and Brennan (forthcoming) (used with permission).
These developments had significant bearing on the WaRM discourse as will be explained in the following.

The review is restricted to industrial and municipal waste handling practices in the developed world, with a particular emphasis on the UK and the US. However, these developments are broadly representative of the remainder of the developed world (O’Brien 2008). Furthermore, although RLEs play a role inseparable from preventative strategies, such as efficiency and functional replacement (Kurz 2006:285) and other strategies such as incineration (Lounsbury et al 2003), for reasons of brevity these strategies are only included where necessary to understand the development of the WaRM discourse. As such, this review does not claim to be an exhaustive history of this discourse, but merely discusses the broad developments that serve to anchor the emergence of the circular economy in a broader context. Neither should this review be taken as evidence that the discussed strategies were widely shared or implemented in the past (e.g. Desrochers (2000), Boons (2012)) or that multiple social narratives regarding WaRM did not or cannot co-exist (Dryzek 1997, O’Brien 2008).

Fig. 2.02 depicts the succession of evolving ideas regarding WaRM that are relevant to circular economy’s emergence. As is in line with the typical developmental trajectory of umbrella concepts, one can identify an excitement period as well as a transition into the validity challenge period. These periods are preceded by the embryonic, intermezzo and expansion periods that together can be regarded as the preamble leading up to the articulation of the umbrella concept. The preamble discussed here starts earlier than in Blomsma and Brennan (forthcoming), in order to deepen the understanding of the role of RLEs in the whole of the WaRM discourse as applicable to the industrial age. This allows for establishing that circular economy’s focus on RLEs as a means of value generation and the prevention of value destruction, is indeed novel.

Next, the developments particularly influential during the five periods identified are discussed in turn, paying particular attention to what RLEs are emphasised, the part of the industrial system they are directed at (scope) and the goal that WaRM was expected to serve (purpose).

2.2.2. Circular economy’s emergence: from preamble to validity challenge

Before starting with the narrative, a short background about the period before the mid-19th century. Pre mid-19th century, thrift had been an integral part of life: it was common to reuse what was already owned. Moreover, household refuse was frequently separated, stored and used in bartering with peddlers for new goods. When no further use could be found, however, refuse was thrown out on the street, where scavengers salvaged what they could still sell. The rest was left behind where it was deposited, since centrally organized waste handling and sewage systems were still largely absent. The salvage operations performed by peddlers and scavengers provided the main channels through which wastes were collected and sold back to industry, with wholesalers fulfilling an intermediary role as aggregators (Strasser 1999, O’Brien 2008). In this manner household waste was directly linked to industrial production. Industrial waste had not yet come to dominate the waste trade (O’Brien 2008). Moreover, the existence of waste was not uniformly seen as a problem. Rather, it was seen as ‘matter in the wrong place’\(^1\) and by some even as representative of untapped opportunities for those willing to invest effort and exercise sufficient ingenuity to capture its value (Miller 2000).

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\(^1\) This expression is attributed to Lord Chesterfield by Mary Douglas (in: Strasser 1999) and to Lord Palmerston (in: O’Brien 2008).

\(^2\) In practice it is often difficult to distinguish between cascading and recycling, since recycling is often a cascade
Developmental path of the circular economy concept

Fig. 2.02 Schematic overview of the past periods of development of the circular economy concept, including an expansive view on the preamble to the articulation of the concept in the excitement period. The included strategies list the RLEs emphasised during particular periods.

1840-1910 Embryonic period

During the period from 1840 – 1910 the first RLEs were in their nascent period, which is why this period is titled the ‘embryonic period.’ The present RLEs were either framed as part of urban sanitation practices (Melosi 2005) or seen as aiding industrial and economic expansion (O’Brien 2008). Two developments in particular put this into context. Firstly, practices related to household refuse changed. A multitude of factors contributed to this: dealing with waste had become increasingly associated with poverty and criminal activity; the introduction of mail-order rendered barter an invalid payment option; and, germ theory had demonstrated the relationship between waste and disease carrying vermin highlighting the importance of hygiene (Strasser 1999, O’Brien 2008). Moreover, at the end of this period household waste was commonly collected and subsequently incinerated or dumped in either water or on land, sometimes preceded by reduction: a process through which grease, fertilizer and other useful products were recaptured from the waste stream (Rathje and Murphy 1992). These developments had disconnected household waste generation from production activities since refuse flows were now redirected away from manufacturing. This meant that the importance of household waste in the waste trade decreased. By the end of this period household refuse was no longer perceived as something valuable in the public eye. Instead, its presence was perceived as negative, something preferably disregarded (O’Brien 2008). One could see this as the first indication of a growing cognitive distance between society and its waste.

At the same time, the importance of industrial waste increased (O’Brien 2008): not only relative because the importance of household waste decreased, but in absolute quantity, too: industry
was producing ever-larger amounts of co- and by-products alongside desired products, many to little use or profit. This led to the creation of substance cascades: a process that transforms substances through various use phases in a controlled manner, which may or may not require additional processing steps before substances are suitable for use in a subsequent application (Simmonds 1876). Through substance cascading, sellable products are created and the generation of waste is postponed or precluded.

The implementation of such alternative applications of waste did not follow automatically from the recognition of their technical feasibility. Rather, the presence or absence of political will or pressure from citizens can decide for or against their implementation (O’Brien 2008). Although there are examples of (moderate) success in addressing negative effects of production during this period (Boons 2009a), O’Brien observes the presence of a general “inability or unwillingness to police the behaviour of extractive and manufacturing businesses” (O’Brien 2008:26) during this period.

Reversely, society was also not immune to the creation of cascades. In some cases, cascades proved the motor of innovations with far-reaching societal impact: the availability of affordable paper through the use of rags in its production, the creation of an air transportation industry in the case of hydrogen and the use of coal tar and glycerine for a variety of purposes, such as pharmaceuticals and cleaning agents, improving health and hygiene standards (O’Brien 2008).

Apart from cascading, recycling was also first practiced at industrial scale during the embryonic period, particularly of metals. Iron and steel had become important industrial products during the earlier stages of the industrial revolution, which created waste streams of these materials that were fed back into production. For example, old train tracks were made into new ones (O’Brien 2008).

1910-1960 Intermezzo period

During the period between 1910 and 1960 the use of existing RLEs was expanded and more RLEs became applied on industrial scales, particularly in production processes. Despite this, the waste and resource discourse seemed to be focused primarily on what was considered excessive production and consumption under the influence of consumerism (Strasser 1999, O’Brien 2008). Consumerism rose as a result of new attitudes towards sanitation, freedom and convenience. These attitudes were epitomized by the introduction of single-use disposable products as well as the frequent replacement of products with technological or stylistic superior ones.

The invention of sanitary landfill and, in America, the introduction of the garbage disposal, reinforced consumerism as these strategies seemingly offered safe and convenient ways of disposal (Strasser 1999, O’Brien 2008). This further increased the cognitive distance between society and its waste.

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2 In practice it is often difficult to distinguish between cascading and recycling, since recycling is often a cascade in the form of downcycling and both can require additional energy input. Moreover, recycling can turn into a cascade after multiple recycling phases due to contamination or degeneration of material properties beyond processing or performance specifications, at which point other uses for the material have to be found. Nonetheless, here is adhered to the position that a distinction between recycling and cascading is useful: they are regarded as the two ends of a continuum: on the one end cascading facilitates a second or third life of a resource in different applications; on the other end there is infinite recycling, where a material continues to be reused for the same or a similar purpose, which is rarely achieved.
Consumerism proved a resilient idea: both wartime and economic crisis had little effect on consumption trends apart from causing temporary shortages (Strasser 1999, O’Brien 2008). Although RLESs did not completely disappear from the mind of the public during this period, they coexisted in a paradoxical relationship with consumerism: for example, quilting and other such activities originally representative of thrift became optional spare time occupations, for which the appropriate consumables could be purchased in shops (O’Brien 2008).

Although O’Brien argues that consumerism did not make households inherently more wasteful – some activities became more wasteful, others less so (O’Brien 2008) – consumerism was none the less perceived as having this effect and as changing the relationship between society and its waste in ways considered immoral (Sayers 1943, Packard 1960). Packard illustrates that consumption – and implicitly the creation of waste – was commonly portrayed as virtuous or dutiful. Seen from this perspective, it was as if RLESs had lost their significance, which is why this period is dubbed the ‘intermezzo period.’ Packard himself, however, vehemently distances himself from consumerism. His and other critique on consumerism problematized the act of creating waste and called for its abolishment and for the reinstatement of thrift and sufficiency.

In the meantime, within industry, reclamation activities continued to grow markedly (Lipsett 1951). For one, the idea of substance cascading continued to exert influence (Spooner 1918, Talbot 1919, Lipsett 1951, 1963). The application of recycling was furthermore extended and applied to glass, paper and plastic (Lipsett 1963). Moreover, additional RLESs find industrial applications. For example, reconditioning was applied in the automotive industry where vehicles were repaired (Strasser 1999). Also, through remanufacturing ‘like new’ products were created from old ones (Lipsett 1963), and gasification of organic materials was introduced in domestic waste processing (Kershaw 1928). In addition to this, the waste trade further matured as illustrated by the introduction of standards and the establishment of formal waste handling institutions (Strasser 1999).

**1960-1985 Expansion period**

So far, consumers and their wastes featured prominently. The period between 1960 and 1985, however, brought back into sharp focus the role of industry, especially in relation to addressing negative end-of-life and waste handling effects. The set of RLESs highlighted during this period are therefore primarily related to end-of-life processes of both industrial and municipal waste, but preventative measures also featured. This period is named the ‘expansion period’ as the attention was, for the first time, directed at both the production and end-of-life phases of industrial systems.

Two developments were crucial to the progression of the WaRM discourse in this period. The first was renewed interest in the idea of responsible management of resources earlier put forward by thinkers such as Thomas Malthus, John Stuart Mill and Hans Carl von Carlowitz (Lacy and Rutqvist 2015). Publications such as, for instance, *Silent Spring* (Carson 1962), *Tragedy of the Commons* (Hardin 1968) and *Operating Manual for Spaceship Earth* (Buckminster Fuller 1969) gave a second wind to these ideas by problematizing, respectively, toxicity and scarcity. During this period awareness that environmental pollution had a profound impact beyond local geographies (Commoner 1971), became linked with the realization that human and environmental well-being were linked. Moreover, the realization grew that such problems were directly linked to resource use and processing. These ideas were illustrated by Kenneth Boulding; he named the then current situation the “open cowboy economy” and contrasted this with the
desirable situation that he described as the “closed spaceship economy” (Boulding 1966). With this, Boulding implies that resources are not infinite and that refuse never really goes away.

These ideas were further progressed by Stahel and Reday-Mulvey (1981), who conceptualised a “closed-loop economy” (Murray et al 2015). This line of thinking culminated in the Limits to Growth report (Meadows 1972) which formalized the call for rethinking economic systems and industrial practices. This message was to continue to sound into the next period, see for instance such publications as the Brundtland report (WCED 1987) and Factor Four (Weizsacker et al 1998).

The second key development was progress in biology, ecology, physics, systems thinking and the management and business sciences, as well as the interplay between these fields (see for reviews describing these interactions: Fischer-Kowalski 2002, Boons 2009b, Capra and Luisi 2014). New disciplines were created, such as environmental economics and eco-design or design for the environment. This same development eventually also brought forth the field of industrial ecology (Frosch and Gallopoulos 1989). These fields and disciplines not only generated new insights, but also new attitudes such as a readiness to learn from nature and the idea of modelling society after nature. This brought forth a range of seminal works, such as The Closing Circle (Commoner 1971), Small is Beautiful (Schumacher 1973) and Design for the Real World (Papanek 1972). These ideas would continue to inspire, as indicated by such successive seminal works as Biomimicry (Benyus 1997) and Herman Daly’s work on ecological economics (Daly 1991).

During this period waste continued to be framed as a negative force, but now for different reasons: the associated environmental, social and economic cost were now more widely acknowledged and understood. Prevention, and, where possible restoration, of (further) damage to human and environmental well-being became central to the WaRM discourse. However, no clear consensus emerged as to what were appropriate WaRM practices. On the contrary: debates erupted around the appropriateness of strategies. Some strategies started to fall out of favour: the increasing scarcity of space for landfilling in some places, such as the Netherlands and Japan, and the increasing financial and environmental costs of incineration in others, such as North America (Murray 1999), brought to the fore the question of what strategies should be applied and under what circumstances. Recycling, similarly, was reframed during this period. Initially, it served charitable and community purposes and was seen as a moral duty to the environment. Gradually, however, it transformed into a large scale for-profit industry (Lounsbury et al 2003). Interestingly, the purpose ascribed to recycling does not change: it continued to be seen as serving to reduce the negative end-of-life effects of matter that was no longer wanted by its previous owner. Furthermore, during this period, the concept of cascades was extended to include product cascades: the relocation of a product to a user who requires less or different functionality of a product (Stahel and Reday-Mulvey 1981, Stahel 1982).

**1985-2013 Excitement period**

From 1985 onwards, there is room again to view waste in a more positive light: as a resource and a source of value (O’Brien 2008). The development of new ways of representing and analysing social life during the 70s and 80s, among which was life-cycle thinking (Boons and Howard-Grenville 2009), would prove instrumental in this. Life-cycle thinking highlighted new strategies for dealing with resources, primarily related to extending the use phase and delaying or even preventing landfilling, such as product-service systems, with which the interest in product
longevity, repair, refurbishment, upgradeability and remanufacturing were also renewed, and, more recently, urban mining.

With this, the number of RESs available to industry grew yet again: although some fell out of favour, the overall effect was that the set of strategies increased. Moreover, the meaning attributed to several strategies already in use became richer and more complex. Cascading, for example, was extended to webs and sequences of substance and energetic cascades (Chertow 2000, Pauli 2010), longevity approaches became more nuanced as ‘optimal product lifespan’ was introduced (Bakker et al. 2014), recycling was reframed as a source of raw materials and waste-to-energy again became an acceptable ‘last resort’ strategy when all other options for value extraction had been exhausted (EMF 2013).

During this period sustainable development was reframed as an opportunity and addressing this global challenge was viewed as a means of managing risk, saving costs, and as an opportunity to deliver economic growth and innovation (Hart and Milstein 2003). In addition, increasingly waste and resource strategies were viewed as intimately intertwined through synergies and trade-offs. An example of the former was the belief that win-win situations exist where multiple benefits can be generated from a single intervention. This view rose to prominence during the UN Conference on Environment and Development (UNCED 1992), gained traction as the concept of the triple bottom line (Elkington 1994, 1997) and was taken up by the business community (Porter and Van der Linde 1995). An example stressing trade-offs is the introduction the concept of the ‘food-water-energy nexus’ (Keairns et al. 2016). In short, the waste and resource debate had become increasingly demanding and complex (Hultman and Corvellec 2012, Silva et al. 2016) and it was evident that a more systemic approach to WaRM was required.

Consequently the discourse around waste and resources intensified. This was evidenced by the appearance of such umbrella concepts as zero waste, extended producer responsibility, sustainable consumption and production, green economy and the momentum gained by industrial ecology. Moreover, a multitude of WaRM frameworks burst onto the scene, which suggests that there was much need for clarifying the relationships between different WaRM practices. Such frameworks were – and still are – characterized by a comprehensive set of heuristics in the form of a set of core values and a group of guidelines or principles in service of these values.

WaRM frameworks were typically put forward and used by two types of actors. One type of actor were policy makers that wished to use circularity as a legislative tool. Yong (2007), Yuan et al. (2015), Murray et al. (2015) and Ghisellini et al. (2015) expound on the spread of circularity policy around the globe, from Sweden to Germany, from Japan to China and Korea, often building on or replacing earlier policies related to waste management. The European commission likewise introduced guidance in the form of the Waste Hierarchy (EC 2008) that replaced earlier national policies. Formal guidelines on the area of circularity in the US are absent to this day, but the Environmental Protection Agency has previously provided guidance in the form of documents such as Life Cycle Design Guidance Manual (EPA 1993).

The second group that became interested in WaRM frameworks were businesses. Various consultancy and support services targeted at businesses start to be offered by organizations that

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3 Google n-gram shows that the use of these concepts in written documents increases percentage-wise after 1990 and continues to increase up to 2008 (which is the upper limit for which data is freely provided).
promote their respective frameworks, among which are Cradle-to-Cradle™ (Braungart and McDonough 2002, 2013), the Performance Economy (Stahel 2006), the Blue Economy (Pauli 2010) and the Circular Economy (EMF 2013). Notable in this respect also is Datschefski’s (2001) Towards Total Beauty framework, that includes ‘cyclic’ as the first of five principles. Other efforts similarly attempted to make accessible and popularize the idea of pursuing loops and cycles among businesses. Contributions in this category are The Ecology of Commerce (Hawken 1993) and The Natural Step (Robért 2002). The latter builds on earlier cooperative work that uses thermodynamic arguments to show that resource cycling is unavoidable if humanity wishes to operate within planetary boundaries, developing the idea of a “cyclic industrial era” (Eriksson and Robèrt 1991). Other, less well-known examples popularizing resource life-extension are the report Industrial Ecology (Tibbs 1993), which talks of a “cyclic economy,” and the report Eco-efficiency and Materials (Young ET AL 2001), that speaks of a “cyclical economy.” Note the varied terminology used to describe the emergent circular economy concept, despite Pearce and Turner having introduced the term “circular economy” in 1990 (Pearce and Turner 1990). Although this term found some adoption (see: Cooper 1994, 1999), terminology was diverging rather than converging: such terms as revalorization (Parkinson and Thompson 2003) and closed-loop production (Abdallah ET AL 2012) are also in use.

Eventually, as already mentioned, the term ‘circular economy’ became widely adopted in its current form and meaning, due to promotional efforts of both the Ellen MacArthur Foundation (EMF 2013) and the World Economic Form (WEF 2014). Despite the continued rise in interest in the concept – both in the academic world (Lieder and Rashid 2015) and in the world of business, as can be seen by the ever-growing group of companies associating themselves with the Ellen MacArthur’s ‘Circular 100’ (EMF 2016b) – this wide adoption of the term is an appropriate moment to end the excitement period. Now that conceptual clarity and political validity of the discourse around the concept have been established, a more critical type of engagement with it also starts to take place. This is the reason for designating this as the start of the ‘validity challenge period’.

Present: validity challenge period

The developments until this date have not yet resulted in theoretical or paradigmatic clarity regarding circular economy as-an-umbrella concept. In fact, the opposite seems to be true: the present is characterised by a plurality of interpretations. Not in the least, the term ‘circular economy’ is used both to refer to EMF’s own framework known as the ‘butterfly diagram’ as well as to circular economy as-an-umbrella concept4. Fig. 2.01 is further evidence of the multitude of frameworks that vie for supremacy of their proposed interpretations of what a circular economy should or could look like. Individual narratives are extensively critiqued: Bakker ET AL (2010), Potting and Kroeze (2010) and Reijnders (2008), for instance, critique the Cradle-to-Cradle™ framework, respectively, for being focussed too much on materials alone, for not being expansive enough in scope to account for effects beyond human and environmental health and for a misplaced belief in the non-hazardousness of biological materials. In the same spirit, Welch ET AL (2017) point out inconsistencies in the narrative of the EMF: where the ‘butterfly diagram’ creates the impression of user and consumer centrality, whilst in textual definitions users and consumers are seemingly absent, creating apparent inconsistencies in the framework. Similarly, Bulkeley and Gregson (2009) critique the Waste Hierarchy: their research shows that much policy aimed at implementing this framework has been oriented towards promoting end-of-pipe

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4 Although in this research, it will be clear by now, I use ‘circular economy’ to refer to the umbrella concept.
solutions, despite prevention playing such a prominent role in this framework. Many of the frameworks included in Fig. 2.01 are critiqued in similar ways. A critique that can be added to this from considering Fig. 2.01 is that none of the frameworks seems to employ a rigid underlying structure or logic to organise the included strategies. That is: they might apply organising principles, but these do not have a robust empirical or theoretical basis.

Other sources of critical engagement, such as Murray et al. (2015) and Gregson et al. (2015), for example, question whether current interpretations of the circular economy concept are indeed in line with the creation of societal and environmental benefits. Also, Allwood (2014) argues that there are limitations to the benefits RLESs can generate, when the negative impact of energy use is neglected. Increased critical engagement with the concept can be found outside of academic journals also: for example, Lemille (2016) critiques the absence of power from the current circular economy discourse and Lawson (2016) draws into question the archetypical examples typically used to characterize circular economy, such as Zipcar and AirBnB, dismissing these as truly representing RLESs.

There has furthermore been a realisation that tools to operationalize the circular economy concept are lacking. To fill this gap, circular metrics have recently emerged, such as by EMF and Granta (2015). In additional to this, new tools have been proposed to aid in circular economy inspired business model innovation and product design (Bocken et al. 2016, Lewandowski 2016, EMF and IDEO 2017). Given the definitional issues, wider critique and operationalization debate, it is appropriate to place the circular economy, in terms of the developmental trajectory of umbrella concepts, at the beginning of the validity challenge period, see Fig. 2.03.

**Circular economy’s distance travelled along the developmental path of umbrella concepts**

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**Fig. 2.03 Representation of the circular economy’s distance travelled along the typical trajectory that umbrella concepts develop along (in blue), and the remaining journey ahead (in grey). Based on Hirsch and Levin (1999), adapted and expanded for circular economy.**

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2.2.3. Analysis of circular economy’s developmental path

The preceding illustrates that the WaRM discourse, during the period discussed, can be characterized as a debate on what outcomes WaRM should generate, what strategies should be selected for this, how these strategies should be executed and how the selected strategies relate to each other. By 1985 this discourse had evolved to demand increased value extraction opportunities as well as a reduction of value loss and destruction, without clear solutions having
presented themselves. Rather, a wide range of WaRM strategies were available among which a considerable number of RLESs – the respective meanings of which were often rich and varied – that did not have an obvious relation to each other. This ambiguity made apparent that a knowledge gap had emerged with regards to what constitutes appropriate WaRM. The circular economy concept attempts to fill this gap by making explicit the capacity of RLESs to extend the productive life of resources and that in this capacity the potential lies to increase value extraction as well as decrease value loss and destruction. Other umbrella concepts do not articulate this, or do not articulate it with similar clarity.

The historical narrative furthermore revealed that, despite the fact that some RLESs have a long history, the circular economy itself is still emergent: the embryonic, intermezzo and expansion periods are but a preamble to circular economy’s articulation in the excitement period. Fig 2.03 illustrates that it is reasonable to expect the concept to further develop: the further work period still lies ahead, after which the concept will either cohere, collapse or continue to exist as a contention. This shows that the concept cannot yet be considered rigorous or coherent: whether RLESs can indeed deliver on their projected potential still requires verification (York and Rosa 2003). Instead, circular economy as-an-umbrella-concept should be considered as a proposal for a new direction for the WaRM discourse to explore.

A final key insight can be extracted from the historic review. It was shown that the WaRM discourse evolves under the influence of the changing meaning attributed to what is considered appropriate WaRM. O’Brien summarizes this as follows by characterizing the WaRM discourse as a “social process of valuation and the industrial, political and economic means of its realisation” (O’Brien 2008:5). Accepting this implies that one conceptualizes the WaRM discourse as a process centring on the generation and negotiation of meaning, in this case what WaRM are considered valid. Regarding the circular economy concept in this light means that it is both an outcome of a meaning generation process as well as a tool to progress this process further. The process that establishes, maintains and challenges meaning is referred to as meaning work (Snow and Benford 2000). Circular economy related meaning work, then, refers to the means by which a set of RLESs and other WaRM strategies are attributed with meaning and enacted.

The next chapter discusses the phenomenon of meaning work in more detail and the implications of conceptualising the phenomenon of interest as circular economy related meaning work.

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3. How meaning work works

Shedding light on circular economy related meaning work

Having established meaning work as an appropriate grounding for researching circular economy in the previous chapter, this chapter discusses the implications of conceptualising circular economy in this manner. Explained first is the significance of meaning work, its role in change processes and the scope of circular economy related meaning work. Next, two major research traditions into meaning work, framing and sensemaking, are introduced and their suitability for researching circular economy related meaning work is explained. Using the core texts Goffman (1974), Weick (1995) and Weick et al (2005), the two perspectives are contrasted and compared, establishing similarities and complimentary differences that clarify what is paid attention to when researching meaning work. Thus laid bare is the core function of meaning work: to create recipes for action by establishing coherence, addressing uncertainty and determining a course of action. This is the trigger to examine more closely how WaRM frameworks create action recipes in Chapters 04 and 05 and culminates in the synthesis of the Circularity Compass in Chapter 06. Three additional implications of meaning work are distilled that are relevant in relation to establishing a research approach: meaning work is contextual, meanings change and part of the meaning constitutes how it is acted upon. These are insights that feed into Chapter 07 Research design. See also Fig. 1.02 to understand how this chapter relates to the remainder of the thesis.

3.1. Meaning work: an introduction

3.1.1. Meaning work matters

Meaning work, also designated as signifying work or meaning construction (Benford and Snow 2000)⁶, is the process that establishes, maintains and challenges our understanding of the world. As part of meaning work “[actors] vest objects, utterances, actions and so forth with subjective meaning” in order to “make their world intelligible” (Frost and Morgan 1983:207). The purpose of meaning work is thus to organize an actor’s experience of the world by assigning structure and significance to events that allow for determining their status in reality (Goffman 1974). Through determining this status it is possible to know what is going on, whether or not it is relevant to the actor and the manner in which that actor should engage. In other words: meaning work is about determining what ideas, sense or understanding to adhere to when acting.

When multiple actors take part in meaning work it is generally characterized by what Fiss and Hirsch (2005) describe as “discursive struggles.” That is: actors continuously seek to either reaffirm or challenge the social and cultural relevance and impact of meanings. If new meanings emerge, successfully challenge established meanings and become widely accepted and adopted this can lead to the transformation of value chains, industries, markets and even societies (Rao et al 2003, Anand and Watson 2004, Fiss and Hirsch 2005, Benner and Tripsas 2012). As such,

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⁶ Traditionally, the term ‘meaning work’ is used in the context of social movements. Others, such as Kaplan (2008), Creed et al (2002) and Gray et al (2015), have shown that the work of Benford and Snow can be productively extended to other levels of analysis. For this reason, the definition of meaning work is used here to describe the phenomenon independent of - but applicable to - the levels of analysis ranging from the micro (individuals), the meso (groups) to the macro (societies).
meaning work can impede change when it confirms existing and entrenched meanings, but can facilitate change if these are successfully challenged (Benford and Snow 2000, Gray et al. 2015).

3.1.2. Meaning work in the context of waste and resources and circular economy

The historical shifts in the scope and purpose of WaRM discussed in the previous chapter can be seen as instances where new ideas were successful in challenging established meanings. When such ideas operate at scale and endure over time particular ways to manage waste and resources assert themselves and become established in industrial systems (Lounsbury et al. 2003, O’Brien 2008, Boons 2009a, Corvellec and Hultman 2012, Silva et al. 2016). This involves the alignment of decisions and actions with meanings, referred to as enactment, and leads to the adoption of particular technologies and the creation of particular executive and supervisory organizations and institutions. As a result of these enactment processes waste and resources come to flow in particular ways, as opposed to a range of alternative ways. Specifically in the context of circular resource flows Boons and Howard-Grenville (2009) point out that industrial systems “do not self-organize automatically in such a way that loops are closed,” but that people shape these systems based on their perceptions and beliefs.

In this light, the degree to which circular economy aids in implementing sustainable resource management will depend on the degree to which circular economy related meaning work is able to establish that implementing RLEs is different from continuing with current practices, whether or not RLEs are considered a viable alternative to current practices and their alignment with sustainable development.

3.2. Two perspective on meaning work: introducing framing and sensemaking

Reviewed here are the framing and sensemaking perspectives as they represent the two major research traditions into meaning work. Moreover, these perspectives have been successfully used to link individual, group, organizational and institutional levels of analysis through various diffusion and adaptation processes (Maitlis and Christianson 2013, Cornelissen and Werner 2014). The origin of both perspectives lies in the field of social psychology, that had turned its attention to cognition and had become interested in the ways in which actors shape their environment (Hodgkinson and Healey 2008, Kaplan 2011). This brought to the fore the influence of meaning generation, its negotiation and how its enactment shapes society (Walsh 1995, Kaplan 2011). These insights were further developed within sociology and organizational science, respectively resulting in the framing and sensemaking perspectives. As such, meaning work is at the heart of both framing and sensemaking.

Although the two perspectives are associated with their respective disciplines, it is not straightforward to characterize both literatures. For example, the perspectives are both used within organizational science. See for applications of framing, for example, Kaplan (2008) and Creed et al. (2002), and for sensemaking Basu and Palazzo (2008) and Balogun et al. (2015). Through interacting with this field, both perspectives have influenced each other as is evidenced by the frequent cross referencing of such seminal papers as Starbuck and Mililken (1988), Porac et al. (1989), Gioia and Chittipeddi (1991), Gioia and Thomas (1996) and others. Further complicating a characterization is the fact that both perspectives make use of many of the same concepts, such as frame, bracketing and enactment (explained below).
It is possible, however, to characterize both bodies of knowledge using the work of the ‘founding fathers’ Erving Goffman and Karl Weick\(^7\) as their work has served – and continues to serve – as guides for much subsequent research, albeit almost never in tandem (compare: Maitlis and Christianson (2013) and Cornelissen and Werner (2014)). Naturally, there are a few exceptions to this, notably Fiss and Hirsch (2005) and Hamilton (2016). Next, by way of introduction, both perspectives are characterized by discussing the preoccupations of Goffman and Weick.

**The framing perspective: “What is it that’s going on here.”**

In 1974, already a celebrated sociologist, Erving Goffman published *Frame Analysis* (Goffman 1974). In this work, Goffman examines “the way we take it that our world hangs together” (ibid:440). To this purpose he investigates what special situations, such as games, jokes, deceit, performances, accidents and experiments reveal about the processes by which meaning is generated in everyday life.

Of particular interest to Goffman are the automatic processes that are always on-going which generate meaning as and when events transpire, in the flow of their unfolding. The special situations that he singles out reveal how certain aspects of meaning generation are actively altered or suspended by the participating agents such that a different meaning is created. For example: the same sequence of events can be described as an experiment, a practice or a demonstration. Adopting either description as true results in a different assessment with regards to what it is that is ‘going on’ (Goffman 1974). This reveals that definitions of situations are based on frames: that is, on “basic elements” or “principles of organization which govern events […] and our subjective involvement in them” (ibid:10). As such, a frame is the assessment of one or more aspects of the world that serves to determine whether something is relevant to an actor and in what manner. Thus, frames are composed of “little tacit theories about what exists, what happens, and what matters” (Gitlin 1980:6, in: Gray ET AL 2015) and as such “sort out and organize the complex stimuli of everyday life” (Creed ET AL 2002:36).

Goffman identifies a range of strategies used to distil relevant information about a situation and establish frames, such as drawing on previously established beliefs and knowledge, the learned social expectations associated with certain roles, the rules associated with the start of stop of a sequence of events, the disregard of certain information in favour of seemingly salient information, etc. These strategies are largely automatically applied, without the actor having to pause or becoming explicitly aware that an assessment is made.

All everyday experience, according to Goffman, is susceptible to being transformed by the adoption of different frames as frames are applied, assessed and if necessary adjusted on an on-going basis, making reframings common events. The framing perspective, as used here, is therefore understood as those aspects of meaning work that concern the automatic *in-flow attribution or generation of meaning*.

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\(^7\) Choosing these authors implies that the perspective taken on meaning work differs from, for example, the cognitive semantic view of framing (described in Gray ET AL 2015, Cornelissen and Werner 2014) and used by, for example, March and Simon (1958). In the case of sensemaking, this furthermore implies that more colloquial references to making or establishing ‘sense’ are out of scope (see: Maitlis and Christianson 2013).
The sensemaking perspective: “How can I know what I think, till I see what I say?”

In the seminal Sensemaking in Organizations (Weick 1995) Karl Weick summazizes a number of preceding papers (e.g. Daft and Weick 1984, Weick 1993), as well as work by other authors that he considers insightful with regards to sensemaking. The perspective is further expanded and amended in Weick et al. (2005).

Sensemaking draws heavily from cases that illustrate the “struggles to reduce ambiguity” (Weick 1995:13), which are often particularly high-risk and high-pressure situations, as such situations are thought to magnify the influence of meaning work onto the unfolding of events. Of particular importance is whether or not certain information is noticed and acknowledged as significant, generating that Weick calls a cue, and how this cue is subsequently interpreted. What might seem like “short moments” and “small actions” — where cues are interpreted and subsequent action instigated — are significant in that they impact the unfolding of events (Weick et al. 2005:410-9). In fact, Weick poses, these moments can have large consequences in extreme environments as well as in organizational life.

Central to sensemaking is the connection that is created between a belief and an action that has generated some type of cue. According to Weick this “cue + relation + frame” (Weick 1995:110) is what creates a unit of meaning: “a cue in a frame is what makes sense, not the cue alone or a frame alone” (ibid). That is: meaning emerges as the result of a stimulus being linked to a previously established assessment about aspects of the world. This meaning guides following actions that can in turn create a cue that can undergo the same process of linkage to a frame, ad infinitum. As such, Weick regards acting as a kind of probing, serving to examine the assumed relation between cue and frame.

Opportunities for sensemaking arise when the flow of events is interrupted: when probing results in the encounter of something unexpected or unaccounted for. In these instances the meaning of the cue in question has to be determined by relating it to one or more different frames or by adjusting the frame it was linked to, before meaning can be reinstated. Often this is accompanied by a pause or interruption in the action sequence previously committed to. The sensemaking perspective is therefore understood, here, as engaging with the aspects of meaning work that involve the attribution or generation of meaning from cues from the environment, which present themselves as violated expectations that disrupt the flow of events.

Although both perspectives seemingly engage with different aspects of meaning work, they are similar with regards to key aspects of conceptualizing this phenomenon and complimentary where other aspects are involved. The following two sections are dedicated to discussing these similarities and differences, respectively. Each section is concluded with a discussion of the implications of conceptualising circular economy as an expression of meaning work.

3.3. Framing and sensemaking: key similarities

The similarities of the framing and sensemaking perspectives can be uncovered by use of the core texts Goffman (1974), Weick (1995) and Weick et al. (2005). Three such similarities merit discussion. An overview of illustrative quotes from the core text in support of these can be found in Fig. 3.01.
### Overview of similarities between the framing and sensemaking perspectives

<table>
<thead>
<tr>
<th>Framing</th>
<th>Sensemaking</th>
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#### Meaning work deals with uncertainty

- “[W]e intendedly write so that ambiguity is ruled out.” (p.442)
- “Given their understanding of what it is that is going on, individuals fit their actions to this understanding and ordinarily find that the ongoing world supports this fitting.” (p.247)
- “Sensemaking is not about truth and getting it right. Instead, it is about continued redrafting of an emerging story so that it becomes more comprehensive, incorporates more of the observed data, and is more resilient in the face of criticism.” (2 - p. 415)
- “Sensemaking is understood as a process that is [...] driven by plausibility rather than accuracy.” (1 - p. 17)

#### Meaning work enables action

- “[A]n operating fiction might be accepted, at least temporarily, [so] that acts of daily living are understandable because of some primary framework (or frameworks) that informs them.” (p.26)
- “[S]ensemaking is about plausibility, pragmatics, coherence, reasonableness, creation, invention, and instrumentality.” (1 - p. 57)
- “Beliefs that counteract interruptions and facilitate ongoing projects are treated as accurate.” (1 - p. 59)

#### Meaning work is materially and socially embedded

- “Activity [...] that organizes matter for the interpreter [...] is located in a physical, biological and social world.” (p.247)
- “[O]ur bodies always participate in the everyday world whatever our interest at the time.” (p. 5)
- “[T]he context [...] rules out wrong interpretations and rules in the right one.” (p.440)
- “[T]o sense something, there must be something there to create the sensation.” (1 - p. 14)
- “Sensemaking is grounded in both individual and social activity.” (1 - p. 6)
- “[W]hat an extracted cue will become depends on context.” (1 - p. 51)

#### Actors actively shape meaning work

- “A significant feature of any strip of activity is the capacity of its participants to ‘disattend’ competing events – both in fact and in appearance – here using ‘disattend’ to refer to the withdrawal of all attention and awareness.” (p. 202)
- “Mere perceiving [...] is a much more active penetration of the world than at first might be thought.” (p. 38)
- “[I]t is reasonable to say that each utterance or physical doing that the individual contributes to a current situation will be rooted in his biographical, personal identity.” (p. 293)
- “[P]eople create breaks in the stream and impose categories on those portions that are set apart.” (1 - p. 35)
- “Once this occurs ‘the world is simplified.” (2 - p. 411)
- “[T]he combination of a past moment, an event, and the present moment of experience creates a meaningful definition of the present situation.” (1 - p.11)
- “[S]eeing what one believes and not seeing what that for which one has no beliefs are central to sensemaking.” (1 - p. 87)

#### Meaning is dynamic

- “Over time, as supporting evidence mounts, significant changes in beliefs and actions evolve.” (2 - p. 416)
- “[M]eanings vary as a function of the content and the connection. Thus there is no such thing as a fixed meaning [...].” (1 - p. 132)
- “The process of sensemaking is intended to include the construction and bracketing of textlike cues that are interpreted, as well as the revision of those interpretations based on action and its consequences.” (1 - p. 58)
- “I use the word enactment to preserve the fact that [...] people often produce part of the environment they face.” (1 - p. 50)
- “[S]elf-fulfilling prophecies are the prototype for human sensemaking. People create and find what they expect to find.” (1 - p. 35)
- “The issue turns on faith or the lack thereof, because it sets self-fulfilling action in motion.” (1 - p. 38)

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*Figure 3.01 Overview that lists and organizes the relevant quotes from the seminal works of Goffman and Weick, for easy comparison of the framing and sensemaking approaches to meaning work.*
3.3.1. Meaning work deals with ambiguity and enables action

The first aspect of meaning work that Goffman and Weick highlight concerns its purpose, which is not necessarily to establish what the world is really like. Instead, its primary goal is to deal with ambiguity, whether this stems from equivocality, complexity or uncertainty, and to enable action. Goffman reasons that in day-to-day activities, much in the same way as in the special situations he analyses, great care is usually taken to 'rule out' ambiguity (Goffman 1974:442). As long as acknowledged stimuli do not dispute the meaning that is thus established, that meaning is considered valid.

Observe furthermore the following statements by Goffman. He poses that when individuals fit their actions to their understanding of what is going on and the “ongoing world supports this fitting (sic)” (Goffman 1974:247), the established meaning is taken to be “more or less adequate” (Goffman 1974:440). That is: the feedback generated by actions is generally sufficiently congruent with the meaning attributed to a situation and allows for effective coping or what is perceived as such. Goffman goes on to suggest that: “[A]n operating fiction might be accepted, at least temporarily, [so] that acts of daily living are understandable because of some primary framework (or frameworks) that informs them” (Goffman 1974:26). This statement implies that meanings merely have to be good enough, not necessarily accurate.

Now consider the sequence of events that is enclosed in these statements by Goffman. Firstly, drawing on various stimuli the meaning of a particular situation is established. This then enables actors to act and probe the situation in a manner that tests their assessment. Next, the stimuli that this generates can again be used to direct action. As such, meaning work can be said to enable action, or to render a situation actionable to the actors involved.

Weick reasons along the same lines as Goffman, which is evidenced by his statement that meaning work is a process that is “driven by plausibility rather than accuracy” (Weick 1995:17). This statement expresses the same sentiment that meanings merely have to explain what is going on in a situation sufficiently well, rather than be accurate in any absolute sense. A second statement in support of this can be found in Weick ET AL (2005):

“Sensemaking is not about truth and getting it right. Instead, it is about continued redrafting of an emerging story so that it becomes more comprehensive, incorporates more of the observed data, and is more resilient in the face of criticism” (ibid:415).

This fragment emphasizes that accuracy is not the primary goal of meaning work.

Weick furthermore poses that meaning work prioritizes enabling action over the deliberation of all incoming stimuli (Weick 1995) and puts emphasis on meaning work as an enabler of action, by linking it with pragmatism and instrumentality: “[S]ensemaking is about plausibility, pragmatics, coherence, reasonableness, creation, invention, and instrumentality” (Weick 1995:57). This point is similar to Goffman’s in the sense that meaning work is about rendering the world actionable.

Following Goffman and Weick it can thus be said that meaning work follows a satisficing approach aimed at creating action recipes: a meaning is seemingly ‘good enough’ if it facilitates

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8 Although this expression features in the context of the writing of text specifically, it appears towards the end of the book in a section where Goffman compiles the transformations that experience is susceptible to. Given this wider context the quote appears in, its meaning is taken to be generally applicable to framing as a whole.
action (Simon 1979). This is not to say that meaning work is error free: “[m]isframings” can result “in a “systematically sustained, generative error” (Goffman 1974:308). Here Goffman refers to situations where the established meaning is not accurate, but facilitates action none the less, which prolongs the duration of the meaning’s apparent usefulness. However, meaning work can be self-corrective, too: since meaning work is an iterative process these errors can be uncovered and corrected (more on meaning work as a process below).

**Implications for understanding circular economy related meaning work – I**

The above implies that recipes for action are created through establishing coherence, addressing uncertainty and determining a course of action, implying that understanding how and why meanings are made to cohere is an important part of understanding meaning work. As such, understanding what aspects of WaRM are relevant in creating action recipes that involve RLESs is at the core of circular economy related meaning work. This means that what RLESs are thought possible, why a particular RLES or set of RLESs is chosen and how this contributes to the intended goals are aspects that constitute the meaning attributed to circular economy. Important in relation to the generated meaning also is how uncertainty is dealt with. This is likely to be expressed by the existence of different options for different strategies or their specific execution, as well as the magnitude of resources transformed by the intended strategies. Ultimately, these considerations result in an assessment of the feasibility and desirability of circular economy. This means that a judgement is made with respect to the concept’s status and required action, that is: whether the concept is relevant, feasible and desirable. To this purpose, Chapter 04 and 05 explore what aspects are relevant in creating recipes for action in the context of WaRM by reviewing and analysing a selection of WaRM frameworks and the WaRM discourse more broadly.

### 3.3.2. Meaning work is contextual in nature and involves an active effort on behalf of actors

The second commonality between the perspectives on meaning work by Goffman and Weick is that it is conceptualized as materially, cognitively and socially embedded. Goffman: “Activity […] that organizes matter for the interpreter […] is located in a physical, biological and social world” (Goffman 1974:247). Weick agrees, explicitly in the case of cognitive and social embeddedness: “Sensemaking is grounded in both individual and social activity” (Weick 1995:6), and implicitly in the case of material embeddedness: “there must be something there” in the material world that creates the stimuli that are assigned meanings (Weick 1995:14). This implies, since the material and social circumstances of situations will differ, that both Goffman and Weick consider meaning work as a situated or contextual effort.

However, Goffman poses, stimuli from a given context are not passively processed by actors engaging in meaning work: stimuli are generally so rich, varied and complex that they cannot be taken in and considered all at once in real-time. Instead, actors cope by filtering them: some stimuli are “disattended,” which means that “attention and awareness” is withdrawn from these stimuli (Goffman 1974:202). Filtering relies on roughly three types of strategies. The first are strategies that are part of the human cognitive apparatus. An example of this is bracketing: the addition of (meta)physical markers in time and space that designate where an activity begins and ends (Goffman 1974). Another example is the creation of categories that allows for grouping objects and distinguishing between them.

The second type of filtering strategy relies on an actor’s past experience and accumulated knowledge to determine what stimuli are salient. Goffman: “[l]It is reasonable to say that each
utterance or physical doing that the individual contributes to a current situation will be rooted in his biographical, personal identity” (Goffman 1974:293-4). With this fragment Goffman indicates that actors bring previous events, codified in beliefs and accumulated knowledge, into the present. As such, past experiences can be an important factor in meaning work.

The third filtering strategy uses social rules as a basis for filtering, such as those associated with roles and relationships. For example, it is not strange when a stand-up comedian positioned under a hot stage light, hydrates or wipes away perspiration. It would, however, be strange if the performer takes a personal phone call on stage. Similarly, the audience is expected to behave in a certain way: to clap and engage when appropriate and to be silent when required. As such, roles and relationships have associated affordances: behaviours that are within scope for certain roles and relationships. Behaving outside of those affordances creates nonsensical behaviour.

These cognitive, individual and social filtering processes lead to the loss of potentially relevant information: effective filtering strategies are therefore paramount when undertaking meaning work. Goffman acknowledges the importance of these filtering strategies, when stating that: “Mere perceiving [...] is a much more active penetration of the world than at first might be thought” (Goffman 1974:38), emphasizing the active role that those engaging in meaning work have in shaping it.

Weick agrees with Goffman that actors shape meaning work. The expanded definition of his ‘unit of meaning’ is illustrative in this respect: “[T]he combination of a past moment + connection + present moment of experience creates a meaningful definition of the present situation” (Weick 1995:111). This quote makes two salient points. Firstly, the importance of knowledge retained from past experience. Since information retention is not perfect: “[P]eople create breaks in the stream [of on-going experience] and impose categories on those portions that are set apart” (Weick 1995:35), that which is retained is a simplified version of the original (Weick ET AL 2005). Moreover, according to Weick, one sees what one believes and one does not see “that for which one has no beliefs” (Weick 1995:87), meaning that actors will have internalized a set of convictions regarding cause and effect relationships as well as a set of normative judgements that have bearing on present perception. Although Weick does not categorize filtering strategies, he does acknowledge the loss of information their application leads to.

The second key point that the extended definition of Weick’s ‘unit of meaning’ offers is with regards to the connection that is made between the past and the present moment. In Weick’s view actors undertaking meaning work also create or establish this connection: there are no a priori grounds on which to do this. This implies that by making one connection instead of another, the unit of meaning can be assigned a different value whilst still connecting the same past and present moment. On this aspect of meaning work Goffman is not explicit: he merely states that “a spate of activity” can be “framed in a particular way” (Goffman 1974:201), but does not elucidate how this is achieved.

Implications for understanding circular economy related meaning work – II
In short, Goffman and Weick both recognize the contextual nature of meaning work as well as the role that actors have in shaping it, which is in line with Benford and Snow’s (2000) conceptualization of meaning work. As such, research into circular economy related meaning work has to be studied in a real-life context. That is: as opposed to determining the conceptual mental models practitioners hold regarding hypothetical applications of circular economy, one
has to focus on the meaning the concept is assigned in the context of a product group, the business and the industry as relevant to a particular case, taking into account the other WaRM practices that are believed to be in place and how the intended RLESs relate to other business practices and objectives and existing value networks. This influences the research methodology as it dictates that practitioners have to be conceptualized as embedded within their respective business and sector environment: as a result chosen it was chosen to research how 15 participants partaking in innovation projects inspired by the circular economy concept, see for further explanation Chapter 07 Research Design.

3.3.3. Meaning work is processual and enacted

Discussed next is the third and final commonality of meaning work that both Goffman and Weick emphasise included here, which is the fact that meaning work does not produce static outcomes. Goffman observes: “[P]ersons seem to have a very fundamental capacity to accept changes in organizational premises which, once made, render a whole strip of activity different from what it is modelled on and yet somehow meaningful (sic)” (Goffman 1974: 238). Here, Goffman describes an instance of reframing: a situation where the original premises on which a meaning is based are re-examined, found to be flawed and replaced with other premises that allow for a new meaning to coalesce. In the same vein, Weick asserts that: “Over time, as supporting evidence mounts, significant changes in beliefs and actions evolve” (Weick et al. 2005:416). And: “[M]eanings vary as a function of the content and the connection. Thus there is no such thing as a fixed meaning [...]” (Weick 1995:132). These fragments indicate that Weick agrees with Goffman that meaning can be changeable.

However, a changing meaning is not just the result of a changing environment: cognition and action exist in a recursive relationship. That is: cognition shapes action and vice-versa. Goffman explicitly states that meaning work has a “recursive character” (Goffman 1974:299): that it is “sustained both in the mind and in activity” (Goffman 1974:247), which has the effect that “social life takes up and freezes into itself the understandings we have of it” (Goffman 1974:563) in a self-fulfilling manner. What Goffman describes here is that in ambiguous cases deciding and acting according to a certain assessment can affirm or create the very stimuli that confirm the original interpretation.

Weick likewise acknowledges this aspect of meaning work: “people often produce part of the environment they face” (Weick 1995:30). An illustrative example of this is the capacity of people to enact laws: through aligning one’s actions with a new law time and space is delineated in new ways and categories and features of the environment are created that did not exist before. Weick designates this aspect of meaning work with the term enactment. And, like Goffman, Weick refers to this as being potentially self-fulfilling in the sense that acting in a way as if one thing is true and acting in a way that denies it to be true can both affirm those initial assessments. Or, as Weick summarized it: “People create and find what they expect to find” (Weick 1995:35). Weick stresses the importance of beliefs in this process: “The issue turns on faith or the lack thereof, because it sets self-fulfilling action in motion” (Weick 1995:38). As such, beliefs have a pivotal role in enactment processes. The role of enactment processes in meaning work is also the reason of meaning work's importance in relation to change processes.

**Implications for understanding circular economy related meaning work – III**

The take-away message relevant for researching meaning work that can be distilled from the above, is that meaning work should be conceptualized as a process. This observation is in line
with Benford and Snow who state that meaning work is a “processual phenomenon” (Benford and Snow 2000:614). In this light, the outcomes of meaning work should be regarded as provisional snapshots of an on-going process of emergence. As such, to understand meaning work means not only to understand the assigned or attributed meaning, but also why and how it changes or, if applicable, what inhibits it changing. In the context of circular economy related meaning work this implies that multiple snapshots of the meaning attributed to the concept are required, as the meaning attributed to it is likely to evolve as the concept is explored and applied. As a result: interviews were conducted in three phases at different stages of the projects: when the projects were on-going or were due to commence, on average seven months after the first interview and on average 28 months after the first interview, see for further explanation Chapter 07 Research Design.

3.4. Framing and sensemaking: key complimentary difference

3.4.1. Cognition versus action

One major difference between the framing and sensemaking perspectives is that Goffman emphasises cognition where Weick emphasises action. Although the perspectives acknowledge that cognition and action both play significant roles in meaning work, Goffman and Weick do not pay equal attention to these two aspects in their respective seminal works. Take Goffman, who makes the following statement about the importance of cognitive processes in meaning work undertaken by an actor:

“[The actor] is likely to be unaware of such organized features as the framework has and unable to describe the framework with any completeness if asked, yet these handicaps are no bar to his easily and fully applying it.” – Goffman (1974:21).

This fragment shows that in Goffman’s view actors are likely to be unaware of the meaning work performed. What’s more, the outcomes will generally “disappear into the smooth flow of activity” (Goffman 1974:39). Since the outcomes of meaning work can come about without the actor having to pause or becoming explicitly aware that an assessment is made, the cognitive processes that brought them forth are also mostly invisible. Without making these processes visible an important aspect of human behaviour is inaccessible to us. Performing the task of creating visibility of these processes forms the premise of Frame analysis and it explains why Goffman emphasises the cognitive aspects of meaning work.

On the other hand, Weick bases Sensemaking in organizations on the premise that action is central to meaning work (Weick 1995:32). The following fragment from Weick ET AL (2005) elucidates the reasoning behind this:

“[T]he concept of action suggests that it is more important to keep going than to pause, because the flow of experience in which action is embedded does not pause; and, the concept of retrospect suggests that so-called stimuli for action such as diagnoses, plans for implementation, and strategies are as much the products of action as they are prods to action” – Weick ET AL (2005:419).

This fragment illustrates that the sensemaking perspective centres on action and that cognitive processes are considered a phenomenon related to and part of acting.
Complementarity if difference, implications circular economy related meaning work

The difference between Goffman and Weick, then, is a difference with regards to where to ground the processual aspects of meaning work. That is: Goffman gives meaning work a foundation in cognitive processes, where Weick grounds his perspective in the capacity of acts to probe the environment. However, since action and cognition exist in a recursive relationship these differences are not irreconcilable, but can be regarded as complimentary. This can be understood by considering the sequence of meaning work: a cognitive assessment leads to a probing action, which leads to the next cognitive assessment and so on, in a near infinite succession. In this sense, action and cognition cannot be meaningfully separated and have to be considered a single unit.

The above implies that researching circular economy related meaning work requires the inclusion of both action and cognition. That is: not only the established interpretation of the concept, but also the manner in which it is acted upon is part of the meaning attributed to it. Attention therefore needs to be given to what is acted upon as well as what is not acted upon and the overall status of the proposed RLESs. See for an explanation of how this was used to analyse cases Chapter 07 Research Design.

3.5. Circular economy related meaning work in this research

In summary, the similarities and complimentary differences make that together Goffman’s framing and Weick’s sensemaking provide a powerful theoretical framework for researching meaning work, and with it circular economy related meaning work. That is: the core of both perspectives – the creation of action recipes – is further explored in the remainder of this thesis, as opposed to using either of the traditions in the classic or literal sense.

Next, a closer examination is provided of how action recipes are created in the context of WaRM that has a large RLES component: Chapter 04 and 05 explore what aspects are relevant in creating recipes for action in the context of WaRM by reviewing and analysing a selection of WaRM frameworks and the WaRM discourse more broadly, before synthesising the relevant aspects uncovered in these chapters in Chapter 06. Chapter 07 will return to the aspects of meaning work relevant for the research design.
4. How waste and resource frameworks create recipes for action

What aspects are relevant in creating an interpretation of a set of resource life-extending strategies?

This chapter explores in more detail how recipes for action can be created by reviewing and analysing eight WaRM frameworks, selected for the importance they attribute to RLEs (Blomsma forthcoming). Two analytical lenses are used to organise this discussion. The first is the concept of collective action frames (CAFs) (Benford and Snow 2000). By conceptualising the selected frameworks as CAFs, the step-by-step approach they follow in formulating actionable WaRM approaches becomes evident. CAFs are thus identified as an important pillar for the Circularity Compass. Next, the frameworks are organized in categories, guided by the application of the concept of institutional logics (Thornton et al. 2012). This makes explicit the relevance of how waste and resources are conceptualized when creating action recipes and implies that the labels currently used to describe the resource transformations that RLEs represent, such as ‘recycling’ and ‘reuse,’ are inadequate and that a more systematic means of understanding waste and resources is required. This chapter is organized as follows. First, the selected frameworks are introduced. Next, the concept of CAFs is explained and an example is given of how WaRM frameworks can be described using this format. This is followed by the introduction of the concept of institutional logics and a discussion of the categorization that was made. This chapter concludes with a discussion of how both the CAF functions and logics aid in understanding circular economy related meaning work.

4.1. WaRM frameworks included in review and analysis

Eight WaRM frameworks are included in this review, which are all generic in character and thus not specific to a company or industry. They furthermore include a conceptual diagram and a comprehensive set of heuristics in the form of principles or guidelines, which are based on a systematic approach to WaRM of which a detailed description is available.

The eight frameworks were selected through snowballing from the frameworks included in the Circular Economy framework or ‘butterfly diagram’ by the Ellen MacArthur Foundation (EMF 2013), as this framework itself is an amalgamation of three frameworks. Thus included are: Cradle-to-Cradle™ (Braungart and McDonough 2002), Blue Economy (Pauli 2010, 2012) and Performance Economy (Stahel 2006)⁹. A continued search led to the inclusion of: The Waste Hierarchy (e.g. DotE 1995), Industrial Symbiosis (e.g. Lowe and Evans 1995), Sustainable Materials Economy (Geiser 2001), Product Life Cycle System (EPA 1993) and Material Efficiency (Allwood et al. 2011). When eight frameworks were collected, collection was halted as the intention here is not to provide an exhaustive overview of all WaRM frameworks in which RLEs play an important role. Instead, the purpose is to provide insight into how WaRM frameworks produce coherent interpretations: the included set was judged sufficiently large and diverse for meaningful contrasting and comparing.

Deliberately excluded from the set were (design) philosophies such as The Natural Step (Robèrt 2002) and biomimicry (Benyus 1997), which merely invoke cycling as a principle, but do not

⁹ Core references are used here and in the following to designate the WaRM frameworks, for reasons of brevity. Table 4.01 gives an overview of all sources used to characterise a particular framework.
clarify what strategies to use, how they should be executed and how they relate to each other. The Circular Economy framework (EMF 2013) itself is also excluded from this review; instead the issue of unification attempts is revisited in the analysis and discussion section that concludes this chapter.

Furthermore excluded from this review are frameworks that are more appropriately thought of as ‘schools of thought’ or assessment methods, such as industrial ecology (Frosch and Gallopoulos 1989), natural capitalism (Hawken et al. 1999) or ecological footprint (Schmidt-Bleek 2008). Although important in the resource discourse in the sense that they offer broad guidance in the area of WaRM, they do not offer specificity comparable to the comprehensive set of heuristics included in the selected frameworks.

By necessity, the majority of the material included in this review is grey literature: although all authors representing natural persons have academic associations, the main works in which they discuss their frameworks are not peer reviewed in many cases. Which sources this affects is indicated in Fig. 4.01, 4.02 and 4.03. Throughout this section the short critique on (some of) the frameworks discussed in section 2.2.2. Circular economy’s emergence: from preamble to validity challenge will not be repeated here: instead, I return to the shortcomings of the frameworks in a more general sense in section 4.4. Insights from analysis of WaRM frameworks.

4.2. WaRM frameworks as collective action frames

4.2.1. CAF functions and their applicability to WaRM frameworks

Collective action frames (CAFs) are discursive instruments that render the presence or absence of something meaningful and that create a action recipe for changing the current situation in a more desirable direction (Benford and Snow 2000). CAFs have three characteristic functions: punctuation; elaboration, divided in the sub-functions diagnosis and prognosis; and motivation (Creed et al. 2002). Each function is briefly explained below and examples are given to illustrate how the selected WaRM frameworks perform these functions. These functions are furthermore given circular economy specific interpretations and labels, in order to effectively use them for structuring the examination of individual WaRM frameworks.

Punctuation as purpose

Punctuation entails directing the attention to an issue of importance: it is the discursive act of assigning a greater importance to something, through which it gains a status of greater importance. The punctuation-function provides a “conceptual handle” that establishes validity for linking specific aspects, issues, events and beliefs (Benford and Snow 2000:623). An important role is this linking process is played by normative judgements: it involves portraying the absence or presence of something as problematic and the preferred situation as attainable.

WaRM frameworks perform the punctuation-function by directing the attention to the importance of the way waste and resources are dealt with. Further, they link what is identified as inappropriate management or mismanagement of waste and resources to the presence of certain problems or the absence of particular benefits. WaRM frameworks typically focus on different (sets of) problems or benefits, thus defining what will be referred to as their purpose in distinctly different ways. For example: the Blue Economy (Pauli 2010) argues that hunger and unemployment need not exist and that all basic human needs can be provided for if resources
are managed better. The Waste Hierarchy (EC 2008), on the other hand, has a more narrow focus and poses that both environmental harm and landfi lling can be reduced or avoided by improving WaRM practices.

Elaboration: mechanism, perpetuation and prevention

Elaboration builds on the punctuation-function and provides more detail on the cause of a problem or the absence of a benefit, as well as starts to point to appropriate solutions. It is therefore split into the sub-functions of diagnosis and prognosis (Creed ET AL 2002).

Diagnosis as mechanism

Diagnosis identifies what it is about the workings of current systems that withholds benefits or creates detrimental effects (Benford and Snow 2000). This, then, represents the core of the problem that needs to be addressed.

WaRM frameworks perform this function by identifying what, in their view, is wrong with the functioning of industrial systems. For example, Industrial Symbiosis poses to match industrial input and output to the carrying capacity of the earth by optimizing manufacturing systems through (re)introducing relevant relationships between production facilities in the form of resource exchanges (e.g. Lowe and Evans 1995). Alternatively, the Performance Economy suggests that a variety of issues, among which stagnating levels of wealth and growth and excessive resource consumption, can be solved through implementing radical performance improvements (Stahel 2006). Since the identification of the issues simultaneously reveals its nature, a high-level mechanism for change is also uncovered by the act of making a diagnosis.

Prognosis as perpetuation and prevention

Prognosis involves the formulation of a general line of action: through suggesting what strategies are deemed appropriate this function directs the more practical aspects of the desired change (Benford and Snow 2000). This function thus specifies through what action or actions change is accomplished.

In the case of WaRM frameworks, the rationale for choosing strategies is often provided by a comprehensive set of heuristics in the form of a list of guidelines or principles, which provide the reasons for selecting appropriate strategies, how they should be executed and how the included strategies relate to each other. The chosen strategies generally consist of two main categories: preventative strategies and RLES(s). These two categories feature as separate elements when discussing the frameworks, as prevention and perpetuation.

Prevention refers to strategies that prevent resources from being used or that prevent certain undesirable effects from occurring. Prevention plays an important role in frameworks such as the Waste Hierarchy (EC 2008) and the Blue Economy (Pauli 2010): in these frameworks prevention is prioritised over RLEs. In other frameworks, such as Cradle-to-Cradle™ (Braungart and McDonough 2002), prevention plays a relatively minor role generally, but a large role in specific areas. Specifically: preventing the use of toxins plays a large role within Cradle-to-Cradle™.

Perpetuation refers to the RLES or RLEs included in a framework. Cradle-to-Cradle™ (Braungart and McDonough 2002), for example, emphasises recycling within industrial systems and composting, which equates to cycling in nature. Industrial Symbiosis, on the other hand, emphasises material and energetic cascading between processes and production facilities.
Note that WaRM frameworks can also contain an oppositional stance towards WaRM strategies which are deemed unfit for application. Cradle-to-Cradle™ (Braungart and McDonough 2002) portrays eco-efficiency as ineffective, casting it in a negative light by stating that efficiency is the pursuit of “less bad” which is “no good” (Braungart and McDonough 2013:17). These ‘counter framings’ (Benford 1987) further simplify the selection process of WaRM strategies. Counter framings are not further discussed here.

*Motivate as proaction*

The last characteristic function of CAFs is *motivation*. This function serves to articulate a rationale for which parties should act to bring about the desired change and for what reasons (Benford and Snow 2000). Or, in condensed form: who should be *proactive* and why.

For example, the Blue Economy (Pauli 2010) and Cradle-to-Cradle™ (Braungart and McDonough 2002) see business as the primary actor, as it is thought to be in the self-interest of business to manage waste and resource well. Cradle-to-Cradle™ furthermore poses that designers can play a key role in bringing about the required change. Sustainable Materials Economy (Geiser 2001), Material Efficiency (Allwood et al 2011) and Product Life-Cycle System (EPA 1993), however, emphasise that a myriad of actions by many parties is required.

4.2.2. CAF functions applied to WaRM frameworks: an example

Next, it is shown how the CAF functions can be used to describe WaRM frameworks, using the Waste Hierarchy as an example. Preceded by a short introduction about the framework, Waste Hierarchy’s position regarding *purpose and mechanism, prevention, perpetuation and proaction* are briefly discussed. The overviews of the other seven included WaRM frameworks thus analysed can be found in *Appendix 01 WaRM frameworks reviewed and analysed*.

*The Waste Hierarchy in CAF terms*

The Waste Hierarchy, based on Lansink’s Ladder developed in the 1970s (Kemp and Van Lente 2011), is a part of the European Waste Directive: a legislative framework for dealing with non-hazardous waste. Introduced in 1989 and updated since, it defines key waste related concepts and responsibilities for member states (EC 2008). The Waste Hierarchy is often referred to as ‘3R,’ as it is colloquially referred to as ‘reduce, reuse and recycle’ (e.g. Yoshida et al 2007, Sakai et al 2011). The directive encourages application of the Waste Hierarchy, but does not enforce it.

*Purpose and mechanism*

The Waste Hierarchy is focussed on generating better environmental outcomes, mainly through reduced landfilling. However, the directive stipulates that application of the Waste Hierarchy needs to be in line with the broader goals of the directive and that it is to be applied pragmatically. That is, application of the hierarchy needs to take into account the “general environmental protection principles of precaution and sustainability, technical feasibility and economic viability, protection of resources as well as the overall environmental, human health, economic and social impacts” (EC 2008:10).

The Waste Hierarchy assumes that more environmentally favourable strategies than landfilling are (often) available, but simply not considered. By direction the attention to alternative strategies and choosing them where possible, as defined by the “best practicable environmental option” or “BPEO” (DotE 1995:6), resources can be effectively rerouted from landfill. As such, the Waste Hierarchy targets a choice or decision mechanism. Alternative strategies, however, are
not equally effective. This is captured by the hierarchical ordering principle that gives the Waste Hierarchy its name: strategies are thought to have a declining capacity to reduce environmental impact from reduce to recover, with disposal representing a last resort. However, no operation should be singled out, rather the set should be thought of as an “integrated approach, where each option contributes to the overall recovery of waste (DotE 1995:5).” For this reasons the strategies are depicted as interlocking gears in the conceptual diagram in Fig. 3.01.

**Prevent**
According to the Waste Hierarchy, prevention should be applied before all other strategies. Prevention is defined as all measures taken that prevent a substance, material or product from becoming waste, that prevent the adverse impact of substances or that reduce the amount of harmful substances in materials of products (EC 2008). These measures address the input side of the input-output ratio central to the object logic.

**Perpetuate**
The Waste Hierarchy’s remaining principles – reuse, recycling and recovery – are aimed at facilitating the prolonged use of resources, either in product, material or energetic form and as such addresses the output side of the input-output ratio that is central to the object logic. Here, the highest-level strategy should be sought that is still acceptable within the BPEO.

**Proactive**
With an appropriate way of thinking about would-be waste (the Waste Hierarchy) and matching incentives (such as legislation based on extended producer responsibility and the polluter-pays principle), the Waste Directive aims to mobilize both European member states and industry. The latter has a responsibility to implement ever-improving BPEOs.

4.2.3. Discussion of CAF functions and WaRM frameworks
The preceding showed that circular economy related meaning work can be understood in terms of the CAF functions. These functions point to sources of meaning work that need to be resolved if an actionable interpretation of WaRM is to be established. That is: the CAF functions as defined here in the context of WaRM represent aspects of WaRM that need to be articulated, whether explicitly or implicitly, for action recipes in this space to be considered viable.

In a sense, the CAF functions offer a step-by-step approach in formulating what their authors believe to be actionable WaRM frameworks. First, a situation is problematized through determining the presence of certain problems or the absence of particular benefits. Remediating this situation is what constitutes a framework’s purpose. Next, a diagnosis is made that establishes a high-level change mechanism. By adding a general line of action in the form of a prognosis that provides practical guidance, i.e. by identifying prevention and perpetuation strategies, practical strategies are put forward. Lastly, through the proaction function, a concrete reasons for acting is provided. Summarising: these functions, from purpose to proaction, serve to go from a general observation regarding WaRM to concrete actions that can be taken by specific actors. In this manner a measure of internal coherence within a framework is created. For these reasons, the role of CAF functions in the creation of viable as well as coherent frameworks, they are identified as an important pillar for the Circularity Compass.
However, CAFs only capture part of the process that leads to the formulation of action recipes. To show that conceptualizations of waste and resources also play an important role, the WaRM frameworks are further analysed, guided by the concept of institutional logics.

4.3. Conceptualizations of waste and resources underpinning WaRM frameworks

4.3.1. Institutional logics: an introduction

Institutional logics are abstract cognitive devices that permeate cultures and societies: they constitute widely shared belief systems that provide meaning to action on the micro-level of individuals, the meso-level of organizations and the macro-level of cultures (Rao et al. 2003, Thornton and Ocasio 2008). The role of institutional logics in meaning work is that they provide the foundational ideas for organizations and individuals to draw on, interpret and expand on within the limits they pose (Friedland and Alford 1991:248). As such, they simultaneously determine and restrict the meanings and actions that are possible (Rao et al. 2003) and define the solution space that is considered appropriate when confronting issues (Drost and Cross 2001).

Different institutional logics are associated with different institutional orders, or different areas of life such as home life, religion, occupation or organization. Examples of logics are the ‘market logic,’ characterised by a belief in financial theories such as portfolio and risk management and ‘corporate logic’ characterized by bureaucratic rational decision making (Thornton et al. 2012). An example of logics in the area of sustainability is provided by Heiskanen (2002), who conceptualises life-cycle thinking as an institutional logic that influences the way environmental problems are conceptualized and responsibility allocated. Here, the institutional logics concept is applied to the order of WaRM and is simply referred to as logics.

4.3.2. Categorising WaRM frameworks guided by logics

Through using logics as an added analytical tool, it is possible to articulation the fundamental beliefs regarding the nature of waste and resources that underpin WaRM frameworks. As such, the logic concept supplements the CAF concept by facilitating the articulation of the most basic starting points of WaRM frameworks.

The logics underpinning the included WaRM frameworks were identified through an iterative process where various groupings were made and examined with regards to internal coherence and overlap between groupings, until the groupings were judged robust. This resulted in the categorization presented in Table 4.01. The following analysis shows that the included WaRM frameworks are not unique in the basis they use for assigning meaning to WaRM, but draw on three distinct logics: the object logic, the containment logic and the sequence logic (Blomsma forthcoming). The first logic conceptualizes resources as largely passive in shaping resource management practices, beyond inherent technical and financial limitations. Waste, in the object logic, refers to the suboptimal input-output ratios WaRM can generate. The containment logic, on the other hand, poses that resources have a much more active role and that value extraction processes and materials shape each other. Regarded as wasteful is the loss of the potential of materials. In contrast, the sequence logic emphasizes the role of time and conceptualizes resources and the costs associated with their management, as time-dependent variables. Here, waste is defined as the premature loss of value extraction opportunities, regardless of the form of the resource. Next, each logic, how it is interpreted as well as elaborated upon by the WaRM frameworks that wield it is discussed in turn.
### Conceptualizations of waste and resources underpinning WaRM frameworks

<table>
<thead>
<tr>
<th>Logic title and definition</th>
<th>Object logic</th>
<th>Containment logic</th>
<th>Sequence logic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aims</strong></td>
<td>Aims to reroute would-be waste away from landfill to another location where it is of use</td>
<td>Aims for the containment of resources in the appropriate metabolism</td>
<td>Aims for the completion of a sequence of phases that each preserves maximum value</td>
</tr>
</tbody>
</table>

| Concept. of resources: | Resources, beyond inherent technical and financial limitations, play a minimal role in shaping resource management practices and therefore seen as on the receiving end of actions. | No meaningful separation exists between a resources’ properties and the means by which it is made, used and treated at the end-of-life: resources and value extraction processes shape each other. | Resources, and the costs associated with their management throughout their productive lives and at the end-of-life, are defined as time-dependent variables. |

| Waste defined in terms of: | \( \text{Quantity} \) – sub-optimal input-output ratios. | \( \text{Loss of potential of materials} \) – depletion of material stock and/or deterioration of its quality. | \( \text{Time} \) – premature loss of value extraction opportunities. |

| A loop is successfully closed when: | ... the arrival of a would-be waste at a location where it serves as a resource. | ... materials are contained within or return to their appropriate metabolism. | ... a string of life-cycle phases that each allowed for the extraction of value ends by applying a 'last resort' strategy. |

| Emphasis on stocks/flows: | Flows: reduction in magnitude or redirection towards a next destination. | Aims primarily for the preservation of material stock levels. | Aims primarily for the preservation of product stock levels. |

| Solution space: | Improving input-output ratios through reducing either the amount of inputs necessary (more intensive use of resources already in use) and/or by repurposing outputs as (co- or by-) products or resources in their own right. | Matching material to metabolisms through material R&D, material restriction and material retention. Manage material purity through appropriate product design, such as design for disassembly. | Identifies and prioritizes many possible routes for cycling, with emphasis on product cascades. Requires tracking and active direction of resources throughout their useful life. |


*Table 4.01 Overview of the three logics that could be compiled by grouping the eight selected WaRM frameworks.*
4.3.3. The object logic
Frameworks drawing on the object logic are the Waste Hierarchy (EC 2008) and Industrial Symbiosis (e.g. Lowe and Evans 1995). See Fig. 4.01 for a brief overview of these frameworks using the CAF functions as well as their key principles and conceptual diagrams.

Waste and resources within the object logic
The core of the object logic is that resources, beyond inherent technical and financial limitations, play a minimal role in shaping the practices through which they are managed: resources are conceptualized as on the receiving end of particular actions, processes or operations. As a result, waste generation is seen as a consequence of sub-optimal input-output ratios and waste as primarily a matter of quantity.

The solution space and the meaning of cycling within the object logic
To improve input-output ratios the object logic suggests that either the input amount needs to be reduced and/ or outputs need to be repurposed as (co- or by-) products or resources in their own right. The reduction of inputs can be achieved directly by improving process efficiencies or indirectly by negating the need for virgin inputs, through using the same input more intensively. Reusing cooling fluid or recycling scrap are examples of this. Repurposing, on the other hand, can be achieved through redirecting a would-be waste away from landfill to a subsequent destination where it can be used productively. Both strategies can be intertwined: repurposing also has the potential to reduce the need for virgin input.

Within the object logic it is assumed that waste ceases to be a problem by either sufficiently reducing inputs through prevention and efficiency measures and/ or by adequately redirecting outputs by rerouting a would-be waste away from landfill to a destination where it functions as a resource. A loop or cycle is thus considered closed when the would-be waste arrives at the next destination where it is of use. As a result, the emphasis of this logic is on resource flows, as opposed to stocks. This implies that all interventions addressing actions that cause resource flows to have sub-optimal input-out ratios are valid interventions within the object logic, whether that be through improvement of existing process or a redesign of these processes.

**Interpretations of and expansions on the object logic**
Both the Waste Hierarchy and Industrial Symbiosis are underpinned by the desire to optimise input-output ratios and are aligned in their pursuit of better environmental outcomes, whilst aiming to promote, or at least not excessively inhibit, the generation of economic benefits and are therefore categorised as drawing from the object logic. However, due to their different interpretation of the object logic they are both unique frameworks. They differ, for a start, with regards to which part of the input-output ratio central to the object logic they address: the Waste Hierarchy targets both input and output sides, where Industrial Symbiosis only directly addresses the output side.

Moreover, both frameworks target different change mechanisms: the Waste Hierarchy suggests that resources are not put to optimal use because of a lack of awareness and inadequate decision processes where it regards waste. Industrial Symbiosis, on the other hand, suggests that manufacturing systems are not optimized due to a lack of relevant relationships between production facilities. The former targets a cognitive barrier that obstructs establishing better WaRM practices, whilst the latter addresses a relational and infrastructural problem.
Frameworks drawing on the Object logic

Waste Hierarchy (WH)

Key principles
Hierarchical organisation of strategies in order of reducing importance:
- reduce (both quantity and harm)
- reuse
- recover (incl. recycling, reclamation, treatment)
- dispose (last-resort strategy)

Purpose & mechanism
The WH aims to create better environmental outcomes (i.e. reduced landfilling), by facilitating better decision-making. It is assumed that other strategies than landfilling are often available, but simply not considered. It therefore offers guidance on the effectiveness of alternative strategies that direct resources away from landfill.

Prevention
Primary principle through reduce: encompasses all measures aimed at reducing quantity, impact or other harm.

Perpetuation
Can take multiple forms: either in product form through reuse, the recycling of a material, or chemical or energetic recovery.

Proaction
Industry should make decisions based on the Waste Hierarchy, and legislators should provide the incentives for industry to do so, by enacting legislation based on extended producer responsibility and the polluter-pays principle.

Industrial Symbiosis (IS)
sources: e.g. Lowe and Evans (1995), Korhonen (2005), Chertow and Park (2016)

Key principles
Appropriate scale is thought key, as IS is a balancing of a broad enough offer of by-products, whilst having a small enough scale for cooperation. Suggested scales are:
- within facility, firm or organization
- among co-located firms
- among non-co-located firms
- virtually

Purpose & mechanism
To create environmental and economic benefits in a manner that matches industrial input/outputs to the carrying capacity of the earth. This can be achieved through optimizing manufacturing systems by reintroducing relevant relationships between production facilities.

Prevention
IS negates the need for virgin inputs and should avoid use of toxins.

Perpetuation
IS pursues the increased utilization of energy and substances (i.e. water, material by-products and wastes) through cascading. Cascades often transform resources in some way: as a consequence they do not return to their original virgin-like state. The exchange of substances can resemble a web-like structure if many exchanges are involved.

Proaction
Depending on your position whether IS can be designed or should be guided, there is a lead role for either government or industry, intermediaries and digital facilitation, respectively.

Fig. 4.01 WaRM frameworks drawing on the object logic. Depicting the Waste Hierarchy and Industrial Symbiosis frameworks by means of a conceptual diagram, a summary of the key principles and the CAF functions.
As a result of considering both sides of the input-output ratio and conceptualising the problem as cognitive in nature, the Waste Hierarchy highlights a wide variety of resource strategies. Conversely, Industrial Symbiosis’ focus on the output side and conceptualizing the problem as a relational or infrastructural problem leads to a focus on a much narrower set of solutions, which primarily consist of substance and energetic cascades. An additional outcome of this is that both frameworks differ in the role assigned to prevention, which plays a much larger role in the Waste Hierarchy than it does in Industrial Symbiosis.

However, the object logic also restricts both the Waste Hierarchy and Industrial Symbiosis. Through conceptualizing resources as largely on the receiving end of actions, the logic has a strong emphasis on industrial processes, whether manufacturing or end-of-life processes. As a result both frameworks elaborate on the object logic in the same way: by envisioning a relationship between application sites of their respective strategies. The Waste Hierarchy poses that its strategies are not adopted in isolation, but that each strategy contributes to the recovery of waste. Similarly, Industrial Symbiosis, when applied at scale, is envisioned to lead to industrial food webs where not only many facilities are involved but also many different resources are exchanged. In addition to this, Industrial Symbiosis is frequently supplemented with ideas stemming from cleaner production, such that increased resource productivity and as well as reduced pollution go hand-in-hand\(^{10}\).

The above shows that, despite having a common basis in the form of the object logic, both frameworks are able to create a unique vision with regards to what constitutes appropriate waste resource management, due to the possibility of interpreting the logic differently. However, it was also shown that a logic does not provide infinite possibilities for interpretation and expansion, but that the object logic restricts the frameworks with regards to the interpretations possible, although logics can be supplemented by additional concepts and ideas.

4.3.4. The containment logic

The frameworks drawing on the containment logic are: the Blue Economy by Gunter Pauli (2010), Cradle-to-Cradle™ by Braungart and McDonough (2002) and Sustainable Materials Economy by Kenneth Geiser (2001). A brief overview is provided in Fig. 4.02.

Waste and resources within the containment logic

Contrary to the object logic, the containment logic conceptualizes resources as having a large role in shaping resource management practices. This logic assumes that no meaningful separation exists between resource properties and the means by which it is processed, used and treated at the end-of-life. Rather, resources and the processes that facilitate value extraction from these resources shape each other and can thus be considered a single unit of analysis. Optimal value extraction takes place when material selection, processing, use and end-of-life treatment allow for the desired type of value to be extracted, whilst the potential to continue to do so in the future is preserved. If not preserved, then the possibility should exist to restore the potential of materials. The conservation of potential, here, refers to the preservation of material stock levels in a way that secures human and environmental well-being, without generating negative effects in doing so. Thus, waste occurs, in the containment logic, when the potential of materials is lost due to systems that prevent material potential to be recaptured or restored.

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\(^{10}\) As was pointed out to the researcher by an anonymous reviewer of Blomsma (forthcoming).
The solution space and the meaning of cycling within the containment logic

The interdependent relationship between materials and value extraction processes has an important implication: both have to be designed together for WaRM to be effective. Practically, this implies the necessity of material metabolisms: systems where the choice for a material, its means of processing, use and the end-of-life treatment results in optimal value generation and no (or negligible) potential loss. As such, no (or a negligible) amount of material is allowed to escape or leak from the metabolism. Moreover, material quality must consistently be kept on or returned to the highest possible level. This is achieved through RLES that facilitate retention or return of a material to the metabolism that can provide the required purification or revitalisation treatment.

All threats to successful loop-closing, such as leakage, contamination, degradation of performance properties and the use of toxins or inappropriate additives should be avoided or neutralized, along the entirety of the value chain. An important way of facilitating this is to make sure that materials are selected or designed with cycling in their respective metabolism in mind and that product design facilitates cycling.

Interpretations of and expansions on the containment logic

All three frameworks grouped under the containment logic consider resources and the processes that facilitate value extraction from these resources as a single unit of analysis. Moreover, all three frameworks explicitly direct attention to the fact that due consideration needs to be given to the alignment of material selection with processing, use and end-of-life procedures if wasteful outcomes are to be avoided.

However, as is the case with the frameworks drawing on the object logic, the frameworks drawing on the containment logic also assign different meanings to the logic Blue Economy, for example, designates the biosphere as the preferred metabolism for cycling. Cradle-to-Cradle™ and Sustainable Materials Economy, on the other hand, distinguish between two and three metabolisms, respectively. This is the result of different ideas regarding the mechanism that should be utilized: in Blue Economy the mechanism invoked could be summarized as ‘work with nature,’ within Cradle-to-Cradle™ this is ‘work with and mimic nature,’ and in Sustainable Material Economy it could be summed up with ‘work with, mimic and realign to nature.’

The three included frameworks furthermore differ in the emphasis that they put on prevention: Cradle-to-Cradle™ acknowledges that preventing the use of toxins is important, but is otherwise unconcerned with efficiency, the pace of material throughput or consumption levels. Blue Economy and Sustainable Materials Economy, in contrast, put great emphasis on various forms of prevention, among which toxicity and efficiency.

As is the case with the object logic, the containment logic also restricts the interpretations that are possible: the logic emphasizes material stock levels and even the product strategies related to it are aimed at reclaiming materials. Examples of this are strategies such as design for disassembly and modularity. However, the Sustainable Materials Economy shows that the containment logic can be expanded upon. This framework includes strategies aimed at preservation of the product form, such as product life-extension and product-service-systems. This in contrast to the Blue Economy, for example, that merely distinguishes between two routes for cycling, both taking place within the biosphere: composting or cascading with eventual composting. Cradle-to-Cradle™, on the other hand, assigns a RLES to each of its two
Frameworks drawing on the Containment logic

The Blue Economy (BE)
sources: Gunter Pauli (2010), (2012)

Key principles
21 principles summarised in four non-exclusive categories:
- replace something with nothing
- cascade through multiple kingdoms
- celebrate diversity
- generate multiple benefits

Purpose & mechanism
BE aims to better serve basic human needs, such as food security, fertile soil, clean water, medicines and jobs, whilst staying within planetary boundaries. BE poses that this can be done through working with natural processes, as they have the ability to transform apparent scarcity into sufficiency and even abundance.

Prevention
Cycling is not always the preferred solution: it may be more appropriate to dematerialise and replace something with nothing.

Perpetuation
Cycling happens in the biosphere and as such only biocompatible and biodegradable materials are to be used. Cycling can happen: 1) through letting nature directly transform and absorb materials at the end-of-life, or 2) by cascading substances through successive biological kingdoms, whilst extracting value at multiple points.

Proaction
It is in the interest of business to manage waste and resources more efficiently: multiple revenue streams can be generated this way.

Cradle-to-Cradle™ (C2C)

Key principles
- waste equals food
- use current solar income
- celebrate diversity
With later addition of:
- cascades
- generate multiple benefits

Purpose & mechanism
C2C aims to improve and preserve human and environmental health, remedying a “materials-in-the-wrong-place problem,” whilst continuing to serve current wants and needs. This is achieved through application of eco-effectiveness: managing materials either through using or mimicking the nutrient cycles in biological food webs.

Prevention
Focuses on preventing the use of toxins. Otherwise not concerned with efficiency, preventing throughput or consumption levels.

Perpetuation
C2C distinguishes between two main metabolisms: the biocycle and the technocycle. C2C can be implemented through designing materials and products for cycling in the appropriate metabolism, the creation of material banks and the practice of material pooling.

Proaction
Business should act in a way that removes the need for regulation and regulators should not provide perverse incentives. C2C requires that designers educate themselves and design accordingly.

Sustainable Materials Economy (SME)
source: Kenneth Geiser (2001)

Key principles
- Dematerialisation: close material loops, increase intensity of material use, substitute services for products.
- Detoxification: reduce dissipation of degradable toxic materials, reduce use of persistent, bioaccumulative & toxic materials, develop environmentally appropriate materials.

Purpose & mechanism
SME aims to optimize the use value of materials, add no new risks to everyday life, minimize inter-generational risk transfer and enhance the biosphere and natural resources through designing out harm by working with, mimicking and realigning to nature.

Prevention
Main focus on prevention through key principles of detoxification and dematerialisation (i.e. such as reducing material throughput).

Perpetuation
Dematerialisation can also be achieved through cycling, which takes place within one of three metabolisms: the biosphere, the technosphere or a hybrid form. It entails such strategies as: product adaptation and upgrading as well as reconditioning and remanufacture. Detoxification ensures safe return to the biosphere.

Proaction
SME advocates an integrated approach based on life-cycle thinking and continuous improvement using multi-disciplinary knowledge and involving a wide range of actors from governments to customers.
metabolisms, thus emphasizing composting and recycling. Since these strategies require the
destruction of the product form, Cradle-to-Cradle™, as described in 2002, and Blue Economy, do
not aspire to preservation of the product form, where Sustainable Materials Economy explicitly
includes such RLESs. Much later, Cradle-to-Cradle™ was extended with the addition of cascades
alongside recycling and composting (Braungart and McDonough 2013), which again evidences
that logics can co-exist and mingle.

The above again shows that WaRM frameworks drawing on a logic are able to create a unique
vision with regards to what constitutes appropriate WaRM, whilst also being restricted by the
elaboration possibilities provided by it. The latter results in salient similarities between the
frameworks remaining apparent.

4.3.5. The sequence logic
The frameworks using the sequence logic as their starting point are: Product Life-Cycle System
(PLCS) (EPA 1993), Performance Economy (Stahel 2006) and Material Efficiency (Allwood ET AL
2011). Fig. 3.03 gives a brief overview of these frameworks.

Waste and resources within the sequence logic
The sequence logic distinguishes itself from the other logics by emphasising the role of time: its
main objective is to maximise extracted value within a budget of reasonable costs, for a given
time period. Costs can consist of financial, labour, energy, excess use of materials or other forms
of costs. The sequence logic thus takes a time-dependent cost-benefit approach to value
extraction. Consequently, waste is viewed as the premature loss of value extraction
opportunities or as exceeding the budget of reasonable costs when attempting to preserve value
extraction opportunities. Both value and waste are contextual variables in the sequence logic.

The solution space and the meaning of cycling within the sequence logic
The sequence logic suggests organizing resource strategies sequentially: at the end-of-life a next
use should be sought that retains or captures the highest possible value. This means that there is
an emphasis on preservation of product-stock levels, since the investment in this form is
generally relatively highest compared to the rest of the industrial system in terms of cost,
materials, energy, labour, etc. The sequence logic therefore demands that product-cascades are
exploited before other strategies are applied, which means that such strategies as redistribution,
sharing, maintenance, repair, upgrading and remanufacturing are prioritized. Other strategies
become relevant when value can no longer be extracted from the product form. There can be
various reasons for this: the product form is too severely degraded or some form of
obsolescence has occurred, which means there is no merit in additional investment in it.

After all other strategies have been exhausted, a sequence ends or is reset by applying a ‘last
resort’ strategy: a strategy that represents the only feasible way to (re)capture what remains of
the investment made in extracting and purifying raw materials, such as recycling, composting,
landfilling or incineration. Completion of a successful loop or cycle is thus not a single operation,
but a composite of a string of many actions, processes or operations. After each use phase a
decision has to be made how best next to use the resource, for which appropriate information,
such as the type and degree of product wear and tear but also material composition and
contamination is essential. Here, information refers to those data necessary or involved in
directing resource flows. Within the sequence logic, resource management goes hand-in-hand
with information extracting and management.
Frameworks drawing on the Sequence logic

Product Life-Cycle System (PLCS)
sources: Environmental Protection Agency (1993)\(^\text{5}\)

- Purpose & mechanism
  PLCS aims to reduce health risks and environmental impact, or pollution across all media, through application of systems thinking in the product and process design and development stages.

- Prevention
  Six of the seven categories identified by PLCS have a preventative theme or aspect. For example: reduced material intensiveness, improved process management and efficient distribution.

- Perpetuation
  Four of PLCS’s seven categories have a focus on perpetuation: product system life extension (e.g., re-manufacturability, reuse), material life extension (e.g., recycling, energy recapture), efficient distribution (e.g., reuse of packaging) and improved management practices (e.g., reuse).

- Proaction
  A coordinated effort between all parties involved in the product system in the design stage, across the functions of design, engineering and management, using multi-disciplinary knowledge.

Key principles
Names seven categories of design strategies:
- Product system life extension
- Material life extension
- Material selection
- Improved management
- Reduced material intensiveness

Performance Economy (PE)
sources: Stahel (2006)\(^\text{6}\), (2014)\(^\text{7}\), Stahel and Clift (2016)\(^\text{8}\).

- Purpose & mechanism
  PE is the remedy to stagnating levels of wealth and growth, excessive resource consumption, high levels of waste and rising levels of debt and unemployment through the pursuit of radical performance improvements, such as radical efficiency, utility, smart solutions (bio and nanotechnology), miniaturisation and system solutions.

- Prevention
  Prevention is a major focus within PE, primarily through the dematerialisation of utility and increasing the value per material unit.

- Perpetuation
  All cycling strategies are permitted in both Loop- and Lake Economy. However, when ownership transfers from a manufacturer to another party information is lost (transaction cost) which makes cycling less effective. Retention of the product shape should be prioritized in both.

- Proaction
  Businesses need to operate service-oriented models that integrate extended producer responsibility, aided by appropriate legislation.

Key principles
Hierarchical organisation of cycling mechanisms.
In order of reducing importance:
- lake economy
- loop economy - product specific route
- loop economy - material specific route

Material Efficiency (ME)
sources: Allwood ET AL (2011), Allwood and Cullen (2012)\(^\text{9}\).

- Purpose & mechanism
  ME aims for a 50% reduction in CO\(_2\) emissions, whilst assuming a doubling of material demand. Using a mathematical formula as a guide, seven ‘levers’ are identified that can be set between boundaries determined by the scope for technology and behaviour led change.

- Prevention
  Five of the seven ‘levers’ have a preventative theme or element: improving energy efficiency, improving the material yield ratio, dematerialization (lightweighting), longer lasting products (i.e. improving durability) and demand reduction.

- Perpetuation
  Three groups revolve around cycling or contain strategies that facilitate cycling: longer lasting products (product cascading), component re-use and recycling.

- Proaction
  ME requires the simultaneous action from businesses, the government and individuals. In particular, businesses linked in product chains need to coordinate better.

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Fig. 4.03 Frameworks drawing on the sequence logic.
**Interpretations of and expansions on the sequence logic**

The Product Life-Cycle System, Performance Economy and Material Efficiency are all geared towards preventing what is considered premature value loss through orchestrating a string of actions that starts with retaining or recapturing the investments that brought about the product form, and ends or is reset with application of a ‘last resort’ strategy. As such, it is appropriate to categorize them as drawing on the sequence logic.

A large part of the similarity of these three frameworks is determined by the fact that the sequence logic demands that preventative approaches are emphasised above all other strategies. The fact that all three frameworks aim to achieve somewhat different goals and identify different mechanisms has little effect on this: the majority of strategies suggested by the respective frameworks revolve around prevention or have a preventative aspect to them. Efficiency and product longevity are therefore central to all frameworks drawing on the sequence logic. In a sense, this is restricting the RLESs possible. For example, the frameworks drawing on the sequence logic do not acknowledge that preventative strategies can also have detrimental effects. Where, for example, Blue Economy contends that considerable value can be extracted from cascades (Pauli 2010), which implies that having large amounts of materials to cascade can be beneficial.

However, the sequence logic also leaves room for different interpretations. The role of information is an example of this. The Performance Economy contends that the transfer of ownership is associated with a transaction cost that causes the loss of information vital to effective cycling. As a result, it attributes greater importance to closed-loop cycling than to open-loop cycling and therefore cycling within a single organization or value chain is preferred. With this, the provision of information is elevated from support mechanism to co-determinant; a role beyond Product Life-Cycle System and Material Efficiency assign to information.

The frameworks drawing on the sequence logic thus use a common starting point that are interpreted differently and elaborated on within the boundaries of the logic, which results in the unique characters of the respective frameworks, whilst similarities continue to exist.

**4.4. Insights from analysis of WaRM frameworks**

This chapter illustrated that circular economy related meaning work is not a random process, but that there is structure to it. This process can be thought of as starting by drawing on a particular set of definitions regarding waste and resources, which together form the WaRM logic. This set of definitions determines the solution spaces that can be employed as only those interpretations and elaborations are possible that fit within the boundaries of the logic and that do not conflict with it. Meaning work then proceeds by establishing specific ways to act by use the CAF functions of purpose and mechanism, prevention, perpetuation and proaction. As such, both the CAF functions and the definitions of waste and resources are key aspects in circular economy related meaning work and these elements therefore form the pillars of the Circularity Compass.

Additional aspects, such as resource quality, energy and information, were also shown to play a role in the included frameworks, albeit these were attributed varied importance. The preservation of information is a key consideration in the Performance Economy’s proposal for manufacturers to retain ownership of their products, whilst in the Product Life-Cycle System it is merely suggested that materials are labelled with identifiers. Moreover, energy is a key
consideration in the Blue Economy and Cradle-to-Cradle™, but it is not an integrated part of the Waste Hierarchy. As such, the role of these aspects is in need of clarification.

Before the Circularity Compass can be constructed from these aspects however, it is worth considering the following two points. Firstly, dealing with different logics can problematic. This is illustrated by the Circular Economy framework (EMF 2013), which is a unification attempt of Cradle-to-Cradle™, Blue Economy and the Performance Economy, supplemented with additional schools of thought. As such, this framework attempts to unify a range of different logics. However, this framework lacks many of the nuances that are explicitly part of the original frameworks, such as the prominent role of information in the Performance Economy, the importance Blue Economy attributes to preventative approaches, and Cradle-to-Cradle™’s goal to move away from all forms of downcycling. This illustrates that unification attempts can lack depth or internal consistency if differences in waste and resource definitions are not addressed.

At the same time, elaboration attempts do not have to be problematic as it was illustrated that WaRM frameworks can also be very flexible. Think of the examples of Industrial Symbiosis and Cradle-to-Cradle™ that were, respectively, supplemented with concepts from cleaner production and extended by the addition of cascades. A similar development has also affected the Circular Economy framework (EMF 2013), where the circular aspects that were previously at the heart of the framework have now become part of the RESOLVE framework: REgenerate, Share, Optimise, Loop, Virtualise, and Exchange (EMF 2015). Many of these aspects represent or are related to different aspects of cycling, but the elements of ‘optimise’ and ‘virtualise’ go beyond this by explicitly including efficiency and dematerialisation.

How, then, to proceed with the construction of the Circularity Compass: how can it be ensured that an analytical framework is created that is able to capture the range of different attitudes towards WaRM? The answer to this is twofold. Firstly, a mechanism is required for capturing the relationship between RLESs and other WaRM strategies. This becomes apparent when one considers the role of recycling in three WaRM frameworks drawing on different logics. The Waste Hierarchy, for instance, suggests that recycling be applied when this is practical and desirable from both an economic and environmental perspective. The object logic the Waste Hierarchy draws on allows for this strategy to be executed in a variety of ways, as long as the would-be waste arrives at a location where it can be put to productive use, even if this leads to downcycling. According to Cradle-to-Cradle™, however, downcycling should be avoided: the containment logic, after all, stipulates that recycling should lead to the recyclate being restored to a like-virgin state, or as close to this state as possible. In the Performance Economy, on the other hand, as is in line with the sequence logic, recycling happens after a succession of other strategies has already taken place. Here, recycling is considered appropriate when it is part of a set of last resort strategies or is indeed the only last resort strategy available for (re)capturing value.

As such, despite the fact that the label ‘recycling’ is used in these three frameworks, the RLES it designates serves different functions, has different type of transformations associated with it as well as different conditions for its application, dependent on the role it fulfils in relation to other strategies. The same applies to other strategies such as ‘reuse.’ This makes it apparent that, in order to understand a RLES fully, one needs to understand how it relates to other RLES and other WaRM strategies. In other words: RLESs cannot be understood in isolation.
Secondly, instead of using the logics uncovered in this chapter, a more systematic way of capturing the range of definitions that exist with regards to waste and resources is required. After all, the logics articulated in this chapter, although helpful in uncovering the relevance of waste and resource conceptualizations, are based on only eight WaRM frameworks. Moreover, it cannot be assumed that the context of practitioners will precisely match any of these frameworks. What is necessary, therefore, is a systematic way of understanding both waste and resource definitions.

To address both these points – how RLEs can be understood in relation to each other and how to systematically conceptualize waste and resources – Chapter 5 Conceptualizing resource transformations explores two debates in the WaRM discourse that result in a better understanding of resource transformations: the particle-versus-product debate and the renew-versus-consume debate. The following, Chapter 06 The Circularity Compass v1.0 explains how these aspects will be taken into account in the empirical part of this research, as well as how the aspects of resource quality, energy and information will feature.
5. Conceptualizing resource transformations

Resource states and types of waste

The previous chapter brought to the fore that RLESs need to be understood in relation to each other as well as that waste and resources need to be conceptualised in a systematic manner that allows for capturing the range of existing definitions. To this purpose, this chapter explores the nature of resource transformations and the (intended) outcome of these transformations. This chapter is divided in three parts, the first two of which cover implicit debates in the WaRM discourse. The first section examines the conceptualizations of ‘resource’ by describing what is referred to as the particle-versus-product debate; the second part examines conceptualizations of ‘waste’ by means of discussing the renew-versus-consume debate. This leads to the identification of two conceptual tools: firstly, the three resource states – particles, parts and products – which provides a structure for organising the route a resource travels, as well as indicating how different RLESs relate to each other. The second conceptual tools is a waste typology. Both these conceptual tools will be used to construct the Circularity Compass in Chapter 06. The third and final part of this chapter briefly discusses the relation of these conceptual tools to the WaRM frameworks of the previous chapter as well as the broader WaRM literature.

5.1. Particles, parts and products: conceptualising the route resources travel

This section introduces the particle-versus-product debate, which revolves around two different perspectives prevalent in the WaRM discourse regarding conceptualizing resources. It underpins such critical discussions of what RLESs to pursue as can be found in, for example, Huber (2004:29-32) and Allwood (2014). As the name of the debate implies, one position that can be adopted is to conceptualize resources from the perspective of particles; another is to conceptualize it from the perspective of products. However, if one is to understand how RLESs relate to each other these two perspectives need to be integrated. After all: the collection of RLESs grouped under the circular economy as-an-umbrella-concept contains a mix of strategies that affect particles and products. How such integration can be achieved is discussed in the last part of this section.

5.1.1. Two perspectives on resources: the particle-versus-product debate

Next, the particle versus product-debate is discussed by explaining in more detail the two apparently dichotomous positions and illustrating the manner in which the WaRM frameworks from Chapter 04 draw on these perspectives.

Particles perspective

The particles perspective conceptualizes a resource as a collection of particles-of-a-kind: as a particular quantity of particles that share one or more properties that exists in a form where the value extraction possibilities they represent to a possible end-user are only broadly defined. Particles-of-a-kind, in other words, are those particles referred to with the label of ‘material,’ such as elements and molecules, but also mixed molecules of different types such as alloys and other composite materials, such as wood.

Viewing a resource’s journey through the economy from the perspective of particles means that the extraction or production of particles, their subsequent dispersion and what happens to them
at the end-of-life become important focal points. Cycling, in the strict, means that particles return to the state they were in when first extracted, produced or manufactured. This return to a virgin-like\footnote{The term ‘virgin-like’ is used here in acknowledgement of the fact that it might not be technically feasible to reproduce the virgin state entirely.} state requires operations to extract the particles from the physical form the particles were given to serve an end-user and to renew them if required. This might involve purification or other treatment that restores as much of the original properties as possible. When this cycle is repeated, the constant factor is the particles’ return to this virgin-like state; products are merely temporary physical forms of enduring or revitalised particles. As such, the preservation of the physical form or shape those particles are given as part of this journey – the form from which end-user extracts value – is not of immediate relevance when adopting this perspective.

An example of cyclic operations in line with the particles perspective is recycling. If one also allows for natural processes to perform renewal, then composting substances in order to return organic nutrients to the soil constitutes a form of cycling as well. Substance cascades can furthermore play a role by extending the productive life of particles, through finding subsequent applications for a material that do not have to be preceded by renewal. As such, substance cascades cannot be classified as cycling in the strict sense, although cascades are associated with circular economy through their resource-life-extending capacity (EMF 2013, BSI 2016). Although not strictly circular, cascades of this type do not necessarily conflict with cycling either: when combined with recycling or composting cascades substances can still be renewed.

The particles perspective is prominent in several of the WaRM frameworks discussed in Chapter 04. Cradle-to-Cradle™, for instance, emphasises the renewal of particles by using metabolisms appropriate to the properties of a substance, depending on whether they are suitable for cycling in the biosphere through composting or are suitable for renewal through recycling. Industrial Symbiosis, on the other hand, directs the attention to substance cascades. Blue Economy combines both these views and proposes not only to cycle materials in the biosphere, but also suggests the use of cascades to maximize the value that can be extracted from them. The Sustainable Material Economy also draws heavily on the particles perspective by suggesting, among other RLEs, recycling and composting.

The particles perspective also plays a role in the other frameworks discussed in Chapter 04, albeit not a central one. Despite recycling not being the preferred strategy in the Waste Hierarchy, it is nevertheless part of the set of solutions put forward by the framework. In Product Life Cycle Systems, the Performance Economy and Material Efficiency recycling or other strategies that target particles are likewise not considered primary strategies, although it is acknowledged that such strategies have a role to play in WaRM.

\textit{Products perspective}

Apart from conceptualizing resources as particles it is furthermore possible to conceptualise a resource from the perspective of a particular physical form from which an end-user is able to extract value, what is generally labelled as a ‘good’ or ‘product.’ The value extraction possibilities that products represent are defined within much more narrow boundaries compared to particles. Depending on the boundary of the system considered, the products perspective may or may not be extended to include other aspects than the product itself, which are related to or attributable to it, such as distribution or the energy and material flows that are involved in using
and maintaining a product. However, regardless of the boundary, viewing a resource’s journey through the economy from this perspective inherently grounds it in the value that a particular physical form is able to deliver, as the physical form is inextricably linked with the value it is designed to provide, whether symbolic or tangible and practical. As such, this perspective inherently directs the attention to a product’s use phase, as this is where value is extracted or delivered.

Cycling, as seen from the products perspective, consists of those operations that prevent a product from losing its ability to deliver value or operations that return it to a state of productivity after this ability was lost or compromised. Through cycling operations a product can undergo renewal either physically, through reconditioning in the form of repair, remanufacture or upgrading, or in relation to its use context, through co-use, product cascading or use in alternate applications. Other examples of strategies that can facilitate value extraction from a product are product longevity approaches that improve product durability, such as the choice for durable materials and maintenance. Various product-service systems can play a role in this.

The products perspective is central to the Product Life Cycle Systems, the Performance Economy and Material Efficiency as these frameworks suggest applying such strategies as reuse, remanufacture, refurbishment and upgrading before any other strategies through which a product loses its structural integrity, where possible. The products perspective furthermore features in the Waste Hierarchy: in this framework reuse is the second most important strategy.

5.1.2. Use of and critique on both resource perspectives: the need for integration
The particle versus product-debate does not only influence the WaRM frameworks discussed here; it is prevalent in material science and the side of industrial ecology that revolves around material flow analysis (MFA). Although different definitions of particles-of-a-kind are wielded in these areas, the same assumption with regards to the wide range of possibilities for value extraction that they represent applies to all. In MFA studies, for example, it is common to consider chemical elements, such as iron and nickel (Brunner and Rechberger 2005). In contrast, a broader definition is used in material science: here uniformity is defined by chemical and mechanical bonding. Thus, polymers and alloys are also considered as particles-of-a-kind (Allwood and Cullen 2012).

The particles perspective is typically adopted when addressing questions relating to the preservation or depletion of material stock-levels, environmental and human health, the facilitation of economic functions and complex water-food-energy nexus interactions as adopting this perspective allows for generating insights into complex flows otherwise invisible (see for examples: Graedel 2010, Allwood and Cullen 2012, Keirns et al. 2016). The particles perspective’s ability to generate such high-level insights is the reasons that the World Economic Forum regards this perspective as catalytic in transitioning to a circular economy (WEF 2014:48). However, the particles perspective is not free of critique. For example, the processes to separate chemical elements after they have been bonded or mixed might not exist, and a return to a virgin-like state can demand such energy investments as to defy environmental or economic sense (Allwood et al. 2011, O’Rourke et al. 1996, Frosch and Gallopoulos 1989).

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52 See pages 52 and 53 where the end-use of steel and aluminium is depicted.
The products perspective, on the other hand, is typically used to look at improvement opportunities for product design and use, the impact of user acceptance and behaviour and questions relating to the preservation of product stock levels (Baumann and Tillman 2009). It therefore dominates in design studies (Chapman 2005, Cooper 2010), where the various reasons for product discard – e.g. damage to the product, changing needs or the product being superseded by superior technology (Solomon 1994, Cooper 2004) – have long since been studied. This perspective is furthermore wielded by the side of industrial ecology that performs life-cycle assessment (LCA) (e.g. Suh et al. 2010, Pizzol 2015).

Through implementation of the strategies associated with the products perspective such benefits as the retention of embedded energy (Allwood et al. 2011) and increased employment as a result of renewal operations (Stahel 2006) can be generated. However, there is evidence to suggest that user behaviour can undo the intended environmental gains in systems aimed at increasing access to or extending the life of products (Tukker 2013). Moreover, without consideration of a product’s optimal lifetime, total energy use can increase, negating savings made through preserving the product shape (Bakker et al. 2014). Also, preserving the product form does not always make sense, as a product can become obsolete, such as, for instance, in the case of typewriters. If the sole focus in such cases is on longevity and no attention is given to recyclability, materials can be lost (Allwood and Cullen 2012).

Thus, although both perspectives have limitations, both perspectives also cover important aspects of the WaRM debate: one cannot be said to be superior to the other. The more salient point here, is that the particle versus product-debate seems to suggest that RLESs come in two types or ‘flavours’. This implies a dualism or dichotomy where RLES transformations are conceptualized in two different ways, making it impossible to study the circular economy concept in a consistent manner. Instead, the relationship between particles and products can be better understood by conceptualizing them as resource states that are mediated by a third state: the parts state.

5.1.3. The parts state: a mediating state between the particles and parts state

The apparent dichotomy of the particles and products perspectives can be resolved by drawing on thermodynamic principles, in particular the notion of entropy. That is: by conceptualizing particles and products as resource states mediated by a third state, the parts state (Blomsma 2015a). In this conceptualization, particles are considered as collections of materials, molecules or substances that are relatively high in entropy, or low in order. Products, on the other hand, are low in entropy and high in order: they are the goods that take on particular physical shapes required for performing a function. The mediating state describes an intermediary state where entropy is neither particularly low nor high: it is the state of parts, assemblies and sub-assemblies. As such, the value extraction possibilities of parts are defined within more narrow boundaries than is applicable to particles, but parts do not yet allow end-users to extract value. Together, the particles, parts and products states represent the principal forms a resource can take. From this also follows that a resource transformation can be defined as the movement of a resource between these three states.

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13 The author heard it described this way in a meeting where policy makers and industrial ecology scholars discussed possibilities for circular economy oriented policy: 25th of April at Institute for European Studies (IES), title of meeting: “Industrial Ecology: Science, the Environment and the Circular Economy.”
The added value of the mediating parts state becomes apparent when looking at a generic manufacturing life-cycle, from sourcing, through various stages of manufacture, use and eventual end-of-life (e.g. Huber 2004, Krajewski ET AL 2010). See Fig. 5.01: it becomes possible to divide this life-cycle into three areas, where each resource state features in the forward as well as in the reverse value chain. This connects the particles and products perspectives, thus resolving the apparent dichotomy between them.

**Route map for resource transformations organised by resource states**

<table>
<thead>
<tr>
<th>Resource states</th>
<th>Generic manufacturing life-cycle</th>
<th>State issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>high entropy (disorder)</td>
<td>Raw material</td>
<td><strong>Material choice and sourcing issues</strong></td>
</tr>
<tr>
<td>PARTICLES STATE</td>
<td>Treatment I</td>
<td>Preservation of material stock levels</td>
</tr>
<tr>
<td></td>
<td>Manufacture I</td>
<td>Environmental and human health</td>
</tr>
<tr>
<td></td>
<td>Treatment II</td>
<td>Macro-economic functions</td>
</tr>
<tr>
<td></td>
<td>Manufacture II</td>
<td>Food-water-energy nexus</td>
</tr>
<tr>
<td>PARTS STATE</td>
<td>Use</td>
<td><strong>Parts and sub-assembly issues</strong></td>
</tr>
<tr>
<td>parts, assemblies, sub-assemblies</td>
<td>Logistics</td>
<td>Design for X</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- e.g. reman, repair, upgradeability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Quality assurance and planning</td>
</tr>
<tr>
<td>PRODUITS STATE</td>
<td>Use</td>
<td><strong>Product and use issues</strong></td>
</tr>
<tr>
<td>function, use, relationship</td>
<td>Logistics</td>
<td>Improvement of product design, use, EoL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- e.g. energy in use, optimal product life-time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User acceptance and behaviour</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- e.g. design for emotional durability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Preservation of product stock levels</td>
</tr>
<tr>
<td>low entropy (High order)</td>
<td>Use</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 5.01 Schematic overview of a generic manufacturing life-cycle, divided in the three resource states: the particles state, the parts state and the products state. Furthermore depicted are the various points where processes within the same value chain can exchange resources, as well as points where resources can exit. Furthermore included is a short overview of state-specific issues.**

In this conceptualization, two major resource transformations can take place: the transition between the particles and parts states (blue dashed line in Fig. 5.01) and the transition between the parts and products state (yellow dashed line). When using the template of this figure to visually maps flows in a similar manner to systems diagramming and in particular to ‘Sankey diagrams’14, the manufacturing as well as the end-of-life of a product consisting of multiple parts can be understood as follows, see Fig. 5.02 (top two boxes). First, the materials with the required properties are produced or manufactured. From these materials parts are created that are then used to assemble the final product. After a period of use, the product reaches its end-of-life. Various scenarios can take place next.

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14 Allwood and Cullen (2012) include a short history of Sankey diagrams on page 17, and provide examples of Sankey diagrams throughout the book.
Examples of resource transformations using the route map

**LIFE-CYCLE of PRODUCT CONSISTING OF MULTIPLE PARTS - discard scenario**

- **Discard**
  - Product is collected and landfilled.

**RLEs for PRODUCT CONSISTING OF MULTIPLE PARTS**

**examples for RECYCLING**

- **Recycling - scenario 01**
  - Product is collected, materials reclaimed by shredding the product and separating the resulting granulate for processing outside of the original value chain.

- **Recycling - scenario 02**
  - Product is collected, materials reclaimed by disassembly and separating the materials. Subsequent processing outside of the original value chain.

**examples for REUSE**

- **Reuse - scenario 01**
  - Product is redistributed to another user without intermediate processing.

- **Reuse - scenario 02**
  - Product is collected, (partially) disassembled, reconditioned, reassembled and returned to use.

**RLEs for a SIMPLE PRODUCT CONSISTING OF A SINGLE PART**

**examples for RECYCLING**

- **Single recycling scenario**
  - Product is collected, materials reclaimed by shredding the product and separating the resulting granulate.

**examples for REUSE**

- **Single reuse scenario**
  - Product is redistributed to another user without intermediate processing.

Fig. 5.02 Examples illustrating how distinguishing between various resource states can clarify both what is meant by ‘recycling’ and ‘reuse’ by describing what states a resource travels through. For reasons of simplicity, no losses are assumed to occur and the various materials a product could consist of are depicted as a single flow.
Either, the product is discarded and collected with the household waste to be landfilled, effectively exiting the value chain, as depicted in the discard scenario in Fig. 5.02. Another scenario would be to collect and recycle the product. There exist two principal options for this. Firstly, this could be done by shredding the product and separating the various materials. In this case, the parts state is disregarded at the end-of-life, as resources transition directly from the products state to being treated as a source of materials, i.e. particles. This is the scenario depicted in ‘Recycling – scenario 01’ in Fig. 5.02. The second option involves disassembly: thus going through the parts state. This scenario generally offers more possibilities for separating different (grades of) materials, but is also likely to require more labour, whether performed by hand or automated. This scenario is depicted in ‘Recycling – scenario 02.’ As such, by describing the succession of resource states a resource moves through during its ‘life,’ scenarios designated with the label ‘recycling’ can be more precisely understood.

The same goes for operations designated with the label ‘reuse.’ For example, if the product reaches its end-of-life when it is still functional, it could be redistributed to another user. This type of reuse takes place wholly in the product state, as depicted in ‘Reuse – scenario 01’ in Fig. 5.02. However, if the product is no longer functional, but can be restored to a functional state by, for example, repairing or replacing parts it could also be reused. This scenario requires (partial) disassembly and as such takes place in the parts state before the product is reassembled and returned to the product state. This is depicted in ‘Reuse – scenario 02.’

Were the product in question a simple product, consisting of a single part, the parts state could have been discounted as non-applicable, see bottom box Fig. 5.02. Acknowledging the presence or absence of the parts state is another way in which the proposed typology of resources aids in distinguishing resource transformations. In this regard, it is important to note that the parts state, when present at the end-of-life, always fulfils its function ‘in service’ of the other two states: it either aids in recapturing materials, or it aids restoring products to use.

Using Fig. 5.01 as a visual mapping tool in the manner illustrated in Fig. 5.02, thus makes it possible to understand the transitions resources undergo. And, if required, multiple strategies could be mapped together. Fig. 5.01 can thus be thought of as a conceptual route map for resource transformations and offers the means for a consistent examination of resource transformations, unifying both the particles and products perspectives in a single framework and offering the possibility of studying the relationship between RLESs and other WaRM strategies.

The presence of the parts state is in line with some of the WaRM frameworks discussed in Chapter 04: the Product Life-Cycle System, Performance Economy and Material Efficiency. These frameworks put forward such RLESs as repair, upgrading and remanufacturing, aimed at remediating a particular deficiency related to a specific part or subassembly. Addressing this deficiency, by means of (partial) disassembly and reassembly with new or restored parts, returns the whole product to a state where it can continue to deliver value. The parts state is furthermore implied in Cradle-to-Cradle™, as in this framework it is the ability to separate mono-material parts that facilitates the return of a material to its respective metabolism.

Articulated next is the second implicit debate in the WaRM discourse that plays a role in determining how to meaningfully distinguish between RLES transformations.
5.2. Developing a waste typology: the renew-versus-consume debate

This section examines the renew-versus-consume debate, using a simplified designation for this debate compared to Lacy and Rutqvist (2015) who describe this debate by contrasting the two terms “wasted life-cycle” and “wasted capacity”. This debate is relevant for conceptualizing a RLES’ function, or the type of waste or wastefulness it addresses.

5.2.1. Two perspectives on waste: the renew-versus-consume debate

With regards to what constitutes waste or wastefulness two perspectives are generally invoked. The first perspective, that prioritises the renewal of resources, regards the creation of waste the result of not renewing resources or not closing life-cycles. Alternatively, one can regard not using a resource to its fullest capacity – not using the value generating capacity of a resource ‘up’ – as wasteful. Next, these two perspectives are discussed as well as how they relate to the WaRM frameworks discussed in Chapter 04.

**Renew, or the wasted life-cycle perspective**

This perspective poses that a resource is wasted if its quality deviates from a particular level, to the degree that it falls outside the range designated for value creation. Referred to here are cases where the means exist to restore or rejuvenate a resource in a manner that restores its functionality in relation to a fixed or evolving quality level: to neglect doing so means that value is lost unnecessarily. As such, this perspective emphasises strategies that turn end-of-life into new or extended life that is not (significantly) different from the previous life. The RLESs thus identified are recycling\(^{15}\) and composting for particles, and maintenance, repair, remanufacture for products. Product durability, as a means of preventing a life-cycle to become wasted, also falls within the solutions this perspective points to. Other strategies within scope are those strategies that allow products to meet evolving quality levels are refurbishment and upgrading.

The resource renewal plays a central role in Cradle-to-Cradle™ as evidenced by this framework’s aim to preserve or restore the quality of materials. Blue Economy also draws on the wasted life-cycle perspective when suggesting the use of biodegradable and biocompatible materials so that they can be returned to the biosphere to be renewed. Resource renewal furthermore plays a role in Product Life-Cycle Systems, the Performance Economy and Material Efficiency, which emphasise the repair and reconditioning of products.

**Consume, or wasted capacity perspective**

The resource consumption perspective poses that a resource is wasted if more value or utility can be extracted from it by changing the definition of quality per use case: this perspective considers cases where the end-of-life of a resource in a particular context does not have to be the end of value extraction from that resource altogether, as there might be other uses or contexts where the resource can continue to deliver value. This perspective differs from the resource renewal perspective in that it does not require restoration or improvement of quality levels. Rather, it poses a relative or relational view of quality, where its definition can differ per use case. Waste occurs if the value extraction halts, independent of how the quality of the resource at the time relates to its original definition. As such, this perspective points to strategies that consume, ‘use up,’ or exhaust the capacity of resources to deliver value through intensified use: think of substance cascades, downcycling and waste-to-energy for particles, and product cascades, alternate use, sharing and co-use for products.

\(^{15}\) Recycling, as used here, explicitly refers to those types of recycling that (largely) maintain material quality. This is not possible for all materials, but nevertheless applies to various materials such as metals and nyons.
Industrial Symbiosis and Blue Economy are prime examples of frameworks that draw heavily on the resource consumption perspective, since substance cascades play a central role in these frameworks. This perspective is furthermore part of frameworks such as the Performance Economy and Material Efficiency, in which product cascades are put forward as appropriate solutions. The resource consumption perspective furthermore features in the Performance Economy in the form of its suggestion to use product service-systems to intensify the use of products.

5.2.2. Use of and critique on both perspectives on waste: unique solution spaces

Both sides of the renew-versus-consume debate have relevance beyond the WaRM frameworks discussed here, as both perspectives are commonly applied to materials and products alike. For example, an example of commercial application of resource renewal is the development of polyester fibres with the aim to recycle them without the usual degradation of the molecular chain length (Sustainia 2014). Fairphone and Project Ara are examples of commercial application of resource renewal in the context of products: these smart phones are based on a modular architecture, facilitating repair and upgrading, respectively facilitating that the phones are restored to a functional state when part failure occurs or allowing them to evolve alongside changing quality or functionality standards. Critique on this perspective consists of the technical and thermodynamic limitations that restrict renewal of a particular form (Prendeville ET AL 2014).

An example of commercial application of the resource consumption perspective is the case of British Sugar, that uses the co and by products of sugar production to create a range of additional revenue streams, such as animal feed, bioethanol and tomatoes (Short ET AL 2014). In this example, the company maximises value generation by making sure that all, or at least the majority of resources available to it, leave its facilities as sellable products. In effect, it has ‘used up’ the original resource base to its fullest potential. Other examples are provided by Botsman and Rogers (2010), who describe a wealth of product sharing and co-use practices that intensify the use of otherwise dormant capacity. Prominent examples from Botsman and Rogers are car and tool sharing schemes. These examples variedly have a non-profit or commercial character. The resource consumption perspective can be critiqued for not accounting for end-of-life effects as the choice for more durable materials can lead to reduced recycling outcomes, such as when ceramics or composite materials are chosen to extend product life.

The existence of both perspectives and being able to shift between them can be useful in identifying different improvement opportunities, since the strategies suggested by these two perspectives do not overlap, but point to unique and complimentary solution spaces. As such, these perspectives can be thought of as different possibilities for addressing waste and should not be regarded as mutually exclusive options: the fact that both perspectives feature in multiple of the WaRM frameworks supports this.

This does not mean that the two solution spaces suggested by both perspectives operate independently: trade-offs and synergies exist between them. For example, extending product life can complicate recycling as lead-in times prevent investment in the appropriate infrastructure and inhibit innovation (Allwood 2014). Similarly, product service-systems exist that allow for increased utilization of product capacity, whilst also extending the life of products by applying reconditioning (Tukker 2013, Stahel 2006).
5.2.3. Waste typology
Since both perspectives on waste offer RLESs that can be productively applied to prevent or delay the generation of waste, they can be used to provide insight into the function of RLESs by using them as a basis for a waste typology. The proposed typology is depicted in Fig. 5.03: the x-axis of the typology contains resource renewal and consumption as categories; the y-axis uses particles and products as categories for the definition of resources for additional clarity. The particles state is not included here, because its role is always defined in relation to either the particles or products state. However, its presence is alluded to by the double dotted line between the products and particles state. Next, each quadrant of the typology is briefly discussed.

<table>
<thead>
<tr>
<th>Resources defined as:</th>
<th>Waste or wastefulness defined as a lack of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>Closing loops</td>
</tr>
<tr>
<td></td>
<td>keeping substances in cycles of (near) equal quality</td>
</tr>
<tr>
<td></td>
<td>e.g. recycling*, composting</td>
</tr>
<tr>
<td>Products</td>
<td>Extending loops</td>
</tr>
<tr>
<td></td>
<td>more use from substances through controlled transformations</td>
</tr>
<tr>
<td></td>
<td>e.g. substance cascading, downcycling, waste-to-energy</td>
</tr>
<tr>
<td>Long life loops</td>
<td>extending product life</td>
</tr>
<tr>
<td></td>
<td>e.g. maintain, product durability, reconditioning (repair, refurb., remain.)</td>
</tr>
<tr>
<td>Intensifying loops</td>
<td>tapping into un- or underused capacity</td>
</tr>
<tr>
<td></td>
<td>e.g. product cascading, alternate use, sharing, co-use</td>
</tr>
</tbody>
</table>

*: Recycling, as used here, refers to those practices that (largely) maintain material purity and quality.

**Fig. 5.03** Depicts the typology of resource transformations. The x-axis of the typology contains ‘resource renewal’ and ‘resource consumption’ as categories for the definition of waste; the y-axis uses ‘particle’ and ‘product’ as categories for the definition of resources.

- Closing loops
The closing loops-function applies to the particles state. To implement closed loops solutions means that substances, whether materials or chemical elements, are contained within or return to cycles that preserve or restore the quality levels of particles (e.g. substances, materials, molecules) to a particular level. As such, substance quality is often defined within narrow limits: quality deviations are only permissible to the degree that they do not affect the performance of particles for a particular function. Recycling is the primary strategy in this quadrant for non-biological materials, and composting for biological materials.
• Extending loops
To extend loops is to extract more value from particles through controlled transformations. The quality of particles as defined in one use-case is generally different from the definition of quality in the next use-case. Strategies that fit within this quadrant are substance cascading, downcycling and waste-to-energy schemes.

• Long life loops
Long life loops serve to extend the possibility to extract value from a particular product. Strategies in this category serve to keep a product performing on consistent or evolving standards of performance, such as maintenance, repair, refurbishment, remanufacturing, upgrading, but also product durability approaches such as the choice for low-wear materials and technologies fit in this quadrant.

• Intensifying loops
Intensifying loops allows for tapping into un- or underused capacity of a product, and includes strategies that facilitate the subsequent use of a product for either its intended purpose of for alternate purposes. Quality and/or utility value of a product are redefined in each use-case. Think of redistribution strategies such as sharing, co-use and product cascades, but also alternate use.

This typology can be used, together with the route map, to describe RLEs accurately, see Fig. 5.04. Here, the second recycling and second reuse scenarios from Fig. 5.02 are repeated, but with added distinctions regarding what function these scenarios might serve.

Examples of resource transformations using the route map and waste typology

**RLEs for PRODUCT CONSISTING OF MULTIPLE PARTS, with RLE function added**

<table>
<thead>
<tr>
<th>Examples for RECYCLING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Recycling - scenario 02a</strong></td>
</tr>
<tr>
<td>Product is collected; materials reclaimed by disassembly and separating the materials. Materials are recycled through open-loop recycling.</td>
</tr>
<tr>
<td><strong>Recycling - scenario 02b</strong></td>
</tr>
<tr>
<td>Product is collected; materials reclaimed by disassembly and separating the materials. Materials are cascaded or downcycled in another value chain.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Examples for REUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reuse - scenario 02a</strong></td>
</tr>
<tr>
<td>Product is collected, (partially) disassembled, upgraded, reassembled and returned to the same user for continued use.</td>
</tr>
<tr>
<td><strong>Reuse - scenario 02b</strong></td>
</tr>
<tr>
<td>Product is collected, (partially) disassembled, maintained, reassembled and redistributed to another user.</td>
</tr>
</tbody>
</table>

*Fig. 5.04 Repetition of the second recycling and second reuse scenarios from Fig. 5.02, with addition of waste typology icons, indicating what purpose the strategies serve.*
For instance in ‘recycling - scenario 02a’ the product is collected, materials reclaimed by disassembly and careful separation. These materials then go on to be recycled in an open-loop recycling process. In ‘recycling - scenario 02b’ the initial steps are similar, but instead of recycling in a manner that maintains product quality and purity, the materials are cascaded or downcycled. Recycling scenarios 02a and 02b thus have markedly different outcomes. The second example describes a similar difference for reuse scenarios: in ‘reuse - scenario 02a’ a product is collected, (partially) disassembled, upgraded through the addition of more up-to-date technology, reassembled and returned to the same user for continued use. In contrast, in ‘reuse - scenario 02b’ the product is also collected, (partially) disassembled, but merely undergoes a cleaning procedure before being reassembled and redistributed to another user, who might use the product in a different setting and with different intentions. By combining the waste and resource typologies to describe RLEs, it can be made clear what outcome a particular strategy serves.

5.3. Route and function, WaRM frameworks and logics
In this section the relation of the typologies as developed in this chapter are compared to the logics developed in Chapter 04 How waste and resource frameworks create action recipes and it is shown that the typologies offer a flexible means of describing the WaRM frameworks.

Consider, Industrial Symbiosis, for instance. This framework focuses on the particles state and aims to address the wasted capacity of particles and as such revolves around extending loops. The Blue Economy, likewise focuses on the particles state and on the wasted capacity of particles, but also acknowledges the need for resource renewal by advocating cycling by means of the biosphere. As such, it consists of a mix of closing and extending loops. Cradle-to-Cradle™ also addresses the particles state, but primarily aims to address resource renewal of particles by focussing on closing loop strategies. Sustainable Material Economy is also grounded in the particles state, and acknowledges the importance of both closing and extending loops, as well as ventures into the products state by acknowledging reuse and reconditioning as strategies that can contribute to the reduction of waste. Product Life-Cycle Systems, Performance Economy and Material Efficiency, on the other hand, suggest that RLEs applied in the products state have the largest effect and can thus be thought of as grounded in the products state, although the particles state is also acknowledged as having a role to play when other strategies have been exhausted. The logics as described in Chapter 04 can thus also be captured by the resource and waste typologies described in this chapter.

Classifying these frameworks in this manner also illustrates a point made in Chapter 02 regarding the frameworks in Fig. 1.01 and 2.01: that the organising principles applied in the frameworks do not have a robust foundation. Describing the frameworks in terms of their definitions of resources and waste, however, uncovers that a more fundamental theoretical structure exists that could underpin such frameworks.

The last two chapters have revolved around identifying the aspects relevant to creating action recipes for the implementation of WaRM, and RLEs in particular. Next, these aspects are synthesized in an analytical framework that is suitable for capturing how practitioners interpret the circular economy concept in the context of innovation projects.
PART II

Research methodology
6. The Circularity Compass v1.0

An analytical framework for capturing the meaning attributed to circular economy

Drawing on the previous chapters, this chapter synthesizes the Circularity Compass v1.0: an analytical framework that is suitable for capturing the meaning practitioners attribute to the circular economy concept. The three pillars that were identified in these chapters - the CAF functions, resource states and the waste typology - are assembled into a whole. This chapter is structured as follows. First, a vignette is described that serves as an example by which the Circularity Compass can be introduced and explained. Next, the framework is deconstructed to show how it was synthesized. Lastly, the rules for mapping cases are outlined.

6.1. Introducing the Circularity Compass v1.0

Below, a vignette is described that serves to illustrate how the Circularity Compass can be used to capture how circular economy is interpreted in on-going innovation processes. It describes an example of a hypothetical early-stage innovation process conducted by a company that has identified a problem and aims to address it by the application of RLESs. That is: potential solutions have been identified and are being explored, but no definitive answers have yet emerged.

6.1.1. Example vignette

Imagine a product made from two parts, consisting of the same material and of approximately equal size. For reasons of simplicity, it is assumed that no losses or contaminations occur along the value chain. Of the raw material mined for this product, only half is used in the production of the material: the remainder is landfilled. The mining of the raw material is considered energy intensive and is the most significant component in the product’s carbon footprint. This footprint is seen as problematic, as it is negatively affecting the company’s reputation. That is: value is being destroyed from the perspective of the company, but also from the perspective of the environment.

The production of the material, the parts and product assembly do not require any additional materials. The parts are joined by a mechanical non-reversible press connection. Use of the product eventually causes one part to become irreparably damaged and as a result the whole product is discarded. Even though the material the product consists of is technically recyclable, it is currently landfilled, because waste management companies do not generally have the infrastructure or capability for recycling it. This is the situation as depicted in Fig 6.01, designated as the problematized or business-as-usual situation.

The company that produces the product decides it wants to reduce its carbon footprint to improve its brand reputation: that is, it decides to stop value destruction and if possible, create value by improving brand reputation compared to competing brands. The company initiates an innovation project inspired by circular economy thinking, investigating whether reducing the reliance on the raw material would be a way to reduce the emissions associated with the production of the product. The fact that one of the parts is damaged in use is considered an
Depiction of problem situation described in vignette using Circularity Compass v1.0

Fig. 6.01 Example of a case mapping using the Circularity Compass v1.0. Depicted here is the situation that the company perceives as problematic and aims to address through exploring whether the application of strategies associated with circular economy can address this situation.
insurmountable barrier to reuse of the whole product and this option is therefore quickly rejected. Three additional barriers to reuse of the intact part are identified, for which possible enablers are conceived. Firstly, the discarded product needs to be collected. The company has only a handful of large clients, so this can be overcome by implementing a relatively simple recovery infrastructure and matching procedures. This would involve the installation of collection bins for the discarded product and collecting these bins when new product is delivered.

The second barrier to reuse of the second part lies in the fact that reversing the press connection is difficult and likely to damage it. The idea is conceived that this can be overcome by altering the product geometry that allows for replacing the current non-reversible connection with a reversible one. Possibilities to automate this process are unclear, as is the impact on current assembly processes.

Since the material is technically recyclable, the company also considers the possibility of implementing a recycling system. However, it is uncertain as to the best way to achieve this. Closed-loop recycling equipment is available, but it is uncertain if recyclate can be used and in what quantities without compromising product performance, as the treatment is expected to degrade the technical properties of the recyclate compared to virgin material. If not all the recyclate can be reused in the company’s own system, is might be possible to sell the recyclate as a raw material for another process or product. Closed loop recycling, however, is deemed worth exploring, as the company recognizes in this an opportunity to reduce its reliance on virgin material intake and reduce associated costs. At the same time possibilities might also exist to partner with a specialised waste processor, where the company would receive recyclate back. The cost-effectiveness and a life-cycle analysis of these options will determine the feasibility and desirability of the proposed options.

Moreover, the project is also taken as an opportunity to re-evaluate manufacturing techniques and the product design with regards to whether increased efficiencies can be achieved. That is: whether the same functionality could be provided with less material through lightweighting.

With the identification of this range of barriers and possible enablers the company effectively considers the WaRM configuration as depicted in Fig. 6.02, designated as the ‘proposed solution.’ Depicted are the RLEs as they co-exist at the stage of the project described in the above: a long-life loop for one of the parts, and two possible recycling routes for the remainder of the material. For the latter, both loops are depicted as overlapping, to indicate that they co-exist as possibilities. These two arrows are furthermore given a fuzzy edge, to indicate that the quantity of materials that might flow through these routes is yet uncertain, as it still has to be determined how much material can be recycled. This furthermore implies that uncertainties exist regarding the required amount of virgin material as well as the waste that is generated in mining it, which is why these flows are also indicated with a fuzzy outline.

The following explains in more detail the different elements that feature in Fig. 6.01 and 6.02 and how they were derived from the CAF functions, resource typology, waste typology as well as the aspects of resource quality, energy and information as identified in Chapter 04.
Depiction of proposed solution described in vignette using Circularity Compass v1.0

**Proposed solution**

| Goal & mechanism | Reduce CO₂ emissions by reducing use of raw materials |

**Actor(s):**
- Specialized waste processor
- Customers

Uncertainty with regards to possibility to use recyclable and in what quantity.

No treatment infrastructure and procedures in place; material technically recyclable.

No disassembly capabilities enabled by new product assembly, new assembly process and automated disassembly.

No recovery infrastructure and procedures in place; enabled by relatively small number of customers and non-demanding solutions for collection.

**Status of solution:** of interest, active exploration ongoing

**Key**
- Material flow with uncertain magnitude
- Material flows existing as options
- Closing loops strategy
- Long life loops strategy
- Preventative strategy
- Additional benefit
- Barrier with an overruling enabler
- Insurmountable barrier

**Fig. 6.02** Example of a case mapping using the Circularity Compass v1.0. Depicted here is the proposed solution as explored in the innovation project underway.
6.2. Deconstructing the Circularity Compass v1.0

The Circularity Compass v1.0 can offer a view of industrial systems by showing how resources flow through different manufacturing and end-of-life treatment stages. The template consists of a number of structural elements, a collection of icons and a set of mapping rules. The following discussion elucidates how these were arrived at and how the CAF functions, the resource typology and the waste typology are represented. See for a summary the first page of Appendix 03 Case mappings using the Circularity Compass.

**Structural elements**

‘Structural elements’ are those elements that have a fixed position in the Circularity Compass and thus make up the visual template that provide the basis for mapping both the business-as-usual situation and the proposed solution. These elements make a mapping series easily accessible with regards to their similarities and differences.

- **Unit of analysis as applied by participants to a case**
  This is in acknowledgement of the fact that one might adopt the perspective of a subassembly, product, product group or even a collection of products when considering a particular case. Clarifying this in the ‘unit of analysis’ box aids in determining to what degree cases are comparable. In case of the vignette, the unit of analysis is straightforward: it consists the whole of the product group. That is: it consists of all flows associated with the product, as opposed to merely considering an individual product.

- **Problem, goal and mechanism (purpose and mechanism)**
  The problem and goal boxes allow for capturing the CAF functions purpose and mechanism: it is a placeholder for a short summary of the perceived problem, the related goal and how this goal is to be realised. In the case of the vignette the problem, goal and mechanism are, respectively, the energy intensiveness of the raw material used causing reputational risk and the desire to reduce CO₂ emissions by reducing the use of virgin raw materials.

- **Routes divided by resource states (perpetuation - I)**
  To capture the perpetuation aspects of WaRM frameworks and WaRM strategies more generally, the route map depicted in Fig. 5.01 is used. This provides a structure to map resource flows on as they are occurring or are intended to occur, where the line thickness is representative of the magnitude of a particular flow. This is similar to how Sankey diagrams are constructed. However, in Sankey diagrams all flows add up to one hundred per cent at every cross section of the diagram. This is not the case with the Circularity Compass: as meanings develop, as discussed in Chapter 03, it has to be acknowledged that the presence and role of RLESs might change. As was indicated in the vignette: at the start of an innovation process various options for RLESs might still exist. Capturing these possibilities and how and why their presence alters will provide insight into how circular economy related meaning work progresses. For these reasons the Circularity Compass is designed to accommodate developing interpretations: overlapping flows and flows with a blurred outline in Fig. 6.02 at the particles state indicate these uncertainties. Specifically: the blurred outline indicates the uncertainty as described in the vignette regarding the amount of material that can be recycled; the overlapping flows indicate the uncertainty whether or not recycling should take place in-house or whether an open-loop configuration involving a specialised waste processor is preferable.
In the Circularity Compass a distinction is furthermore made between pre- and post consumer waste streams (EPA 1993, Allwood et al. 2011) by the presence of a route that connects the various stages of manufacturing with the raw materials route.

- **Actors (proaction)**
  These boxes are reserved for identifying actors of which the cooperation is necessary in operating the WaRM system under consideration. In this manner the CAF function of proaction can be captured: i.e. who should act and why. In the vignette the customers are mentioned, as they have a role to play in collection of the product. Specialised waste processors also feature, because in the example the possibility of using their services is being explored.

- **Status of proposed solution**
  This box is reserved for indicating a participant’s assessment of the circular economy concept, summarizing the judgement or attitude of the participant towards the concept. Chapter 03 discussed that this is an integral aspect of meaning work, since cognition and action are both part of the meaning attributed to circular economy. As such, it is not only the interpretation of the concept – what RLESs are used and why – but also the status of the concept that is part of the meaning attributed to circular economy: is the proposed solution considered worthy of exploring or implementing.

  **Icons**
  Apart from structural elements a collection of icons is applied to the template, in order to provide additional information about a case.

- **Type of waste (perpetuation - II)**
  As discussed in Chapter 05, in order to fully define a RLES, it is not sufficient to indicate what transformations are present, but its function needs to be indicated also. For this, the typology of Fig 5.03 is used and a matching icon for each function is devised. Fig 6.02 indicates how these are used in combination with the route map: by placing the appropriate icons on the RLES they apply to. Through applying the closing-loop icons to the end-of-life routes in the particle state it is thus made clear that what is being considered here is recycling, as opposed to a substance cascade, where, for example, a material might be used as a filler or used in an application less demanding than the material is suitable for. In the latter case the icon for extending loops would need to be used. Likewise, by assigning the icon of long-life loops to the route in the parts state, it is made evident that the life of the product is being extended and that this does not represent a case of product cascading or alternate use, in which case the icon for intensifying loops would need to be applied.

- **Prevention**
  Prevention and preventative strategies can be important WaRM practices, as was shown in Chapter 04. Since preventative strategies are not the focus of this research no additional typology is used for these strategies. Instead, an icon similar to those that indicate the function of RLESs is used and wherever preventative strategies feature they are labelled with a short description. In the example of Fig 6.02 an icon for preventative strategies accompanied with the description ‘lightweighting’ captures the company’s efforts with regards to attempting to provide the same functionality with less materials.
• Barriers and enablers
Two types of icons are used to indicate barriers. A red stop-sign icon is used for barriers that are deemed prohibitive to the implementation of a particular strategy. In the example this represents the product deforming being regarded as prohibitive for directly reusing the product. An orange stop-sign, on the other hand, indicates barriers that are perceived as surmountable, given the right enablers. Enablers are indicated using an icon depicting an opened lock. The vignette contains three barrier-enabler combinations. Firstly, there is the barrier of product collection, which is thought to be surmountable by the installation of collection bins for the discarded product and collecting these bins when new product is delivered. Secondly, there is the barrier of the press-connection. For this, options can be considered to change the fastening method applied when assembling the product, which involve change the product geometry. Lastly, no treatment infrastructure is in place in the business-as-usual situation. To overcome this, the company in the example is exploring the possibilities to acquire equipment to do so or use a third party already in possession of the appropriate treatment facilities. Barriers and enablers can also feature independently.

• Additional benefits
Benefits, other than those described by the overarching goal, are indicated with a green plus-sign. In the example this is the additional benefit or reducing the company's reliance on virgin materials.

• Other elements
Where information plays a role this is indicated with an ‘i’ icon. For issues related to energy a lightning-icon is used. As the importance of these aspects is as of yet uncertain, as was discussed in Chapter 04, they, like preventative strategies, are not further specified here. The vignette, in the problem situation, the energy icon features, to indicate that the quantity of energy used is considered an issue to be addressed by the company.

All icons can be provided with additional information related to the specifics of a case. The colour of the descriptive text indicates the status of that information: red indicates whether something is considered problematic, orange indicates whether uncertainties exist around a particular aspect. Coloured text was used in the vignette to clarify the status of descriptions.

**Mapping rules**
In creating mappings the following mapping rules were applied or will be applied in creating the case mappings for the empirical part of this research. These rules are the result of pragmatic considerations when visually depicting verbal data, whilst retaining relevant distinctions, acknowledging uncertainty or respecting confidentiality.

• Flows should be considered as an ‘order of magnitude’
As exact quantities of material flows may not be known or be considered commercially sensitive the magnitude of the flows can represent an ‘order of magnitude,’ rather than exact quantities. It can thus be the relative magnitude of flows that is indicated in a mapping.
• Flows are simplifications
  Flows can either represent a single material, a group of materials of the same type or materials otherwise grouped. Complex flows, consisting of many different substances, may be simplified when required to keep the mapping intelligible.

• Flows can be split
  If a flow is subject to different distribution routes during the forward and reverse logistics stages, flows can be split to indicate this.

• Flows can skip states
  Not all states and not all parts of a state are applicable in all cases. If states or part of them are not applicable to a case, they are greyed out to indicate that they do not apply to a proposed solution.

• Flows can be merged if they cannot be meaningfully separated
  If stages from a life-cycle cannot be meaningfully separated, they can be merged into a single arrow. This can apply to solutions where, for example, the logistics phase cannot be meaningfully separated from the product assembly phase.

• Minimal line thickness applies
  For flows too thin to be clearly visible when their proportion to other flows is accurately depicted, a minimal line thickness is applied.

Discussed next is how data was collected that allowed for using the Circularity Compass in a manner such that insight could be generated into circular economy related meaning work.
7. Research design
Data collection, processing and creating case mappings

This chapter explains how the meaning work framework described in Chapter 03 How meaning work works informed the choice for a qualitative research approach by means of case studies. The main source of data consisted of semi-structured life world interviews with 15 participants partaking in innovation projects inspired by the circular economy concept, spanning 19 focal companies and 23 product (groups). Data was collected in three phases: during phase 01 the project had not yet started or was underway. A second interview was conducted after the initial exploratory phase had been completed, on average 7 months after the first interview. A third and final phase of interviews took place on average 28 months after the first interview. The interviews were transcribed, coded and supplemented with additional data sources. Relevant information was exported to a graphical software package where they were collated in the form of visual case mappings using the Circularity Compass. This chapter concludes with a discussion of research limitations.

7.1. Research method: case studies

In Chapter 03 it was stated that the process by which practitioners imbue the circular economy concept with meaning is conceptualized as meaning work for the purposes of this research. This focus on understanding human knowledge and experience points to the suitability of a qualitative research approach. Using meaning work as the theoretical framework furthermore has three implications for the research design and data analysis. The first – the need to study a phenomenon in-context – is discussed next. The remaining two – pertaining to the need to take multiple snapshots and to analyse what is and is not acted upon – feature in the following research design and data analysis sections, respectively.

The requirement to study a phenomenon in-context means that said phenomenon has to be studied in the environment where it takes place or occurs, as opposed to a hypothetical or laboratory setting. This means that case study research is an appropriate research method as it has been put forward as suitable for understanding the subjective and situational creation of meaning (Yin 1984, Stake 1995). Adhered to here is the definition of case study research as used by Savin-Baden and Major (2013), who define case study research as research where the phenomenon of interest is studied in-context, that is bounded in some manner and where the end result constitutes a documented account of what was encountered. This definition is grounded in similar definitions by Merriam (1998) and Yin (1994), and finds support in Flyvbjerg’s (2004) approach to case study research. In line with this definition the phenomenon of interest in this research – circular economy related meaning work – is studied in context by determining the meaning attributed to circular economy by individuals in the context of corporate innovation projects inspired by the concept. Furthermore, this research is bounded by the time period covered within this research. The latter limits the possibility to follow an innovation project from initiation to implementation, as the commercialisation of innovations may take many years. Lastly, case reports were produced in the form of case mappings using the Circularity Compass.
7.1.1. Case selection

Research participants were recruited through contacting InnovateUK (formerly: Technology Strategy Board), a funding body in the UK, shortly after it had advertised circular economy themed bid competitions. The purpose of this competition was to provide a group of businesses with the means to explore key aspects of a proposed product design or business model aligned with circular economy and to assess both the feasibility and desirability of continuing the innovation project with commercialization of the idea as the intended end result. To be more specific: the bid explicitly called for new product designs with a lower environmental impact and/or designs that would reduce dependence on strategic materials. It invited projects that would radically rethink the design of products, components and/or systems with the aim to retain or regenerate materials and parts within the economy over several cycles of use. Projects had to be business-led and a distinctive design contribution was required. Projects could either be collaborative or led by a single company (InnovateUK 2012).

All awarded bids facilitated exploratory projects to run for 2 to 6 months during 2013, some of which were extended due to delays into early 2014 (duration as reported by participants). As such, this bid was aimed at facilitating the early stages of the innovation process (Koen ET AL 2001). Also, since all participants had chosen to label their project as related to circular economy, they can be said to have had at least a basic understanding of the ideas related to it.

Intermediaries at the funding body were given a flyer prepared by the researcher that explained the researcher’s interest in sustainability oriented innovation and invited successful bid applicants to take part in the research. The intermediaries forwarded the flyer to successful bid applicants and provided the researcher with the contact details of bid applicants who had positively responded to the invitation. Next, the researcher contacted the participants directly in order to confirm participation and to establish a date, time and location for the interviews.

Henceforth, the designation of ‘project’ is used to refer to the funded early stages of the innovation process; ‘innovation project’ is used to refer to the entirety of the innovation trajectory, for which some cases received additional funding. Furthermore, the situation that participants were attempting to move away from is designated as ‘business-as-usual’ and the proposed idea as the ‘proposed solution.’ The term ‘circularity’ is used as a technical term to refer to a magnitude or a proportion of flows with a circular character.

In total 15 participants took part in the research, spanning 19 focal-companies and 23 unique (re)design projects, see Table 07.1. The number of projects is larger than the number of participants, because participants #11-#15 were awarded multiple bids or were working on multiple (re)designs projects as part of a single bid. In case of the latter, projects were designated as separate cases when they concerned distinctly different products. It also transpired that two participants, participants #11 and #12, both worked on two of the cases, creating overlap between the collected case data.

To be able to distinguish between these variations the following case-designation system was devised. Cases where participants were undertaking a single (re)design project are indicated with a number only (‘case #01’). Where a participant was involved in multiple (re)design projects, these are distinguished between by adding a lower-case letter: case #11a and #11b therefore indicate two separate projects undertaken by the same participant. The letters indicate unique cases: #11c and #12c but also #11d and #12d thus indicate two participants working on the same
(re)design projects. These are counted as a single case. The lower case letters used range from ‘a’ to ‘l’.

A second number was added when cases could not be classified as entirely separate projects, but represent variations on the same project. Cases #13i1 and #13i2, for example, represent two different solutions to the same problem situation. The same goes for cases #15i1-3: here, no separate case mappings were drawn, as the proposed solution takes the form of different products, of which the case mappings are identical. Cases #15i1-3 are therefore counted as a single case. Lastly, only numbers were used to distinguish between cases #07-1, #07-2, #07-3 and #07-4 as they represent variations where the same proposed solution is envisioned to address different aspects of the problem. For this reason, these are also counted as a single case.

For reasons of confidentiality the name of the focal companies and participants as well as details of the specific products cannot be disclosed. However, the following classifications are offered to convey important aspects of the dataset.

- Classification of products
  All included cases revolve around commercial products with a physical form, as opposed to purely digital products. Although there are projects in which digital connectivity plays a role, this is always to facilitate the extended life of tangible resources. The cases can be divided into four categories. The first category is ‘electric’ and covers products that contain electrical motors or other electrical elements from which they derive their functionality. ‘Housing & living’ groups products that can be found in or around the house and that do not contain electrical elements. Products that have as their primary function to convey information or attract attention are grouped under ‘display & presentation.’ ‘Miscellaneous’ contains products that could not be justifiably placed in the other three categories. For consistency, the creation of products is referred to as ‘manufacturing,’ even when other terms, such as ‘building’ or ‘mixing,’ might be used in the specific product context.

- Classification of role of participants
  Participants who were part of the strategic management team of the focal companies leading the bids were classed as ‘strategic management;’ participants otherwise employed by the firm were classified as ‘engineer/manager.’ When the focal company did not employ a participant but involved him or her as an external expert, he or she was classed as ‘(design) consultant.’ Of the participants three were female and 13 male.

- Classification of focal companies
  The ‘focal company’ was defined as the company identified by participants as the company intended to play a key role in the commercialisation of the proposed solution, frequently the company that would own and implement the proposed solution. Focal companies were classified either as ‘SME’ or ‘large,’ as indicated by the publicly available classification of the companies by the funding body. This classification was adjusted to ‘start-up’ in the cases where the participant disclosed having started the company within the last three years. The focal companies can represent an intended client in cases where the participant was a (design) consultant, as the focal company was not always actively involved in the early stages of the innovation project.
### Classification of cases included in dataset

#### Classification of products

<table>
<thead>
<tr>
<th></th>
<th>Phase 01</th>
<th>Phase 02</th>
<th>Phase 03</th>
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<tr>
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<td>7 (#06; #11a, b, c; #12c, e; #14h)</td>
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<td>9 (#01; #04; #07; #11d; #13f; #13/2; #14g; #15j)</td>
<td>8 (#01; #04; #07; #11d; #13f; #13/2; #14g; #15j)</td>
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<tr>
<td>Display &amp; presentation</td>
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<td>5 (#02; #03; #15; k, l-4)</td>
<td>4 (#03; #15; k, l-4)</td>
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<tr>
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<td>4 (#05; #08; #09; #10)</td>
<td>4 (#05; #08; #09; #10)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>17 (15 discounting overlap)</td>
<td>25 (23 discounting overlap)</td>
<td>21 (no overlap present)</td>
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</tbody>
</table>

#### Classification of role research participants

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<th></th>
<th>Strategic management</th>
<th>Engineer/manager</th>
<th>(Design) consultant</th>
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<tr>
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<tr>
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<td>7 (#03; #06; #07; #10; #12c; #12d; #12e)</td>
<td>9 (#08; #11c; #11d; #14g; #14h; #15i; #15j; #15k; #15l)</td>
</tr>
<tr>
<td></td>
<td>8 (#01; #04; #05; #09; #11a; #11b; #13f; #13/2)</td>
<td>4 (#03; #06; #07; #10)</td>
<td>4 (#08; #11c; #11d; #14g; #14h; #15i; #15j; #15k; #15l)</td>
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<tr>
<td><strong>Total</strong></td>
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<td>25</td>
<td>21</td>
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</table>

#### Classification of focal companies

<table>
<thead>
<tr>
<th></th>
<th>Start-up</th>
<th>SME</th>
<th>Large</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>2 (#09; #13f; #13/2)</td>
<td>7 (#01; #02; #03; #04; #05; #08; #11a-b)</td>
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<td></td>
<td>2 (#09; #13f; #13/2)</td>
<td>8 (#06; #07; #12; #14h; #15i; #15j; #15k; #15l)</td>
<td>7 (#06; #07; #14h; #15i; #15j; #15k; #15l)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>12</td>
<td>19</td>
<td>17</td>
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*Table 7.01 Overview of the different classes of products, role of participants and the type of company in each phase of the research.*

The diversity in products, participant roles and company sizes is expected to generate a wide variety of interpretations of the circular economy concept, which should facilitate rich insights into circular economy related meaning work.
7.2. Research design: semi-structured interviews in three phases

7.2.1. Data collection: semi-structured life world interviews and supplementary sources

Studying meaning work requires insight into beliefs. The main source of data used for this research therefore consisted of semi-structured life world interviews: interviews aimed at obtaining descriptions of the participant in order to interpret the meaning of a phenomenon of interest (Brinkmann and Kvale 2015). An implication of conceptualising the phenomenon of interest as circular economy related meaning work is that a single observation or snapshot of the meaning attributed to the concept does not suffice, as meanings are subject to change. Consequently, interviews were conducted in three phases at different stages of the innovation projects: when the projects were due to commence or were on-going, seven months (on average) after the first interview and 28 months (on average) after the first interview, see Fig. 7.01. This research design can therefore be classified as longitudinal case study research.

**Overview of research design**

![Diagram](image)

*Fig. 7.01 Schematic depicting the timing of the interview phases relative to the initial funded project.*

The interviews centred on providing the researcher with an understanding of the innovation process as experienced by the participant and exploring aspects of this process that participants indicated as salient. During all interviews the participants were asked to reflect on the concept of ‘designing for a circular economy’ in order to determine their understanding of the circular economy concept. As such, the emphasis was on the exploration of circular economy on a conceptual level as opposed to, for example, the quantification of different resource flows.

Interview data was supplemented with additional data. Of all cases a project summary describing the intention of the project was available, ranging from 19 to 172 words, with an average of 103 words, including the title. Participants #05, #07, #08 and #15 made available (part of) the project proposal; and participants #03, #04, #05, #07 and #08 furthermore provided (part of) the final project report. A further 16 project videos were collected, ranging in length from 1:58 to 10:52 minutes, with an average length of 4:38 minutes. Of these videos 15 were released for public viewing, in one case the video was used for internal purposes only.

Other supplementary data was used in cases #04, #07, #10, #11/12c-e and #13/1-2, which consisted of such documents as government or sector reports describing waste management practices in a particular industry, news articles, slides, documents or recordings of presentations by the focal company or of partner companies discussing the project, relevant aspects of it or
relating to the general approach to circular economy. An overview of the data used per case can be found in Appendix 02 Overview of data collected per case. The additional data was used to supplement the interview data closest to its generation. For example: the project summaries were used to supplement the first interview; the project reports and videos were used to supplement the data from the second interview.

7.2.2. Data collection phases
As stated above: interview data was collected in three phases. During phase 01 the project was about to start or was underway. A second round of interviews, seven months (on average) after the first interview, was conducted after the project had been completed, although not in all cases all final deliverables had been submitted yet. For example, the final report or project video had yet to be submitted to the funding body. A third and final round of interviews was conducted 28 months (on average) after the first interview. All participants took part in at least two interviews: 10 participants took part in all three interviews. The Circularity Compass was introduced to the participants in phase 03, since its development took place in parallel to the first two phases of data collection. Next, each phase is discussed in turn, see also table 7.02 for an overview of the core statistics of each data collection phase. Appendix 02 Overview of data collected per case contains more detailed information concerning the number of interviews per case, the collected data per case as well as the exact timing of the interviews in relation to the project and each other. For reasons of confidentiality the time lines for all projects in this overview have been normalized. That is: all projects are depicted using an indicator of equal length across all cases. The timing of the interviews should thus be understood as relative to the overall duration of the project.

<table>
<thead>
<tr>
<th>Overview of core statistics interviews</th>
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<tbody>
<tr>
<td>Phase 01</td>
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<tr>
<td>Participants</td>
</tr>
<tr>
<td>Tiles</td>
</tr>
</tbody>
</table>

Table 7.02 Overview of the core statistics of the interviews conducted.

**Phase 01**
During phase 01 data collection focussed on understanding the nature, scope and reasons for undertaking the project(s). For this phase the researcher prepared by looking at the company website and the participant’s personal professional history, if available online. At the beginning of the interview the researcher briefly introduced herself and her affiliations before explaining the exploratory nature of the research and its aim to gain insight into sustainability oriented innovation. Next, it was explained to the participant that the researcher would be using a list of topics to guide the interview and that it would be possible to add anything that the participant
felt was relevant at the end of the interview. The participant was reassured that the researcher was interested in his/ her views and that the interview did not represent a test of any kind. The introduction was concluded by asking permission to start recording, explaining that care would be taken to anonymise the results. Permission to record was granted by 11 of 12 participants. In 11 cases the interview took place before the project had started, in the six remaining cases the project was already underway.

The topic guide used for this phase of the research was as follows, covering the themes of:
• The project: nature, scope, goals and reasons to engage in the project and the role of project partners, where applicable;
• History of the project: how and by whom the project was initiated;
• Expectations for the project with regards to possible barriers and enablers;
• Possible next steps after completion of the project;
• Designing for a circular economy: if and in what way it differs from innovation projects not guided by this idea;
• Views of the future with regards to what developments are expected to affect the focal business and industry in the future.

This topic guide was tested in a pilot interview with a representative of a company who had recently lost a bid for the same circular economy related innovation project. The pilot interview was discounted from the analysis.

At the close of the interview the researcher expressed interest in conducting a follow-up interview to discuss insights gained into innovating for a circular economy during the project. To enable data collection in the second interview, a data collection method was added based on contextmapping, which is aimed at facilitating the capture of insights that participants might find difficult to articulate (Sanders and Stappers 2011). The premise of contextmapping is that offering participants playful and creative exercises to complete at leisure can facilitate reflection on a topic. Not only does this provide participants with ample time for reflection in a pressure-free environment, it also aids in accessing deeper knowledge regarding a topic, which can lead to the collection of better quality data. For these reasons, participants were given three foam tiles with the request to finish the statement on the tiles and bring these to the subsequent interview. The statement read: ‘When designing for a circular economy keep calm and …’. Instructions accompanying the tiles explained that the purpose of this was to formulate one of more pieces of advice directed at someone about to undertake a circular economy related innovation project or to oneself if undertaking another such project.

Three interviews were conducted over the phone due to time constraints; the remainder was conducted face-to-face. During three interviews other people besides the participant were present and taking part in the interview. Two recordings were lost due to a technical error. These cases have not been included in the analysis of phase 01. In case #06 recording was not permitted and the main source of information consisted of field notes (Arthur ET AL 2014), of which a narrative was constructed for use in the analysis. In the case of phone interviews the foam tiles were sent to the participants through the post.

**Phase 02**
The interviews in the second round were focussed on the results of the completed projects as well as on capturing learning and changing views regarding the circular economy concept. In
advance of the second interview all participants were sent a print-friendly version of the foam tiles and reminded that the advices written on these tiles would be used to guide the interview. This version was also brought to the interview by the researcher.

During the interview, new participants were given an introduction similar to the participants in phase 01. Repeat participants were given a brief reminder regarding the goal of the research and that the interview should not be regarded as a test. Repeat participants were furthermore given a reminder with regards to when the previous interview took place and what the status of the project was at the time. After this, permission was asked to start the recording, under the same conditions as in phase 01. Permission to record was granted by 14 of 15 participants.

After a brief discussion of key events and outcomes, participants were asked to reflect on earlier expressed goals and expectations as well as to elaborate on planned next steps, where applicable. To facilitate this a topic guide with prompts specific to each participant was constructed in advance, using the recording from the first interview. If the participant had made any information available in advance of the interview, questions were added to the topic guide where appropriate.

The topic guide used for in the second interview contained the following topics:

- The project: current status, outcomes and next steps;
- Progression of project: unexpected, annoying or confusing aspects or events;
- Reflection: on goals and expectations;
- Discussion of advice-tiles;
- Designing for a circular economy: if and in what way it differs from innovation projects not guided by this idea.

The advices were either written on the foam tiles, the print-friendly version of the tiles or otherwise put in writing in advance of the interview by eight participants. Two participants filled out the print-friendly version during the interview. Participant #13 asked for more time to consider and a follow-up interview was conducted approximately two months later over the phone. This interview is counted as part of the second interview with this participant. In all cases the advice the participants had to offer was discussed during the interview. All interviews during this phase were conducted face-to-face, apart from the follow-up interview with participant #13.

Given the intention of all but one participant to continue with next steps to further develop or implement the solutions explored as part of the project, a decision was made to conduct a final round of data collection. Between the end of the second interview phase and the beginning of the third the Circularity Compass was further iterated by drafting mappings of the cases, in which the mapping rules explained in Chapter 06 The Circularity Compass v1.0 were devised. A preliminary version of the Circularity Compass discussed in Chapter 08 Results phase 01 was subsequently used in the third interview phase to both clarify the participant’s interpretation of the concept and elicit discussion about other available conceptual solutions.

Two participants had changed jobs between the second and third interview. As this was a number of months after the second interview, a third interview was still thought valuable. Moreover, any successor would not have necessarily been able to answer any clarifying questions regarding the previous stages of the process.
**Phase 03**

The interviews in phase 03 were conducted in two stages: the first stage was aimed at uncovering new information about the project and the second at verifying the case mappings that were made based on the previous interviews. This separation was introduced to maximise the possibility of uncovering new information, and reducing the possibility that the participant would be influenced or distracted by the interpretation offered by the researcher.

The phase 03 interviews proceeded as follows. First, participants were given a brief reminder regarding the goal of the research as well as with regards to when the previous interview took place and what the status of the project was at the time. Next, it was explained that the interview would consist of the two aforementioned stages. After this, permission was asked to start the recording, under the same conditions as in phase 01. Permission to record was granted by all 13 participants. All interviews were conducted face-to-face.

**First stage**

To guide the first stage of the third interview phase case specific topic guides were made and brought to the interviews. The topic guide contained the following topics:

- The project: current status, outcomes and next steps;
- Progression of project: unexpected, annoying or confusing aspects or events;
- Reflection: on goals and expectations;
- Designing for a circular economy: if and in what way it differs from innovation projects not guided by this idea;
- Clarifying questions regarding the proposed solution.

**Second stage**

To introduce the second stage, the participants were introduced to the Circular Compass and its triple layer structure by means of a blank version, with the individual routes identified. A diagram explaining the waste typology was also briefly discussed. Both Circularity Compass and types of waste were at an earlier stage of development than used to create the final mappings included in the appendices. In particular, reinvention and reconstitution had not yet been identified as separate strategies and the types of waste consisted of merely three strategies, then named slowing loops, closing loops and intensifying loops. This explanation lasted on average 7:12 minutes, ranging from 4:30 to 14 minutes.

After this explanation the participant was presented with the mappings of their case(s), which consisted for each case of two mappings: one of the problem or business-as-usual situation, and one of the proposed solution. For this a printed template of the Compass was provided with indicated on it the circular strategies as used in the case in question, hand-drawn using markers. Next, using coloured sticky notes the routes were assigned their respective functions, much in the same way as in the final mappings: the sticky notes contained the first letter of the functions, which matched the icons on the explanation sheet. Markers and additional sticky notes were on the table throughout the second stage of the interview. In the mappings presented no distinction was made between the first and the second interview, merely the most recent or complete interpretation was presented back to the participant.

By partially creating the mapping in the presence of the participant he or she is introduced to the mapping in stages, allowing the participant time to absorb the explanation of the researcher. Also, this allows for discussing of the various aspects of the mapping as it is developing. By
presenting the mappings to the participants in what was clearly not yet a finished state, as indicated by its hand-drawn appearance, the aim was to create an atmosphere where the participants were encouraged to discuss and make changes without feeling burdened with having to correct the researcher (Sanders and Stappers 2011). Where changes to the case mappings were made as a result of this interaction, this is indicated in the respective mappings in Appendix 02.

7.3. Data processing and analysis

7.3.1. Transcripts, coding and creating case mappings

All recordings were transcribed: 18 interviews were transcribed by the researcher and 22 by a professional transcribing company, due to time restrictions. Transcription by the researcher was done using the F5 software package. The verbatim level chosen for transcribing was ‘clean verbatim’, as opposed to strict or full verbatim, thus allowing for minor edits that enhance readability through, for example, the dismissal of verbal fillers. Next, the transcripts as well as the corresponding audio recordings were imported in Atlas.ti, a database software package suitable for qualitative analysis. Recorded parts of the introduction as well as thanking the participant and explaining next steps were exempt from coding. These discounted parts did not count towards the reported duration of the interview.

Whilst reading the transcripts aspects relating to the WaRM management were coded as either relating to the business-as-usual situation or the proposed solution. This was done whilst simultaneously listening to the recordings, in order to make sure that the researcher could draw on audio cues for establishing an accurate interpretation of the participant’s explanation. Particular attention was given to information that related to material constitution, WaRM strategies present or explored, benefits created, barriers and enablers as well as uncertainties regarding these aspects.

Quotations regarding the problem or business-as-usual situation as well as those relating to the solutions considered were collated and exported to Adobe Illustrator CS6 to the respective placeholders describing these situations. This collated information was used for creating the visual representations or case mappings. Fig. 7.02 explains, by means of (fictive) screenshots of the software packages used, how the interview recordings were transformed into visual case mappings.

From the information thus collated case mappings were created for each interview stage. Where possible this interpretation was checked against the additional data sources available and amended or further completed as required. Mappings from previous interviews were amended if clarifying information was provided in a subsequent interview. However, if no new information about the problem situation was uncovered during a subsequent interview, no new mapping was created. To allow room for new information and to be able to distinguish new information for previously uncovered aspects of a case, descriptions associated with icons were removed from one mapping to the next. The icon itself was left, if the aspect in question was judged to be still relevant. Moreover, the overall status of the innovation project during each interview phase was also indicated on the mappings: see the bottom of case mappings.
During the mapping process, cases were continuously compared and contrasted in order to articulate the salient commonalities and differences between them. This allowed for iteratively development of the Circularity Compass and add more detail to its route or strategy typology and the mapping rules used. These changes are discussed in the subsequent chapters discussing the results. See Appendix 03 Case Mappings using the Circularity Compass for the individual case mappings.

**Process overview of the creation of case mappings**

*Fig. 7.02 Visual explanation of how case mappings were created. First step: assign code to a selected text, designating whether it relates to the business-as-usual situation or whether it conveys information about the proposed solution and its status. In this example placeholder text is used to.*
7.3.2. Analysing case mappings

Next, the case mappings were analysed by comparing the business-as-usual mapping depicting the situation the participants were attempting to alter, with that of the proposed solution and examining if and how the proposed solutions developed, as made visible by the case mappings. The meaning work framework guided how this was undertaken. Meaning work poses that action and cognition exist in a recursive relationship, which implies that not only the established interpretation, but also the manner in which it is acted upon is part of the meaning attributed to the circular economy concept. During the analysis, aspects of the proposed solution that were further explored or acted upon as part of the innovation project were identified as well as those aspects that had received relatively little attention or were not included as part of the innovation project. The congruency or discrepancies between aspects that are acted upon and those that are not are further discussed in the results chapters.

7.4. Limitations of research methodology

In this particular research design cases are defined as the interpretation of circular economy by single participants, as they understand the concept for the duration of the research. This implies that a richer picture could have been created if the boundaries of the cases had been chosen differently. For example, more participants could have been recruited per case revealing additional information, as well as contrasting and complementing views. The time span of the research could furthermore have been extended, providing more information with regards to how meanings evolve.

More holistic and complete insights could also have been generated by choosing a different approach altogether, such as biographical or ethnographical research (Savin-Baden and Major 2013). A biographical approach, for example, would have shed more light on if and how past experiences have shaped participant’s current beliefs about circular economy. An ethnographical approach, in contrast, would have provided a more fine grained understanding of how the meaning attributed to circular economy was established, maintained and changed. However, the aim of this thesis was to explore the interpretation and enactment of circular economy within the businesses context, as no clear research tradition had been established in this area. For this reason it was preferable to include a larger number of cases, instead of two or three more in-depth cases, as it enabled a broader overview of different interpretations. As such, it was deemed premature to examine the influence of past experiences or the need for a more fine-grained understanding regarding certain aspects of circular economy. Moreover, research approaches that require more intense engagement with commercial entities are more likely to be inhibited by willingness to dedicate time to research and concerns around confidentiality.

Yet other quantitative approaches could have been used for exploration of circular economy related meaning work, such as a questionnaire or survey. However, this would have required an unambiguous vocabulary in relation to WaRM and clear and widely shared definitions of RLESs, which do not exist at present. Such an approach would also not have facilitated being able to explore the meaning attributed to circular economy with regards to aspects relevant in the experience of participants, but unanticipated by the researcher.

One important limitation with regards to the research design relates to allowing for retrospective corrections of the case mappings, particularly giving participants the opportunity to react to and
correct the mappings made by the researcher. As the Circularity Compass has a particular structure, it might lead participants so adjust their views and indicate additional or alternative routes, no longer giving an accurate representation of the strategies considered at the time. However, given the exploratory nature of this research, it is preferable to seek verification of the researcher’s interpretation. What is more, as will be discussed in the next chapters, participants considered improving or implementing various strategies in the majority of cases, which makes the addition of more routes retrospectively less relevant.

Secondly, by researching innovation projects by a particular funding body this research is limited to projects that met the criteria of that particular bid, in relation to the brief and other criteria the funding body might have used. From this group successful bid applicants, participants were able to self-select for participation in the research. Both these factors could have led to the selection of a certain type of case and participant for this research. However, there are no indications that the cases were biased towards either a particular type of product, company or participant: Table 7.01 shows the diversity of views represented in this research.

Lastly, due to the limited time available for the interviews, the case mappings that were discussed with the participants only contained the mapped flows and the types of waste present RLEs were thought to address and not, for example, the barriers and enablers as mapped by the researcher. They were therefore only able to react to part of the interpretation of the researcher. These shortcomings can be overcome by further work in this area.
PART III

Results section
8. Results phase 01

Developing the Circularity Compass, the importance of the particles and parts state and RLES configurations

This chapter presents the results of the first phase of data collection conducted as the projects were either due to commence or were on-going. A total of 17 cases features. First, the adjustments that were made to the template of the Circularity Compass and the associated mapping rules as a result of accommodating relevant distinctions between cases are discussed by means of illustrative examples. Next, the business-as-usual situations of each case are compared and each business-as-usual situation is compared with its matching proposed solution. Lastly, the proposed solutions are compared with each other. This leads to two key insights: the importance of the particles, parts and products states as well the importance of RLES configurations.

8.1. The route-map template of the Circularity Compass v2.0

Through a series of iterations, see Fig. 8.01 (next page), the template of the Circularity Compass v1.0 was adapted to create v2.0, as seen in Fig. 8.02. Primarily, routes were added in the resource states to be able to effectively distinguish between the solutions proposed in the included cases. Through this a route typology was created that distinguishes between different RLESs in more detail. The included RLES are organised according to their potential for physical renewal as seen from a product perspective and when compared to the initial product specifications: strategies with little renewal capacity are placed at the bottom and those with extensive renewal capabilities at the top. For example: a product is not physically renewed as a result of as-is reuse, where reuse through surface alterations allows for the restoration of functionality through superficial modifications of the product. More extensive renewal is possible through reconditioning when refurbishment or upgrading are applied. Reinvention, on the other hand, can lead to the product being changed beyond recognition by creating it anew. Closed-loop recycling, finally, has the capacity to recreate the product on a molecular level, to create the next generation of products in that product line or to create entirely new products altogether. Next, the routes identified within each resource state are discussed, with examples of the relevant distinctions that could be made between cases as a result of this route typology.

See Appendix 03 Case mappings using the Circularity Compass for the individual case mappings: the mappings related to the first interview phase are marked with ‘interview 01.’ Case mappings may contain corrections made as a result of clarifying information from subsequent interviews: thus affected aspects of case mapping are individually marked to indicate this.

8.1.1. Direct reuse, as-is reuse and surface alterations

The Circularity Compass v2.0 distinguishes between three different routes in the product state: direct reuse, as-is reuse and reuse with surface or superficial alterations. The inclusion of direct reuse allowed for distinguishing one of the RLESs used in cases #02 and #09 from the remainder of the cases: these two cases contained a RLES scenario aimed at replacing a single use or disposable product. In case #02 this was envisioned to be accomplished by the product remaining within the use location, where various users might handle it, as opposed to it being recycled. In case #09, on the other hand, the user was likely to remain constant, whilst the use location could vary depending on where the user transports it.
Iterating the Circularity Compass v2.0

Fig. 8.01 Chronological depiction of a selection of iterations the Circularity Compass went through.
Fig. 8.02 Depiction of the Circularity Compass v2.0 with added descriptions of the extended route typology and the organizing principles that determines their relative positions. Simplified mapping example of case #01 included.
The implications of both scenarios are similar: to facilitate this type of reuse the product needs to be easy to handle and store between uses. In fact, the total benefits created need to overcome the benefits that disposal offers in the form of minimal handling and storage concerns. In the former these benefits would take the form of financial savings and a contributions towards meeting a company’s emission targets; and in the latter this was to be achieved by creating a more fun, fashionable and personal use experience. In both these cases the product was or was in the process of being redesigned to make it suitable for displacing a disposable alternative. In this manner this reuse strategy was distinct from other strategies pursued by participants and it was therefore identified as direct reuse: reuse that poses an alternative to single use or disposable products, but that does not require centrally organized reverse logistics to facilitate it.

As-is reuse and reuse with surface or superficial alterations are, as opposed to direct reuse, both enabled by formal or centrally organized redistribution processes that involve a form of reverse logistics. Here, the functionality of the resource is extended through either a change in use location or a subsequent user gaining access to it. In as-is reuse, however, the product remains unaltered, where reuse with surface or superficial alterations allows for changes of the product that aid in restoring or extending its functionality that can be done to a product without disassembling it, such as cleaning, decontamination, polishing or the application of a new skin or coating. As such, mere redistribution and redistribution combined with a process that results in a degree of renewal can be distinguished from each other.

This distinction allows, for example, to identify the RLESs used in cases #07 and #11c where surface or superficial alterations take place, but not as-is reuse. In these cases a degree of processing is involved, but the product is not disassembled. The typology thus allows for clarifying where superficial renewal is or is not part of the proposed solution.

Furthermore added to this iteration of the Circularity Compass is an unspecified route that is depicted as originating in the parts level and connects to the use phase (bottom right of Fig. 8.01, outside of main ellipse). This route depicts the possibility of additional inputs in the form of parts into the use phase, through (partial) disassembly and reassembly processes at the location of use. In cases #04, #06, #11a, #12d and #13/1 the presence of this route is discussed or implied.

The reason for depicting this RLES as outside of the main ellipse is twofold. Firstly, if rigidly adhered to the main structure of the Circularity Compass, it would have been required to add multiple routes in the middle of the diagram. These would have crossed the other reuse routes adding confusion rather than clarity to the template. Secondly, it would not have been appropriate to do so, as it creates the impression that these processes performed by the user are the same as those performed by skilled employees using specialist equipment in a controlled environment. Although both processes can achieve similar or the same outcomes, it has to be acknowledged that processes performed at the location of use are likely to have different affordances. For example: diagnosis, repair or maintenance equipment has to be brought to the location of use, or, alternatively, the product has to be designed in such a manner that the user can perform the necessary activities by him or herself. Thus, to retain both simplicity and salient distinctions a placeholder in the form of a single unspecified route was added. Where applicable, this route has been identified as reconstitution, maintenance, reconditioning or reinvention.
8.1.2. Reconstitution, maintenance, reconditioning and reinvention

As well as distinguishing between additional routes in the products state, the Circularity Compass v2.0 contains four additional routes in the parts state. Reconstitution, firstly, represents a route where the product is disassembled and reassembled in a different configuration. This strategy facilitates flexible use of a product’s value delivering capacity by reassembling it as required. The possibility for creating different configurations, however, is defined within narrow boundaries: parts or modules (are perceived as) fit(ting) together in a limited and predefined number of positions. The renewal that maintenance can offer is likewise limited: although such operations as repair, cleaning or lubrication of parts can restore or extend the product’s ability to deliver value, the original product specification is never entirely restored.

The restorative capacity of reconditioning, on the other hand, can go beyond the restorative capacity of maintenance through performing operations such as remanufacturing, which restores the product to an as-new condition. Reconditioning furthermore has the capacity to renew a product in a manner that is different from or exceeds the product’s original specifications through refurbishment and upgrading. However, a central frame or module dictates that the overall shape of the product remains recognisable. In other words: the original specifications of the product remain, to an important degree, applicable.

Reinvention, in contrast, allows for the product and its properties to be created anew. Here, the boundaries for creating different configurations are primarily defined by the limits imposed by the connections of parts or modules: the overall shape of the product can look radically different from one cycle to the next. A helpful analogy would be the Danish children’s construction set Lego®, where the possibilities for assembly of the different pieces is near infinite due to the standardized male-female connections that all modules contain.

This typology of RLES within the parts state allows for making the following salient distinctions between and within cases. Consider cases #02 and #04, for example, where reconstitution plays an important role. The product in case #02 was redesigned such that it consisted of two modules - part A and part B - instead of a single part. These two modules could be put together in a single specific manner only. By giving one of the modules different surface properties it became possible to generate the desired product properties as required by the situation. This way one needs to keep on stock a single main module (part A), together with a number of modules each with varying surface properties (part B), where there otherwise would have been a need to keep complete products on stock equivalent to the number of B-parts.

Case #04 is similar and different from case #02 in the following manner. Case #04 pursued a modular approach where the product could be disassembled and subsequently assembled in the same manner in a different location, thus allowing for reconstitution. However, the redesign was also meant to facilitate other RLESs, made possible by the same modular approach. Among these were reconditioning and reinvention: not only would it be possible to give existing versions of the product new properties, i.e. reconditioning the product, it would furthermore be possible to recreate the product such that it could serve radically different purposes and would not resemble its previous form, i.e. reinventing it. As such, even though both case #02 and #04 apply a modular approach, the route typology clarifies the manner in which cases #02 and #04 are similar, but also the manner in which they are different by describing what additional routes are pursued in case #04.
Next, consider cases using *maintenance* and *reconditioning* as part of their proposed solution. Maintenance is part of the solutions considered in cases #06, #08, #11a and #14h; reconditioning is part of cases #04, #06, #10, #11a, #11c, #11d, #14h and #15j. The lack of complete repetition of cases indicates that this typology allows for distinguishing between the degree of renewal that is proposed as part of a particular solution. Without this, for example, it would not have been possible to distinguish between the parts level RLESs used in cases #08 and #11a. The former case considers a maintenance strategy, where the product is disassembled through a simple procedure, decontaminated and reassembled before being returned to use. Existing wear and tear is not addressed, and as a result of the cleaning procedure additional wear and tear is likely. The latter case, however, explores the possibility to upgrade the product with new parts that contain improved technology. As such, case #08 represents a much more superficial renewal than case #11a and thus merit distinguishing between.

Furthermore added to the Compass is an unspecified route positioned outside of the main ellipse that connects the parts and particles states, similar to the addition of an unspecified route connecting the parts state to products phase as described in the previous section. This route indicates that materials or substances flow through a different channel than is the case with primary manufacturing: it is a useful distinction to make, as scheduling, the size of batch or product runs and storage and distribution might involve different procedures from those wielded in primary manufacturing processes. This route was present in cases #03, #05, #11a and #12e.

### 8.2. Application and addition of mapping rules for creating case mappings

#### 8.2.1. Discounted routes

Not all routes were applicable to all cases. That is: not all RLESs could be meaningfully thought of as being available in all cases. Rather, in some case mappings routes were discounted, which are indicated in the case mappings by reduced opacity of the grey arc(s). In a portion of cases this is due to the parts state being entirely discounted: this is discussed in section 8.3 *Approaches to circular economy*. Discussed here is the discounting of individual routes, based on the nature of the product. For example, all forms of reuse possible within the products state, can be discounted in cases #01, #04, #11a and #11b for a variety of reasons. In case #01 the product performs its function through deformation, invalidating all reuse options in the products state. In case #11a and #11b the product’s value delivering capacity at the use stage is usually exhausted when it reaches its end-of-life: their value delivery capacity is entirely ‘used up.’ In case #04, on the other hand, the products state RLESs are not available due to the product requiring at least partial disassembly for it to fulfil its function elsewhere. For these cases, it is therefore not meaningful to consider products state reuse scenarios as valid options.

Direct reuse does furthermore not apply to cases #03, #05, #06, #07, #08, #11c, #12c and #13f-1-2. In cases #03 and #08 this is due to the product function being inherently linked to a continuous change in its use location and associated disassembly actions. In case #07 direct reuse can be discounted because the product is dissipative in nature, rendering direct reuse impractical. In the remaining cases a single-use alternative is absent or such a solution would result in nonsensical or highly impractical situations. A clarifying analogy for this would be a chair in the living room of a family home: this is not an object that one would dispose of after every use to replace it with a new one.
Reinvention was furthermore discounted in cases #06, #08, #09, #11a, #11b, #11/12c, #12e. In these cases, the product form was dictated by a central frame or module, negating the possibility for reinvention.

Discounting routes does not mean that by adjusting the concept or product design these routes could not become a possibility. Rather, due to the current form of the product or the chosen concept these routes are not available. Their reduced opacity in the case mappings should thus be interpreted as an indication that the current manner in which a particular function is fulfilled prohibits the use of certain routes or renders the use of such routes nonsensical, as opposed to these routes being theoretically impossible.

8.2.2. Use of gradients
In five cases, #01, #04, #07, #09 and #13/1-2, a gradient was added to one or more of the flows. This gradient indicates a transition from a state where individual parts or components can be distinguished between, to a state where this distinction is no longer meaningful. Mixing substances, but also the use of non-reversible assembly methods, can have this effect. After such operations have taken place, the resulting composite is essentially a new substance. This distinction clarifies the nature of the resource of which the life is being extended through application of a RLES. In case #01, for example, the new substance that results from such a transition can be recycled without the original components having to be extracted beforehand, as opposed to the closed-loop recycling strategy that was under investigation in case #07. Here, research and developments efforts were on-going that investigated the possibility of re-extracting a particular material from a composite blend for closed-loop recycling. This in contrast to the RLES that was under investigation as part of the project and that was to be implemented more short term, i.e. reuse through superficial alterations, where it was the composite that was to see its productive life extended.

Case #04 represents a markedly different case compared to the other cases where a transition to a composite is indicated. Here, in the business-as-usual situation a composite was created during the final manufacturing stage, which was reversed at the product’s end-of-life through processes that cause the loss of the potential for value delivery potential parts might still contain. This is due to such a process typically employing destructive disassembly techniques. The solution envisioned by the participant was therefore aimed at preventing such a composite state from occurring by ensuring that parts can easily be reclaimed and reused. As such, the inclusion of gradients in the case mappings allows for visually identifying important aspects of solutions.

8.2.3. Merged arrows, blurred flows and overlapping flows
In various cases use was made of the mapping rules that allow for merging arrows, depicting flows with a blurred outline and depicting flows as overlapping. In cases #02, #03 and #04, for example, the manufacturing and treatment arrows were merged with the logistics arrows to account for the fact that these stages are not separate stages in these cases. Where in a typical manufacturing process the final assembly precedes forward logistics and disassembly precedes reverse logistics, in these cases final assembly as well as disassembly will occur at the use site. As such, logistics and manufacture/ treatment have become indistinguishable.

Blurred flows were furthermore used in the mappings of cases #01, #03, #05, #06 and #13/1-2. This indicates that the magnitude of these flows, or their proportion in relation to each other,
was regarded as uncertain at the time of the interview. In cases #01, #03, #06, #13f1-2 it was regarded part of the project to clarify the quantity or proportions of these flows.

Moreover, in cases #02, #03, #04, #06, #08, #11c, #12e and #13f1-2 flows were mapped using overlap. This indicates that, at this stage of the project, different strategies existed as options. That is: these strategies were thought of as potential solutions to the business-as-usual situation, but it was as of yet uncertain what strategy or what combination of strategies represented the preferred solution. In cases #02, #08, #11b, #12e and #13f1-2 it was considered part of the project to resolve these uncertainties.

The frequent use of blurred and overlapping flows indicates that, at the time of the first interview, considerable uncertainty existed among participants concerning the precise description of the pursued solution on a conceptual level.

8.2.4. First new mapping rule: closed-loops, semi-closed loops and open loops
A new mapping rule was established to more clearly distinguish between different recycling scenarios. In cases #01 and #02, for example, the designation ‘semi closed-loop’ was added to the ‘closing loop’ icon. This is to clarify that although the material returns to the original manufacturer, it is not a given that the material will be recycled into a new version of the same product. As these companies manufacture a range of products from the same raw materials returned material is likely to be added to a stockpile out of which a range of new products can be manufactured. The addition of ‘semi closed-loop’ thus clarifies the manner in which recycling takes place.

8.2.5. Second new mapping rule: use of icons in conjunction with the parts state
Another mapping rule was introduced to clarify the nature of the resource at the parts state. In case #04, for example, the reconditioning and reinvention route affects parts only, where reconstitution applies to the entire product. For this reason the labels ‘parts’ and ‘product’ were added to the ‘long life loop’ and ‘intensifying loop’ icons. This allows for distinguishing between situations where, for example, it is the replacement of a part that constitutes the reconditioning of a product versus operations where the part itself is reconditioned. For consistency, these labels were added wherever the parts state applies.

8.3. The problem situation and the role of resource states in the proposed solution – I
When comparing the case mappings marked as ‘interview 01’ depicted in Appendix 03 Case mappings using the Circularity Compass, one will notice that no two mappings are exactly the same. Discussed in the following are the key similarities and differences observed when comparing the business-as-usual situations, the proposed solutions as well as the difference between the business-as-usual situations with the proposed solutions.

8.3.1. Business-as-usual or problem situation - I
The problem or business-as-usual situations as viewed by the participants can be divided in three groups, see Table 8.01. The first group consists of environmentally driven or environmentally led cases: these are projects where reducing the amount of materials landfilled or reducing carbon emissions was the primary objective. Cases #06, #11b, #12d and #13f1-2 are in this group. The cases being environmentally driven, however, did not mean that participants did not aim to
generate other benefits such as increased profits or an improved product offering, merely that these other benefits are seen as instrumental in delivering the overarching goal of less environmental impact.

<table>
<thead>
<tr>
<th>Categorization of the problems the proposed solutions aim to address - I</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Primarily environmentally driven cases</td>
<td>5</td>
</tr>
<tr>
<td>Primarily non-environmentally driven:</td>
<td></td>
</tr>
<tr>
<td>sustainability as an integral part of delivering goal</td>
<td></td>
</tr>
<tr>
<td>cases</td>
<td>3</td>
</tr>
<tr>
<td>Multidimensional cases</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 8.01 Overview of the categorisation of problem descriptions as provided by the participants.

In the second group of cases the creation of other benefits than environmental ones were the primary goal. Sustainability, however, was seen as an integral part of delivering these benefits. For example, in cases #02 and #03, interviewees have stated that customers have previously inquired after reusable alternatives to the single use products offered at the time. Developing these alternatives, as is the goal in these cases, can thus be seen as a manner of ensuring that the product offering of the company continues to meet customer requirements. The primary goal of participant #09, on the other hand, was to create a product that customers enjoy using through creating a fun, fashionable and easy to use product experience, with the possibility of personalising the appearance of the product. The sustainability aspect of this case would lie in the use of a cascaded material that is currently considered a waste stream, of which large quantities are available. The use of this material was to be a key part of the marketing strategy: its intended use was for the creation of a narrative that the participant hoped would appeal to consumers on an emotional level, making sustainability an instrument as well as a manner in which to deliver a product.

In the remaining cases, #01, #04, #05, #07, #08, #11a, #11/12c and #12e, a summary of the problem situation is not so easily provided. Rather, participants describe a multitude of issues that the proposed solution aims to address that together make up the perceived problem. Two cases examples can be given that are representative of this group. Take case #01, for instance. During the interview the participant described how the material currently used for the application requires non-renewable raw materials and that it can release toxic fumes under certain conditions. For various alternatives suggested as replacements of the raw materials the participant indicated that there are other, arguably more important, uses. He furthermore comments on the association of various supply chains with conflict and how other proposed solutions can ignore the local availability of materials. At the same time, there was another waste stream, which was being landfilled. Through the proposed solution participant #01 aimed to address these combined issues, as the use of the waste stream would prevent it being landfilled and at the same time prevent the use of a virgin raw material. The material properties of the new material thus created furthermore meant that off gassing would no longer take place. The new product would also differentiate itself in the market through its sustainability and
recyclability credentials, thus appealing to new customers. Importantly, the participant expected this product to generate higher margins for the focal company than the current alternative.

A second example can be found in case #05. This participant expressed his discontent with current mass production systems. According to him, not only does this system result in products that are marked up beyond what he views as reasonable for the quality that is provided, it also causes users to be less emotionally connected with the products they own, since they were not able to influence their functionality or appearance. As a result, products are not as emotionally durable as they could be. This system furthermore results in businesses having a limited life span, as the participant viewed a system solely pursuing cost competition as a short-term business strategy. Moreover, this system is reliant on transportation of products over long distances and leads to fewer craft and skill related jobs being available in the local economy, resulting in the loss of such knowledge. The proposed solution of case #05 aimed to address these combined social, environmental and economic issues by redesigning the product and, at the same time, its manufacturing process, resulting in reduced logistics, increased emotional durability and a more robust product design that can be repaired if necessary. Implementation of the proposed solution would, according to the participant, furthermore allow his company to move into a profitable product niche that was growing and potentially high-margin and would create a novelty factor that was thought to appeal to consumers.

What was true for cases #01 and #05 was true for all cases in this group: the participants viewed a set of problematic issues as related in a manner that is typical of wicked problems. Problems of this type are difficult to solve because of the interconnected nature of its components and cannot be reduced to a simple summary that highlights just one or two aspects of the situation (Churchman 1967). Case mappings where this applied are therefore designated as ‘multidimensional.’

Multidimensionality of a problem situation, however, did not mean that participants weighed all aspects equally. Case #04 offers an example of this. Despite recognizing a multitude of issues within the industry, such as unfair business practices, waste generated during manufacturing or the lack of adaptability leading the product to reach its end-of-life prematurely, participant #04 emphasised one issue: how the current focus on energy-in-use within the industry, as exemplified through various certification schemes, comes at the expense of attention paid to the energy used during end-of-life processing of materials, particularly recycling. This issue was clearly stood out to this participant as a major issue and one of the root causes generating many of the other problems in the multidimensional problem situation described. If such an emphasis was present, this was indicated in the individual case mapping by highlighting the major problem(s) in question.

8.3.2. Role of particles state – I
Discussed here is the role of the particles state and particles state considerations in the included projects, see also Table 8.02. In cases #01, #06, #08, #09 and #13/1-2 the role of the particles state was of seminal importance in the pursued innovations. In three of these cases - cases #01, #06 and #08 - the aim was to replace a material currently used with one that was expected to have a more favourable environmental impact, either through being rerouted from landfill or through sequestering carbon in its creation. In case #01 the new material was described as benign and compostable and in cases #06 and #08 the new material was described as bio-based.
All three projects centred on exploring the possibilities and limits of the materials in question and sought to determine whether it was suitable for the intended application.

In case #09 the particles state also proved of seminal importance. Similar to cases #01, #06 and #08, this project aimed to replace a material currently used with a new material, part of which was considered a waste stream. Different from the other cases however, as already mentioned earlier, participant #09 intended to create a narrative around the use of this would-be waste to attract attention to the product by using the waste in a new product related to the same industry that had generated it.

However, to use the intended waste stream, it had to be mixed with a virgin material, creating a composite. Providing proper treatment of the cascaded material, finding the right grade of the virgin material and establishing what additives would generate the required product properties constituted a large part of the project (much larger, in retrospect, than the participant had expected, as would become clear in the third interview). Ultimately, it was the participant’s intention to create a product that could be safely composted, which implied that all used materials had to be bio-based. Through the additional role of the particles state in the marketing approach, its role goes beyond that which was pursued in cases #01, #06 and #08, where it was targeted as a source for the creation of a more favourable environmental impact.

In cases #131-2, in contrast, the intention was not that the new material would serve as a replacement of a virgin material per se. Instead, this project was inspired by the participant’s desire to find additional and higher value applications for a mixed material waste stream consisting of bio-based as well as synthetic materials. If successful, the participant reasoned, larger quantities of this waste stream could be diverted away from landfill than in the business-as-usual situation. In order to realise this goal, the participant dedicated almost the entirety of the project to exploring whether the material was suitable for the creation of two specific product ideas: properties such as colour, thickness, stiffness, and whether it was sufficiently hardwearing were explored. For this, cooperation was sought with current processors of this waste stream and the parameters of their processing method were examined.

In short, in cases #01, #06, #08, #09 and #131-2 the focus was on the creation of a new material or the use of an existing material for a novel application. Through this, the thought was, (greater quantities of) would-be waste can be given a (higher quality) subsequent use or environmental impact reduced.

In an additional six cases – cases #02, #03, #05, #11a, #11b, #12d – the particles state furthermore had an important supportive role to play in the sense that a significant amount of attention was directed towards the materials chosen for the proposed solution. For example, material choices were (re)examined, alternative materials sought and tested, and the influence of the material choice on the manufacturing process scrutinized and reconsidered.

In all these cases – both where the particles state was the central focus and those where it had an important supportive role – the consideration of the particles state was a direct result of facilitating the proposed RLES. The exception to this was case #05, where the exploration of various materials was primarily related to creating the novelty that was to be part of the value proposition to the customer.
Cases involving key considerations regarding the particles state

| Particles state considerations play a key role | 6 | 
| cases | #01, #06, #08, #09, #13|1, #13|2 |

| Particles state considerations play a supporting role | 6 |
| cases | #02, #03, #05, #11|a, #11|b, #12|d |

Table 8.02 Overview of cases that had, were or were planning to adjust the parameters for the particles state as part of the project or the larger innovation project.

8.3.3. Changes with regards to the role of the parts state - I

Discussed next, is the role of the parts state in the business-as-usual situation compared to its role in the proposed solution of the included cases. The role of the parts state did not change in five cases. For example, in cases #04 and #06 the parts state was consistently present: these cases concern complex products where a limited degree of parts state RLESs takes place in both the business-as-usual and the proposed solution scenarios. In cases #01 and #07, on the other hand, the parts state was discounted in both scenarios, due to the nature of the products: case #01 constitutes a deforming product and case #07 a dissipative product, rendering parts state RLESs meaningless. In case #12c the parts state was consistently applied to the manufacturing stage only, as this state did not play a role in the business-as-usual situation or the proposed solution. Cases #13|f1-2 are not included in the following discussion, as the business-as-usual situation relates to an entirely different product context than the solution considered: other than the substance cascade that links the two contexts, they are unrelated and a comparison of both scenarios is therefore futile. The remaining cases all saw a change with regards to the role the parts state plays.

As can be seen in Table 8.03 case #02 and #09 saw the introduction of the parts state as an element of the proposed solution, where it had been absent in the business-as-usual situation. In these two cases the products previously did not consist of multiple parts, but were redesigned to consist of two or more parts or modules. Secondly, in nine more cases the parts state did not play a role at the end-of-life stage in the business-as-usual situation, but was acknowledged as relevant in the proposed solution. Here, (partial) disassembly facilitated RLESs that would otherwise not have been possible. This entailed the redesign of modules, connections or end-of-life treatment systems.

Cases involving changes with regards to the role of the parts state

| Parts state plays new role in forward chain | 2 |
| cases | #02, #09 |

| Parts state plays new role in EoL value chain | 9 |
| cases | #02, #03, #05, #08, #11|a, #11|b, #11|c, #12|d, #12|e |

Table 8.03 Overview of cases that either come to engage with the parts state in both the forward and end-of-life value chain or that come to assign it a role it at the end-of-life stage in addition to considering it in the forward value chain. Underlined are the cases where the change in the role of the parts state is the direct result of the intended application of RLESs.
In nine of the in total 10 cases that see a change in the role of the parts state this is due to this state facilitating one or more RLESs. Moreover, the RLESs were viewed as a source of value generation due to it facilitating the flexible use of product capacity, extending the product life and/or facilitating the recapture of parts and materials. The difference is accounted for by case #09, where the manufacturing process, which could be said to be the result of processing a particular cascaded substance, necessitates the introduction of parts. It could thus be said to be an indirect result of facilitating a RLES, although in this case the end-of-life RLESs is not the source of value generation: instead, it is the use of a particular cascades waste material, together with the user experience that are the sources of value creation.

8.3.4. Role of products state – I
It has to be noted that a large amount of projects had, were or were planning to redesign the product shape and/or its functionality as part of the project or the larger innovation project. That is: in a total of 13 cases interventions had taken place, were underway or were planned that were intended to change the overall appearance or functionality of the product. A short description that characterise the proposed changes follows. See also Table 8.04.

<table>
<thead>
<tr>
<th>Cases involving considerations regarding the products state</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Products state considerations play a key role cases</td>
<td>13</td>
</tr>
<tr>
<td>#01, #02, #03, #04, #05, #08, #09, #11a, #11b, #11/12c, #12d, #13f1, #13f2</td>
<td></td>
</tr>
<tr>
<td>Products state provided constraints only cases</td>
<td>3</td>
</tr>
<tr>
<td>#06, #07, #12e</td>
<td></td>
</tr>
</tbody>
</table>

Table 8.04 Overview of cases that had, were or were planning to redesign the product shape and/or functionality as part of the project or the larger innovation project.

In cases #01 and #08 alternative product designs were to be explored: due to the choice for different materials compared to the business-as-usual situation, the traditional way of using the products would no longer apply. Therefore a new way of using these products had to be found. In case #12d alternative product designs and new ways of using the product were also considered, although at this stage it was unclear whether new materials had to be used.

In case #02, in contrast, the product had already undergone redesign as part of the preparation for the current project. The new design improved product functionality and, as stated earlier, product handling. These two changes had changed the product geometry.

As part of cases #03 and #05 overall product style or appearance were indicated as important aspects for the new product design. In particular, these project set out to create more price-competitive products with the appeal of a product in the high-end segment. Product styling likewise played a major role in case #09 where the product was redesigned compared to products then on the market. The product geometry was adjusted for a more convenient user experience and ease of transportation and storage, although the participant did not see this as the main aspect of the proposed innovation.
The product state considerations for cases #13\text{i} and #13\text{j} constitute a mix of those already described. Here, product style, geometry and how to use the selected materials to produce a design that would be fit-for-purpose in terms of strength received much attention.

In cases #11a and #11b, on the other hand, the primary intention was to redesign product functionality. Specifically, in case #11a the possibilities to redesign the overall product shape were limited, due to the requirement for the product to continue to function with existing infrastructure. In case #11b the possibilities to redesign the physical shape of the products were less limited and it received some attention, but the primary attention directed at the product state seemed directed at rethinking product functionality.

Case #11/12c, which concerned a product that would contain a collection of other products, the total assembly had to be considered. That is: the collection of products was not the focus, but the vessel that would contain it and the system that would generate the functionality offered to the customers was. As such, the focus was on the customer journey and how quality of the offered functionality could be ensured. For this reason, storyboards were created to generate insight into the customer experience. A similar efforts was undertaken in case #11/12d.

This did not mean that in other cases the products state did not play a role. Rather the product provided the constraints within which the proposed changes in materials and/or parts would have to take place without changing the overall product or its functionality. An example of this was case #06: here, the overall shape of the product was intended to stay the same and the new parts, made of the intended material, had to fit within the existing product architecture. In case #07 and #12e the existing product similarly provided the constraints: the proposed changes were not directed at radically changing product appearance or user functionality.

8.4. Altering or introducing RLES configurations - I

Next, the number of RLESs in the business-as-usual situation is compared to the number present in the proposed solution: the projects can be classified as either aimed at altering or expanding a configuration, or building or introducing one. That is, in the case of altering or expanding a configuration either two or more RLESs were present in the business-as-usual situation and the aim of the innovation project was to expand or improve this configuration; in case of building or introducing a configuration no or a single RLES was present and the aim was to introduce one or more RLESs that would bring their total number to two or more. Preventative strategies were not included in the strategies that count towards configurations: only RLESs. Both categories are discussed next: see also Table 8.05.

<table>
<thead>
<tr>
<th>Relation of projects with other RLESs - I</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Alter or expand current RLES configuration cases</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>#02, #03, #04, #06, #11a, #11b, #12e</td>
</tr>
<tr>
<td>Create or build RLES configuration cases</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>#01, #05, #07, #08, #09, #11/12c, #12d, #13\text{i}, #13\text{j}</td>
</tr>
</tbody>
</table>

*Table 8.05 Overview of the RLESs present in the envisioned solutions. Indicated with an underline are the cases where a new business model was thought necessary to facilitate the envisioned RLESs.*
8.4.1. Altering or expanding existing configurations
Cases #02, #03, #04, #06, #11a, #11b, and #12e are examples of projects that aimed to alter or expand existing configurations. This was thought achievable through either the introduction of a new strategy, a shift in emphasis from one strategy to another, addressing a particular barrier attributed with generating sub-optimal outcomes of cycling or a combination of these interventions. In case #02, for example, the business-as-usual situation was one where a substance cascade was used as (one of the) input(s) and where semi closed-loop as well as open loop recycling was taking place. The proposed change that was being investigated as part of this project was whether reuse through reconstitution could result in (additional) commercial and environmental benefits. This new strategy was intended to supplement the RLESs already in place rather than replace them, although such a change would have reduced reliance on existing strategies. As such, case #02 was already characterized by the application of RLESs in the business-as-usual situation and the project intended to change the reliance on set of RLESs to another.

In contrast with case #02, the business-as-usual situation of case #03 was not characterized by a high degree of circularity. Here, RLESs were little used - primarily recycling and substance cascades with a marginal role for reuse. The aim of the project was to increase the use of these strategies for a specific product segment. Particular emphasis was placed on reuse through reinvention, as a lack of possibilities for reinventing the product was perceived as the main driver for the product currently being single or limited use. Moreover, little used strategies such as open-loop recycling and substance cascades, also received considerable attention, as shown by the attention paid to the recyclability of the chosen materials at the end-of-life and the use of recyclate as raw material input wherever possible.

Case #04, similarly, aimed to shift the emphasis from one set of RLESs to another. In this case the business-as-usual RLESs consisted of the reuse of parts, recycling and substance cascades, with an emphasis placed on the latter two. Application of these strategies resulted in a high degree of circularity. However, in the participant’s view the energy used for recycling was often disregarded when determining the environmental impact of products. This has led, according to the participant, to a skewed assessment where environmental impact was still needlessly high. Importantantly, reuse was not seen as a viable option for this reason. Moreover, the current product design and assembly methods were not conducive to the reuse of parts: parts offered limited compatibility and the use of non-reversible bonding methods made reuse impractical. To overcome these challenges the participant aimed to create a new modular product design, with added through life benefits in the form of adaptability of the product. These benefits were imagined to take the form of easy relocation of the product, where this is currently impractical and not financially attractive. Small modifications to the product would also be possible by adding or removing parts and it would furthermore become possible to use the parts to create an entirely new product with different characteristics. With this, the participant aimed to shift the emphasis from recycling and cascading to reuse through reconstitution, reconditioning and reinvention.

Case #06, on the other hand, although maintenance and reconditioning were also taking place, was entirely aimed at creating better recycling outcomes. The problem, according to the participant, was that recycling practices in the business-as-usual situation transformed high-grade materials into lower grades unnecessarily. In effect, what is described as recycling is often a substance cascade. This represented an important source of value loss in the participant’s view.
The solution proposed by the participant was to replace (part of) current materials with a new material. This material was expected to allow for a different recovery process at the end-of-life, which would mean that the quality of the material would not deteriorate and would thus lead to better recycling outcomes. As such, this project was aimed at addressing a particular barrier to effective cycling in an existing configuration.

Combinations of these approaches were also encountered. Cases #11a, #11b and #12c, for example, aimed to introduce new strategies as well as improve on existing ones: the introduction of reconditioning was examined in cases #11a and #12e, and maintenance (repair) by the user in case #11b. In addition to this, in all three cases mention was made of improved recycling outcomes being part of the intended outcomes.

8.4.2. Introducing new configurations
In cases #01, #05, #07, #08, #09, #11/12c and #12d participants intended to introduce or build new configurations. In these cases no or only a single RLES were considered applicable to the business-as-usual situation. The intended configurations were of varied nature, but were all aimed at addressing the problems perceived to be present in the business-as-usual situation. The participant of case #01, for example, believed that a material currently used for a specific application would become scarce in the future and that there was a lack of sustainable replacements. He therefore aimed to utilize a substance cascade as one of the main ingredients in a new composite material. Introducing the cascade meant that locally available materials could be used as opposed to internationally shipped materials. The local material was furthermore judged to be in plentiful supply, not a source of conflict and no other (significant) uses existed for it, as it was being landfilled. Moreover, the new material was associated with additional benefits: it promised superior performance compared to the material used in the business-as-usual situation; in contrast with the existing material it was known to not release toxins when stressed; and it could be produced using relatively little energy. At the end-of-life the new material was expected to be at least partially recyclable, through semi closed-loop recycling, where the remainder could safely function as a soil improver through composting. The application of these RLESSs would create a configuration that did not exist in the business-as-usual situation.

Cases #05, #07, #08, #09, #11/12c and #12d similarly propose new RLES configurations. Case #05 aimed to introduce a product longevity approach in the form of what the participant believes to be a more durable product design, as the redesigned geometry of parts was thought to reduce stress concentrations that would otherwise lead to failure. The same design change was thought to enable maintenance and reinvention through allowing repair with the same as well as different materials, thus further extending the product’s life span. Case #07 centred on utilising unused product capacity by redirecting a waste stream left over at the product’s end-of-life. This required some superficial alterations to be done to the product, thus applying reuse through surface/ superficial alterations. At the same time, efforts were on-going with regards to the possibility to implement closed-loop recycling, although these developments were at an research and development stage.

Also proposing a configuration where there previously was none, was case #08. Here the possibilities for reuse systems were explored, specifically the application of maintenance in the form of a simple disassembly procedure followed by cleaning of the product and reassembly. Recycling and composting were furthermore seen as strategies that could supply part of the
solution. Case #09 focussed on direct reuse, whilst also using a cascaded material as input and enabling safe composting at the end of the product’s life. Participants in case #11/12 focussed on using underused product capacity by reuse through surface alterations, with the possibility for maintenance and reconditioning strategies to supplement this solution. Case #12: was aimed at introducing a maintenance strategy that would extend the product’s life, whilst also exploring the possibility for recycling and composting.

Although the business-as-usual situation in cases #13/1-2 related to an entirely different product context than the proposed solution, these cases nevertheless can be said to have been aimed at the creation of configurations: it was envisioned to utilize a substance cascade, as well as ensure that either recycling or composting at the end-of-life would be possible. Moreover, in case #13/1 maintenance (repair) and reconditioning (upgrading) were furthermore considered.

8.4.3. Relationships between RLESs

The observation that in all cases participants consider RLES configurations, as opposed to considering such strategies in isolation, indicates that they regard a multitude of RLESs to be applicable to problem situations at the same time. The relationships participants see between RLESs, however, take numerous forms. Firstly, RLESs impact each other through the magnitude of resources that flow through them. For example, the participants in cases #02 and #04 saw the introduction of reuse strategies as impacting the recycling and cascading strategies already in place in the business-as-usual situation, since reuse would reduce the amount of materials recycled or cascaded during a period.

Secondly, participants saw RLESs as having different environmental impacts. For example, the participants #02, #03, #04 and #09 compared the environmental impact of recycling and reuse and arrived at the conclusion that reuse is likely the more environmentally favourable option. Consequently, these participants proceeded to focus on the realisation of reuse strategies, although recycling or composting continued to play a role in these cases.

Thirdly, participants also identified trade-offs between RLESs. That is: situations where the introduction of one strategy negatively impacts another. Case #06 is an example of this: here it was thought important that the recycling improvement under investigation did not negatively affect the other RLESs in place, among which were maintenance and reconditioning through repair and remanufacturing operations. Participant #05, on the other hand, expressed that compromising product durability to a degree would be acceptable, as long as repair and reinvention were possible. Overall, in his view, this would still extend the productive life of the product.

Fourthly, and in contrast to the third point, participants regarded RLESs as cooperative or synergistic. Case #11a offers a case in point: here the participant aimed to introduce reconditioning and improve recycling outcomes at the same time through the same intervention. That is, through servitisation of the product, involving the introduction of a new business model and setting up infrastructure dedicated to processing the product at the end-of-life, reuse and recycling could both be facilitated. Together, these strategies would significantly reduce the amount of virgin material required to manufacture the product as well as the amount of material landfilled at the end of its life. Also illustrative in this respect was the desire of participant #13 to not create a ‘new’ waste. For this participant it was not sufficient to turn a substance cascade into a new product, thus rerouting this material away from landfill. Instead, the participant
included as one of the design criteria for the product that it had to be recyclable or compostable in turn. In this manner, RLEs are connected through their capacity to ‘circularize’ different parts of the industrial system: cumulatively contributing to the overall extension of resource life.

Thus, four different relationships between RLEs were identified by participants: 1) a causal relationship where the use of one strategy impacts the flow magnitude through another, 2) a comparative relationship that focuses on the different environmental impact of strategies, 3) a subtractive relationship in the form of trade-offs as well as 4) an cumulative relationship in the form of cooperative or synergistic effects on resource life-extension.

It is furthermore worth noting that participants also identified such subtractive and cumulative relations between RLEs and preventative strategies. In case #06, for example, the participant expressed that any negative effect of the material change on current durability and energy-in-use performance would be prohibitive for the material’s application. Not only had the company dedicated significant resources to improve product performance on these metrics, but the reputation of the brand had become intertwined with these performance characteristics. For these reasons, the participant indicated that if this proved the outcome of the project, the new material would not be used. In contrast to this, participant #01 described how the new composite material not only facilitated the use of a substance cascade that would otherwise have been landfill, it also meant that less energy had to be used for the manufacturing of the product, resulting in a lower overall embedded energy.

The creation of possibilities
Cooperative and synergistic relationships of RLEs, however, were subject to assumptions not further explored or not acted upon, in a number of cases. That is: in some cases no action was undertaken to ensure that influence could be exerted in locations in the value chain relevant to implementing the whole of the proposed solution. In case #01, for example, the infrastructure required for recycling was absent in the business-as-usual situation. The participant acknowledges this, but stated that developing this would be as issue to revisit in the future, once their product would be used at scale. The substance cascade that forms one of the material inputs for this product was realisable in the short term, but the composting and semi closed-loop recycling were viewed as long-term objectives.

Similarly, in case #03 facilitating the recycling part of the RLE configuration seemingly relied on the provision of information regarding the product’s recyclability, in particular on the product receiving certification that indicated its recyclability. This in itself was intended to result in increased recycling rates. However, in one particular use scenario this would take place outside of the focal company’s sphere of influence. It is therefore not self-evident that this will indeed occur.

Likewise, in case #06, as well as requiring customers to return the product to the designated end-of-life treatment channels, the proposed recycling strategy furthermore required future recycling infrastructure to be adapted to facilitate extraction of the material. Assumptions or unresolved issues of this nature are furthermore prominent in cases #07, #09 and #11b. For this reason, it can be said that these cases revolved, at least in part, around the creation of possibilities. That is: participants aimed to address one or more barriers seen as inhibiting (better outcomes of) RLEs directly, whilst being aware that other barriers also played a role that were not necessarily addressed as part of the innovation project. Addressing these latter barriers was ignored, not
clarified, not thought within the capabilities or responsibility of the company or deferred to a time in the future, postponing the implementation of the complete proposed solution. This in contrast to cases #02, #04 and #11a, where the participants dedicated ample attention to establishing the connections required for implementing the entirety of the proposed solution.

8.4.4. Changes in business models
Regardless of whether the goal was to alter or introduce a configuration, in six of the cases the proposed configuration change was thought to require the introduction of a business model currently not or not widely used in the product group: cases #02, #03, #04, #11a, #11/12c, #12d and #13f1-2. In all cases the then current business model was one of ownership transfer through sales. The proposed transition was, in cases #02, #03, #04 #11a and #11/12c, to the provide a service based on a subscription or pay-as-you-go hire structure. In case #13f1-2 a change of this type was being speculative. In case #12d, in contrast, the new business model was to take the form of a buy-back mechanism.

A change in business model was also part of the proposed in case #05. Here, however, it concerned a new route to market through offering online ordering and customization, combined with different levels of exclusivity of the product design. As such, this proposed new business model was not related to facilitating resource life-extension. Mostly, the new business models were at the idea stage during this phase of data collection and different options still existed.

8.4.5. Single intervention, multiple RLESs
From the first data collection phase a last observation can be made regarding how participants approach circular economy. In fives cases, #01, #03, #04, #05 and #11a, the change of a single aspect of the product design was expected to facilitate a number of RLESs. In case #01, it was the introduction of a particular material that would facilitate using a substance cascade as one of the main inputs, which was also thought to enable recycling and composting at the end-of-life. Similarly, the use of modularization was thought to facilitate multiple RLESs in cases #03, #04, #05 and #11a. Specifically, in case #03 it was to facilitate as-is reuse, reuse through surface alterations and reinvention; in case #04 reconstitution, reconditioning and reinvention; in case #05 increased reparability and reinvention; and in case #11a reconditioning and pre-concentration were thought to become possible, which in turn was thought to facilitate better recycling outcomes.

In cases #04, #05 and #11a, in particular, participants explicitly expressed that the flexibility of their proposed solution was central to the benefits that the new product design offers. In their view it was important to avoid rigid lock-in of a product form or technology as this limits future possibilities.

8.5. Summary of results phase 01
So far, a number of observations can be made. Firstly, consider the development of the Circularity Compass and associated mapping methodology. The route typology contained within the Circularity Compass v2.0 offers a more detailed understanding of the RLESs that can be identified within the various resource states and how they differ with regards to their renewal potential. Also, newly introduced mappings rules allowed for capturing more relevant distinctions between cases.
Next, note the role of the resource states. Participants expressed having directed or planning to direct effort at thinking about aspects related to the particles, parts and products state. Looking at Tables 8.02 – 8.04 one will note not only that a large number of cases feature in each table, but also the overlap between tables. This means that considerations across multiple resource states are the norm, not the exception. Saliently, it indicates that circular economy related meaning work generally takes place not on a single resource state, but across two or more. It also relates back to the observations regarding ‘single intervention, multiple RLESs’ in the sense that one intervention can facilitate RLESs at multiple resource states. Particularly remarkable were the large number of changes that were perceived with regards to the role of the parts state. This might indicate that to (better) facilitate RLESs, an understanding of interventions at this state as well as the relationship of this state with other resource states is required.

Third, consider the importance of RLES configurations. The observation that in all cases RLESs feature in configurations – that is: in sets of two or more – is relevant, as it indicates that participants regard a multitude of RLESs to be applicable to problem situations, as opposed to considering and pursuing strategies in isolation. Moreover, it was shown that participants identified various relationships between RLESs: that is causal, comparative, subtractive and cumulative relationships. An observation was also made that RLESs and preventative strategies can exist in subtractive and cumulative relationships. Taken together, these observations indicate that RLESs take on their meaning in relation to other RLESs as well as other WaRM strategies.

Lastly, note that uncertainties still existed in the proposed solutions described by the participants, as noted by the blurred and overlapping flows in the case mappings. This is not remarkable, given that they were either still on-going or had yet to start their exploration of them. What was remarkable, however, was the fact that in some cases it was indicated that action would be undertaken to address some, but not all, of the identified barriers. Instead, these cases seemed to revolve, at least in part, around the creation of possibilities. Whether this changed during the remainder of the innovation projects will be returned to in the following chapters.
9. **Results phase 02**

The importance of the particles and parts state and RLES configurations reiterated & additional flows uncovered as salient

This chapter presents the results of the second data collection phase, conducted on average seven months after the first phase. A total of 23 cases featured. This phase took place post-completion of the projects and thus after the exploratory stage of the intended innovation projects had been realised. This chapter is structured as follows. First, a brief explanation is provided of the new case mappings that feature in this round. This is followed by a discussion of where the new cases sit in relation to the patterns observed in the first research phase and whether these patterns continue to hold true for the existing cases. Indeed, the importance of the particles and parts state as well as RLES configurations is reiterated. What furthermore becomes apparent is the importance of other material flows related to the product, as well as energy and information flows and considerations relating to infrastructure. Lastly, the status of the proposed solutions at the time of the second interview is discussed. Apart from one terminated project, all participants regarded the proposed solutions as worthy of further exploration and development, although progression was uncertain in many cases.

9.1. **No further changes to template and mapping rules of Circularity Compass**

For cases where the first interview was conducted during this phase, a mapping of the business-as-usual situation as well as of the proposed solution was made. A total of seven new cases feature: #11d is not counted as a new case, due to the overlap of data sources with case #12d. For cases where a second interview was conducted, a new mapping was made for the proposed solution only. The exception to this are cases #02, #04 and #05, where information was uncovered that indicated that the participant’s perception of the problem had changed and a new mapping of the business-as-usual situation was therefore deemed appropriate. These new mappings, however, are largely adjustments of the previous problem situations and as such not radically new.

To make room for new information in the new case mappings, descriptions relating to icons that were part of the previous mapping were omitted. Instead, the icons to which the descriptions applied were left in place if a particular aspect of a case continued to apply. Where new information was uncovered, descriptions have been altered to reflect this. See *Appendix 03 Case mappings using the Circularity Compass* for the case mappings: the mappings related to this phase are marked with ‘interview 02.’

No changes were made to either the template or the mapping rules of the Circularity Compass as a result of the new mappings: the template and mapping rules were fully able to accommodate the additional cases and the new case descriptions.
9.2. The problem situation and the role of resource states in the proposed solution – II

9.2.1. Business-as-usual or problem situation - II

As mentioned above, three new business-as-usual case mappings were made due to the participant’s understanding of the problem situation having changed. These are discussed in turn, starting with case #02. During the project participant #02 had gained a better understanding of where within that particular value chain waste was being generated. As a result of increasing online sales in this sector the role of this ‘display & presentation’ product as well as its supply chain was changing: in the future there would be less demand for the product, whilst its supply chain was getting more complex. That is: the different sales channels – online and in-store retail – would have to be separated if the product was not to be wasted. Moreover, the participant seemed to have a better understanding of the scale required for implementation, which limited the solution space: automation of the proposed solution was now regarded as the only feasible option, where manual processing previously seemed an option also.

The second new business-as-usual mapping was created for case #04. Although the problem situation remained multidimensional, a series of conversations with stakeholders had shifted the participant’s focus with regards to what was the primary problem. Where he previously saw the energy required for recycling as the main issue, he had now come to view the inflexibility imposed on products by present product design and manufacturing practices as the main source of waste within this value chain. It was this inflexibility, the participant now believed, that caused the product to prematurely reach its end-of-life or that necessitates costly and wasteful adaptation. As such, the participant’s views with regards to the source and type of the waste addressed by the proposed solution had changed. This did not, however, change the participant’s views with regards to the proposed solution itself. One of the changes this affected related to seeing a wider group of actors as direct stakeholders in the innovation project: as well as manufacturers, legislators and financial bodies were now also seen as potential contributors. A second effect of this shift related to having clarified a target market for the proposed solution, which was a different customer segment than previously discussed.

For case #05 a new business-as-usual mapping was made as well. Where the participant’s unit of analysis previously focussed on a specific subassembly, the data collected during the second phase indicated that it was more appropriate to map the whole product. Specifically, the participant saw reparability as not only capable of extending the life of the subassembly that was the focus on the project, but as extending the life of the whole product. Thus, an additional flow was included to indicate the other parts of the product; and the flow of the subassembly was scaled down to better represent its relative quantity. This broader scope did not change the case’s classification as introducing a new RLES configuration.

Of the new cases five were primarily environmentally driven, bringing the total of primarily environmentally driven cases to 10: cases #14g, #15i, #15j, #15k and #15l. This is not to say that other considerations did not play a role in these new cases: in cases #15i-l cost savings were seen as an integral part of delivering environmental benefits. Nevertheless, the trigger for these projects was the potential to improve environmental outcomes. The remaining two cases, cases #10 and #14h, can be considered multidimensional as increased material scarcity, increased legislative pressures and other additional and interrelated factors played a role in the motivation behind initiating the project, similar to the multidimensional cases described in the previous chapter.
### Categorization of the problems the proposed solutions aim to address - II

<table>
<thead>
<tr>
<th>Category</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primarily environmentally driven cases</td>
<td>10 #06, #11b, #12d, #13f1, #13f2, #14g, #15i, #15j, #15k and #15l</td>
</tr>
<tr>
<td>Primarily non-environmentally driven: sustainability as an integral part of delivering goal cases</td>
<td>3 #02, #03, #09</td>
</tr>
<tr>
<td>Multidimensional cases</td>
<td>10 #01, #04, #05, #07, #08, #11a, #11/12c, #12c, #10 and #14h</td>
</tr>
</tbody>
</table>

*Table 9.01 Updated overview of the categorisation of problem descriptions as provided by the participants, now including the total of all cases included in this research.*

#### 9.2.2. Additional benefits articulated beyond original scope of project

In the existing cases #03, #11a and #11b additional benefits were articulated compared to the first interview. In case #03 these benefits related to the manufacture of the product, which was thought to be quicker due to the modular approach allowing for easier assembly. In cases #11a and #11b the newly articulated benefits related to benefits that accrue to the potential user, such as a lower energy bill and lower overall costs due to increased longevity of the product.

Likewise, in two of the new projects, cases #15i and #15j, benefits were articulated beyond the reduction of environmental impact, which was the trigger for these projects. In both cases these benefits related to improving the durability of products, due to reparability and increased strength respectively. Furthermore, in case #15i faster assembly was indicated as an additional benefit, which was the result of a reduced number of parts. These observations are salient as they illustrate that environmentally driven projects can generate user benefits even when these might not be obvious at the start of the project. These additional benefits could enable the adoption of proposed solutions, since users do not have to be solely altruistically motivated.

#### 9.2.3. Role of particles state – II

The important role of the particles state in circular economy related meaning work, as established in the previous interview phase, also applied to the new cases, see also Table 9.02. In the same manner of cases #01, #06, #08, #09, #13f1 and #13f2, new cases #15i and #15k assigned the particles state a key role by focussing on the creation of a new material or the use of an existing material for a novel application. Through this, so participant #15 believed, (greater quantities of) would-be waste could be given a subsequent use. The addition of these two cases brings the total of cases where the particle state was of primary importance to eight.

Specifically, cases #15i and #15k involved the use of substance cascades as input, which in case #15k exclusively concerned biological materials. Much in the same way as in case #09, in case #15k the participant linked the choice for the material to the provision of a marketing narrative, where the waste stream of a particular industry was to be used in a new product related to said industry. This was thought to create a poetic appeal that could be used to attract the attention of potential customers.
In three of the new cases, cases #10, #14h and #15j, the particles state furthermore had an important supportive role in that a significant amount of attention was directed towards the materials chosen for the proposed solution, in the same way observed in cases #02, #03, #05, #11a, #11b, #12d in the previous chapter. The addition of these three cases brings the total of cases where the particles state had an important albeit not primary role to nine.

To illustrate: cases #10 and #14h explored the possibility to extend the influence of the focal company over end-of-life material flows. By facilitating preconcentration of particles of-a-kind through the creation of dedicated infrastructure, it was believed that recycling outcomes could be improved and more value created from these flows than was the case in the business-as-usual situation. Importantly, the focal company would be able to capture (part of) this value as opposed to the third parties that were, at the time, the sole beneficiaries of this residual value.

Changes in product design were not an immediate focus of these projects. In case #15j, on the other hand, the product design was changed to allow for easier separation of material streams, facilitating better recycling outcomes. However, this aspect of the project was not the main source of value creation offered to the owner of the product: these lay in the reduced through-life costs.

In all new cases discussed here, that is: cases #10, #14h, #15i, #15j and #15k, the consideration of the particles state was a direct result of the RLES that were targeted.

<table>
<thead>
<tr>
<th>Cases involving considerations regarding the particles state (updated)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Particles state considerations play a key role</strong></td>
</tr>
<tr>
<td>cases</td>
</tr>
<tr>
<td><strong>Particles state considerations play a supporting role</strong></td>
</tr>
<tr>
<td>cases</td>
</tr>
</tbody>
</table>

Table 9.02 Updated overview of the categorisation of problem descriptions as provided by the participants, now including the total of all cases that had, were or were planning to adjust the parameters for the particles state as part of the project or the larger innovation project (updated version of Table 8.02).

9.2.4. Changes with regards to the role of the parts state – II
Six new cases can be added to the five cases identified in the previous phase where the parts state plays an unchanging role in both the business-as-usual situation as well as with regards to the RLESs considered: cases #10, #14g, #14h, #15i, #15k and #15l. The notable exception to this is case #15j. For this case, the participant explained, the innovation effort was directed at simplifying the product design such that at the end-of-life it did not require disassembly, but could be regarded as a material ready to be treated for recycling. To enable this, the product was redesigned such that it consisted of a single material. Enabling this was a change in the geometry of individual parts such that assembly did not require additional fasteners made from other materials.
Case #15j reiterates the importance of the parts state in circular economy related meaning work, albeit for an entirely different reason than was discussed in the previous chapter. In this chapter it was shown that in nine cases the parts state played a new role with regards to facilitating RLESs in the forward value chain, the end-of-life value chain, or both. Specifically: by explicitly considering the parts state where it was not previously acknowledged, RLESs could be introduced or better facilitated. In case #15j, however, the opposite occurs: by adjusting the geometry and composition of parts, the parts state does not have to be considered at the product’s end-of-life. That is: the product can be considered a material as soon as it is discarded and no disassembly or disassembly of parts is required before it receives its end-of-life treatment as a material.

Although the parts state was already explicitly considered in the business-as-usual situation in both the forward as well as in the end-of-life chain of cases #10 and #14h, these projects nevertheless demonstrate a re-evaluation of the role of the parts state. That is: in the business-as-usual situation of these two cases various end-of-life strategies relating to reclaiming used parts were described to be in place. This was not only to the benefit of reclaiming materials, as described in the previous section, but extended to the repair, remanufacturing and resale of used parts. However, it was largely third parties that benefited from the residual value generated by the recapture of these parts. Both participants indicated that they expected it to be possible to increase the quantity of parts which have their productive life extended through better organizing the relevant infrastructure. Practically, this meant that dedicated infrastructure had to be created, where the focal company could exercise increased control over the end-of-life process through, amongst other things, the provision of specialised knowledge.

### Cases involving changes with regards to the role of the parts state (updated)

<table>
<thead>
<tr>
<th>Parts state plays new role in forward chain</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>cases</td>
<td>#02, #09</td>
</tr>
<tr>
<td>Parts state plays new role in EoL value chain</td>
<td>9</td>
</tr>
<tr>
<td>cases</td>
<td>#02, #03, #05, #08, #11a, #11b, #11c, #12d, #12e</td>
</tr>
<tr>
<td>Parts state takes on new significance</td>
<td>2</td>
</tr>
<tr>
<td>cases</td>
<td>#10, #14h</td>
</tr>
<tr>
<td>Parts state ‘designed out’ for EoL</td>
<td>1</td>
</tr>
<tr>
<td>cases</td>
<td>#15j</td>
</tr>
</tbody>
</table>

*Table 9.03 Updated overview of cases that either come to engage with the parts state new ways (updated version of Table 8.03). Underlined are the cases where the change in the role of the parts state is the direct result of the intended application of RLESs.*

What is striking about these two cases is that the focal companies had not previously regarded end-of-life parts as a source of value, or at least not to the same degree. This offers additional support for the importance of the parts state in circular economy related meaning work, even when at first glance the business-as-usual situation does not look radically different from that of the proposed solution. See for an updated overview of the (changed) role of the particles state in all cases Table 9.03.
9.2.5. Role of product state – II
To the projects described in the previous chapter that had, were or were planning to redesign the product shape and/or its functionality two more cases have to be added: cases #15k and #15l, bringing the total to 15. See also Table 9.04. Specifically, in case #15k, a new design was created, with a radically different visual style than the product is was intended to replace. In cases #15i-3, new product designs were created also: although the product forms themselves were not radically new, they nevertheless had to be made suitable for the manufacturing process required for processing the cascaded material used in these products.

In the same manner described in the previous chapter, the role of the product state in some of the new cases was limited to providing the constraints within which the proposed innovation had to take place. That is: in cases #14g, #15i and #15j the proposed changes were not to affect overall product appearance and did not offer new functionality to the user. Rather: existing performance characteristics were to be met and, if possible, incrementally improved upon.

In cases #10 and #14h, on the other hand, product state issues did not play a significant role. Instead, as described in the above, the attention was directed at recapturing end-of-life parts and particles through reorganising the infrastructure through which these resources flow. The aspect of infrastructure will be discussed in more detail below as it plays a role of importance in other cases also.

<table>
<thead>
<tr>
<th>Cases involving considerations regarding the products state (updated)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Products state considerations play a key role</strong></td>
</tr>
<tr>
<td>cases</td>
</tr>
<tr>
<td>#01, #02, #03, #04, #05, #08, #09, #11a, #11b,</td>
</tr>
<tr>
<td>#11/12c, #11/12d, 13/1a, 13/2, #15k, #15l</td>
</tr>
<tr>
<td><strong>Products state provides constraints only</strong></td>
</tr>
<tr>
<td>cases</td>
</tr>
<tr>
<td>#06, #07, #12e, #14g, #15i and #15j</td>
</tr>
</tbody>
</table>

*Table 9.04 Updated overview of cases that had, were or were planning to redesign the product shape and/or functionality as part of the project or the larger innovation project (updated version of Table 8.04).*

9.3. Altering or introducing RLES configurations - II
Just like the cases that featured in the first phase, the new cases can be classified as either aimed at altering an existing RLES configuration, or as introducing one, see Table 9.05.

9.3.1. Altering or expanding existing configurations
The new cases that aimed to alter or expand an existing configuration were: cases #10, #14h and #15j, bringing the total number of cases in the dataset with this goal to 10. These new cases each aimed to address a particular barrier thought to result in sub-optimal outcomes of the current configuration. Specifically, in case #15j this was achieved through changes in the product design that allowed for lightweighting during manufacturing (this would increase the amount of materials that could be recycled directly, instead of after many years of use) and changes in the geometry of parts such that different materials could be separated more easily for better recycling outcomes.
On the other hand, in cases #10 and #14h, the envisioned change related to the manner in which the then current end-of-life routes were facilitated. As discussed, these two focal companies lacked or had only limited control over end-of-life flows in the business-as-usual situation. By redirecting these flows through systems controlled or more tightly controlled by the focal company, it was thought possible to recapture (part of) the residual value within the focal company. As such, seen from a conceptual perspective, the existing configurations were not to be fundamentally changed, merely altered such that the focal companies gained (a level of) control over the resource flows.

### Relation of projects with other RLES - II

<table>
<thead>
<tr>
<th>Relation of projects with other RLES</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alter or expand current RLES configuration cases</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>#02, #03, #04, #06, #10, #11a, #11b, #12c, #14h, #15j</td>
</tr>
<tr>
<td>Create or build RLES configuration cases</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>#01, #05, #07, #09, #11/12c, #12d, #13f1, #13f2, #14g, #15j, #15k, #15l</td>
</tr>
</tbody>
</table>

Table 9.05 Overview of the presence of RLESs: whether the proposed solution represented an alteration or expansion of a situation where two or more RLESs were already present, or whether one or more RLESs were introduced such that two or more RLESs would be present. Indicated in with an underline are the cases where a new business model was thought necessary to facilitate the envisioned RLES(s). (Updated version of Table 8.05.)

9.3.2. Introducing new configurations

In the remaining new cases, cases #14g, #15i, #15k and #15l, a RLES configuration was introduced where there previously were no or only a single RLES present. In case #14g, for example, closed-loop recycling and reuse were considered, where only a pre-consumer recycling loop existed. Cases #15i, #15k and #15l, furthermore, proposed the introduction of one or more substance cascades where there previously were none in use. For case #15l this brings the total of RLES considered to two, as, according to the participant, the material was likely to be used in a subsequent substance cascade. In cases #15i and #15k additional RLESs such as open and closed loop recycling and composting were named as well.

In the cases where a second interview was conducted configurations remained important: no radical changes were observed in the routes targeted by the participants compared to the first interview. This is not to say that certain RLESs or particular options for executing those RLESs were excluded or no longer seen as viable or desirable as a result of the project: this is discussed further in the section 9.4 Status of solutions - I.

9.3.3. Relationships between RLESs

The above observations reiterate the importance of RLES configurations in circular economy related meaning work already observed in the previous chapter. In this chapter it was furthermore stated that RLESs have various relations to each other, some of which were identified or implied by the new participants also. Take case #15j, for example. The proposed changes in this case related to improving pre-consumer recycling volumes, which in turn reduced the amount of materials to be sent to recycling at the end-of-life of the product. The same causal
relationship existed between strategies in cases #10 and #14h: if more parts are reused as in line with this scenario, less go on to be recycled in any given time period.

Furthermore, in case #15k, the choice for biocompatible substance cascades was intended to facilitate composting at the end-of-life, thus linking cascading and composting in a synergistic relationship. The same goes for the material chosen for the substance cascade in case #15i: this material was chosen, in part, for its recyclability. Just as in case #15k, this would generate a synergy between two strategies, here cascading and recycling.

**The creation of possibilities**

Among the new cases there were also examples of cases that revolved, at least in part, around the creation of possibilities. The previous chapter listed six such cases, cases #01, #03, #06, #07, #09 and #11b, where participants aimed to address one or more barriers seen as inhibiting (better outcomes of) RLESS directly, whilst being aware that one or more other barriers also played a role but that were not necessarily directly addressed as part of the innovation process. Or, if addressed, the evidence that the proposed solution would be effective in addressing the targeted barrier was lacking or unclear. This applies particularly strongly to three of the new cases, cases #15i, #15j and #15k, bringing the number of cases where the creation of possibilities plays an important role to nine. The solutions proposed by these interventions relied, for an important part, on the provision of information to the user at the end-of-life stage. This information provided the user not only with insight into the appropriate end-of-life treatment, but also with nearby locations that could provide the appropriate treatment. The effectiveness of providing this information was not further explored or confirmed: a large degree of uncertainty thus remained whether the proposed intervention would be effective.

No change in status was observed in relation to the six existing cases where the creation of possibilities was described to play a role in the previous chapter.

### 9.3.4. Changes in business models

The new cases also feature a number of proposed changes in the business model of the focal company. In cases #10 and #14g an extension of current business model was proposed, where the logic of a sales-centred business was to be supplemented with that of a reclaim or recapture aspect. That is: the core sales logic of the business would not change in the near term, but would be extended by a the addition of a new business unit that would specialize in reclaiming residual value from parts and materials contained within the company’s products.

In case #14h discussion within the project team was on-going regarding whether servitisation would be feasible and whether this was to take the form of a lease structure or a buy-back arrangement. New business models were not discussed in the context of cases #15i-l.

### 9.4. Types of flows, their relationship and the role of infrastructure

This section examines more closely what type of flows participants were considering, as well as the role of infrastructure in the proposed solutions. As much of this follows from analysing the role of preventative strategies, this is where this section starts. It goes on to consider the relationship between the various identified flows as well as zooms in on the role of infrastructure.
9.4.1. Role of additional material flows, energy flows and information flows
Preventative strategies were indicated to play a role in 13 cases, featuring a total of 21 instances. In short: approximately half the participants thought of preventative strategies as part of the proposed solution when preventative strategies are taken as a group. It can thus be said that preventative strategies had a prominent role in the proposed solutions. This invites a closer examination of these strategies, leading to two further observations. Firstly: participants considered preventative strategies to apply to physical flows in 8 cases (11 instances). This can be split into those flows directly involved in the manufacturing of products (5 cases, 8 instances), and additional flows (3 cases, 3 instances). These latter flows are more appropriately thought of as co-used flows as they are to be used alongside or with the product, but are not part of the product itself. Such other flows were important in other ways also, which is discussed further below in the section dedicated to describing the role of co-used flows.

Preventative strategies were furthermore also thought to affect an entirely different type of resource: energy. That is: in seven of the cases prevention featured 10 instances in relation to energy. The nature of the considered energy flows is discussed in more detail in the below.

The important role of energy also draws the attention to information flows, since the role of both energy and information were identified as in need of clarification in section 4.3 Insights from the analysis of WaRM frameworks. When considering the role of information flows, it becomes apparent that these also play a salient role in creating WaRM action recipes. See for an overview of the role of the various identified flows Table 9.06.

The next two observations look at relationships. Discussed first is the relationship between preventative and life-extending strategies. The last observation that is made in this section relates to the connections that exist between the different flows. These two matters will be returned to after the discussion of the various material, energy and information flows in the included cases.

**Directly involved material flows**
For a start consider the preventative strategies affecting the material contained within a product or those used in manufacturing processes. Preventative strategies that feature in this category were: lightweighting (cases #01, #04 and #05), non-toxicity (twice in case #01) and responsible sourcing (cases #03 and #07). The latter refers to strategies that involve selection of raw materials with less environmentally impact and ensuring environmental best practice in their extraction. The list of strategies in this category is completed by the application of a design change that was intended to improve the product’s durability by reducing the stress build-up in critical parts in case #05, and the efficient use of the product in case #07, which concerns a dissipative product.

**Co-used material flows**
Moreover, in cases #08, #11/12d and #15j, which feature reduced use of a flow co-used with the product. Examples of such flows are transit packaging, but also water required for cleaning the product between uses. That such flows can be significant is illustrated by case #08: the participant estimated that, for the business-as-usual situation, the environmental impact of this co-used flow was comparable to that of the materials contained in the product. In the participant’s views the reduction of this flow was therefore equally as important as reducing the
impact of the materials contained within the product. For this reason, the participant aimed to redesign the product in such a manner that the co-used flow could be significantly reduced.

<table>
<thead>
<tr>
<th>Flows considered</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material flows directly involved with (manufacturing of) product</strong></td>
</tr>
<tr>
<td>Reduction/ efficiency/ durability cases (instances)</td>
</tr>
<tr>
<td>Toxicity cases (instances)</td>
</tr>
<tr>
<td>Responsible sourcing cases</td>
</tr>
<tr>
<td><strong>Co-used material flows</strong></td>
</tr>
<tr>
<td>Reduction/ elimination cases</td>
</tr>
<tr>
<td>Facilitating RLESs cases</td>
</tr>
<tr>
<td>Generation cases</td>
</tr>
<tr>
<td><strong>Energy flows – reduction cases (instances)</strong></td>
</tr>
<tr>
<td><strong>Information flows – enabling return cases</strong></td>
</tr>
</tbody>
</table>

*Table 9.06 Overview of what other flows are considered by participants alongside the material flows directly involved in creating the product.*

Other examples of the salience of co-used flows can be found in case #11/12d. In this case the role of the co-used flow in facilitating the forward and reverse logistics of the product was considered. This included exploring how the co-used flow could play a direct role in facilitating the proposed RLES configuration.

Furthermore, in case #14g, it was considered how the reused product could generate a supply of goods intended to be co-used with the product. The reuse of the product was to have a function in the manufacture of these goods, which in turn would be used in conjunction with new versions of the product. As such, the reused product was to play a role in the generation of a co-used flow.

In a total of five cases additional material flows were considered alongside those contained within or used in the manufacture of the product, with the aim to either reduce or eliminate them, use them to facilitate the proposed RLESs or generate other material flows.
Energy flows
In seven of these cases prevention featured ten instances in relation to energy: four times in relation to a low energy-in-use strategy in place in the business-as-usual situation (cases #04, #06, #10, #11a) and five times in relation to new energy reduction strategies. Of these new strategies one related to reduced energy demands during manufacturing (case #01), two to the use of renewable sources (twice in case #02) and three to reduced energy-in-use (cases #11a, 2 instances and #11b). The prevalence of energy related preventative strategies indicates that energy flows are considered an important part of circular economy related meaning work.

Information flows
For this reason, the participant aimed to redesign the product in such a manner that the co-used flow could be significantly reduced In addition to this, information flows were identified as another salient type of flow: in 11 cases information flows were attributed an enabling role in the proposed solution. This related directly to providing information to whomever would handle the product at the end-of-life, usually the user, regarding the appropriate end-of-life treatment. Such information flows were relevant to facilitating RLEs in cases #01, #03, #15i, #15k and #15l. It is the provision of such knowledge that was assumed to result, or result more often, in the required end-of-life treatment of the resources in question. In case #01, for example, the possibility was explored to embed information within the materials of the product, enabling quality control and preventing fraud as well as facilitating the identification of the focal company as the product’s manufacturer. This identification was seen as a crucial step in the process that would eventually return the product to a site where it would receive specialised recycling treatment.

In cases #10 and #14h the role of information was similar to that of cases #01, #03, #15i, #15k and #15l in the sense that its role was to ensure appropriate end-of-life treatment. In contrast to these cases, however, its role was not merely to facilitate awareness among product handlers about appropriate end-of-life treatment. Instead: the role of information was to connect the supply of used parts and secondary materials with demand for them. The proposed mechanism for this were marketplaces facilitated by the focal companies, where the focal companies would generate revenue either by the direct sales of parts or a percentage of transactions conducted on the marketplace.

In cases #11a and #11/12c, information was likewise viewed as playing a role in ensuring the quality of the utility the product was intended to provide, through predicting part or module failure and replacing it with a new part or module before this occurred. Ultimately this form of maintenance was expected to extend the overall life of the product as well as ensure continuity of product utility. Similarly, in case #11b it was information about how to repair the product made available to the user that was expected to extend the product’s life. In cases #11a and #11b information was furthermore associated with reducing energy flows in the use phase of the product.

A different role for information in enabling the extension of resource-life can be found in case #11/12d. Here, information exchange was envisioned to incentivize the user to dispose of the product using the appropriate end-of-life channels by offering a financial reward. This required a means of exchanging personal details such that the user would be able access these rewards. In this scenario a user would return the product and gain, on a digital account, a small credit or discount to use in a subsequent purchase with the same focal company.
As such, information was seen as having the potential to prolong resource life, either by creating awareness of the correct end-of-life treatment, by linking supply and demand of used parts and secondary materials, facilitating maintenance, and incentivising product users to dispose of end-of-life products through the appropriate channels.

**Relationship between prevention and resource life-extension**

In relation to preventative strategies as applicable to material flows it is worth highlighting that prevention and resource life-extension were intimately related in some cases. For example, in case #01 the choice for a particular substance cascade meant that the product could be lightweighted compared to the then current alternatives on the market, whilst this material could also be recycled and composted. A second example is provided by case #08: here, the choice for a particular renewable material was linked to the possibility of using less of a resource that was co-used with the product in the business-as-usual situation.

Furthermore, in cases #04, #06, #10, #11a, #11b participants expressed that the application of RLESs should not negatively affect current energy-in-use performance or, if possible, should contribute to improving it. This indicates that RLESs and energy flows were seen as possibly subtractive, that is: trade-offs exist between RLESs and energy use, and synergistic, that is: RLESs and energy use are positively related through interventions that generate benefits in both areas. Case #11a offers a striking example of how intricately energy use and RLESs can be related: here, the proposed RLESs were explicitly aimed at reducing the energy-in-use of a product by facilitating its upgrading with more energy efficient technology throughout its life-time.

**Material, energy and information flow are intertwined**

A last and more general observation can be made from the preceding: participants thought of material flows, both those contained within and those co-used with the product, as well as energy and information flows as intertwined. Take, for example, information and energy: in case #11a information was thought to play a role in enabling the product to adapt to user behaviour, thus delivering additional benefits in the form of convenience and, saliently, resulting in energy savings. In case #11b information about how to use the product, in the form of direct feedback to the user, was likewise thought to enable energy savings.

Material and information flows were similarly described as intertwined. Take case #01, for instance, where the possibility was explored to embed information within the materials of the product. A similar observation can be made for cases #03, #10, #11b, #15i, #15k and #15l: in these latter cases it was the provision of information to the user or handler of the product that was thought to facilitate RLESs, whether that was reuse, repair or recycling. In cases #11a, #11/12c, #11/12d and #14h, on the other hand, material and information flows were related in the sense that information exchange played some role in the provision of the service offered. Here, it was not the provision of information itself that was thought to facilitate the proposed solution, but it enabled or unlocked other benefits for users. In this manner information flows would indirectly align material flows with the proposed RLESs.

The previous discussion of the relationship between RLESs and preventative strategies already commented on how energy and materials flows can be related. Specifically, in case #01 the choice for the cascaded material meant that an alternative product could be produced with less embodied energy. In case #02, the participant expressed seeking control over energy costs as related to manufacturing, realised by installing renewable energy generating capacity at one of the
production plants. As such, in both these cases participants perceived a direct relationship between quantity of material processed and energy used. In cases #04, #06, #10, #11a and #11b participants furthermore expressed that energy-in-use must not be compromised by the application of RLESs. Specifically, material choices what would aid RLESs, but that would negatively affect energy-in-use were dismissed as undesirable: in this manner energy use and material flows can be indirectly and negatively related. Also, case #11a showed how RLESs can be in service of reducing energy-in-use by facilitating upgrading the product with a more energy efficient technology when this becomes available. As such, material and energy flows can also be positively related. A third relationship was also uncovered: participants #08 and #15 pointed out that substance cascades can take the form of the incineration of materials, generating electricity.

9.4.2. Technical product aspects versus physical and informational infrastructure
Within the dataset 13 cases focussed on addressing technical aspects relating to the product design: meaning particle, parts and products state issues directly relating to the product. This was determined by a key role within the project being played by the creation of a prototype of (parts of) the product, material testing or both. Eleven of these prototypes consisted of physical prototypes or samples of the product or parts of it: #01, #03, #05, #07, #09, #11b, #12c, #13f1, #13f2, #15i, #15k. In cases #01, #07, #15i and #15k these prototypes were formally tested, respectively through destructive testing under extreme conditions, submission to quality control procedures or focus group testing aimed at determining the appeal of the product to potential customers. Alternatively, in cases #15j and #15l digital prototypes in the form of CAD designs were produced to gain a detailed insight into relevant technical aspects. In case #06 material samples were acquired and submitted to formal test procedures used within the company to determine material performance.

A further five cases, cases #02, #07, #10, #14g and #14h, focussed not on the product design, but on changes in the physical infrastructure. That is, these projects focussed on aspects to do with the systems handling and transporting material flows. In case #10, for example, changes in the physical infrastructure were examined, which involved the creation of regional treatment centres. In case #14h such changes were initially also examined, but dropped when it was realized that the intended treatment was already being provided, albeit not in centralized locations but at distributed sites.

Two additional examples furthermore illustrate the importance of infrastructure considerations in circular economy related meaning work. In case #02, for example, a product prototype had been created previously and the project therefore investigated how the reuse infrastructure around this product could be organised in terms of transport and automated treatment, consisting of disassembly and repackaging. In case #07, likewise, the focus was on automating and scaling up the process of being able to use previously unused product capacity. Aggregating unused product in (a) central location(s) was instrumental to facilitating the proposed solution: it was through this that economies of scale could be generated and product quality more easily safe-guarded.

These two foci – technical aspects and infrastructure – were not mutually exclusive: cases #11a, #11/12c and #11/12d dedicated attention to addressing both technical aspects relating to the product as well as to infrastructural changes. It is also not implied that infrastructure considerations did not play a role in cases that focussed more on technical product aspects. Rather, the infrastructure that was intended to be part of these proposed solutions did not have
to be created, or was for the most part in place. This applied to eight cases: #03, #05, #09, #11b, #12c, #15i, #15j, #15k. In these cases, such infrastructure was simply used or used in new ways.

Apart from considering physical infrastructure, cases #10 and #14 also considered informational infrastructure: those systems that handle and transmit information flows. In both cases, part of this infrastructure was already in existence, but had to be extended or adapted to be suitable for the specific proposed RLESs. The idea in cases #10 and #14 was to improve connectivity between various actors within the value chain. The proposed solution in case #04, on the other hand, required the creation of a system that would allow for a large quantity of different product parts and modules to be compatible with each other. Effectively, this implies the creation of a standard, which can be said to be a different form of informational infrastructure compared to actor connectivity. In these cases related to infrastructure, both physical and informational, the output consisted of an evaluation of different scenarios through which to the proposed RLESs could be achieved: no tests or trials were conducted.

Case #02, as already mentioned, furthermore addressed the issue of energy infrastructure by installing renewable energy capacity at one of the production facilities. Generally, the prevalence of infrastructure considerations indicates that it played an important role in innovating for a circular economy.

9.5. Status of solutions – I

9.5.1. Remaining uncertainties: the use of blurred flows and overlapping flows - I
In the first phase of data collection it was shown that a considerable amount of uncertainty existed among participants regarding the precise description of the proposed solution on a conceptual level, which was indicated by the frequent use of blurred and overlapping flows in the case mappings. These indicated uncertainties with regards to the quantity of a flow and the existence of different routes as options, respectively. Some of these uncertainties had been resolved by the time the second round of data collection took place. In case #01, for instance, flows no longer needed to be depicted as blurred: it had been established that the proportion of recyclate could be as high as fifty per cent without negatively affecting the material properties in subsequently cycles. This was a much higher proportion than had been expected. At the same time, this gave certainty with regards to the amount of material that should be processed through composting: the remaining half.

The results of the material testing in case #06, in contrast, were less encouraging: it had become apparent that the material under investigation was suitable for application in a much more limited proportion of the parts than had been expected. Moreover, in cases #13/1–2 the cascaded mix of materials was better understood as a result of information gathered from material reprocessors. This meant that one of the end-of-life routes, composting, would not be a feasible RLES. This left only recycling at the end-of-life side of the case mapping. In these two cases the blurred outlines as well as the relevant overlapping flows were therefore removed.

Blurred flows, however, continued to exist in the mappings of case #03 and #05. In case #03 this indicates that, although different materials were tested, further development with regards to what materials to use in the final product was deemed appropriate. In case #05, as durability
testing was not yet undertaken, it remained uncertain with what frequency repair would be required. The blurred flows in these case mappings were therefore retained.

In the same manner of blurred flows overlapping flows were partially resolved. The dismissal of composting in cases #13f-1-2 was already mentioned. Furthermore, in case #02, one of the possible routes for facilitating reconstitution was dismissed as not desirable due to the large amount of transport involved. However, the project had not resulted in a clear distinction between the desirability of direct reuse and reuse through reconstitution, which therefore remains depicted with an overlap.

In the mappings of cases #03, #04, #11/12c, #12e and #13f-1-2 overlapping flows continue to be present in the case mappings as these RLESs remained present as possibilities: no definitive conclusion had been reached regarding the (relative) feasibility or desirability of these routes. The overlap in the mapping of case #08 was also preserved, as the focal company had not yet evaluated the outcomes of the project. In the seven new cases overlapping flows were used to describe part of the solutions in cases #10 and #15: in both these cases the overlap indicates the possibility to recycle materials either in an open or closed loop system.

As such, a total of five instances of uncertainty regarding the capacity of a route or the co-existence of routes were resolved (#01, #06, #13f1, #13f2), which means that a total of 10 instances remained (#03, #05 / #02, #03, #04, #08, #11/12c, #12e, #10 and #15). Thus, a significant amount of uncertainty continued to exist, even after the projects had concluded.

9.5.2. Projects terminated, on hold and on-going

Other uncertainties continued to exist in all projects: see orange text in the case mappings. These uncertainties related to, for example, the detailed product design, the business model or potential legislative barriers and could still render the proposed solution unfeasible in most cases. Given the relatively short duration of the projects, it is unsurprising that these uncertainties had not yet been resolved. Regardless of these uncertainties, however, participants generally made the assessment that their proposed solution was feasible.

The exception to this are the assessments that participants #02, #06 and #13 made. Participants #02 and #13 indicated not yet having made sense of the project results. That is: they indicated not yet having digested the project outcomes to the degree that it had become apparent whether they indicated feasibility or unfeasibility. Like the other participants, however, these two participants expressed the intention to continue with further development. The main reason for this is that the two participants continued to consider their respective proposed solutions as desirable.

The only case where the innovation project was clearly declared terminated was case #06: the new technology targeted for improved recycling outcomes was deemed unsuitable for application at the time, as its limited replacement of currently used materials meant that the solution became uneconomical. It was furthermore discounted as being relevant in the near future, as further development of the technology was deemed necessary.

Thus, with the exception of participant #06, participants regarded all other proposed solutions as worthy of further exploration and development. However, they did not always expect such
development to progress immediately. See Table 09.7 for an overview of the status of the innovation projects at the time of the second interview.

Specifically, progression of cases #08, #11/12c, #11/12d, #12e, #14g and #14h was uncertain due to a lack of clarity regarding the focal company’s willingness to adopt the proposed solution. This was for varied reasons: in cases #08, #14g and #14h a meeting with project members discussing next steps had yet to occur; in cases #11/12c, #11/12d and #12e the uncertainty stemmed from the fact that the company strategy was under review and it was unclear whether or not the proposed solutions would be compatible with the new strategy.

Participant #13 furthermore expressed general uncertainty with regards to what next steps to undertake, which made progression uncertain. It was suggested by the participant that further discussions with project stakeholders could potentially resolve this. This same uncertainty also played a role in case #02, although it seemed primarily subordinate to other business priorities: the business strategy for the upcoming year was being formulated, and although the proposed solution was to be a part of it, it was uncertain what and how big a role it would play in the overall strategy. Important for progressing this innovation project, the participant indicated, was finding a first customer willing to be a partner in further development of the proposed solution. Other business priorities taking precedence was also the reason for not progressing case #01: the proposed solution was reported to have joined the product development cue of the focal company, where so far other projects had enjoyed preferential treatment.

<table>
<thead>
<tr>
<th>Status of proposed solution after 7 months</th>
<th>Number of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status descriptions</td>
<td>Case number</td>
</tr>
<tr>
<td>On-hold temporarily</td>
<td>2</td>
</tr>
<tr>
<td>Intention expressed to continue further</td>
<td>#01, #02</td>
</tr>
<tr>
<td>development in the near future</td>
<td></td>
</tr>
<tr>
<td>In the process of acquiring financial</td>
<td>5</td>
</tr>
<tr>
<td>means to continue innovation project</td>
<td>#03, #04, #07, #09, #11a</td>
</tr>
<tr>
<td>Searching for customers to implement</td>
<td>4</td>
</tr>
<tr>
<td>proposed solution</td>
<td>#15i, #15j, #15k, #15l</td>
</tr>
<tr>
<td>Internal development</td>
<td>3</td>
</tr>
<tr>
<td>Terminated</td>
<td>1</td>
</tr>
<tr>
<td>No intention for further development now or</td>
<td>#06</td>
</tr>
<tr>
<td>in the near future</td>
<td></td>
</tr>
<tr>
<td>Uncertain</td>
<td>8</td>
</tr>
<tr>
<td>No decisions yet made by focal company</td>
<td>#08, #11/12c, #11/12d, #12e, #13i, #13i2, #14b, #14h</td>
</tr>
</tbody>
</table>

Table 09.7 Overview of the status of the proposed solution 7 months (on average) after the first interview was conducted, as indicated by the participants.

In five other cases attempts were being undertaken to secure financial means for further development of the projects, either through bidding for additional funding or finding initial customers interested in adopting the proposed solution. This applied to cases: #03, #04, #07, #09, #11a and #15i-l. In case #11a this involved establishing a collaboration with additional
partners. The proposed solutions of cases #15i, #15j, #15k, and #15l were deemed sufficiently developed and to be fit for selling and adapting to specific customer requirements; this participant therefore indicated being in the process of contacting potential clients or progressing the designs with already established contacts, depending on the project.

Choosing instead to commit internal means for further development were cases #05, #10 and #11b. The reason for this was, in case #05, that this was in line with how the company usually operated. A deadline to apply for further funding was furthermore missed. In case #10 the participant expressed that the proposed solution was considered commercially sensitive. Internal development was therefore attractive as it meant that tight control could be retained and commercially sensitive data would not have to be exposed. For these reasons the participant sought permission to continue assessment and development internally. To this end a series of meetings with internal stakeholders had been scheduled. In case #11b it was preferred to further amplify the value of the proposed solution, as this would strengthen the negotiation position before contacting potential manufacturing partners.

In cases #11c, #11d, and #15 participants indicated that they expected that the prototypes would play an important role in generating internal or customer buy-in. Participant #07 likewise indicated that the evaluations of the scenarios generated as part of the project would likely function as an internal communication tool in aid of generating buy-in for continued development. Participant #03 indicated that the prototype had already proved instrumental in generating internal buy-in, as it had allowed for the proposed solution to become real and tangible, proving that it could work in reality and thus bringing on board a vocal internal critic.

As such, at the time of the second interview, the focus of the 22 proposed redesigns still considered desirable, in 20 of these cases attention had turned from the development of the proposed solutions to considering stakeholders in the innovation process, whether internal or external to the focal company. As such, these was still a need to generate the clarity and a need to generate the means and/or political support to continue development or implementation of the proposed solution: e.g. cases #01, #02, #03, #04, #07, #08, #09, #10, #11a, #11/12c, #11/12d, #12e, #13f1, #13f2, #14g, #14h, #15l, #15j, #15k and #15l.

9.6. Summary of results phase 02
The results of the second round of data collection largely reiterated earlier observations. Firstly, the Circularity Compass and associated mapping methodology continued to serve well in mapping relevant aspects of cases. Secondly, participants had directed effort at addressing issues associated with more than a single resource state as they had earlier states they would. Furthermore reiterated was the importance of RLES configurations: in the existing cases configurations continued to play a role in the proposed solutions and the new cases were also directed at either adjusting or introducing one.

What the larger dataset in this phase furthermore brought to fore, was the importance of co-used flows, as well as energy and information flows. It was shown how these flows were intimately related. It was also shown that infrastructure considerations were prevalent, whether concerning physical, informational or energy infrastructure. Together these two observations indicate that thinking in terms of product-systems as opposed to mere products was prevalent in the dataset. This means that the focus was not merely on technical aspects of the product alone,
but also included a range of relevant manufacturing and logistics processes, and its through-life management.

Lastly, the status of the proposed solutions at the time of the second interview was reviewed. Apart from one terminated project, all participants regarded the proposed solutions as worthy of further exploration and development, although progression was uncertain in many cases. Despite the fact that many uncertainties still existed, many participants expressed enthusiasm for continuing development. This last observation was the reason for a third and final data collection phase, discussed in the next chapter.
10. Results phase 03

Large proportion of projects terminated or on-hold indefinitely

This chapter discusses the results of the third and final data collection phase conducted on average 28 months after the first interview. This discussion focuses on the status of the projects as a large proportion of projects was found to have been terminated or to be on-hold indefinitely despite the earlier expressed feasibility and desirability of the proposed solutions.

10.1. New case mappings
The interview in this phase consisted of two stages: the first stage aimed to uncover new information about the project and the second to verify the case mappings that were made based on the previous interviews. New case mappings were only made if new information was disclosed during the first stage of the interview that indicated the participant had altered his or her views regarding the proposed solution. Consequently, no new case mappings were made for cases #06, #10, #11c-d and #14g-h. Also: no new case mappings were made for case #02 and cases #12c-e due to not being able to secure interviews within the time constraints of the research.

The most salient changes related to resource flows were found in case #07 and case #11a. Specifically, in case #07 four case mappings were created that represented varieties on how a single proposed solution could be implemented differently. These variations were intended to serve different customers, both internal and external to the company, which meant that differences with regards to barriers and intended implementation existed. It furthermore meant that they affected different parts of the product system and that circularity would become possible in both the post- and pre-consumer part of the value chain.

 Likewise, a new case mapping was created for case #11a. This new mapping contained an adjusted version of the proposed solution: where it previously relied on disassembly and upgrading at the point of use, this was no longer the case in the new proposed solution. Instead, the whole product was to be returned to a central location for disassembly and upgrading, whilst the user would be sent a replacement product.

In the remaining cases changes in the mappings relate not to resource flows, but to uncovering new barriers, primarily related to gaining support in the value chain. This is further discussed below. See for all case mappings from this phase Appendix 03 Case mappings using the Circularity Compass: the mappings related to this phase are marked with ‘interview 03.’ No changes were made to either the template or the mapping rules of the Circularity Compass as a result of these mappings.

The information from the second part of the interview was used to improve the case mappings from data collection phases 01 and 02. Where this led to amendments this is indicated in the mappings in Appendix 03 Case mappings using the Circularity Compass. As such, this information has already been discussed in the previous two chapters.
10.2. Status of solutions - II

After an average of approximately 28 months between the first and the final interview of a total of 23 unique solutions that were investigated, only one solution was implemented. Of the remainder five were still in development, 11 were on hold or terminated and of a further six solutions the status was uncertain. The latter was due to participants #02 and #12 not participating in the third phase of interviews and participant #14 not having been in contact with the focal company since the second round of interviews. See Table 10.1 for an overview of project status and the reasons disclosed by participants. The large proportion of terminated and on-hold projects is a striking result in the light of the earlier expressed feasibility and desirability of the proposed solutions. The following section discusses the implemented and on-going projects, before turning to the projects that were terminated or on-hold.

10.2.1. Implemented and on-going

Case #15 was the only solution that was implemented at the time of the third phase of data collection. However, the participant explained that this had not been a straightforward process. After the second interview, the initial manufacturing partner had gone bankrupt. This was when the customer stepped in: the customer wished to progress the proposed solution and with their help a second supplier was found. The participant then arranged a transfer of IP from the bankrupt company to the new manufacturer, so that production could be started.

Participant #15 furthermore stated that conversations were on-going with regards to applying solution #15 on a much larger scale. He also expressed considering other adjustments to the design that would further reduce the product’s environmental impact. As such, the project can be said to have been successful in demonstrating that situations exist where both environmental and commercial benefits can be generated with the application of RLESs, as was the participant’s intended goal.

In cases #07 and #11a the additional time since the second interview had allowed the proposed solutions to progress further. In both these cases new partnerships were formed or existing partnerships expanded as well as additional (external) funding acquired. Specifically, advanced prototypes had been built and trials were due to commence within six months after the third interview, with the aim to test both the feasibility of the solution at some scale and assess the desirability of the solution from a user perspective through focus groups. As already stated above, in both cases the view on what resource flows were to be circularised and how had changed compared to the second phase of data collection. Specifically, in case #11a, where previously the product was to be disassembled and reconditioned by the user, the product was now to be disassembled and reconditioned by the manufacturer. A version of the same product was to be sent to the user as a replacement. On the other hand, in case #07 the change was in fact an extension: in three scenarios the prosed solution affected the post-consumer resource flows in the same way, whilst in a fourth scenario the prosed solution would allow for pre-consumer recycling.
### Status of proposed solution after 28 months

<table>
<thead>
<tr>
<th>Status</th>
<th>Number of cases</th>
<th>Case number and reason for status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implemented</strong></td>
<td>1</td>
<td>#15: support from customer drove implementation of solution; in the process of scaling up implementation</td>
</tr>
<tr>
<td>Product in production</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Development on-going</strong></td>
<td>2</td>
<td>#07: partnership continued for further development, prototypes produced, trial due to commence</td>
</tr>
<tr>
<td>Active efforts undertaken to develop solution further</td>
<td></td>
<td>#11a: new partnership formed for further development, prototypes produced, trial due to commence</td>
</tr>
<tr>
<td><strong>Development has taken on a different form</strong></td>
<td>3</td>
<td>#04: found and pursuing other niches to develop solution</td>
</tr>
<tr>
<td>Development proceeds by experimenting in other product niche or by pursuing implementation of a different scale</td>
<td></td>
<td>#05: developing technology application in a different niche, where RLESs capacity is largely unused</td>
</tr>
<tr>
<td><strong>On-hold indefinitely</strong></td>
<td>9</td>
<td>#01: awaiting customer engagement for further development</td>
</tr>
<tr>
<td>Intention or desire expressed to continue development of solution in future, although precise time uncertain</td>
<td></td>
<td>#03: awaiting customer engagement/ other funding opportunities for financial support</td>
</tr>
<tr>
<td><strong>Terminated</strong></td>
<td>2</td>
<td>#06: material targeted inadequate for meeting product requirements</td>
</tr>
<tr>
<td>No intention for further development now or in the near future</td>
<td></td>
<td>#13/1: terminated cooperation with designer of product</td>
</tr>
<tr>
<td><strong>Uncertain</strong></td>
<td>6</td>
<td>#02: no new information uncovered</td>
</tr>
<tr>
<td>No new developments to report</td>
<td></td>
<td>#11/12c: no new information uncovered from participant #12, participant #11 not aware of any new developments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#11/12d: no new information uncovered from participant #12, participant #11 not aware of any new developments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#12e: no new information uncovered from participant #12, participant not aware of any new developments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#14g: participant not aware of any new developments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>#14h: participant not aware of any new developments</td>
</tr>
</tbody>
</table>

*Table 10.1 Status of the projects at the time of the third interview, conducted on average 28 months after the first interview, with a short description of the reason for progressing or not progressing.*
In cases #04, #05 and #10 the development of the solutions had not stopped, but had taken on a different form. In case #04, for instance, additional funding was secured. This allowed for the development and realisation of a prototype in a different product niche than the participant initially envisioned targeting. This had not been without difficulties: initially, a follow-up bid had not been successful due to disagreement within the development team with regards to how to position the benefits of the proposed solution. This failure had forced the participant to explore other niches that could be employed for further development. As a result, instead of working in a large consortium to develop the solution in an integrated manner as was intended, the participant was exploring the potential to use customer projects with flexibility or reuse requirements to progress learning for the proposed solution. As such, the efforts of this participant were still directed at further developing the over-arching vision that the initial proposed solution represented, but was taking a more pragmatic approach to doing so: instead of iterating using a limited number of large projects explicitly focused at developing the proposed solution, the participant had shifted to using smaller projects where a synergy could be created between developing the proposed solution and meeting a client’s specific brief.

In case #05, in contrast, further development within a different niche meant that the RLES central to the original solution did not take centre stage any longer. Rather, a niche was found that allowed for further exploring the possibilities of the high speed automated customization technology necessary for the envisioned solution, in a context that was judged to be less demanding in terms of safety, durability and strength, and where failure was less likely and less critical. This new niche was in a different industry sector compared to the product that had previously been the focus of the redesign efforts. The participant expressed a desire to, once particular difficulties were solved, use the lessons learned to return to the development of the original product.

The scenarios explored as part of the project in case #10, on the other hand, were further explored and developed in a centralized effort. That is: the mother company had taken up the effort which had initially been a project led by a local branch of the company. A representative from the mother company who had been involved in the efforts of the local branch had now taken up the effort, whilst the participant initially interviewed had changed jobs. This job change as well as confidentiality prevented uncovering further information.

10.2.2. On-hold and terminated projects
Apart from one implemented solution and five ongoing innovation trajectories, nine other innovation projects were on hold for an undetermined period of time. In these cases participants had not been able to further develop the solution for a variety of reasons, but had not given up on it entirely. One reason for this was that a lack of financial means, whether in the form of additional funding or a commitment of a first customer, proved prohibitive. For instance, in case #01, #03, #09 and #13/2 participants indicated that the technical aspects of the solution were in need of further development, but that the financial means were not available or that an investment of this kind posed too great a financial risk to the focal company at the time.

In addition to this, participant #03 indicated that implementation of solution #03 required financial means for the creation of a set of modules large enough to be able to effectively assess the feasibility of the proposed solution. Here, a single prototype was not thought adequate for testing the proposed solution thoroughly, as the availability and flexibility of a set of modules was to be the very aspect of the solution to be tested.
In case #08 the direct possibilities to interest potential commercial parties in further developing any of the bio-material based directions had been exhausted. However, the participant expressed still being committed to persevering with the concept and to continue attempting to find partners interested in further developing the idea.

The participant in case #09 encountered similar scale issues: in order to acquire the desired additives for testing, a large investment was required beyond what the focal company could bear. This was due to the fact that the additive was currently not in production and economies of scale would only be reached if a large order was placed. This posed too great a risk for the company, as it was not guaranteed that the additive would be suitable for the intended application. Thus, cases #03 and #09 both experienced scale as prohibitive factor in continuing experimenting and developing the respective proposed solutions.

Case #09 furthermore encountered various other problems in the value chain: the manufacturing facility that was to process one of the raw material streams had become in-operational and the intended manufacturer of the final product had gone bankrupt. The participant indicated that personal motivation became exhausted as a result.

Case #05 likewise encountered losing access to an important manufacturing facility. In contrast to case #09, however, this did not prove prohibitive for further development as a new supplier could be found. This was not without disadvantages: the participant explained that the loss of the working relationship with the original manufacturer limited the possibilities for further experimentation.

In case #11b a lack of progression was not due to technical or supply chain difficulties. Rather, when attempting to patent an important part of the new product design, it was discovered that a similar patent already existed (had, in fact, been filed relatively recently). This meant that the design had to be rethought, which led it to become a low priority development that had not yet been returned to at the time of the third interview.

As well as a lack of funding, uncertainty with regards to how to progress the innovation trajectory also inhibited further progress in case #13/2: the doubt and uncertainty expressed during the second interview had not been resolved. The participant expressed being in need of advice with regards to next steps regarding this project. Unresolved uncertainty was also implicit in case #14: where the participant during the second interview had pointed to the fact that uncertainties existed around the size of the end-of-life market and cannibalization potential which prevented the focal company from committing to the proposed solution at the time. The participant expressed being uncertain how to acquire the information necessary to resolve this stalemate, as this required cooperation from the focal company.
Moreover, participants of cases #01, #03, #09, #11, #13 and #14 explicitly indicated that at the time of the third interview their attention or that of the focal company was directed at other projects and business priorities at the expense of the proposed solutions. This implied that these innovation projects were unlikely to progress in the near future. This is not to say that when circumstances change, development might be resumed. Such a change in circumstances is not thought likely, or at least requiring long term development, in case #06 and #13/1 and these development trajectories are therefore designated as ‘terminated.’ Specifically, in case #06, as was indicated previously, the material technology that was the focus of the project was deemed too immature by far and in case #13/1 the relationship with the product designer had been terminated, implying that a new partnership had to be formed before development could continue, which seemed unlikely given the designer’s intellectual ownership of that particular design.

10.3. Summary of results phase 03
Summarising: 11 projects, at least, were unable to move past the stage of gaining political and financial support for further development. However, in none of these cases this was attributed to the proposed solution. Only in case #13 the participant indicated considering the possibility to design the proposed solutions by use of cascaded substances only, which meant dropping the initially considered end-of-life RLESs, and to revisit the possibility to recycle the thus created product at a later stage, when revenue from sales was being generated. As such, participant #13 was the only participant that engaged in a re-evaluation of the proposed application of the circular economy concept. Indications of such a re-evaluation were not encountered in the remaining on-hold and terminated projects.
PART IV
Discussion & conclusion
11. Discussion

Seven key insights and directions for further work

This chapter synthesizes the results from the three data collection phases. Discussed first are the aspects found relevant in circular economy related meaning work. Considered next is the Circularity Compass v2.0, which is followed by a discussion of the prevalence of resource life-extending strategy (RLES) configurations in the dataset. Featured last is an examination of the progression of the innovation projects. Seven insights into how meaningful action recipes are created in relation to circular economy in particular stand out from the research. Participants considered 1) the particles, parts and products states as playing important roles in circular economy related meaning work; 2) other flows besides those directly related to the manufacturing of a product, such as material flows co-used with the product as well as energy and information flows, and frequently directed their attention to the infrastructure required in facilitating these flows; 3) those strategies that allow for the flexible use of product capacity as valid interpretations of what constitutes a RLES; 4) RLESs in sets of two or more, where they were frequently thought of as intimately related to each other; 5) addressing one or more barriers seen as inhibiting appropriate waste and resource management directly, whilst other barriers were subject to assumptions not further explored, or not acted upon; 6) various RLESs as possible outcomes of a proposed intervention, without the need to completely resolve targeted routes; and, lastly, 7) the majority of participants experienced difficulties progressing the proposed solutions due to an inability to generate financial and political support. In each section attention is given to the implications of these insights as well as to potential further work.

11.1. Relevant aspects in circular economy related meaning work
This section revolves around the first two key insights: the importance of the particles, parts and products states as well as the importance of other flows besides those directly related to the manufacturing of a product and attention directed at infrastructure issues. These insights flow from the following discussion, which reviews what was revealed about the data through the application of the collective action frame framework, or CAF framework. The CAF functions are used to organise the discussion, which means that it will discuss the problems that the cases intended to address; what was identified as appropriate solutions in terms of prevention as well as perpetuation; and the actors that were required to take a proactive approach in implementing the required change. Questions that arise as a result of the generated insights are discussed throughout; concrete suggestions for further work conclude this section.

Problem and mechanism
Start with considering the problem situation as described by the participants. From the case mappings of the business-as-usual situation it will be apparent that participants defined their respective problem situations differently: there were 10 primarily environmentally driven cases, three primarily non-environmentally driven cases and 10 multidimensional driven cases. This shows that resource life-extending strategies, or RLESs, were seen as able to address a wide range of problems as well as those problems that can be classified as wicked problems. The latter in particular is striking for two reasons. Firstly, the circular economy’s link with wicked problems contrasts with the simpler problem-solution combinations proposed by some of the waste and resource management frameworks, or WaRM frameworks, reviewed and analysed in Chapter 04.
Think of, for instance, the Waste Hierarchy or Industrial Symbiosis: in these frameworks the highlighted problems consist of a narrow set.

This finding could indicate that it may well be the aggregate of a multitude of perceived benefits that makes a proposed solution appear attractive. Therefore, in order to understand why a particular (set of) RLESs appear(s) attractive, it is insufficient to highlight a single or limited set of benefits where more benefits are present. Instead, these situations warrant an examination of what perceived benefits of RLESs are present, how they are related and what the mechanisms are through which they are generated. This indicates that the development of circular economy performance indicators – an area that is currently in its nascent phase – should take into account a rich set of considerations thought meaningful by practitioners, if the effectiveness of the circular economy concept is to be understood.

A second – and related – reason for why circular economy’s attribution with the capacity to address wicked problems is striking, is the fact that it shows the encompassing nature of the solution spaces that circular economy highlights. This begs the question of whether viewing circular economy as addressing multiple problems or generating multiple benefits makes its adoption more or less likely. For both points an argument can be made. On the one hand, if circular economy is viewed as addressing a single problem, costs and benefits can be compared in a direct manner along the relevant dimensions. For example, from the perspective of reducing carbon emissions, a cost-benefit analysis can be made which could consist of the magnitude of the investment required and the reputational benefits gained. Although costs and benefits might not be directly comparable in monetary terms, it is possible to make a judgement whether the gain outweighs or justifies the costs. When many different costs and benefits are added as in the case of wicked problems, such an analysis becomes more complicated. This could delay decision-making or confound it altogether. Moreover, understanding what benefits to highlight could aid in more effective promotion of the circular economy concept.

Prevention
In the three result chapters four observations were made in relation to the role of preventative strategies – those strategies that prevent a resource from being used in the first place. The first three observations related to prevention and resource life-extension specifically, the latter to the relevance of different types of flows. For a start, prevention featured prominently: in 13 cases, a total of 21 instances. This indicates that in little over half the cases preventative strategies were considered as part of the proposed solution.

Second, preventative strategies featured in relation to 1) materials contained within a product or those used in manufacturing processes (5 cases, 8 instances), 2) co-used material flows or those materials used alongside or with the product (3 cases, 3 instances) and 3) energy flows (7 cases, 10 instances). This indicates that participants considered different types of flows.

Third, participants thought of preventive and resource life-extending strategies as intimately related. For example, in case #01 the choice for a particular substance cascade meant that the product could be lightweighted compared to the then current alternatives on the market. A second example can be found in case #08: here, the choice for a particular renewable material was linked to the possibility of using less of a resource that was co-used with the product in the business-as-usual situation. Participants commented on the existence of a similar relationship
between RLESs and energy use. Specifically, energy flows were seen as potentially negatively affected by RLESs, but also as potentially synergistic with RLESs.

These three observations imply that preventative and resource life-extending strategies cannot be meaningfully researched in isolation. The academic literature, however, has not – as far as the author is aware – systematically accumulated knowledge regarding the relationship between RLESs and preventative strategies or developed a clear view on the conditions that generate desirable synergetic effects between these strategies. Generating such knowledge could aid in improving the outcomes of innovation projects driven by the desire for sustainable resource management. At the same time, this raises boundary issues for research in relation to what waste and resource management strategies should be studied together, whilst maintaining a manageable scope.

Boundary issues also arise from the inclusion of material flows other than contained within the focal product or required in its manufacture. Think of, for instance, case #08. Here, the co-used flow was thought of as comparable in environmental impact to the materials constituting the product in the business-as-usual situation. In the participant’s view the reduction of this flow was therefore of near equal importance compared to reducing the impact of the materials contained within the product. For this reason, the participant aimed to redesign the product in such a manner that the co-used flow could be significantly reduced. This raises the question of what flows should be studied when researching WaRM and how to address trade-offs and synergies. The author knows of little work exploring this question in the context of RLESs and circular economy.

For the final observation in relation to prevention, consider the different types of flows that were discussed: two different types of material flows, the first directly related to products and their manufacture, the second co-used with the product. In addition to this, energy flows were identified as another salient type of flow. Related to energy flows, due to the same call sounding in section 4.3 Insights from the analysis of WaRM frameworks for the clarification of its role were information flows. The participants saw information flows as enabling RLESs in 11 cases (#01, #03, #10, #11a, #11b, #11/12c, #11/12d, #14h, #15i, #15k, #15l), where information flows played various roles, ranging from prolonging product life, to linking demand and supply for used parts and recycled materials.

The inclusion of material flows as well as energy and information flows leads to a more general observation that has wider implications than for preventative strategies alone. That is: apart from material flows directly related to the product and those used alongside it, energy and information flows also play an role in creating WaRM action recipes. Moreover, not only do these flows influence the focal product flows, they furthermore influence each other. For instance, material and information flows, as stated, were perceived as directly or indirectly related in 11 cases (#01, #03, #10, #11a, #11b, #11/12c, #11/12d, #14h, #15i, #15k, #15l). Moreover, energy and information flows were shown to influence each other: in cases #11a and #11b information flows were attributed with the capacity to reduce energy-in-use. Finally, energy and material flows were also thought of as related – both positively and negatively – as expressed by participants #01, #02, #04, #06, #08, #10, #11 and #15.

Taken together, these observations indicate that a better understanding of the relationship between preventative strategies and RLESs and the conditions under which these relationships
occur could aid in shaping sustainable WaRM. From such future work guidelines or other practitioner tools could be derived that aid in formulating synergistic strategies. Moreover, co-used materials flows and energy and information flows need to be added to the aspects relevant to circular economy related meaning work. Future work should be directed at the nature of these relationships and under what conditions they allow for aligning WaRM with sustainable development.

**Perpetuation**

To provide a better understanding of how the participants approached the aspect of perpetuation – that is: those aspects of the proposed solution that relate to RLESs – consider the role assigned by participants to the different resource states described in Chapter 05: the particles, parts and products states. These ‘states’ refer to the following: the particles state indicates a phase where one would speak of resources in terms of materials, molecules and substances and the products state to the phase where resources take on the form of goods that end users can extract value from. The parts state is the intermediary state between particles and products and can be present or absent depending on the complexity and design of a product.

With regards to the products state, it can be said that it received a significant amount of attention: within the dataset 13 physical prototypes were made of (part of) products as part of the project or prior to the project but as part of the overall innovation project (cases #01, #02, #03, #05, #07, #09, #11a, #11b, #12e, #13/1, #13/2, #15i and #15k). In addition to this in two further, cases #15j and #15i, digital prototypes in the form of CAD designs were made. Product functionality was furthermore explored by means of storyboarding in cases #11/12c and #11/12d. Overall, products state considerations played a key role in 15 projects.

Considerations regarding particles state were of primary importance in eight cases (cases #01, #06, #08, #09, #13/1, #13/2, #15i, #15k). In these cases the focus was on the creation of a new material or the use of an existing material for a novel application. The particles state further received extensive attention in another nine cases (cases #02, #03, #05, #10, #11a, #11b, #12d, #14h and #15)). In these cases material choices were (re)examined, alternative materials sought and tested, and/or the influence of the material choice on the manufacturing process scrutinized and reconsidered. With the exception of case #05, the attention given to the particles state was a direct result of facilitating the proposed RLES.

The parts state furthermore played a key role in 14 cases, where a change in the role of the parts state occurred as a direct or indirect effect of altering an existing RLES, introducing an additional RLES or the parts state taking on new significance. This did not always mean that the parts state comes to play a larger role in the proposed solution. In fact, case #15i showed that the opposite can be true: the role of the parts state was to be reduced by redesigning the product such that this state can be disregarded at the end-of-life of a product. This was achieved by redesigning the product such that parts could be manufactured from a single material, which meant that when this product would reach its end-of-life it could be treated as a substance ready for recycling, without requiring disassembly or other treatment.

Cases #10 and #14h furthermore illustrated that the role of the parts state does not have to change conceptually for it to assume new significance. In these cases the parts state played a significant role in the business-as-usual situation both in the forward supply chains as well as at the product end-of-life. However, third parties, not the focal companies, were capturing the
residual value from second hand parts. Recently, the parts state had become regarded as a source of value by the focal companies and the proposed solutions therefore involved redirecting flows through systems controlled or more tightly controlled by the focal companies. The intention was, that this would enable the focal companies to recapture (part of) the residual value to their own benefit. As such, although its role did not change from a conceptual perspective, the parts state took on new significance in both these cases.

What was true for the parts state in cases #10 and #14, also held true for the particles state: the particles state had also become regarded as a source of value that the focal companies could get access to, given the appropriate interventions. The same interventions that would allow these companies to capture the value of end-of-life parts, would also facilitate the companies to generate value from the sales of end-of-life materials. This ‘single intervention, multiple RLESs’ approach was followed in a number of other cases, such as #01, #03, #04, #05 and #11a. What cases #10, #11a and #14 illustrate in particular is how intimately related considerations regarding resource states are for facilitating RLESs: not only can a proposed solution consist of RLESs from multiple resource states, but their implementation can furthermore be linked. Questions that arise as a result of this: are linked strategies more likely to be adopted than strategies that do not have such a relation and are they more or less effective than strategies that do not have such a relation?

The attention given to the particles, parts and products states might not be surprising given the scope of the InnovateUK competition: the bid explicitly called for a design contribution and it listed modularisation as well as design for disassembly and reconditioning as approaches that were likely to be part of successful bids. Moreover, it explicitly stated to welcome projects that reduced the reliance on certain raw materials and those that explored the use of alternative materials. Given this, the attention given the three resource states individually in the projects is perhaps not surprising. However, the attention given to multiple resource states at once across such a high number of cases illustrates, indicates that the participants did not perceive a dichotomy in pursuing particle and product based solutions at the same time. This is contrary to the particle-versus-product dualism that forms one of the major debates in the WaRM discourse, as described in Chapter 05. Instead, practitioners navigate the resource states as they see fit.

This observation raises the question whether there are more or less effective ways by which this process of navigating resource states can unfold. That is: whether an approach where strategies are deliberately ‘ruled out’ or ‘ruled in’ can generate more effective solutions. Foremost, however, this observation emphasises the importance of linking and integrating the existing bodies of knowledge regarding particle, part and product RLESs: an effort that although central to circular economy’s emergence is still at an early stage, as explained in Chapter 02.

A last aspect that warrants discussing here is related to the role of physical, informational and energy infrastructure. That is: the systems handling and transporting flows. Five cases focussed not on product design but on physical infrastructure to direct material flows: cases #02, #07, #10, #14 and #14. Apart from this cases #10 and #14 also considered the creation of informational infrastructure. In addition to this, case #02 addressed energy infrastructure by installing renewable energy capacity. In other projects existing infrastructure could be used or adapted (cases: #03, #05, #09, #11b, #12e, #15j, #15j, #15k). Infrastructure innovation thus constitutes an important aspect in circular economy related meaning work. This type of innovation, however, brings a unique set of challenges: infrastructure inherently deals with scale and economies of
scale, which means that small trials or experiments are either not meaningful or not possible as they can require large investments, making such innovations high-risk. Understanding how barriers related to innovating infrastructure can be overcome or the risk associated with these innovations reduced could thus prove valuable in progressing our understanding of implementing sustainable WaRM. At the same time, this could prove valuable guidance for practitioners whose proposed solutions relate to infrastructure. At present, however, there is little known regarding the role of infrastructure in circular economy driven innovation.

Proaction

Lastly, consider the proaction aspect of the CAF framework. By including this aspect it was possible to identify actors whose cooperation was deemed required in implementing the proposed solution. As such, this provided insight into where participants were dependent on other stakeholders beyond their direct or personal sphere of influence. The role of this aspect is discussed in more detail in section 11.4 Unfolding of circular economy related meaning work. For now, it is sufficient to note that a majority of participants was unable to gain financial and/or political support for their proposed solutions. Further work into how to overcome these barriers is required.

Implications and further work

The previous discussion identified a range of questions, the answers to which will increase our understanding of the circular economy concept. Further discussed here are three themes that were highlighted in this discussion: the use of the CAF framework and the need for knowledge integration.

The preceding has shown that using the CAF functions as they apply to WaRM can be an insightful lens to apply to circular economy related meaning work: all the CAF functions were productively used to describe and compare the various meanings attributed to the circular economy concept in the included cases. This indicates that these elements are indeed salient in circular economy related meaning work. In turn, this implies that they provide a useful basis for further research into circular economy related meaning work. A deeper understanding of these CAF functions could be generated, however, by the addition of more detailed problem descriptions; categories for prevention; categories for material flows such as those directly related to products and their manufacture and those co-used with the product; and, different types of stakeholders in order to unpack in more detail how and why circular economy driven innovation projects progress the way they do.

In addition to this, it was shown that the CAF functions as described in Chapter 04 and 05, need supplementing with additional aspects in order to capture circular economy related meaning work as it was shown that circular economy related meaning work has a much broader scope than those materials contained in a product and those involved in its manufacture. That is: other flows, namely energy and information flows, as well as infrastructure considerations need to be added to the CAF framework.

From the preceding another observation stands out: the need for knowledge linking and integration. Specifically, practitioners frequently navigated the particles, parts and/or products states together and they considered other flows besides those directly related to the manufacturing of a product, such as material flows co-used with the product as well as energy and information flows. Moreover, practitioners considered how these different types of flows
influenced each other. Frequently they also directed their attention to the infrastructure required in facilitating these flows. In addition to this, they thought about how preventative and life-extending strategies influenced each other and considered how to achieve multiple goals with single interventions. These observations lead to an over-arching insight: the need for linking and integrating knowledge in these areas, with the aim to develop what could be called an ‘Integrated Metabolism Framework.’

One avenue for establishing such a framework would be to explore the analogy of the circular economy as a metabolism change, and compare this metabolism change to other historical large-scale metabolism changes such as the impact on the biosphere of the emergence of life and the establishment of agriculture. Authors such as Christian (2011), Lenton and Watson (2011), Spier (2015) and Lenton et al. (2016), building on complexity theory and the work of Eric Chaisson (2001), have observed that when such large-scale metabolism changes happen material, energy and information flows and the accompanying infrastructure change fundamentally. In effect, this work expands upon the ecosystem metaphor currently wielded in the field of industrial ecology (e.g. Lifset 1997, Isenmann 2003, Wells 2006). This research domain explores the implications of industrial systems behaving more like ecosystems, by suggesting there are other natural laws – including those relating to complexity – that could prove insightful in aligning industrial systems with sustainable development.

A second avenue to pursue would be to conduct a meta-analysis of existing work on waste and resource management practices in relation to these relationships. In the field of Industrial Symbiosis, for example, attention has been paid to the creation of infrastructure and the interdependence that resource sharing creates in terms of scheduling (Chertow and Park 2015). By doing this across a number of disciplines related to circular economy, such as transitions science, the technical innovations literature and the large technical systems literature, new insights could be generated. Relevant in relation to this also is the question of what constitute appropriate system boundaries when studying RLESs.

An integrative effort could not only improve our theoretical understanding of large-scale transitions, but could also result in more pragmatic guidance for practitioners if structural relationships between elements are found: amongst other things, it could aid in understanding what is involved in innovating for circular economy, but also in formulating action plans that allow for the implementation of RLESs to achieve the intended goals.

11.2. What the Circularity Compass tells us about circular economy and its limitations

This section is dedicated to elucidating the third key insight: extending the definition of what constitutes a RLES to those strategies that allow for the flexible use of product capacity. For this, it is necessary to review the route typology as proposed by the Circularity Compass v2.0. This version of the Circularity Compass, depicted in Fig. 8.02, included a more detailed typology of RLESs, compared to its predecessor, presented in Fig. 5.01. Within the diagram of Fig. 8.02, RLESs are organised according to their renewal potential as seen from a product perspective and compared to its initial specifications: strategies with little renewal capacity are placed at the bottom and those with extensive renewal capabilities at the top.
The generated template of the Circularity Compass v2.0 largely follows Allwood et al. (2011) with regards to the product state RLESs, by including as-is reuse and surface or superficial alterations. The distinction between maintenance and reconditioning in the parts state is furthermore in line with Parkinson and Thompson’s (2003) typology of remanufacturing practices. These commonalities offer support for these parts of the RLESs typology.

Comparing the typology of the Circularity Compass with the strategies included in the WaRM frameworks in Fig. 1.01 and 2.01, one will notice that the strategies of reconstitution and reinvention are not mentioned explicitly in these other figures. These strategies were nevertheless important strategies in cases #02, #03, #04 and #05. Strikingly, these two strategies do not necessarily require the parts themselves to undergo operations that affect their physical condition. Instead, these operations rely on modular design, storage, redistribution and reassembly processes that allow for the product to be assembled in the desired configuration as and when required. What this implies, is that what can be thought of as a RLES is extended to the flexible use of product capacity. That is: the definition of a RLES goes beyond the redistribution of products, such as co-use, sharing and product cascades can achieve, and neither is it limited to the execution of renewal operations such as repair and remanufacturing.

Moreover, the addition of direct reuse to the template, offers a way to identify scenarios where an alternative to single use is part of the solution space. By acknowledging the possibility or impossibility of direct reuse, it becomes possible to compare like-for-like scenarios. That is, it facilitates the comparison of scenarios where this solution is a viable option versus those where it is nonsensical. As such, the inclusion of existing RLESs in the Circularity Compass template with the addition of direct reuse, reconstitution and reinvention integrates and extends existing typologies.

Furthermore, by the addition of a comprehensive set of mapping rules the proposed typology was developed into a methodology than can serve to provide insight into what solutions are being pursued in particular cases. It has to be recognized, however, that the Circularity Compass has a number of limitations. Firstly, the Circularity Compass allows for different levels of technical detail to be included, complicating direct comparisons. The business-as-usual situation, for example, was described using only a single flow in 6 cases where the product is known to contain multiple materials. Furthermore, in a mere 5 cases a gradient was applied to indicate a non-reversible bonding, which seems a low number for the total number of cases and the nature of the products included. Moreover, on a number of occasions flows had to be depicted using the minimal line thickness, indicating that being able to scale flows or zoom in on particular flows would be a useful feature if the method was to be used in future work. As such, the current mappings are not yet suitable for detailed technical analysis of proposed or implemented solutions.

Secondly, the current case mappings are not consistent with regards to the unit of analysis they employ. The mappings included in Appendix 03 represent the participant’s unit of analysis, which results in adopting such different perspectives across the dataset as a collection of subassemblies, the (segment of) a product group or a collection of products. This implies a lack of consistency with regards to what is regarded as ‘the product’ and also limits the direct comparability of the presented case mappings.
Another aspect with regards to which the case mappings vary is time. In cases #02 and #11/12c, for example, the size of the inputs were reduced in the mappings of the proposed solution compared to the business-as-usual situation, because it was explicit in the case data that this was the expected impact of completing a cycle. In the remainder of the cases however, this was not adjusted, as it could not be assumed that the proposed solution would substitute a material flow within the product system, and thus a direct impact on the required inputs could not be established. Cases #07-3 and #14g are cases in point, where the product’s life was to be extended by means of a charitable application, which means that these flows are not directly replacing a comparable application.

The Circularity Compass furthermore has a bias towards processes that take place outside of the use phase, by delegating the RLESSs that take place at the location of use to a single unspecified route. This and other limitations, such as is limited inclusion of value generated, however, did not inhibit the ability of the case mappings to provide insight into the proposed solutions on a conceptual level. In fact, it was made apparent that no two cases in the dataset proposed exactly the same solution, even in cases where the proposed solutions were broadly similar. For instance, in cases #10 and #14h where the goal was to recapture more of the end-of-life value of both parts and particles within the focal company, the envisioned configuration contained a different number of RLESSs, respectively processing different quantities of resources.

Saliently, the methodology associated with the Circularity Compass brings a new aspect to the contrasting and comparing of case studies by acknowledging that not all routes are available in all cases. This was done, for instance, by greying out direct reuse or reinvention where these strategies were not available, which allows for comparing and contrasting cases in a richer and more accurate manner. The (un)availability of strategies could furthermore feed into the development of circular economy metrics (more on this below).

**Implications and further work**

The route typology contained in the Circularity Compass v2.0 implies a different approach to circular economy compared to the WaRM frameworks listed in Fig. 1.01 and Fig. 2.01. Here, the routes designated tend to refer to operations that a resource can undergo, such as repair, remanufacturing, redistribution. Other interventions such as modularity, product-service systems or co-use are often likewise portrayed as if they represent a specific RLES within the circular economy literature (e.g. Glind ET AL 2015). The proposed typology, however, implies that such processes should not be seen as routes in their own right, but should instead be regarded as tactics that operationalize a particular strategy. Rather, any route or combination of routes as depicted in the Circularity Compass could constitute a strategy. One strategy can be, for instance, the pursuit of direct reuse when replacing a disposable product, supplemented with closing-loop strategies such as composting or recycling. A second example could be to facilitate users to perform maintenance, combined with professional reconditioning that allows for technological upgrading. This implies that studying tactics as phenomena in and of themselves will not generate significant new insights in relation to understanding the circular economy, but it is by understanding the role they play in addressing certain types of waste that new knowledge will be generated.

As such, the Circularity Compass offers a different way of understanding RLESSs. A helpful analogy might be the Business Model Compass by Osterwalder and Pigneur (2010): this tool for describing business models offered a new language and structure to examine business models,
by bringing together a range of elements long since studied in the management and business literature. By bringing together these elements in a particular manner, this tool created a new way of understanding these elements in relation to the phenomenon ‘business model’. The Circularity Compass has the potential to function in the same way for circular economy: it offers a broad structure for investigating how possible resource routes relate, allowing for a more detailed probing of the role of specific tactics. The Circularity Compass could thus be a useful addition to both the academic and practitioners’ toolbox.

The route typology contained within the Circularity Compass v2.0, particularly the addition of strategies that allow for the flexible use of product capacity in the form of reconstitution and reinvention, should be seen as an invitation to review what can be considered a strategy fitting within the circular economy concept. Such a reappraisal of the nature of RLES is in line with the circular economy concept entering the ‘further work’ stage of the developmental trajectory of circular economy as-an-umbrella-concept. In this stage umbrella concepts undergo further theoretical development and definitions are reviewed and, where possible, made more robust.

Further work could improve the mapping methodology in terms of the technical details it captures, quantification, the unit of analysis, the role of time as well as the intra- and inter-coder (or ‘mapper’) reliability. This could pave the way for the creation of larger datasets, containing more mappings, which could subsequently be used for performing statistical or other types of meta-analysis of case studies. Such analysis could be directed at comparing the different solutions on a range of different aspects, making it possible to deepen our understanding of the role of individual strategies and tactics. Moreover, such a database would make it possible to study how various companies are linked in material, energetic and informational webs. Lastly, practitioners could use such a dataset for inspirational purposes by looking at examples from other industries as well as to perform systematic analysis regarding what strategies could be used or improved upon by seeking links with other industries.

11.3. RLES configurations
Another salient aspect of circular economy related meaning work that this research brought to the fore is the importance of RLESs configurations: situations where two or more RLESs are or will be applied. The two key insights that relate to this are: the importance of studying the relationship between RLESs and the need to get a better grip on the value of partially resolving barriers to the implementation of RLESs.

When looking at the total of included cases at the second interview 10 participants acknowledged the existence of an existing RLES configuration: participants aimed to alter this configuration by shifting emphasis from one RLES to another (two cases) or address a particular barrier or set of barriers (four cases) such that better outcomes could be achieved in terms of the preservation of material quality or environmental impact. Moreover, one participant aimed to expand the existing configuration by introducing strategies new to a product or market. In a further three cases a combination of these strategies was applied. In the remaining 13 cases participants aimed to introduce or build new configurations. This indicates that the participants regarded a multitude of RLESs to be applicable to the problem situations at the same time.

Importantly, four different relationships between RLESs were identified by participants: 1) a causal relationship where the use of one strategy impacts the flow magnitude through another,
2) a comparative relationship that focuses on the different environmental impact of strategies, 3) a subtractive relationship in the form of trade-offs as well as 4) an cumulative relationship in the form of cooperative or synergistic effects on resource life-extension. This indicates that information about a particular RLES is not necessarily useful to a participant unless related to another RLES and points to the same need for integration as commented on in the above. It furthermore raises questions regarding whether particular RLES configurations – that is: particular combinations of RLESs – are more suitable to certain contexts and whether certain configurations are more likely to be adopted than others. Answers to these questions are currently lacking in the circular economy literature.

Moreover, the proposed RLES configurations were in at least nine cases subject to assumptions not further explored, or not acted upon. It was posited that cases of this nature revolve, at least in part, around the creation of possibilities. This means that these projects aim to address one or more barriers seen as inhibiting (better outcomes of) RLESs, whilst other barriers were not necessarily addressed. That is, in cases #01, #03, #06, #07, #09, #11b, #15i, #15j and #15k, participants aimed to remove one or more barriers seen as inhibiting (better outcomes of) RLESs directly, whilst being aware that one or more other barriers also played a role but that were not necessarily directly addressed as part of the innovation process. Or, if addressed, the evidence that the proposed solution would be effective in addressing the targeted barrier was lacking or unclear. For example: in case #03 the provision of information about the recyclability of the product was assumed to result in improved recycling rates, but other than the provision of information in the form of product certification, no further action was undertaken to examine or evaluate whether it was reasonable to expect this outcome.

In these cases, it was not self-evident that these proposed solutions would have the desired outcome due to the partial removal of barriers. This might create situations analogous to that of bioplastics: these materials are not treated separately at the end-of-life and thus rarely given the proposed mode of treatment – composting. Thus, if assumptions regarding end-of-life treatment are left unaddressed, efforts might be wasted. This is not to say that the creation of possibilities is not a worthwhile pursuit: they might come to fruition regardless, the remaining barriers might cease to exist or can be addressed at a later stage. However, a better understanding of the circumstances where such partial efforts yield results could help practitioners direct their efforts better.

**Implications and further work**

The importance of configurations implies that the relationships between RLESs are a vital part of circular economy related meaning work. For this reasons the list of Cradle-to-Cradle™ certified products (C2C PII 2016) should not be upheld as successful implementations of circular economy thinking. After all, these examples tend to relate to either compostability or recyclability of products and as such represent the implementation of singular strategies. The case study examples as presented on the website of the Ellen MacArthur Foundation, on the other hand, are more in line with the complexity that this research has shown to the present in the practitioner reality, as they discuss how different RLESs relate to each other (EMF 2016b).

Academic literature should, similar to this latter group of case studies, aim to provide insight into how RLESs relate. Work such as Hilton (2016), Kopka (2016) and Muranko et al. (2016), despite explicitly invoking the circular economy concept, might lead to improving our understanding of reverse logistics, recycling and remanufacturing, respectively, but by not including how these
strategies relate to (other) RLESs an opportunity is lost to learn more about circular economy as an-umbrella-concept. Instead – if meaningful insights are to be drawn regarding how interventions associated with circular economy contribute to sustainable WaRM – research into circular economy should take into account the relationships between RLESs both present and proposed, and study the whole of the configuration, such as in the manner of Hansel (2016) and Andrews ET AL (2016), that discuss the relationship and the creation of synergies between multiple strategies. In summary, and in line with Blomsma and Brennan (2017): RLES configurations should be studied as a unit of analysis in their own right.

11.4. Unfolding of circular economy related meaning work and how WaRM is impacted

Discussed in this section is the question of how circular economy related meaning work unfolds. This leads to the articulation of the final two key insights: first, that proposed RLESs do not need to be resolved completely with regards to their conceptual meaning in order to be considered actionable and desirable, and, secondly, that the majority of participants experienced difficulties progressing the proposed solutions due to an inability to generate financial and political support.

Conceptual solutions do not need to be unambiguous for action

Consider the progression of the uncertainties associated with the proposed solutions, as indicated by overlapping flows and blurred flows in the case mappings. Comparing the descriptions of the proposed solution given by participants in the first interview to the description provided in the second interview a total of five instances of the uncertainty regarding the capacity of a route or the co-existence of routes were resolved. This left a total of 10 instances unresolved. This indicated that aspects of the proposed solution on a conceptual level remained unclear at the time of the second interview. As many projects did not progress, this remained the case at the time of the third interview.

This did not inhibit the proposed solution being regarded as worthy of further pursuit by most participants. The exception to this being case #06, where the technology targeted for improved recycling outcomes was deemed unsuitable for application at the moment. This did not mean that all participants considered the proposed solution as feasible: participants #02 and #13 indicated not yet having made sense of the project results. However, these two participants nevertheless saw their proposed solution as worthy of further exploration and development. In fact, all participants, apart from participants #06 and #13, had next actions planned. This shows that not all ambiguity has to be resolved or disregarded in circular economy related meaning work for action recipes to be considered meaningful and actionable. The generation of options, as discussed in the previous section, offers additional support for this. From these two observations – unresolved instances of ambiguity and barriers left unaddressed – it can be concluded that only partial coherence is required for an interpretation of circular economy to be considered actionable. This seems in line with Taylor (2002) and Boons and Roome (2002) who argue that conceptual fuzziness can facilitate the adoption of a concept as it allows it to be moulded into being suitable for many different applications.

Implications and further work

The fact that actionable WaRM interpretations are not necessarily those interpretations that have all ambiguity regarding the targeted RLESs resolved creates a paradox: although practitioners apparently do not need absolute conceptual clarity, metrics and indicators
generally do. If practitioners cannot express their proposed solution in terms compatible with a particular metric, innovation processes might lead to sub-optimal outcomes as more effective options that do not fit the metrics might not even be considered. Participant #04 illustrated this: he commented on the perverseness of the end-of-life metrics as applicable to his project at the time of the first interview. In his view, these metrics favoured recycling over reuse, inhibiting reuse, which he viewed as the more environmentally attractive option. It is important to prevent the same short-sightedness characterising circular economy metrics. Thus, for the development of circular economy metrics it is important that they align with the mental categories of practitioners and allow for sufficient flexibility within those categories. That is: they need to strike a precise balance between being detailed enough to be meaningful and guide WaRM towards the most sustainable options possible, but flexible or broad enough to accommodate a wide variety of proposed solutions. The current metrics that have appeared on the scene, such as the Material Circularity Indicator (EMF and Granta 2015), should thus be evaluated and further developed from this perspective.

Large proportion of projects terminated or on-hold indefinitely
The final key insight discussed here relates to the large proportion of the projects that did not progress due to an inability to generate financial and political support. Strikingly, at the time of the second interview, of the 22 proposed redesigns still considered desirable, 20 had turned the attention from the (technical) development of the proposed solutions to considering stakeholders in the innovation process, whether internal or external to the focal company, in order to generate the financial means and political support to continue development or implementation of the proposed solution (the remaining cases being either terminated, choosing internal development or the next steps being unclear). This proved a barrier that at least 11 projects were unable to move past. It must be noted that (part of) the reason for this might lie in the nature or type of the projects that were selected by the funding body to receive support: the selected projects might simply have lacked the necessary sphere of influence in the value chain to affect the proposed change.

However, it is not unusual for publicly funded innovation projects to not reach the commercialization stage (Auerswald and Branscomb 2003) and it cannot be excluded that these projects might still progress at a later stage. Assuming, however, that not being able to gain support for the proposed solution is indeed of more general relevance in circular economy driven innovation, raises the question of whether and how this barrier can be overcome.

One suggestion might be to involve the relevant stakeholders earlier in the innovation process. However, participants #07 and #11 specifically comment on the timing of stakeholder engagement. Participant #07 stated that stakeholders are reluctant to get involved if the solution does not yet have the appearance of feasibility. In addition to this participant #11 stated that involving stakeholders too early can, in his view, be detrimental to the development of a solution. Moreover, in relation to cases #11a and #11b, participant #11 stated that the decision to develop the proposed solution internally first was a deliberate one in order to be able to, at a later stage, find partners suitable to the solution, not vice-versa. This raises the question whether there is a window of opportunity where early stakeholder engagement is critical and appropriate, or whether these exist types of projects where such early engagement can better be avoided.
Another suggestion in aid of gaining support might be to review the proposed solution. In case #13 the participant indicated considering adjusting the interpretation of circular economy. Specifically: it was considered to drop end-of-life recycling as a route to pursue in the short term. This would leave as the only RLES the use of a cascaded substance. It was speculated that the issue of recycling the thus created product could be revisited later, when revenue was being generated. Such a phased introduction of the imagined RLESs configuration could prove an important way of coping with the complexity of RLESs configurations. Case #11a has furthermore shown that after the initial feasibility assessment the proposed solution might still change considerably. As such, reviewing the proposed RLESs or the intended implementation plan at appropriate times might aid innovation projects developing further.

**Implications and further work**

These latter two points affirm that in order to progress insight into the application of the circular economy concept a better understanding of how RLES configurations develop and progress is crucial. Are RLES configurations that introduce multiple strategies at once more likely to be adopted than those that are introduced in phases and under what circumstances? This is a question yet unanswered by the circular economy literature, although the Industrial Symbiosis literature might have some initial answers to offer when it comes to substance cascades. Here, it is suggested that encouraging evolution of resource exchange systems might be more effective than central planning (Chertow and Park 2015). Whether this also applies to RLESs strategies more broadly is unclear and further work is necessary. What is worth highlighting in this regard is that only in case #06 the barrier that proved insurmountable was technical, so far as can be concluded from the limited progression of the innovation projects overall. This implies that research into the development of RLES configurations is likely to concentrate on other factors such as economics, legislative and social factors.

In light of so few of the projects progressing, it could be explored whether by using the Circularity Compass not in a descriptive capacity, but as a tool in active innovation projects, could prevent projects from stagnating. It could aid, for example, in reviewing the proposed solution, chart an implementation plan and gain an early understanding of a company’s sphere of influence such that key stakeholders and associated risks can be identified and addressed early.
12. Conclusion

The value of taking into account both action and cognition

This research explored how individual participants attribute meaning to the circular economy concept, investigated what aspects of WaRM are important in this, how the attributed meaning developed when projects progressed and how this influenced the enactment of WaRM practices. The aim of this was to understand how to support practitioners in implementing sustainable WaRM practices. This chapter reviews how this was accomplished and summarizes the key insights and suggestions for further work.

This research started with the establishing of a working definition of circular economy: circular economy as-an-umbrella concept. Circular economy was taken to revolve around assessing and organizing a collection of resource life-extending strategies or RLESs, where the assessment frequently extends to other types of WaRM strategies such as prevention. To understand better what perspective to adopt towards this topic a historical narrative was presented that anchored the circular economy concept in the overarching WaRM discourse. From this, it was evident that circular economy is part of a process attempting to determine what constitutes appropriate WaRM. Specifically, the concept is both an outcome of this meaning generation process as well as a tool to progress it further. As a result, the process that establishes the meaning of the concept was conceptualized as circular economy related meaning work. This positioning implied that understanding how the concept creates internally coherent recipes for action would be key in understanding how the concept is interpreted.

This positioning triggered the investigation into how current WaRM frameworks accomplish this and the role of how both resources and waste is defined. This illustrated there is structure to circular economy related meaning work: it is not a random process. Instead, this process can be thought of as starting by drawing on a particular set of definitions regarding waste and resources. This set determines the boundaries of the interpretations possible. Meaning work then proceeds by establishing specific interpretations of these definitions with regards to the CAF functions of purpose and mechanism, prevention, perpetuation and proaction. Thus identified were the three main pillars for the Circularity Compass: the collective action frame (CAFs) functions as applicable to waste and resource management, and the typologies for waste and resources. With the creation of the Circularity Compass an analytical framework was created that could serve to capture the meaning attributed to circular economy in the empirical part of this research.

Grounding the research in the theoretical framework of meaning work furthermore implied that meaning should be regarded as a contextualized phenomenon, implying that it had to be studied in a real-life context. Thus chosen were 15 participants partaking in innovation projects inspired by the circular economy concept that received public funding for the part of the project aimed at assessing the feasibility and desirability of the proposed solution. This first phase lasted between 2 to 6 months and would become a longer-term innovation project in at least six cases. Through this insights were gained into 23 innovation projects, covering 19 focal companies.
A third implication of adopting meaning work as a theoretical framework was that a single observation or snapshot of the meaning attributed to the concept would not suffice, as meaning work is a processual phenomenon and meanings change as a result. Consequently, interviews were conducted in three phases at different stages of the projects: when the projects were ongoing or were due to commence, on average seven months after the first interview and on average 28 months after the first interview. This allowed for tracking the interpretation of the proposed solutions over the research period and made it apparent that the proposed solutions does not need to be free of conceptual ambiguity in order for action to be possible.

Lastly, meaning work requires inclusion of both action and cognition, as it poses that action and cognition exist in a recursive relationship. This implies that not only the established interpretation, but also the manner in which it is acted upon is part of the meaning attributed to the circular economy concept. This directed the attention to aspects of the proposed solution that were actively explored or acted upon as well as those aspects that received relatively little attention. Thus made apparent was the role of assumptions not further explored or not acted upon. Moreover, this allowed for tracking the overall status of the innovation projects over the period covered in this research: whether they progressed and in what form. This brought to the fore the limited amount of projects that had progressed at the time of the third interview.

Thus, drawing on meaning work as a theoretical framework allowed for both the creation of the analytical framework designated as the Circularity Compass and dictated the research approach appropriate for using it. Following this approach generated a range of new insights in relation to circular economy. Among these insights, most notably, that the meaning work framework as laid out in part I and II of this research provided a useful starting point, but that it should be supplemented with co-used material flows, energy flows, information flows and infrastructure aspects.

As such, the research sub question regarding what aspects of WaRM are important to practitioners in establishing an interpretation of circular economy, how these aspects are imbued with meaning and made actionable can be answered: the definitions of waste and resources; the CAF functions of problem and mechanism; prevention; perpetuation; and proaction play a role; but also co-used material flows, energy flows, information flows and infrastructure aspects. Moreover, the discussion uncovered a need for linking and integrating knowledge in areas, such as knowledge regarding the different RLESs on the different resource states, how RLESSs function in configurations and how RLESSs relate to preventative strategies. The Circularity Compass and associated mapping methodology needs to be made suitable for this as it currently merely allows for signalling the presence of energy and information flows, but not for analysing the direction, magnitude or structure of these flows. Two avenues were suggested for this: exploring the analogy of circular economy as a large scale metabolism change with other historical large-scale metabolism changes such as the emergence of life and the establishment of agriculture, in the manner of Spier (2015) and Lenton et al (2016); as well as conducting a meta-analysis of existing work in relation to these aspects.

With regards to the sub question of how circular economy related meaning work unfolds, the following two observations can be made. Firstly, the fact that actionable interpretations do not have to have all remaining ambiguity regarding the targeted RLESSs removed for it to be considered actionable and desirable. In fact, some projects deliberately did not address all perceived barriers, but aimed for the creation of possibilities instead. This could aid the adoption
of the circular economy concept, but also poses difficulties for the development of metrics: i.e. how to develop metrics that offer enough specificity to compare alternative solutions whilst remaining flexible enough to account for different mental categories employed by practitioners. Secondly, it was shown that a prominent barrier that projects can encounter is the moment (wider) stakeholder support is required for securing the financial means and political support to continue development or implementation of the proposed solution. Further work should therefore be directed at how to progress projects beyond this stage.

With regards to the last sub question of how the circular economy concept influences WaRM practices it can be concluded that it holds potential for affecting change: one implemented solution was in the process of scaling up implementation, five other projects were still underway and of a further six the current status was uncertain, which mean they could or could not have progressed. Longitudinal research is necessary to be able to assess the impact of these projects. Moreover, it cannot be excluded that the projects that were on-hold will never be implemented. If anything, this indicates that further work into how to stimulate or aid the adoption of sustainable WaRM practices is necessary.

As such, the sense or non-sense of the circular economy concept on the level of the economy as a whole remains to be proven: it cannot be said to have reached coherence and validation yet. However, this research has made important steps towards creating conceptual clarity in the circular economy area as well as how to study resource life-extending strategies as a collection of strategies, as opposed to isolated individual strategies. By conducting the theoretical work as well as the action research proposed in this thesis, however, a significant and meaningful contribution to this assessment could be made.
13. Personal reflection

Multidisciplinarity, method and contribution

This section provides a brief auto critique of the thesis. There are many small lessons that will prove valuable in conducting further research such as that printouts and drawings can still beat digital analysis tools and that it is good practice to start interviews with very basic questions that ensure the collection of basic information. However, here I will reflect on how multidisciplinarity, the use of method and articulating a contribution have influenced this research and how, were it possible to turn back time whilst retaining the lessons learned, these lessons would result in conducting the same research in a different manner.

In my education as a design engineer, I was taught that a good designer knows a little bit about many other disciplines: enough to be able to engage productively with various specialists. When doing academic research, however, I quickly learned that it is not sufficient to be a generalist of this kind. To understand a field or discipline one needs to know what the current debates are and how those debates have developed. Without this, one cannot claim to understand how a method is to be applied, what assumptions are embedded in a debate or what a discipline regards as its development paradigm. These are all essential ingredients for generating new knowledge.

This, then, poses a problem for researching circular economy. Circular economy can be approached from a multitude of different perspectives: from product design, reverse logistics, business models, materials engineering, process engineering and other perspectives still. However, adopting any of these perspectives does not help in understanding what it is, why it is here and how it is to be regarded; and adopting all of these perspectives is not feasible. Thus, a strategic choice has to be made with regards to what perspectives to adopt.

Moreover, when I started my research, it had not yet crystallised that I would be focussing on the circular economy concept. Instead, my focus was on sustainable oriented innovation - with circular economy representing a particular instance of such innovation - and my reading was wide and varied around this already broad topic. I roamed from the transitions literature, to papers about business models, and from the core texts on innovation by Rogers and Van de Ven to work on social and environmental accounting and the system sciences. At that time, also, circular economy was not yet gained the importance that it is attributed today.

In other words: when I started this research, it was not obvious that I would write this particular thesis, what methods I would use, or what field I would contribute to. My own background combined with the nature of circular economy resulted in a struggle with regards to what to regard as my 'academic home' and where and how to contribute. This was not easily resolved. Initially, I was discouraged from exploring the background of circular economy. However, having been exposed to Cradle-to-Cradle™ during my design education, to Blue Economy during my foray into manufacturing and then to the Circular Economy framework during the early stages of my research, meant that a suspicion was building with regards to the fact there was something interesting going on: these frameworks were too similar and yet too different to not pose a mystery worth unpacking. I had started asking myself: why are there so many frameworks with a similar core idea, interpreted in such different ways? Key events that further crystallized that this
would be an interesting question to look at were reading The Social Embeddedness of Industrial Ecology, attending the Gordon Research Conference for Industrial Ecology in 2014 and the discussions about circular economy with Geraldine Brennan, a colleague PhD researcher at the time.

However, I did not feel confident about the approach that was forming until encountering the Lounsbury et al. (2003) paper and the work of sociologists Martin O’Brien and Susan Strasser. In the meantime, also, I had seen how multiple scholars whose work I admired were comfortably straddling multiple disciplines or fields. Margaret Archer’s work on sociology, but also the system sciences, and Frank Boons’ on industrial symbiosis as well as on business models among them.

Given this journey it is perhaps not surprising that I ended up drawing heavily from work by sociologists, but also organizational science and industrial ecology. Although it fits this particular research, I cannot say it was by design that this research took its eventual shape. Retrospectively, I would have dedicated more conscious attention to this aspect of the work in order to be able to both deliberately signal this to readers of this thesis as well as explicitly address concerns this might raise. Integrating the framing and sensemaking frameworks (Chapter 03), for example, is something I could have undertaken sooner if I had identified the need to integrate cognition and action in a single framework. The signals that these perspectives stemmed from different disciplines and the need for integration that this implied, is something I will be more aware of in the future. Likewise, organizing the discussion around the WaRM frameworks (Chapter 04) as well as the debates around conceptualising resources and waste (Chapter 05) I will not again mistake for something other than what they are: methodological stepping stones. In future work, where I hope to be privileged to undertake further multi-disciplinary work, I would pay explicit attention to this by reflecting on suitable formats for conducting such integration.

This furthermore ties in with a second reflection point: the development of the Circularity Compass. The Circularity Compass did not start out as an analysis tool. Initially, it was merely meant to be a clarifying and supporting image visualising the proposed solution, with the analysis of the individual cases to be done by using narratives or thick description. Although I was aware of the fact that by creating these images I was aiming to create some kind of overview that would help me understand the various cases, I did not initially recognise it as something with an important methodological aspect to it. It was not until I had undertaken several iterations of this tool that I realised how fundamental the difficulties were that I was experiencing to the waste and resource discourse in general and circular economy specifically and that this was something worth addressing explicitly in my research.

If I had focussed my attention on this instead of adhering to the narrative approach – which, in retrospect, would have been problematic given the data collected - I suspect I could have made more progress with the development of the Circularity Compass. Contributing to this inhibition of exploring the difficulties encountered with the Circular Compass, at the time, was my fear of doing something so unconventional that it would not be a clear contribution to any field or discipline. By adhering to the narrative approach, I was hoping to create something that would more clearly fit with existing methods and build on an existing body of knowledge more clearly. Now, given the positive feedback on my work so far and on the Circularity Compass in particular, I would not shirk from this, but give it the attention it deserves.
A final lesson that I will carry forward in conducting future work is the confidence I have gained in letting go of the details of individual cases in favour of the over-arching patterns. The stories the participants in this research shared with me were incredibly rich and I learned more from them than I could possible include in a document of thesis length. Following a narrative approach for the analysis seemed a good fit for this reason, as it allows for the inclusion of many details. However, it did not fit with what I was trying to understand: I was not trying to understand how the particular participant had ended up being in a particular profession, within a particular company, doing this particular project, but rather how and why they applied the ideas of the circular economy. The nuance between these two positions lies in the fact that the first is primarily historical, the second contextual. This is not to say that these are not related, but they represent a different focus. Recognizing this, I hope, will make me a more effective researcher in the future.

Thus I would summarise the lessons that I am taking forward in future research as follows: embrace multidisciplinarity by giving synthesis of method or theory its due; recognize methodological stepping stones and explore them to sufficient depth; and ‘less is more’: concentrate on where you contribution lies.
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Appendix 01
WaRM frameworks reviewed and analysed
Industrial Symbiosis (IS)
sources: e.g. Lowe and Evans (1995), Korhonen (2005), Chertow and Park (2016) 

A sub-field of industrial ecology (Chertow and Park 2015), Industrial Symbiosis (IS) is not associated with a single organization or a specific person as its advocate, although the first academic paper on IS is generally attributed to Lowe and Evans (1995). Instead, the case study of Kalundborg in Denmark fulfills the role of icon or illustrative symbol: referring to the material and energetic by-product exchanges between the industrial facilities located there and between these facilities and the town (Kalundborg Symbiosis 2014). Included here a description of the Industrial Symbiosis framework: not the field as a whole.

Purpose and mechanism
IS strives to create environmental and economic benefits (Chertow and Park 2015) in a manner that matches “industrial input/outputs to the real limits of Earth’s carrying capacity” (Lowe and Evans 1995:47). The reason for the current absence of these benefits and manner of operation is, according to Lowe and Evans, that “common sense” was “forgotten” when “industrial culture spawned disciplines to manage its operations” (Lowe and Evans 1995:48). That is: optimization of manufacturing systems was neglected due to increasing fragmentation of activities.

The basis of IS, the notion of industrial metabolism (Ayres and Kneese 1969) extended with the natural ecosystems model (Erkman 1997), offers a way of reintroducing relevant relationships in industry. This is achieved by establishing mutually beneficial resource exchanges between production facilities, much in line with nature: industrial “food webs” can be created where water, energy, material by-products and wastes are shared cooperatively across organizations (Chertow and Park 2015). Important principles in IS are diversity, connectance, interdependency, symbiosis, cooperation, community, adaptation and locality (Allenby and Cooper 1994, Benyus 1997, Ehrenfeld 2000, Korhonen 2000, 2001 and 2004, Hardy and Graedel 2002, Geng and Cote 2002. In: Korhonen 2005).

Prevent
IS indirectly contributes to prevention, as it negates the need for virgin inputs. For example, through energy and material cascades the extraction of excessive quantities of virgin raw material, and associated emissions, can be prevented. Although rebound effects can occur (Korhonen 2005). IS is to avoid “locking in continued reliance on toxic materials;” pollution prevention should take priority over applications of IS (Lowe and Evans 1995:51).

Perpetuate
IS pursues the increased utilization of energy and substances through cascading, thus addressing the output side of the input-output ratio central to the object logic both for individual facilities and the industrial system they are a part of. Cascades transform resources in some way: as a consequence they do not return to their original virgin-like state. Exchanges between facilities are therefore likely to be of different resources and can take the form of webs when many facilities are involved (Korhonen 2005).

Proactive
A debate is on-going whether IS can be designed or should be guided instead (Chertow and Park 2016). In the first scenario government plays an enforcing role, where industry takes the lead in the second, with intermediaries and digital facilitation offering support. Once an IS site is in operation, side-wide management is required to ensure its continued existence (Lowe and Evans 1995).
References


The Blue Economy (BE)
sources: Gunter Pauli (2010), (2012)²

Gunter Pauli’s previous experiences as an entrepreneur taught him that “biodegradability and renewability do not equate sustainability” (Pauli 2010:xxvi). His subsequent search for what sustainability entails resulted in the formulation of the Blue Economy, based on principles formulated by the Zero Emissions Institute (ZERI). The associated publication The Blue Economy (Pauli 2010) was designated a Report to the Club of Rome.

Purpose and mechanism
The purpose of Blue Economy is to better serve basic human needs, such as food security, fertile soil, clean water, medicines and jobs, whilst staying within planetary boundaries. More generally, the Blue Economy can be said to pursue the generation of benefits whilst solving local problems with locally available resources. Pauli attributes the Blue Economy with the capacity to “engage (...) regeneration” (ibid:X).

Pauli describes scarcity as “contrived” (ibid:70) and as a “syndrome” (ibid:52) of the current economy. Nature does not suffer from this, but instead transforms “apparent scarcity into sufficiency and ultimately into abundance” (ibid:233). Business should therefore work with natural processes and use nature as a model for its operations. An important aspect to this is systems thinking, which involves taking into account a critical appraisal of the problem and how it can best be solved. Through the Blue Economy’s focus on nature, it singles out the biosphere as the metabolism of choice for cycling.

Prevent
However, Blue Economy stresses that cycling is not always the preferred solution: it may be more appropriate to dematerialise instead. Therefore one should, where possible, first consider whether it is possible to replace something with nothing: a principle that features in multiple guises in the list of 21 principles that define Blue Economy. As such, it stresses the importance of questioning the use of resources and finding functional replacements or other radically efficient solutions. Blue Economy implies that this can often be done, since nature itself continuously does it. The same philosophy applies to the use of energy: nature does not use it in excess and uses renewable sources such as naturally occurring temperature and pressure differential to generate electricity.

Perpetuate
Cycling, where appropriate as a solution, happens in the biosphere and as such only biocompatible and biodegradable materials are to be used. Cycling either happens by letting nature transform and absorb materials after they have performed their functions, or can be delayed through the use of cascades. Cascades, in the Blue Economy, are achieved through the controlled transformation of a substance through multiple use phases and successive biological kingdoms, whilst extracting value or utility at multiple points. The material is transformed through each cascade, which implies that material quality has new meaning at every stage. The more successive cascades follow each other (with addition of extra materials where required), the more opportunities for value creation are generated. Blue Economy assumes that all resulting end-products are safe for nature to absorb as nutrients and start the cycle again.

Proactive
Blue Economy suggests that businesses should adopt systems thinking, which implies, among other things, a willingness to learn new competences and exploit new technologies in order to generates multiple streams of income from a single resource. This, according to Blue Economy, will improve the resilience of a business as well as ensure the most efficient use of resources.
References


Pauli, G., 2010. The Blue Economy: 10 years, 100 innovations, 100 million jobs, Paradigm Publications.
Cradle-to-Cradle™ (C2C)

Cradle-to-Cradle™ comprises an inspirational vision, analytical framework and prescriptive certification programme for product design and material composition. The framework was born from the cooperation between chemist Michael Braungart and architect William McDonough. An outline of the ideas contained within this framework can already be found in the Hannover principles (McDonough 1992), published a decade before the seminal Cradle-to-Cradle: remaking the way we make things (Braungart and McDonough 2002).

### Purpose and mechanism

Cradle-to-Cradle™ aims to improve and preserve human and environmental health, create abundance and counter scarcity so that current as well as future wants and needs can be served. In The Upcycle the authors broaden this vision to doing “good” alongside reducing “bad” (Braungart and McDonough 2013).

These benefits are currently absent, because current systems are not geared towards preserving material quality and productivity and create a “materials-in-the-wrong-place problem” (ibid:211). That is: materials are mixed with materials of other types, which stands in the way of their continued (maximal) productivity and results in downcycling, landfilling or the materials ending up in locations where they cause harm, such as the atmosphere or food chains. The answer to this is eco-effectiveness: managing materials either through using or mimicking nutrient cycles in biological food webs, thus conceptualising materials both literally and metaphorically as “nutrients.” This creates two metabolisms, biological and technological, that function in parallel and ensures “abundance at the molecular level” (Braungart and McDonough 2013:190).

Prevent

Preventing throughput is not a focus within Cradle-to-Cradle™ and therefore efficiency is not a focus. In fact, efficiency is seen as a side effect of equity: efficiency ensures the fair distribution of goods and services (Braungart et al 2007). The authors are also unconcerned with consumption and the pursuit of luxury and instead focus on what they call ‘doing the right things,’ instead of doing them efficiently. However, where toxins are concerned, the authors are clear: the use of toxins should be avoided or phased out wherever possible (Braungart and McDonough 2013).

Perpetuate

Cradle-to-Cradle™, its authors propose, can be implemented through designing for cycling in the appropriate metabolism and the creation of material banks that facilitate the practice of material pooling. That is, the current producers of raw materials no longer sell, but lease materials to companies who give consumers access to them through product-service systems. After the materials return to the material banks, they can be treated appropriately, because the bank possesses the information required to do so (Braungart et al 2007). Cycling should be accomplished using renewable energy only (Braungart and McDonough 2002).

Proactive

Business should act in a way that removes the need for regulation. Importantly, regulators should not provide perverse incentives, such as banning materials without viable alternatives being available, as this can lead to the increased use of other substances even more toxic (ibid). Cradle-to-Cradle™ furthermore requires that designers educate themselves on materials and design accordingly.
References


Sustainable Materials Economy (SME)
source: Kenneth Geiser (2001)

Kenneth Geiser’s book Materials matter: towards a sustainable materials policy (Geiser 2001), is the result of a personal encounter with victims of a factory tragedy and the ensuing quest to prevent such disasters from occurring in the future. The work contains evidence in support of both the necessity and feasibility of a sustainable material future.

Purpose and mechanism
Geiser pleads for a materials policy, both legislative and as practiced within industry, that: “optimizes value from the use of materials, adds no new risks to everyday life, increases natural capital, minimizes the transfer of risks from one generation to another, respects and enhances the natural functioning of the planet’s ecosystems, and ensures no net loss of valuable resources” (ibid:371)

Geiser describes the current situation where remediation in the form of end-of-pipe measures are the norm as an “industrial and technological crisis” (ibid:xvi), brought about by the inability to prevent problems from occurring. Instead harm should be designed-out through paying attention to the design of products and production processes. Critical to this is the development of appropriate industrial materials and corresponding management practices and infrastructure. To achieve this more factors need to be taken into account than cost and performance alone and industry needs to become more socially responsive.

Prevent
Prevention is Sustainable Material Economy’s main aim, embodied in two main principles. The first is detoxification, which entails the reduced dissipation of degradable toxic materials; the reduced use of persistent, bio-accumulative and toxic materials; and the development of environmentally appropriate materials. The second principle, dematerialisation, has two aspects to it. The first are such measures as efficiency and lightweighting, when they reduce ecological costs associated with extraction as well as reduce environmental costs associated with reduced or prevented disposal.

Perpetuate
The second aspect to dematerialisation involves a range of cycling strategies, such as increased intensity of material use through recycling and the substitution of services for products. However, when applying circular strategies, due consideration should be given to which of the three metabolisms a material is cycling within: the biosphere, the technosphere or a hybrid of the two where materials must be treated before safe return to the biosphere is possible. However, cycling can never be perfect and there will always be a “baseline need for material inputs” (ibid:314). Each metabolism furthermore has conditions attached to it that constrains cycling, such as, in case of the biosphere, the flow rate not exceeding the regeneration rate.

Proactive
Geiser points to the absence of a silver bullet: “there is no single policy remedy that can achieve all of this” (ibid:372). He therefore advocates a comprehensive and integrated approach based on life-cycle thinking and continuous improvement. Various scientific disciplines such as materials design, material sciences and information systems are involved in this, as well as actors such as governments, manufacturers, suppliers and customers. This entails, for example, governments enforcing extended producer responsibility and business transforming their business models from sales-oriented to selling services.
Reference

Product Life-Cycle System (PLCS)
sources: Environmental Protection Agency (1993)^

Developed as part of the Pollution Prevention Research Program the Product Life-Cycle System (PLCS) framework suggests the means of cycling as proposed in the Environmental Protection Agency's *Life Cycle Design Guidance Manual* (EPA 1993).

**Purpose and mechanism**
The PLCS aims to reduce health risks and environmental impact (e.g. resource conservation, pollution prevention, preservation of ecosystems and environmental capital) through reducing the “aggregate generation of pollutants across all media” (ibid: iii). This has to be balanced with other considerations, such as product performance, cost, equity, human capital, legal and technical requirements and the maintenance of a viable economy. The absence of the desired balance, according to EPA, is caused by a lack of systems thinking in the product and process design and development stages.

The remedy therefore lies in thinking in “product systems,” defined as a single unit that contains “all activities needed to make, use and retire products” (ibid:16) and includes “management/Information components” (ibid:iii), as “proper information encourages the use of materials and products with reduced environmental impacts and health risks” (ibid:92). This definition extends to services, and points to an array of solutions.

**Prevent**
Six of the seven categories of strategies identified by PCLS have a preventative theme or aspect: product system life extension (e.g. appropriate durability), material selection (e.g. environmental cost of sourcing and processing practices), reduced material intensiveness, improved process management, efficient distribution (e.g. efficient routes) and improved management practices (e.g. phase out high impact products). However, such high-level solutions as limited growth and population control also feature.

**Perpetuate**
Furthermore, four of PCLS’s seven categories have a focus on perpetuation: product system life extension (e.g. remanufacturing, reuse), material life extension (e.g. recycling, energy recapture), efficient distribution (e.g. reuse of packaging) and improved management practices (e.g. reuse). PLCS distinguishes between open- and closed-loop recycling and recognizes that quality differences between different “scrap” grades (home, preconsumer and postconsumer scrap) influences what processes are possible. The framework also mentions the importance of labelling the materials with identifiers such that recycling can be enabled.

**Proactive**
PLCS acknowledges that achieving the desired balance can be a complex task when conflicts exist between “various classes of design criteria, self-interests of the life cycle participants, and the time-cycles affecting product system development and implementation” (ibid:iii). Achieving the desired balance therefore requires “concurrent design:” a coordinated effort between all parties involved in the product system in the design stage, across the functions of design, engineering and management, using multi-disciplinary knowledge.
Reference

Performance Economy (PE)
Various iterations of Stahel’s thinking since he co-authored the 1982 publication of Jobs for Tomorrow (Stahel and Reday-Mulvey 1981) eventually culminated in the 2006 publication of The Performance Economy. The Performance Economy is a framework and inspirational vision targeted at businesses and policy makers alike.

Purpose and mechanism
Stahel characterizes the current industrial economy by stagnating levels of wealth and growth, excessive resource consumption, high levels of waste and rising levels of debt and unemployment. Transitioning to the Performance Economy, however, can bring “increased wealth creation, more jobs and reduced resource (materials and energies) consumption” (sic, Stahel 2006:4). In essence, the framework pursues decoupling.

To achieve these goals, Stahel proposes to focus on performance and the pursuit of radical performance improvements. Performance, as used by Stahel, refers to radical efficiency, utility, smart solutions (bio and nanotechnology), miniaturisation and system solutions. The latter refers to both ‘smart’ systems solutions based on alignment of interests across actors and ‘framework’ systems solutions, such as changes in legislation. An important tool in achieving these goals are the use of new metrics aimed at increasing the value per quantity of material weight.

Prevent
The pursuit of dematerialisation is one implication of a focus on performance. Although the reduction of throughput is a quantity issue, it is an important approach, according to Stahel: “Doing the right things does not distract attention from doing things right” (ibid:287). As such, prevention is a major focus of the Performance Economy. Also, as a general principle, Stahel acknowledges the importance of limiting toxicity to achieve sustainability, even though the Performance Economy does not operationalize this explicitly.

Perpetuate
A second implication of the pursuit of performance, according to Stahel, is that the preservation or recapture of materials for as much and as long as possible, is of vital importance. Although all cycling strategies are capable of achieving perpetuation to some degree, vast differences exist with regards to their capacity to capture value under different circumstances. Value can best be retained with access to high-quality information about the resource, which is the case when manufacturers retain ownership, in what Stahel calls the Lake Economy. Such information is typically lost when ownership is transferred, as is the case in the Loop Economy, making cycling less effective. Preservation of the product shape, however, has the capacity to retain the highest possible value here also. Essentially, the Performance Economy distinguishes between open- and closed loop cycling.

Proactive
Implementing a Performance Economy implies that businesses need to operate service-oriented business models that integrate extended producer responsibility. Appropriate legislation should stimulate this development. Also, tax systems need to be redesigned as to derive revenue from the taxation of the extraction and transformation materials, not labour (Stahel and Clift 2015).
References


Material Efficiency (ME)

Material Efficiency codifies the insights of a 5-year collaborative research project with industry, supervised by Julian Allwood (Allwood et al 2011, Allwood and Cullen 2012). The framework is concerned with engineering materials: the materials used in bulk in buildings, infrastructure and goods, such as steel and aluminium, but also paper, cement and plastic.

Purpose and mechanism
Material Efficiency aims to achieve the 50% recommended reduction in CO2 emissions by 2050, 1990 baseline) (IPCC 2007), whilst assuming a doubling of material demand. The authors use this metric as a proxy for sustainable development.

The framework poses that manufacturing industry is a major source of CO2 emissions, abatement of which can be achieved by providing “more material services with less production and processing” (Allwood et al 2011:368), within foreseeable technology pathways. The authors see this as preferable over heavy reliance on CSS or demand reduction. Using a mathematical formula as a guide, seven groups of strategies are identified, which are portrayed as “levers” to be set between boundaries determined by the scope for technology led change or behaviour led change as identified by the authors.

Prevent
Five of these seven groups focus on prevention or have a preventative element: improving energy efficiency, improving the material yield ratio, dematerialization (lightweighting), longer lasting products (i.e. improving durability) and demand reduction. The latter, the authors conclude, might be unavoidable in some cases, although the degree that is necessary is unlikely to lead to a recession or cause major changes in levels of well-being.

Perpetuate
Three groups revolve around cycling or contain strategies that facilitate cycling: longer-lasting products (upgrading, product cascading), component re-use and recycling. Application of these strategies strongly depends on the stability of functional and cultural demands, changes in technology and material composition, as well as changing standards. Also, for adaptation or reuse products need to be designed such that parts can be easily accessed, through designing according to the ‘onion-skin’ model, and detailed knowledge about its specifications must survive after first use. Material simplification can furthermore aid in stimulating recycling, especially in the case of plastics.

Proactive
Achieving higher levels of Material Efficiency requires simultaneous action from businesses, government and individuals. Businesses linked in product chains need to coordinate in order to prevent over-specification and unnecessary yield losses. This requires all decision makers along this chain, also parties involved indirectly, such as insurers, investors and providers of certification. Changes in business models, from sales oriented to service oriented, are also required. Government needs to remove legislative barriers, lead by exemplary procurement policies and foster the required collaborations within product chains. Individuals can take responsibility within their personal and professional sphere.
References


IPCC (Intergovernmental Panel on Climate Change), 2007. *IPCC fourth assessment report*. 
### Appendix 02

**Overview of data collected per case included in dataset**

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**Appendix 02**

Overview of data collected per case included in dataset.
(continued)

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- **Notes, no recording**
- * Participant location of choice
- **Telephone interview**
- **Other person(s) present**
- **Approx. time job change**

**#10**
- **Company** Large, B-to-B&C
- **Participant** Engineer/manager
- **Product** Miscellaneous
- **Duration funded project (normalized)**

**Additional data**
- **Public project description**
  - Company present. project (2014)
  - Promotional document (2015)

**#11a**
- **Product** Electric
- **Duration funded project (normalized)**

**Additional data**
- **Public project description**
- **Project video**

**#11b**
- **Product** Electric
- **Duration funded project (normalized)**

**Additional data**
- **Public project description**
- **Project video**

**#11c**
- **Product** Electric
- **Duration funded project (normalized)**

**Additional data**
- **Public project description**
  - Project video (#11/12c)
  - Promotional document (11/12c-e)

**#11d**
- **Product** Housing & living
- **Duration funded project (normalized)**

**Additional data**
- **Public project description**
  - Project video (#11/12d)
  - Promotional document (11/12c-e)

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**Additional data**
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- **Duration funded project (normalized)**

**Additional data**
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  - Promotional document (11/12c-e)

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- Other person(s) present
- Approx. time job change

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Appendix 03
Case mappings using the Circularity Compass

Circularity Compass Key

- Material flow
- Material flow of uncertain magnitude
- Material flows co-existing as options
- Focal problem

Text:
- Text indicating a problematic issue
- Text indicating an ambiguous topic

- Insurmountable barrier
- Surmountable barrier
- Enabler
- Barrier with an overruling enabler
- Additional benefit
- Quality degradation
- Preservation of quality

- Landfill
- Preventative strategy
- Closing loops strategy
  - open-loop > indication of applicability of strategy
  - closed-loop > indication of applicability of strategy
  - semi closed-loop > indication of applicability of strategy
- Extending loops strategy
  - parts > indication of applicability of strategy
  - product > indication of applicability of strategy
- Long-life loops strategy
  - parts > indication of applicability of strategy
  - product > indication of applicability of strategy
- Intensifying loops strategy
  - parts > indication of applicability of strategy
  - product > indication of applicability of strategy
- Aspects relating to energy
- Aspects relating to information

Acronyms
- U.o.A. Unit of analysis as applied by participant to case
- EoL end-of-life
- VP Value Proposition

Mapping rules

• **Flows should be considered as an ‘order of magnitude’**
  As exact quantities of material flows were not known or were considered commercially sensitive the magnitude of the flows merely represent an order of magnitude. As such, it is the relative magnitude that of flows that is indicated in a mapping. Moreover, a minimal line thickness is maintained for quantities of flows that would otherwise become invisible on an A4 scale, but that are discussed or indicated none the less.

• **Flows are simplifications**
  Flows can either represent a single material or of a group of materials of the same type. Complex flows, consisting of many different substances, were simplified. The manner in which is indicated in the respective case mappings.

• **Flows can be split**
  If a flow is subject to different distribution routes during the forward and reverse logistics stages, flows can be split to indicate this.

• **Flows can skip states**
  Not all states and not all parts of a state are applicable in all cases. If states or part of them are not applicable to a case, they are greyed out.

• **Flows can be merged if they cannot be meaningfully separated**
  If stages from a life-cycle cannot be meaningfully separated, they can be merged into a single arrow.

• **Minimal line thickness applies**
  For flows too thin to be clearly visible when their proportion to other flows is accurately depicted, a minimal line thickness is applied.

Reading the mappings as a sequence

New mappings were only made if new informarion was uncovered. Where no new mapping was made this is indicated.

To make room for new information, descriptions that were part of a previous mapping were omitted. Instead, the icon to which the description applied was left in place, to indicate that that particular aspect of the case still applied. Where new information was uncovered, the descriptions have been altered to reflect this.
Case mappings Case #01

Case # 01 - interview 01
Business-as-usual
U.o.A. material group

Problem: [multi-dimensional]

Current raw material will be scarce in the future; Alternative raw materials have multiple alternative uses judged more important by participant

Conflict

Locally available raw materials

Current material is toxic under certain circumstances

Material
Current material

Goal & mechanism [multidimensional] replace current virgin material with material cascade in plentiful supply.

Actor(s):
• Manufacturer (customer)

Proposed solution

U.o.A. material group
Product: housing & living

Potential for use as soil improver; improves fertility; adds moisture retention
Benign when landfilled

Non-toxic

Legislative changes enlarged the market
Demand from market for sustainable solutions

No-toxic off-gassing during use

Zero waste manufacturing

Cheaper solution for customer

Less material necessary (by weight); larger margins in sale for customer

Patent on technology expired

No capital expenditure involved in manufacturing

Status of solution: of interest, active exploration ongoing

Actor(s):
• Suppliers of cascaded raw material

Material
Material #1
Material #2
Material #3
Material #4
Material #5 (composite)

† Retrospective correction applied
Case # 01 - Interview 02

Proposed solution

**U.o.A.** material group

**Product:** housing & living

**Goal & mechanism:** Replace current virgin material with material cascade in plentiful supply.

**Actor(s):**
- Suppliers of cascaded raw material
- Manufacturer (customer)

**Status of solution:** Viable, but further development of product is necessary

- Design concept; but design not yet fully resolved
- Cost of manufacturing
- Material properties promising; further development required
- Recovery infrastructure; as of yet absent and no plans for development yet
- Low embedded energy manufacturing

**Material:**
- Material #1
- Material #2
- Material #3
- Material #4
- Material #5 (composite)

*(no new data uncovered; therefore no new mapping of the business-as-usual situation)*
Case # 01 - interview 03

Proposed solution

U.o.A: material group
Product: housing & living

Goal & mechanism:
- [multidimensional]
- replace current virgin material with material cascade in plentiful supply.

Actor(s):
- Suppliers of cascaded raw material
- Manufacturer (customer)

Steps undertaken to protect IP

Material properties promising, further development required

Cost of manufacturing

Lightweighting

Low embedded energy manufacturing

Design concept, but design not yet fully resolved

Recovery infrastructure; as of yet absent and no plans for development yet

Material #1
Material #2
Material #3
Material #4
Material #5 (composite)

Status of solution: viable, but further development of product is necessary [ON HOLD indefinitely]

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 02 - interview 01

Business-as-usual

U.o.A.1 product group (in use in UK) (specific customer segment) (situation before redesign)

Product: display & presentation

Problem: Risk of not being able to meet customer demand for a reusable product.

Disposal of product before end of technical life of product

Geometry and characteristics of product prohibitive for easy reuse

Proportions unclear

Complete in-house system for recycling and manufacturing, facilitating a high degree of control of both processes and correcting any deviations with input of virgin material (virgin material production not in-house)

Goal & mechanism

Ensuring commercial attractiveness of products by offering a reuse system.

Actor(s): + Customers

Material: Material #1

Risk of not being able to meet customer demand for a reusable product.

Case # 02 - interview 01

Proposed solution

U.o.A.2 product group (in use in UK) (specific customer segment)

Product: display & presentation

Goal & mechanism

Ensuring commercial attractiveness of products by offering a reuse system.

Actor(s): + Customers

Material: Material #1

Risk of not being able to meet customer demand for a reusable product.

Case mappings Case #02

Problem: Risk of not being able to meet customer demand for a reusable product.

Disposal of product before end of technical life of product

Geometry and characteristics of product prohibitive for easy reuse

Proportions unclear

Complete in-house system for recycling and manufacturing, facilitating a high degree of control of both processes and correcting any deviations with input of virgin material (virgin material production not in-house)

Goal & mechanism

Ensuring commercial attractiveness of products by offering a reuse system.

Actor(s): + Customers

Material: Material #1

Risk of not being able to meet customer demand for a reusable product.
Case # 02 - interview 02

**Business-as-usual**

**U.o.A.**
- product group (in use in UK)
- (specific logistical channel)
- (situation before redesign)

**Product:** display & presentation

**Problem:** Risk of not being able to meet customer demand for a reusable product.

- Disposal of product before end of technical life of product
- For one of the logistical channels it is impossible to re-capture the product, because the end-user will dispose of it through channels not dedicated to its recycling

**Actor(s):**
- Customers

**Proportions unclear**

**Complete in-house system for recycling and manufacturing, facilitating a high degree of control of both processes and correcting any deviations with input of virgin material (virgin material production not in-house)**

**Geometry and characteristics of product prohibitive for easy reuse**

**Status of concept:** viability unclear, further exploration planned

---

**Case # 02 - interview 02**

**Proposed solution**

**U.o.A.**
- product group (in use in UK)
- (specific customer segment)
- (specific logistical channel)

**Product:** display & presentation

**Goal & mechanism**

Ensuring commercial attractiveness of products by offering a reuse system.

**Carbon footprint of reuse system compared to recycling system quantified:** reduces overall footprint

**Commercial viability:** requires large commitment from customer before investments in automation can be made, which at the moment is not established

**Actor(s):**
- Customers

**Material #1**

---
Case mappings Case #03

Case #03 - interview 01

Business-as-usual
- U.o.A: segment of product group
- Product: display & presentation

Problem: Risk of not being able to meet customer demand for a reusable product.

Lack of enforcement of sustainability guidelines regarding recycling

Disposal of product before end of technical life of product and materials

Due to nature of the product

Possible to achieve 100% recyclability?

Acquire accreditation from sustainability standard agency regarding recyclability as differentiating property of product?

E

Which material (from shortlist 2-3) meets following requirements:
- environmental i.e. from LCA perspective
- functional i.e. robustness
- subjective i.e. style/finish possible

Actor(s): Manufacturers (share sustainability ethos)

Actor(s): Potential early adopters/users (share sustainability ethos)

Disassembly and reassembly meets requirements:
- functional i.e. flexibility of modules to reinvent product, enabled by modularity of which the technical details are yet uncertain

Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients.

Awareness of reuse potential

High visibility and control over use stage enables quality control

Status of solution: of interest, active exploration ongoing

Possible to achieve 100% recyclability?

Acquire accreditation from sustainability standard agency regarding recyclability as differentiating property of product?

E

Which material (from shortlist 2-3) meets following requirements:
- environmental i.e. from LCA perspective
- functional i.e. robustness
- subjective i.e. style/finish possible

Actor(s): Manufacturers (share sustainability ethos)

Actor(s): Potential early adopters/users (share sustainability ethos)

Disassembly and reassembly meets requirements:
- functional i.e. flexibility of modules to reinvent product, enabled by modularity of which the technical details are yet uncertain

Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients.

Awareness of reuse potential

High visibility and control over use stage enables quality control

Status of solution: of interest, active exploration ongoing

Possible to achieve 100% recyclability?

Acquire accreditation from sustainability standard agency regarding recyclability as differentiating property of product?

E

Which material (from shortlist 2-3) meets following requirements:
- environmental i.e. from LCA perspective
- functional i.e. robustness
- subjective i.e. style/finish possible

Actor(s): Manufacturers (share sustainability ethos)

Actor(s): Potential early adopters/users (share sustainability ethos)

Disassembly and reassembly meets requirements:
- functional i.e. flexibility of modules to reinvent product, enabled by modularity of which the technical details are yet uncertain

Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients.

Awareness of reuse potential

High visibility and control over use stage enables quality control

Status of solution: of interest, active exploration ongoing
Case # 03 - interview 02
Proposed solution
U.o.A: segment of product group
Product: display & presentation

Goal & mechanism: Create potential for zero-waste-to-landfill and a product that has the same appeal as current product, by creating a modular product and using recyclable materials

Actor(s):  
• Manufacturers 
  (share sustainability ethos)
• Potential early adopters/users 
  (share sustainability ethos)

Material:  
* Part group #1 (options still exist)  
Part group #2  
Material group #3

Material established that meets requirements:  
• Environmental: i.e. from LCA perspective 
• Functional: i.e. robustness 
• Subjective: i.e. style/finish possible
• Not significantly different from current material, facilitating acceptance in supply chain

Disassembly and reassembly meets requirements:  
• Functional: i.e. flexibility of modules to reinvent product; enabled by modularity

Status of solution: viable, potentially profitable, further development and testing planned

Does it offer the required flexibility in practice?  
Amount of times reused?

Possible to achieve 100% recyclability?  
Acquire accreditation from sustainability standard agency regarding recyclability as differentiating property of product?

High visibility enables quality control  
Business model?
Cheaper solution compared to current product

Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients

Actual costs of manufacturing?

More material required per unit to make modules robust

Easier and faster assembly, cheaper manufacturing

Material established that meets requirements:

Environmental: i.e. from LCA perspective
Functional: i.e. robustness
Subjective: i.e. style/finish possible
Not significantly different from current material, facilitating acceptance in supply chain

Goal & mechanism:  
Create potential for zero-waste-to-landfill and a product that has the same appeal as current product, by creating a modular product and using recyclable materials

Actor(s):  
• Manufacturers 
  (share sustainability ethos)

Acquire accreditation from sustainability standard agency regarding recyclability as differentiating property of product?

Possible to achieve 100% recyclability?

Actual costs of manufacturing?

Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients
Case # 03 - interview 03

**Proposed solution**

**U.o.A.:** segment of product group

**Product:** display & presentation

**Goal & mechanism:** Create potential for zero-waste-to-landfill and a product that has the same appeal as current product, by creating a modular product and using recyclable materials.

**Actor(s):**
- Potential early adopters/users: budget cuts and therefore less usage of product expected, making reducing cost benefits.
- **Material**
  - Material group #1 (options still exist)
  - Material group #2

**Possible to achieve 100% recyclability?**

**Does it offer the required flexibility?**

**Amount of times reused?**

**More material required to make modules robust per unit**

**Material established that meets requirements:**
- Environmental: i.e. from LCA perspective
- Functional: i.e. robustness
- Subjective: i.e. style/finish possible
- Not significantly different from current material, facilitating acceptance in supply chain

**Disassembly and reassembly meets requirements:**
- Functional: i.e. flexibility of modules to reinvent product; enabled by modularity

**Lack of awareness of most users regarding lack of sustainability of current products; marketing activities to convince clients.**

**Easier and faster assembly, cheaper manufacturing**

**High visibility enables quality control**

**Chesper solution compared to current product**

**Business model?**

**Actual costs of manufacturing?**

**Lack of awareness of most users regarding lack of sustainability of current products, marketing activities to convince clients.**

**Possible to achieve 100% recyclability?**

**Cheaper solution compared to current product**

Status of solution: viable, but further development of product is necessary (ON HOLD indefinitely)

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Proposed solution

Actor(s):
• Producers of materials and parts (can be the same actors)

Reversible assembly methods; enabled by redesign of parts

Knowledge with regards to assembly, disassembly and reassembly of product; remediated by accelerated learning

Change in business model from sale to lease; less sensitive to fluctuations in the market

Standardisation ensures compatibility

Improves manufacturing speed

More options for users to adapt product to their needs during its lifetime

Status of solution: of interest, active exploration ongoing

Mix of C, E, L

Parts have become largely unusable due to assembly method and the resulting disassembly processes required

Lack of adaptability

Core focus is on energy-in-use with the product becoming more energy efficient; embedded energy will become more important

Energy required for recycling processes; “false assumptions” about life-cycle of product discount energy used in recycling

Lack of adaptability

Case # 04 - interview 01

Case # 04 - interview 01

Business-as-usual

U.o.A: product group (3 material groups highlighted for clarification)

Product: housing & living

Goal & mechanism [multidimensional]; facilitate reuse (and thus longevity) of components

Problem: [multidimensional]

Business practices that undermine businesses existing for a long time

Difficulties with financing, as the product is seen as bespoke, not as a stock of standard materials

Waste generated during various manufacturing stages
Case # 04 - interview 02

Business-as-usual

U.o.A: product group (3 material groups highlighted for clarification)
Product: housing & living

Problem: [multidimensional]

Actor(s):
• Producers of materials and parts (can be same actors)

Lack of knowledge with regards to assembly, disassembly and reassembly of product; remediated by learning through finding niche applications and building a body of knowledge

Energy required for recycling processes not included in life-cycle assessment

Investment of large amounts of financial resources in creating products that keep capital tied up and are not adaptable and thus prematurely reach the EoL or have to be adapted at great financial cost.

Sole focus is on energy-in-use, whilst the product is becoming more energy efficient, making embodied energy more important

Parts have become largely unusable due to assembly method and the resulting disassembly processes required

Status of solution: viable, potentially profitable, further development and testing planned

Proposed solution

U.o.A: product group (3 material groups highlighted for clarification)
Product: housing & living

Goal & mechanism [multidimensional] facilitate reuse (and thus longevity) of components.

Actor(s):
• Producers of materials and parts (can be same actors)

Standardisation ensures compatibility and quality and aligns interests across the value chain, as all actors now have an interest in flexibly using the value delivering capacity of the product

Actor(s):
• Manufacturers

Lack of knowledge with regards to assemblies, disassembly and reassembly of product; remediated by learning through finding niche applications and building a body of knowledge

Material:  
- Material group #1
- Material group #2
- Material group #3
- Product (composite)
  * three major groups mentioned by participant

Product: housing & living [multidimensional]
(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Problem: [multidimensional]

Business-as-usual

U.o.A: group of subassemblies

Product: miscellaneous

Status of solution: of interest, active exploration ongoing

Proposed solution

User interaction?
Reversible bonding?
Increased strength and durability?
Size of production runs?

Material

Part of subassembly
Part of subassembly
Part of subassembly
Subassembly of product
Subassembly of product

Business model?

High speed automated customized production of parts, simpler production of remaining parts

Design parameters of customization options?

Size of production runs?

Create longer lasting products with higher value due to personalization

Actor(s):

- Producer raw material
- Parts manufacturer
- Facilitate local manufacturing, retaining or creating high skilled jobs

Material

Subassembly of product

Non-reversible durability

Non-reversible durability

Status of solution: of interest, active exploration ongoing

Goal & mechanism

[multidimensional]: create a product that is emotionally durable as well as repairable

No possibilities for customizations/ personalization of product

Inefficient mass production process

Mark-up increases along the value chain resulting in over pricing in relation to the quality of the product

No purpose other than making profit whilst selling products cheap, i.e. no quality products or deeper user engagement with products

Loss of craft and skill

Excessive transport

Weak points

Non-reversible durability

No purpose other than making profit whilst selling products cheap: i.e. no quality products or deeper user engagement with products

Mark-up increases along the value chain resulting in over pricing in relation to the quality of the product

Inefficient mass production process

Loss of craft and skill

Excessive transport
Case #05 - interview 02

Business-as-usual

Problem: [multidimensional]

Uncertainty regarding fit of solution with legislation and standards; i.e. can repairability stand in for durability?

Mark-up increases along the value chain resulting in over-pricing in relation to the quality of the product.

No purpose other than making profit whilst selling products cheap; i.e. no quality products or deeper user engagement with products.

Loss of craft and skill

Excessive transport

Case #05 - interview 02

Proposed solution

Goal & mechanism: create a product that is emotionally durable as well as repairable.

Actor(s):
- Producer raw material
- Parts manufacturer

Material
- Structural part of product*
- Parts of structural part*
- Other parts of product*

* Each various individual parts

U.o.A: group of subassemblies

Status of solution: of interest, active exploration ongoing
Case # 05 - interview 03

Proposed solution

U.o.A: group of subassemblies
Product: miscellaneous

Goal & mechanism: create a product that is emotionally durable as well as repairable.

Actor(s):
- Lost good working relationship with parts manufacturer, which complicates experimentation
- Facilitate local manufacturing, retaining or creating high skilled jobs

Type of material can vary; additional options uncovered

Design parameters with customization options?
- Size of production runs?
- Reversibility?
- Increased strength and durability?
- Standards not an inhibitor as previously thought

Added additional features to design, which improve usability and customization options

User interaction?

Material:
- Structural part of product
- Parts of structural part
- Other parts of product

Status of solution: of interest, active exploration ongoing

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #06

Case #06 - interview 01
Business-as-usual
U.o.A.: product group
Product: electric
Actor(s):
• Recycling industry
Actor(s):
• Users

Problem: Environmental performance of materials used in product is insufficient.

Goal & mechanism
Improve environmental performance of material use, by choosing a renewable material suitable for recycling.

Actor(s):
• Producers of material #1
• Producer of material #2
Characteristics of material: any negative material on general product performance, low-wear technology, repairability and refurbishment is prohibitive.

Status of solution: of interest, active exploration ongoing

Case #06 - interview 01
Proposed solution
U.o.A.: product group
Product: electric
Actor(s):
• Recycling industry
Actor(s):
• Producers of material #1
• Producer of material #2

Non-renewable

Removal: mix of
cleaning

Processing capabilities of future recycling industry is its capabilities to recapture more of the waste stream

Material group #1
Material group #2
All other materials
Case # 06 - interview 02
Proposed solution

Goal: Explore the possibility to use a specific renewable material as replacement for current material group.

Actor(s): • Recycling industry

Material:
- Material group #1
- Material group #2
- Renewable source
- All other materials

Status of solution: Material not (yet) capable of delivering required performance (ON HOLD indefinitely)

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case #07 - interview 01

**Business-as-usual**

U.o.A.: product group (excl. storage container)

Product: housing & living

- Loss of valuable resources
- Problematic waste stream for waste processors
- Increasing public critique
- Increasing costs as a result of obligatory contributions to waste management

**Problem:**

Product:

- Housing & living

Material

Various materials

Various materials

Product (composite)

Simplified depiction: exact composition not discussed

† Retrospective correction applied

---

**Proposed solution**

U.o.A.: product group (excl. storage container)

Product: housing & living

Goal & mechanism

- [multidimensional]
- Reroute the would-be waste away from landfill.

Actor(s):

- Product development department
- Marketing department; fears deterioration of brand value
- Local county council (waste collection)
- Users

Optimal system in terms of:

- Cost and ROI
- Carbon footprint

Efficiency use

Recapture component (at R&D stage)

Perception of customer of new product

Scalability of process, mechanism

Attempted before did not work as expected and does not have sufficient capacity to deal with the entire waste stream

Sufficient volume of waste realizable for recycling might be required

Status of solution: of interest, active exploration ongoing

---

Company publicly committed to addressing waste problem

Materials recycling compatible: possibility of removing those materials

On-going (R&D) efforts to reduce impact of sourced materials

Preventing wasting product capacity unnecessarily

Material

Various materials

Various materials

Product (composite)

Simplified depiction: exact composition not discussed

† Retrospective correction applied
(no new data uncovered; therefore no new mapping of the business-as-usual situation)

Case # 07 - interview 02
Proposed solution

Actor(s): • Product development department
• Local county council (waste collection)
• Users/ public
Growing pressure from actors to solve problem

Material
Various materials*

Status of solution: of interest; product samples meet requirements; further development ongoing
Case #07-1 - interview 03
Proposed solution
U.o.A.: product segment A (excl. storage container)
Product: housing & living

Goal & mechanism: [multidimensional], route the would-be waste away from landfill.

Actor(s):
- Marketing department; has acknowledged value of solving the waste problem
- Customer group A

Material: Various materials*

Scalability of treatment; mechanisation concept not yet proven in practice at scale; cost has come down significantly due to efficiency improvements in treatment process

Impact of treatment method on quality of product?
Impact of regulation with regards to declaring product content?
Automate quality control?

Losses

Status of solution: of interest, manufacturing trial and focus groups in preparation

Case #07-2 - interview 03
Proposed solution
U.o.A.: product segment A (excl. storage container)
Product: housing & living

Goal & mechanism: [multidimensional], route the would-be waste away from landfill.

Actor(s):
- Marketing department; has acknowledged value of solving the waste problem
- Customer group B

Material: Various materials*

Scalability of treatment; mechanisation concept not yet proven in practice at scale; cost has come down significantly due to efficiency improvements in treatment process

Impact of treatment method on quality of product?
Impact of regulation with regards to declaring product content?
Automate quality control?

Losses

Status of solution: of interest, manufacturing trial and focus groups in preparation
Case # 07-3 - interview 03
Proposed solution
U.o.A.: product segment B (excl. storage container)
Product: housing & living

Goal & mechanism: [multidimensional], route the would-be waste away from landfill.

Actor(s):
- Marketing department; has acknowledged value of solving the waste problem
- Customer group C (charitable)

Material:
Various materials*
Various materials*
Product (composite)*
*simplified depiction; exact composition not discussed

Evidence for customer demand from customer groups A & B

Status of solution: of interest, manufacturing trial and focus groups in preparation

Case # 07-4 - interview 03
Proposed solution
U.o.A.: product segment B (excl. storage container)
Product: housing & living

Goal & mechanism: [multidimensional], route the would-be waste away from landfill.

Actor(s):
- Product development department
- Production

Material:
Various materials*
Various materials*
Product (composite)*
*simplified depiction; exact composition not discussed

Evidence for customer demand from customer groups A & B

Status of solution: of interest, manufacturing trial and focus groups in preparation
To create a sustainable product, that aids in creating a more sustainable system aimed at fulfilling a particular human need.

**Goal & mechanism:**

- **Barrier to reuse and recycling:**
  - Contamination (affects handling and use)

- **Future waste disposal and management costs and other enablers:**
  - Increasing attention for sustainability

Material requirements:
- i.e. what materials are fit for purpose?

Functional requirements and geographical use of product:
- i.e. improvement opportunities for both product and system?
- Rule of product in creating a sustainable system in fulfilling a particular human need
- Offering a low-cost solution from locally available materials

**Status of concept:**
of interest, active exploration ongoing

**Material group #2**
Case # 08 - interview 02

Proposed solution

U.o.A.: product group

Product: miscellaneous

Goal: To create a sustainable product, that aids in creating a more sustainable system aimed at fulfilling a particular human need.

Status of solution: of interest, solution selling to value chain actors imminent.
Case # 08 - interview 03
Proposed solution
U.o.A.: product group
Product: miscellaneous

Goal: To create a sustainable product, that aids in creating a more sustainable system aimed at fulfilling a particular human need.

Status of solution: of interest, solution selling to various value chain actors unsuccessful [TERMINATED]

Actor(s):
• Lack of a customer to further explore proposed solutions with

Material
Renewable material

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #09

Case # 09 - interview 01
Business-as-usual
U.o.A.: product (excl. storage container)
Product: miscellaneous

Problem: The use of a single-use disposable product creating waste.

Case # 09 - interview 01
Proposed solution
U.o.A.: product (excl. storage container)
Product: miscellaneous

Goal & mechanism: To create a fun and fashionable product, that solves an environmental problem by reusing waste and using compostable materials.

Actor(s):
• Supplier of raw material #2
• Processor of raw material

Status of solution: Of interest, active exploration ongoing

Material
- Renewable material
  - Renewable material #1
  - Renewable material #2 (grade A)
  - Additive
  - Composite #1

Barrier to reuse:
• not fit for purpose
• not a pleasant user experience

Use waste stream from BAU as input

Established distribution concept

Cost, carbon footprint

Established distribution concept

Established distribution concept

Established distribution concept

Whether identified composite meets requirements:
• functional: i.e. fit for purpose
• subjective: i.e. style, finish

Sourcing treated as trade secret by supplier: impact on marketing uncertain

VP to user: fun, fashionable, easy to use; design details yet uncertain

Composting

Recycling/second use

Status of solution: Of interest, active exploration ongoing
(no new data uncovered; therefore no new mapping of the business-as-usual situation)
(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Status of solution: of interest, further exploration planned

Case # 10 - interview 02

Business-as-usual

U.o.A.: product group
Product: miscellaneous

Problem: EoL value currently for the most part captured by third parties.

Actor(s):
- Recycling industry

On-going efforts to reduce energy-in-use

EoL value captured by third parties, not by focal company

Increasingly valuable raw materials
Scarcity of raw material

Material
- Mix: material composition of products not discussed
- Takes place also, but outside of boundary of project and therefore disregarded in flow quantity

Case # 10 - interview 02

Proposed solution

U.o.A.: product group
Product: miscellaneous

Goal & mechanism: Capture (more) EoL value within focal company, recapturing control of EoL flows and increasing capacity of flows.

Actor(s):
- New entities/cooperations for disassembly and treatment?

Preconcentration improves EoL outcomes

Set of (inter)organisational configurations determined; most desirable scenario requires further investigation

Material
- Mix: material composition of products not discussed
- Takes place also, but outside of boundary of project and therefore disregarded in flow quantity

Status of solution: of interest, further exploration planned
Case mappings Case #11a

Case # 11a - interview 01

**Business-as-usual**

U.o.A: product group

Product: electric

**Problem:** [multi-faceted see below]

**Material**

Various materials

Material group #1

Material group #2

† Retrospective correction applied

**Actor(s):**

• Partners for further development
• Reaction of competitors

**Status of solution:** of interest, active exploration ongoing

**Case # 11a - interview 01**

**Proposed solution**

U.o.A: product

Product: electric

**Goal & mechanism**

“Make sure these materials could cycle infinitely”

**Actor(s):**

• Users

**Definitive design of product?**

**Material**

Various materials

Material group #1

Material group #2

† Retrospective correction applied

**Designated channels used sparingly:**

• current habits inhibit this

Lack of a good recycling system, whilst recycling potential for is high when stream contains no other contaminants

Physical scarcity

Lack of a good recycling system, whilst recycling potential for is high when stream contains no other contaminants

Designated channels used sparingly:

• current habits inhibit this

Important product feature is reduced energy-in-use compared to previous product generation

***Servitization of product currently unknown; but changing attitudes toward ownership in other product categories lower the threshold***

Modularity

Disassembly; new tech for effective disassembly of module

Pure stream allows for preconcentration and thus better outcomes

**Status of solution:** of interest, active exploration ongoing

Physical scarcity
Case # 11a - interview 02
Proposed solution
U.o.A.: product
Actor(s): • Partners for further development
... infinitely"
Goal & mechanism
(make sure these materials could cycle infinitely)

Material
Module (various materials*)
Material group #1
Material group #2
*simplified depiction
exact composition
not discussed
† Retrospective correction applied
Design concept,
but design not yet fully resolved

Actor(s):
• Users

Sales channels?
Directly sent to user
Modularity
VP sufficient attractive to overcome user habits and perceptions, a range of user benefits were identified, such as how added intelligence can further reduce energy in-use and how the service can be made effortless for the user through information exchange.

Status of solution: of interest, active exploration ongoing

Does it work in practice?
Business model?

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 11a - interview 03
Proposed solution
U.o.A.: product group
Product: electric
Actor(s):
• Partners for further development
  (allows for filling knowledge gaps identified)

Goal & mechanism
[multi-faceted]
“Make sure these materials could cycle infinitely”

Does it work in practice?

Different approach to modularity

Material
- Various materials
- Material group #1
- Material group #2
  - Simplified depiction
  - Exact composition not discussed

Sales channels

Status of solution:
of interest, manufacturing trial and focus groups in preparation

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 11b - interview 01

Business-as-usual

U.o.A.: product
Product: electric

Problem: [multi-facetted: see below]

Case # 11b - interview 01

Proposed solution

U.o.A.: product
Product: electric

Goal & mechanism: "Make sure these materials could cycle infinitely"

Actor(s):
• Logistics systems
Actors:
• User

Material constitution?

Design concept?

User interaction at End of Life?

Collection system and logistics for recycling?

Business model? How?

Product's energy-in-use is primary part of carbon footprint: RLESs can therefore not negatively affect these.

Material selection inhibits recycling

Manufacturing processes inhibit recycling

Material group #1
Metals and electronics

Material group #1 (can be different types)

Status of solution: of interest, active exploration ongoing
(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 11b - interview 03
Proposed solution
U.o.A.: product
Product: electric

Goal & mechanism
[Multi-faceted]
“Make sure these materials could cycle infinitely”

Actor(s):
• Logistics systems

Actor(s):
• User

Material
• Material group #1 (can be different types)
• Metals and electronics

User interaction at EoL?

Collection system and logistics for recycling?

Design concept; but design not yet fully resolved

Status of solution: viable, but further development of product is necessary [HOLD indefinitely]

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 11c - interview 01

Business-as-usual

U.o.A.: collection of products

Product: electric

Problem: Idle time of product causes its capacity for value delivery to go unused.

Material Mix

Material composition of products not discussed

Case # 11c - interview 01

Proposed solution

U.o.A.: collection of products

Product: electric

Goal & mechanism: Increase utilisation of product by introducing a service that enables redistribution, reconditioning and repair

Actor(s):
- Return system operators
- Users

Logistics around service:
- Checking presence and state of attachments
- Checking condition of product
- Labour saving solutions (low & high tech) exist in other product groups

Knowledge about disassembly

Return system already in place

Optimise product for reuse system

Status of concept: of interest, active exploration ongoing

Actors:
- Return system operators
- Users

Optimise product for reuse system

Overall environm. impact

Material Mix

Material composition of products not discussed

Retrospective correction applied
Case # 11c - interview 02

Proposed solution

**U.o.A.:** collection of products

**Product:** electric

**Actor(s):**
- Return system operators

**Status of concept:** of interest, ready to go to trial, on-hold

**Goal & mechanism:**
Increase utilisation of product by introducing a service that enables redistribution, reconditioning and repair

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 11d - interview 02

Business-as-usual

U.o.A.: product (excl. packaging)
Product: housing & living

Problem: Product reaches EoL prematurely due to user behaviour.

Actor(s):
• Users

Material*
Material group #1
Material group #2
Material group #3
* proportions of materials vary depending on specific product

Status of solution: viable i.c.w. other solution, but further development of product is necessary [ON HOLD]

Case # 11d - interview 02

Proposed solution

U.o.A.: product (excl. packaging)
Product: housing & living

Goal & mechanism: Maximise productive life material contained in product by introducing a service that enables redistribution, reconditioning and repair.

Actor(s):
• Users
• Manufacturer/reprocessor

Material*
Simplified design compared to BAU
should not be disclosed, could contain multiple materials
* Retrospective correction applied

Use case clarified: judged feasible if combined with other VP, which would offer additional convenience.

Enabled by product redesign (details not disclosed)

Logistics, using existing systems

Enable case clarified: judged feasible if combined with other VP, which would offer additional convenience.

Actor(s):
• Operator of forward logistics change in company strategy

Actor(s):
• Logistics operator

Actor(s):
• Users

Non-reversible bonding

Suitable EoL options currently absent

User can reuse product, but sufficient maintenance is labour and carbon intensive, and often results in premature EoL.

Losses

Maximise productive life material contained in product by introducing a service that enables redistribution, reconditioning and repair.

Life & Experience
Less

Simpliﬁed design compared to BAU should not be disclosed, could contain multiple materials
* Retrospective correction applied
**Case mappings Case #12c**

**Case # 12c - interview 01**

**Business-as-usual**

U.o.A.: collection of products

Product: electric

**Problem:** [multi-faceted see below]

Periodic requirement for products requires levels of material consumption beyond what is deemed suitable.

Pressure on revenue due to product returns.

Taking up landfill space and unnecessarily wasting resources.

**Solution considered**

Actor(s): 

• Users

Overall environment impact

Aiding the user in performing a task such that the end result is more satisfactory:

• access to higher quality product
• better instructions

**Goal & mechanism**

[multi-faceted]

by introducing a service that enables redistribution

**Material**

Material composition of products not discussed

Resource scarcity

Resource price volatility

Status of concept: of interest, active exploration ongoing

**Case # 12c - interview 01**

**Solution considered**

U.o.A.: collection of products

Product: electric

**Problem:** [multi-faceted: see below]

Resource scarcity

Resource price volatility

Case mappings Case #12c
**Case # 12c - interview 02**

**Solution considered**

**U.o.A.**
- Collection of products

**Product:** Electric

**Actor(s):**
- Users

**Overall environm. impact**

Aiding the user in performing a task such that the end result is more satisfactory:
- Access to higher quality product
- Better instructions

**Goal & mechanism**

([multi-faceted]) by introducing a service that enables redistribution

**(no new data uncovered; therefore no new mapping of the business-as-usual situation)**
Case # 12d - interview 01

**Business-as-usual**

<table>
<thead>
<tr>
<th>U.o.A.: product group</th>
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</thead>
<tbody>
<tr>
<td>Product: housing &amp; living</td>
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</tbody>
</table>

**Problem:** [multi-facetted: see below]

- Taking up landfill space and unnecessarily wasting resources
- No suitable EoL collection systems exist beyond landfill
- A measure of reuse by user takes place; but users tend to not provide sufficient maintenance, resulting in the degradation of the product.
- Recondition
- Resource scarcity
- Resource price volatility

**Proposed solution**

<table>
<thead>
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</tbody>
</table>

**Goal & mechanism:** [multi-facetted] by introducing a maintenance service and facilitating closed-loop strategies

- Examine EoL options; uncertain whether through recycling or composting
- Design suitable return system and packaging
- Enabled by modularity

**Actor(s):**
- Users
- Manufacturing brands

**Material**
- Material group #1
- Material group #2
- Material group #3

| Status of concept: of interest, active exploration ongoing |
|---|---|

| Resource scarcity |
|---|---|

| Resource price volatility |
|---|---|

| Proportions of materials vary depending on specific product |
|---|---|
Case # 12d - interview 02
Proposed solution

U.o.A: product group
Product: housing & living
(repeat mapping from #11d)

Goal & mechanism:
[Multi-faceted]
by introducing a maintenance service and facilitating closing-loop strategies

Actor(s):
- Manufacturing brands
- Users

Material:
- Material group #1
- Material group #2
- Material group #3

Proportions of materials vary depending on specific product

Status of concept: of interest, active exploration ongoing

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case # 12e - interview 01

Business-as-usual

U.o.A.: product group
Product: electric

Problem: [multi-faceted see below]

Taking up landfill space and unnecessarily wasting resources

One faulty component leads the whole product to be discarded

Resource scarcity
Resource price volatility

Pressure on revenue due to product returns

Resource price volatility

Material
Material group #1
Material group #2
Material group #3

Case # 12e - interview 01

Proposed solution

U.o.A.: product group
Product: electric

Actor(s):
• Manufacturer of parts/products

Goal & mechanism: [multi-faceted] by introducing maintenance, reconditioning and facilitating closing-loop strategies

Case mappings

Status of concept: of interest, active exploration ongoing
Case # 12e - interview 02
Proposed solution
U.o.A.: product group
Material: electric
Actor(s):
• Manufacturer of parts/products

Goal & mechanism: [multi-faceted] by introducing maintenance, reconditioning and facilitating closing-loop strategies

Status of concept: of interest, active exploration ongoing

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #13f

Case # 13f
Business-as-usual
U.o.A. product group

Problem: Materials landfilled, more potential for recycling of materials and current recycling resulting in low value products only.

Actor(s):
- Brands/ manufacturers

Actor(s):
- Users

Material
- Material group #1
- Material group #2
- Composite #1

Low value cascades

Lack of awareness of end value of material with user

Not a viable option due to degeneration of material and available technical capabilities

Not a viable option due to degeneration of material

(two scenarios considered for proposed solution placed on next page for ease of comparison)
Case # 13f1 - interview 01
Proposed solution
U.o.A.: product
Product: housing & living

Goal & mechanism
reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Actor(s):
• Manufacturer of material

Necessity for addition of materials
• Identify manufacturer for product

Possibilities to recycle or compost

Specifications of material produced
• functional: i.e. safety, durability, dimensions, mechanical
• subjective: i.e. style, finish

Possibility of repair and/or refreshment

Status of solution: of interest, active exploration ongoing

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Case # 13f2 - interview 01
Proposed solution
U.o.A.: product
Product: housing & living

Goal & mechanism
reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Actor(s):
• Manufacturer of material

Necessity for addition of materials
• Identify manufacturer for product

Possibilities to recycle or compost

Specifications of material produced
• exact composition
• functional: i.e. safety, durability, dimensions, mechanical
• subjective: i.e. style, finish

Possibility of repair and/or refreshment

Status of solution: of interest, active exploration ongoing

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2
Case # 13f1 - interview 02
Proposed solution

U.o.A.: product

Manuf. process?

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturer of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Case # 13f2 - interview 02
Proposed solution

U.o.A.: product

Manuf. process?

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturers of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Case # 13f2 - interview 02
Proposed solution

U.o.A.: product

Product: housing & living

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturer of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturers of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturers of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturers of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

Specifićations of material produced:
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

Material
- Material group #1
- Material group #2
- Composite #1
- Composite #2

Goal & mechanism
- reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

Possibility of repair and/or refurbishment

Possibilities to recycle?

Status of solution: of interest, uncertain about next steps

Actor(s):
- Manufacturers of material (not supportive of finding EoL solutions for product)
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)
**Case # 13f1 - interview 03**

**Proposed solution**

**U.o.A.:** product

**Product:** housing & living

**Goal & mechanism:** reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

**Actor(s):**
- Manufacturer of material (not supportive of finding EoL solutions for product)

**Material**
- Material group #1
- Material group #2
- Composite #1
- Composite #2

**Status of solution:** TERMINATED

---

**Case # 13f2 - interview 03**

**Proposed solution**

**U.o.A.:** product

**Product:** housing & living

**Goal & mechanism:** reduce amount of materials landfilled by introducing a substance cascade and facilitating closing-loop strategies

**Actor(s):**
- Manufacturers of material (not supportive of finding EoL solutions for product)

**Material**
- Material group #1
- Material group #2
- Composite #1
- Composite #2

**Status of solution:** of interest, currently no means available for further development (ON HOLD indefinitely)

---

**Proposed solution**

**U.o.A.:** product

**Manuf. process?**

**Necessity for addition of other materials?**

**Specifications of material produced:**
- Functional: i.e., safety, durability, dimensions, mechanical strength
- Subjective: i.e., style, finish

**Possibilities to recycle?**

**Possibility of repair and/or refurbishment?**

**Actor(s):**
- Product manufacturer
- Designer of product (does not regard EoL thinking as a key concern)

**Material**
- Material group #1
- Material group #2
- Composite #1
- Composite #2

**Status of solution:**
**Problem:** Overall environmental impact of product could be improved.

**Actor(s):**
- Manufacturer of product

**Material:**
- Renewable material #1
- Renewable material #2
- Additive
- Composite

**Case # 14g - interview 02**

**Business-as-usual**

**U.o.A.:** product group

**Problem:**

**Solution:**

**Actor(s):**
- Manufacturer of product

**Goal & mechanism:**
Reduce environmental impact by facilitating recycling of EoL product and extend life of returned product that is not yet at the end of its technical life.

**Actor(s):**
- Manufacturer of product

- User

**Status of solution:** of interest, next steps uncertain.
Case # 14h - interview 02

**Business-as-usual**

**U.o.A.:** product group

**Problem:** [multidimensional]

**Actor(s):**
- EoL industry: recyclers, reconditioners, etc.

**Maintenance**

**Status of solution:** of interest, next steps uncertain.

**Material Mix**

- Material composition of products not discussed

---

**Case # 14h - interview 02**

**Proposed solution**

**U.o.A.:** product group

**Product:** electric

**Actor(s):**
- EoL industry: recyclers, reconditioners, etc.

**Goal & mechanism:**
- Recapture EoL value for focal company by offering infrastructure that brings EoL flows under control of focal company

**Maintenance**

**Status of solution:** of interest, next steps uncertain.

**Material Mix**

- Material composition of products not discussed

Case mappings Case #15i

Case # 15i - interview 02

Business-as-usual

U.o.A.: product group
Product: display & presentation

Problem: Overall environmental impact of product could be improved.

Goal & mechanism: Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits i.r.t. the whole life of the product.

Status of solution: of interest, looking for application of solution

Proposed solution

U.o.A.: product group
Product: display & presentation

Material
Material #1
Material #2
Material #3
Material #4

Single material input that is suitable for recycling increases likelihood of the product being recycled as it has become much less labour intensive.

Changes in the geometry of parts allow the product to fulfill its original function, whilst the overall product does not differ significantly from the original product with regards to visual appearance.

Less wear and tear tooling and easier handling of parts.

Lighter, less likely to damage during installation and use.

Information exchange identified as a potential facilitator for facilitating appropriate EoL treatment, measures taken so that information is easily accessible.

Maintenance

Material
Material #5
Case # 15i - interview 03
Proposed solution
U.o.A.: product group
Product: display & presentation

Goal & mechanism

Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits r.t. the whole life of the product.

Actor(s):
- Bankruptcy of supplier material
- No first customer

Material
- Material #5

Information exchange identified as a potential facilitator for facilitating appropriate EoL treatment; measures taken so that information is easily accessible

Less wear and tear tooling and easier handling of parts

Lighter: less likely to damage during installation and use

Status of solution: of interest, continue looking for first customer

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #15j

Case # 15j - interview 02
Business-as-usual
U.o.A.: product group
Product: display & presentation

Problem: Overall environmental impact of product could be improved.

Goal & mechanism: Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits i.r.t. the whole life of the product.

Proposed solution
U.o.A.: product group
Product: display & presentation

Status of solution: of interest, active exploration ongoing

Design of accompanying reusable transit solution means that no packaging is required, less lorry loads are required to fulfil orders and less time spent picking for order-fulfilment.
Case # 15j - interview 03
Proposed solution
U.o.A.: product group
Product: display & presentation

Goal & mechanism: Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits i.e. the whole life of the product.

Status of solution: implemented, exploring other improvements

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #15k

Case # 15k - interview 02
Business-as-usual

U.o.A.: product group
Product: display & presentation

Problem: Overall environmental impact of product could be improved.

Proposed solution

U.o.A.: product group
Product: display & presentation

Goal & mechanism: Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits i.r.t. the whole life of the product.

Generating revenue by processing this waste stream

Simple design fit for assembly at point of use without requiring an installation specialist

Information exchange identified as a potential facilitator for facilitating appropriate EoL treatment, measures taken so that information is easily accessible

Status of solution: of interest, active exploration ongoing
Case # 15k - interview 03
Proposed solution

Goal & mechanism
Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits r.t. the whole life of the product.

U.o.A.: product group
Product: display & presentation

Generating revenue by processing this waste stream

Information exchange identified as a potential facilitator for facilitating appropriate EoL treatment; measures taken so that information is easily accessible

Simpler design fit for assembly at point of use without requiring an installation specialist

Actor(s):
- Health and safety issues with production of material
- Investment in tooling
- No first customer

Material
- Renewable material #1
- Renewable material #2
- Composite
- Material #3
- Biocompatible

Status of solution: of interest, continue looking for first customer

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
Case mappings Case #15l

Case # 15l - interview 02
Business-as-usual
U.o.A.: product group
Product: display & presentation

Problem: Overall environmental impact of product could be improved.

Premature loss of material to other systems

Case # 15l 1-3 - interview 02
Proposed solution
U.o.A.: product group
Product: display & presentation

Goal & mechanism: Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits i.r.t. the whole life of the product.

Using the out-flow of the business-as-usual situation as input

Status of solution: of interest, active exploration ongoing

Material
Material #5
Retrospective correction applied
* dependent on local waste processing facility

Material
Material #5
Retrospective correction applied
Case # 15l 1-3 - interview 03
Proposed solution
U.o.A: product group
Product: display & presentation/housing & living

Goal & mechanism
Demonstrate that overall environmental impact of the product can be improved, whilst generating commercial benefits r.t. the whole life of the product.

Actor(s):
- No first customer

Material
- Material #5

Status of solution: of interest, continue looking for first customer

(no new data uncovered; therefore no new mapping of the business-as-usual situation)
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