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The circular economy: New or Refurbished as CE 3.0? — Exploring Controversies in the Conceptualization of the Circular Economy through a Focus on History and Resource Value Retention Options

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ABSTRACT

Over the last decade, the concept of the circular economy has regained attention, especially related to efforts to achieve a more sustainable society. The 'revival' of the circular economy has been accompanied by controversies and confusions across different actors in science and practice. With this article we attempt at contributing to advanced clarity in the field and providing a heuristic that is useful in practice. Initially, we take a focus on the historical development of the concept of circular economy and value retention options (ROs) for products and materials aiming for increased circularity. We propose to distinguish three phases in the evolution of the circular economy and argue that the concept – in its dominant framing – is not as new as frequently claimed. Having established this background knowledge, we give insights into 'how far we are' globally, with respect to the implementation of circularity, arguing that high levels of circularity have already been reached in different parts of the globe with regard to longer loop value retention options, such as energy recovery and recycling. Subsequently, we show that the confusion surrounding the circular economy is more far reaching. We summarize the divergent perspectives on retention options and unite the most common views a 10R typology. From our analyses, we conclude that policymakers and businesses should focus their efforts on realization of the more desirable, shorter loop retention options, like remanufacturing, refurbishing and repurposing – yet with a view on feasibility and overall system effects. Scholars, on the other hand, should assist the parties contributing to an increased circular economy in practice by taking up a more active role in attaining consensus in conceptualizing the circular economy.

1. Introduction to Confusions in Conceptualizing CE

During the last 5–10 years, the concept of the 'circular economy' (CE) has received growing attention on various levels, among them policymaking, advocacy and consultancy, and science. A Scopus search on the term shows an increase of 50% in academic publications over the past five years, a trend that is even more visible for the Journal of Resources, Conservation and Recycling: the first CE article is recorded in 2007, and over two thirds of the total 101 publications listed on the term stem from the period 2015–2017.

In international politics, the urgency of closing materials loops is also more recently actively promoted by consortia of global actors, like the OECD,[1] the WEF[1] and UNEP[1] through various reports and events (UNEP, 2011, 2016; OECD, 2016; WEF, 2014, 2016). Japan and China were the first key Asian economic players to formally introduce CE policies on national level. In Europe, many states have implemented CE initiatives, policies and pilot programmes, most notably Denmark, Germany, the Netherlands, and the UK are taking the lead (EUKN, 2015). On supranational level, the European Union (EU) is – more slowly – following suit with a CE action plan, including legislative proposals (EC, 2015).

As this article shows, large differences manifest itself globally with regard to CE, yet the potential ascribed to CE of breaking the global "*take-make-consume and dispose' pattern of growth — a linear model based on the assumption that resources are abundant, available, easy to source and cheap to dispose of (…)*" (EEA 2016, p. 9) is widely shared among different societal actors across the globe. The move towards a more circular economic model can hence be interpreted as confrontation with these untenable assumptions. CE is widely posed as alternative model of production and consumption, a growth strategy enabling the

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[1] OECD = Organisation for Economic Co-operation and Development; WEF = World Economic Forum; UNEP = United Nations Environment Programme

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'decoupling' of resource use from economic growth, thereby contributing to sustainable development (UNEP, 2011; McKinsey and Company, 2015; EC, 2015; OECD, 2016; EMAF, 2016a,b; Ghisellini et al., 2014; Geissdoerfer et al., 2017).

More critical voices have questioned the potential ascribed to CE, targeting especially the 'myth of decoupling' (Gregson et al., 2015; Hobson, 2015; Lazarevic and Valve, 2017). The 2011 UNEP report on "Decoupling Natural Resource Use and Environmental Impacts from Economic Growth" reveals that related sustainability concepts and approaches like Industrial Ecology (IE), eco-efficiency and Cleaner Production (CP) have contributed to achieving relative but not absolute decoupling.

With a view on its potential impact, a concern is that CE has been argued to lack conceptual clarity and an accepted definition (Yuan et al., 2008; Lieder and Rashid, 2015). Recent literature reviews have made first attempts at discerning key conceptual elements of CE and its link to other sustainability related concepts (see Ghisellini et al., 2014; Geissdoerfer et al., 2017). However, as Blomsma and Brennan (2017) argued, "theoretical or paradigmatic clarity regarding the concept of CE has yet to emerge" (p.610). An important example, is the framing of CE as new, innovative, and transformative in character, and simultaneously, as easy match with existing ecological modernization initiatives, in some of the literature (Geng and Doberstein, 2008; Liu et al., 2009; Zhu et al., 2010). This almost paradoxical framing suggests that fundamental paradigmatic questions of CE conceptualization remain indeed unsolved.

Consultancy and advocacy have been especially active in framing CE as new, yet easily attainable and lending their expertise to policymakers, the framing is echoed in policymaking. Suggesting a sharp contrast between the current linear and a circular economy, Accenture and Circle Economy write: "Climate change and the impending shortage of raw materials demand a shift from linear to zero-waste circular cycles." (Accenture & Circle Economy 2016, p. 4). Likewise, the Ellen MacArthur Foundation (EMAF) finds that "the call for a new economic model [CE] is getting louder" (EMAF, 2013, p.6). In the scientific literature, the debate is typically more nuanced, however some authors view CE as "a new frame of mind, a new perspective" (Bonciu, 2014, p. 83), "a new path of industrialization" Xiao & Huang (2010, p. 97) or an approach that will require "a paradigm shift in the way things are made" (Preston, 2012, p. 2).

However, looking at the theoretical underpinnings of CE, these are arguably far from new. System thinking and circularity in ecological and economic systems are rooted in literature, dating some decades ago, and these literature streams were themselves inspired by ideas on agricultural and human metabolism dating back to the 18th century (Schivelbusch, 2015) whereas the more specific ideas on CE have been argued to date back to the metaphor of Spaceship Earth (Boulding, 1966). Practically, it can be claimed that advanced economies in Northwestern Europe have created up to 70–90% circularity for key bulk materials including metals and plastics (EEA, 2013), and in developing countries the absence of formal resource 'reutilization arrangements' has led to the emergence of an informal recovery sector (Gu et al., 2016).

Pointing out CE as new and transformative hence seems to ask for characterization of the concept in terms of maturity through a closer look at its historic and geographic evolution. As its first aim, the present article conducts a short literature review on the development of CE (Section 3). We propose – playing with its terminology – to view CE as a refurbished rather than as a virgin concept. Artificially distinguishing three phases of development, we show that many elements of its conceptualization have reincarnated various times with its basic thoughts are found back in other, older key sustainability sub-concepts like IE, CP, Closed-Loop-Supply Chain Management (CLSC) and Ecodesign.

Based on this overview, we put forward the idea that instead of CE being *per se* new or transformative, elements indicative of the new combinations of the 'established teachings' that would characterize a CE concept entailing the potential to induce transformative sustainability change, have to be carefully defined and shaped by scientists and practitioners, precisely at this stage where CE carries momentum in various types of literature. A crude distinction between two schools of thought (reformist and transformational) serves us as vehicle to elucidate some of the main distinctions made in literature.

In line with other authors (Hultman and Corvellec, 2012; Blomsma and Brennan, 2017), we establish as one of decisive elements of a more transformative view of CE, nuanced material hierarchies as operationalization principle of CE, sometimes called R-hierarchies or imperatives. While the 3R-imperatives of 'reduce, reuse recycle' form an accepted notion of CE in theory and practice – see the Chinese policy – there has recently been emphasis on more nuanced hierarchies with shorter loop options like 'redesign', 'refurbish', 'repurpose', as enabling the highest possible value retention of resources over multiple product life cycles.

Hence, the second aim of this article is an in-depth exploration of the understanding of this key operationalization principle used in the literature. Our analysis of 69 academic articles on their conceptualization of R-imperatives, finds this to vary starkly among different scholars and disciplines. Authors not only find varying numbers of R-imperatives, such as 3Rs, 4Rs or 6Rs, but different author(-groups) assign different attributes and meanings which implies that divergent conceptualizations of this key CE principle dominate the literature (see Section 4).

As a response to recent calls for better conceptualization (Blomsma and Brennan, 2017) we go beyond reviewing and synthesize the most common perspectives on R-imperatives into a single systemic typology of 10 resource value retention options (ROs) which we illustrate, as most common in the literature, as a number of Rs. As part of the integrated view, we suggest discriminating two related life cycles, a Product *Produce and Use* Life Cycle and a Product *Concept and Design* Life Cycle in connection with the 10Rs. Through our typology and the visual frameworks, we seek to underline the idea that a concept rooted in system thinking calls for transdisciplinary, scholarly efforts at synthesis and systemic thinking for it to gain potential of system-changing character.

In Section 2, we first outline the research design employed for attaining the aims of this paper, specifically the different types of literature reviews conducted are explained. The following two sections, present the results of the literature reviews on CE history and its conceptual elements (see Section 3), and the progress made with regard to CE policies and measurement of circularity (Section 4). In Section 5, we provide our review and synthesis of R-imperatives or ROs. Finally, Section 6 reflects on the implications for the key stakeholders in conceptualizing CE and provides imperatives for action on future policy and academic approaches.

2. Research Method

This article is based on two distinct literature reviews, and designed to address gaps voiced previously in research related to 1) paradigmatic clarity in the conceptualization of CE and 2) lack of a coherent conceptualization of a specific operationalization principle, the R-imperatives, as outlined in Section 1. According to the typology of literature reviews defined by Grant and Booth (2009) the reviews can be classified as 'critical reviews'. We have chosen for this type of review, because Grant and Booth (2009) propose it as highly suitable method, where rather than pointing out all existing knowledge and research gaps, its objective is pointing to inconsistencies, resolving ideas related to competing schools of thought, and launching new conceptual development.

2.1. Data Collection and Analysis for the Review on CE Conceptualizations

Literature for exploring the development of conceptual elements and various schools of thoughts was obtained through a search in Google Scholar and the Scopus database on the “circular economy” AND variations of the terms ‘history’, ‘development’, ‘definition’ in a search dating to 2016. We scanned and collected articles manually for relevant content on: 1) CE definitions and its links to other concepts as input for the distinction of CE phases (Section 3.1); 2) characterization of CE definitions and schools of thought (Section 3.2); and 3) current CE progress (Section 4). Overall this in-depth study uses a largely qualitative and narrative representations of results. We complemented this approach with two simple bibliometric analysis derived from Scopus operationalized as a Title-Abstract-Keyword search. These depict the rise of CE publications compared to related concepts over the years and the number of connections made between CE and these concepts. This method cannot detect relations drawn by authors in the main body of text. Still, overall these simple methods serve well to back up our main findings more quantitatively and balance the largely qualitative and narrative analysis.

2.2. Data Collection and Analysis for the Review on Value Retention Options

The historic analysis brought forward the idea of value preservation or resource value retention options (ROs) – as we call it in Section 5, as a central common denominator spanning various academic fields and different types of studies, commonly operationalized in the form of a hierarchical ‘R-ladder’ or R-imperatives. Here, ‘R’ stands for various terms starting with ‘re-’ (from Latin: ‘again’), such as ‘re-use’, ‘re-manufacture’ (which we discuss in detail in Section 5). We conducted a search in Scopus and Google Scholar for identification of peer-reviewed, academic contributions addressing R-imperatives. A search exclusively with Latin prefixes risked overlooking options, like ‘cannibalization’ or options related to product design and life extension, as ‘design for longer’. Hence, a great number of search strings were tested out iteratively (see Appendix A). In this process, we found additional papers and a number of relevant books applying the snowball method. All obtained articles were scanned for duplications, relevant information was extracted manually and stored as Excel Datasheet. This included the number of given R-imperatives, definitions, visualizations and other clarifications like business activities related to a specific option.

We determined that we had reached a saturation point of the search when 1) we identified recurrent (groups of) authors advocating similar perspectives in a discipline and 2) we found (groups of) authors dominating the discourse (indicated through high citation by peers). Unless we detected a significant evolution in perspective with recurrent (groups of) authors, we included only the most recent or the most detailed conceptual contribution; the latter was preferred. Overall, both conceptual and empirical papers were included. Papers cited less than five times were generally excluded from the scan; exceptions were made for newer papers (2010–2016) and for several papers from Asia in an effort to cover relevant perspectives from all continents. A total of 69 contributions were analyzed and results are presented as comparative, qualitative account of R-definitions in the literature. In order to show our preference for mixed methods evaluations, we support our second literature review with more quantitative and schematic representation of results in tables and two synthesizing graphical frameworks.

Our methods allowed for an extensive overview of the literature, but the judgement of what constitutes clarifying knowledge with regard to CE and R-imperatives contains a subjective element. This is typical with critical reviews, and we acknowledge it as a research limitation. We tried to restrict any selection biases through inclusion of a wide array of literature and cross-verification among the three co-authors for the grouping and analysis of the R-imperatives. Terms and definitions had to be identified in the text and their meaning interpreted against the context of other obtained literature which made the use of strictly bibliometric methods infeasible. Consequently, a time consuming, iterative process was applied which means high replication efforts.

3. The Circular Economy as a Refurbished Concept

CE dates back much longer than the current use of the notion. In many parts of the globe, most notably in Europe, circularity has a long history. In the following paragraphs, we first show that CE can be artificially divided into three distinct historic phases leading to the current framing of the concept. Recently, Blomsma and Brennan (2017) provided a similar distinction of CE into three phases where they characterize CE as an umbrella concept and as a ‘new framing around prolonging resource productivity’ to derive further avenues for research. We believe that such an overlap in approaches demonstrates the relevance of distinguishing evolutionary phases and framings of a concept. We suggest that different schools of thoughts with more reformist and more radical ideas exist alongside in the current CE 3.0.

3.1. The Circular Economy as an Evolution in Three Phases

Several authors claim that CE can be traced back as far as Quesnay’s “Tableau Economique” (1758) and his assumptions on surplus value from cyclical inputs (Murray et al., 2015). The earliest directed examples at closing *material* loops date back to the 19th century such as the work by P.L. Simmonds (1814–1897) (Cooper, 2011). Besides, historically, there have always been economic sectors evolving from waste usage and by-products like dyes in petrochemicals (Ayres and Ayres, 1996). However, through the industrial revolution, new dimensions of product diversification and material use emerge. After World War II, the global economy accelerates and waste management becomes increasingly problematic and important to regulate. The main concerns are controlling and abating pollution but integrative waste management approaches are still missing (Carter, 2001). At the end of this phase, early warnings of resource depletion and limits to growth emerge. The publication of the Club of Rome (1972) is decisive in inducing the shift to the next phase.

3.1.1. CE 1.0 (1970–1990s): Dealing with Waste

The 1970s, in Europe and the US are the times of command and control policy measures (Otis and Graham, 2000). Alongside environmental movements, the 3R concept of ‘reduce, reuse and recycling’ increasingly gains attention. Governments regulate, businesses mostly follow reactively. The majority of measures in these decades focus on the ‘output side’; waste is not prevented but pollution limited through principles like 'polluter pays' and ‘end-of-pipe’ treatment becomes the rule (Gertsakis and Lewis, 2003; Tyler Miller and Spoolman, 2002). Waste management gets important by means of regulating landfills and incineration, but there is not yet an established thinking in systems, with large amounts of waste being treated outside ‘one’s borders’ or even being dumped in less affluent countries (Moyers, 1991). However, exactly these types of practices, and growing global links through media, like the television, nurture a realization that local and global problems are connected and that such problems can also ultimately affect strong economic nations. It is in this phase that preventive and life-cycle-thinking focused concepts like CP and IE are first introduced and start to contribute to thinking in systems (Gertsakis and Lewis, 2003). Looking at Fig. 1, one can see how a large body of literature on waste management and recycling emerges during these decades, which is later accompanied by a rise in the literature which places systems thinking at center, for example IE and CP. Therefore, the roots of CE can be argued to lie in precisely this phase. However, in practice, input and output measures remain insufficiently connected. Successes remain greatest at the output side, with recycling rates considerably growing between the 1980s and the 1990s, not at last because of further policy measures and voluntary schemes for waste management and recycling by businesses (Bergsma et al., 2014). Scientific literature on the subject also grows steadily in this phase, addressing first improved waste management and later recycling, separation, and collection.

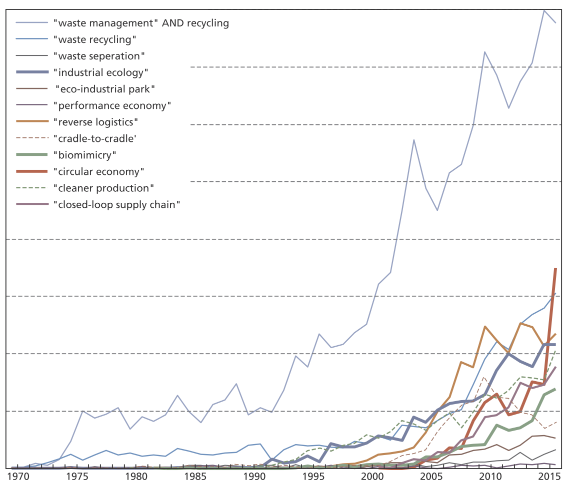

Fig. 1. Scientific Publications in Scopus on Circular Economy and Related Concepts, 1970–2016.

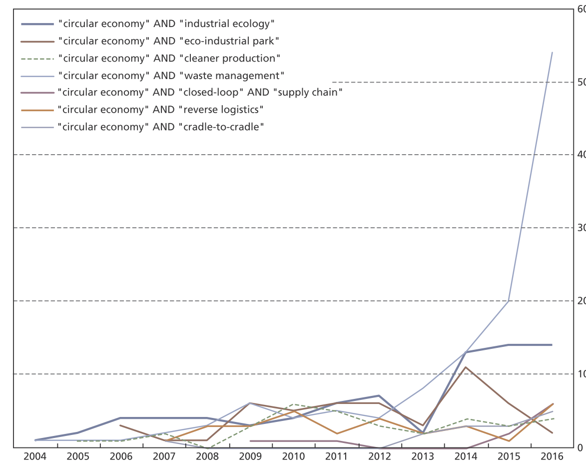

Fig. 2. The Relation of CE to its Predecessor Concepts in Scientific Publications in Scopus. The TITLE-ABSTRACT-KEYWORD search shows that CE is first related to IE and waste management, from the year 2004.

3.1.2. CE 2.0 (1990s–2010): Connecting Input and Output in Strategies for Eco-Efficiency

In this phase, we see a stronger integration among preventive measures and output measures. The idea of a win–win between the environment and business activity, as laid down in the Brundtland Report (WCED, 1987), gets promoted, often under the motto 'pollution prevention pays' (Ochsner et al., 1995). Increasingly, environmental problems are framed as an economic opportunity: proactive businesses can profit from efficiency gains and reputation gains (see for more detail, Blomsma and Brennan, 2017). The dominant framing from the end 1960s and the 1970s about absolute reduction receives less attention. Concepts like IE and life cycle thinking (Boons and Howard-Grenville, 2009) become principles for action, however only on a limited industrial scale and alongside a very technical discourse (Graedel and Allenby, 1995) with social elements of innovation and implementation largely neglected (Vermeulen, 2006). Further concepts like Design for the Environment get established in business in CE 2.0 and increasing attention is paid to questions of prevention and efficiency through design – as it is widely realized that a reduction in residuals ultimately asks for a reduction in inputs (Ayres and Ayres, 1996). Thinking in systems is growing, and scientific data on global warming, water shortages, loss of biodiversity, create a new sense of urgency, in the early years 2000. This is aided by more and faster information sharing through digitalization and the internet which enable connecting the local to the global environmental issues in unprecedented ways.

Although scholars like Stahel and Reday wrote about a closed-loop economy as early as 1976 (see Bourg and Erkman, 2003), and the concept of CE itself was coined in the 1960s, it is only in this phase that CE slowly gains prominence (Murray et al., 2015). This is also visible in Fig. 1: first academic literature emerges in the 1990s, but a sharp increase in publications is seen around the year 2000. Fig. 2 depicts the results of a simple bibliometric analysis on the relation of CE and its predecessor concepts in Scopus, and shows that first literature relating CE to predecessor concepts emerges in 2004. This analysis seems to confirm the claims by several scholars that the links between CE and waste management, CE and IE (including eco-industrial parks) and, CE and CP, are conceptually the oldest and remain very strong to date (see Murray et al., 2015; Iung and Levrat, 2014). It is also visible that the link between CE and the Reverse Logistics (RL) and Closed-Loop Supply Chain (CLSC) literature emerges later (from 2007), while links to cradle-to-cradle (C2C) emerged very recently. Other concepts from Fig. 1 were not included in Fig. 2, as scholars have hardly connected them with CE (e.g. CE and performance economy).

3.1.3. CE 3.0 (2010 ±): Maximizing Value Retention in the Age of Resource Depletion

In terms of framing, from 2010 onwards, several 'borrowed' and 'older' elements are combined in a new or newly emphasized fashion (Blomsma and Brennan, 2017, see 3.2). While the rhetoric still stresses economic gains, ultimate threats to survival of the human race in the light of seemingly insurmountable sustainability challenges are linked to population growth and renewed attention for resource depletion and retaining the value of resources. There is fear that we cannot consume endlessly and that other nations should not catch up with the Western level of exploiting nature – at least not through the same growth path and with similar rebound effects. Against this context, the allegedly newly developed idea of CE gets celebrated for its potential of decoupling growth from resource use (UNEP, 2011). Thereby, it is phrased as a way out of the 'resource trap'.

3.2. Illuminating the Scholarly Debate Through Distinction of Two Schools of Thought

Where we use the division CE 1.0-3.0 in order to suggest that concepts take evolutionary yet undetermined paths including changes of meaning over time, Blomsma & Brennan call the latest CE phase 'validity check' period (2013 +). Indeed, there is a sense of urgency for 'validity' in conceptualization, as writings on CE as "new" and "transformative" often fail to sufficiently point out these elements. Until recently, there was a remarkable lack of effort on side of academics to shape the concept. Hardly any specific definitions were put forward, instead articles elaborated on CE requirements (Zhu et al., 2010; Geng and Doberstein, 2008), its scope and levels (Su et al., 2013), contrasted it with the linear economy (Pitt and Heinemeyer, 2015) or explained its related concepts (Murray et al., 2015; Ghisellini et al., 2014). Geissdoerfer et al. (2017), in their paper on the relation between sustainability and CE, finally put forward a hard definition. They place business activities at center and describe CE as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (Geissdoerfer et al., 2017, 579).

Their definition reveals some of the elements that are pivotal in earlier approaches and become re-emphasized in CE 3.0. Like in CP, IE and the various sustainability design approaches, the idea of resource input reduction and creating loops for reuse stands central. The rhetoric of 'regenerative systems' shows considerable overlap with IE principles (Iung and Levrat, 2014; Ghisellini et al., 2014). Moreover, in CE, the

Table 1
Three Unresolved Key Elements in the Conceptualization of CE 3.0.

Need for…	Reformist School	Transformationist School
…absolute resource input reduction	NO	YES
…modification to the economic order, i.e. capitalist system	NO	YES
…balance among sustainability dimensions	NO	YES

distinction of various preservation stages of resource value using hierarchical 'R-ladders' or imperatives, is an essential operationalization principle. Yet, already in the 1990s, several key IE scholars developed resource retention and 'cascading' hierarchies (see Graedel and Allenby 1995; Stahel 2003; Cohen-Rosenthal and Musnikow, 2003). As many of these distinguish three to five few stages (Graedel and Allenby 1995; Ayres and Ayres, 1996), the more nuanced hierarchies found in CE (see Section 5) arguably form one of the elements where established teachings are recombined in a new way.

The idea of narrowing loops provides that local action and local closed-loops are preferred just like in IE which is commonly put into practice with geographically close entities in eco-industrial parks. However, in CE 3.0 emphasis shifts from geographically close entities to the supply chain, suggesting that CE 3.0 is characterized by closing loops over wider geographical distances where feasible – these ideas show the close connection of CE to RL and CLSC. Another, rather new element is a consideration of a wider system with a more inclusive stakeholder perspective. In contrast to the design approaches which are often connected to single firms and 'inward-looking', or IE, where collaboration is described as one among commonly unrelated businesses, CE 3.0 absorbs these perspectives but adds to old teachings. Typically, the collaborative system is broadened to supply chain partners and stakeholders including consumers, NGOs and government. Lastly, one element that may set CE 3.0 apart from all its predecessors is the combined thinking in business models, and products and materials rather than exclusively in one dimension such as flows. Business models summarize how value is created, captured and distributed among the involved parties (Bocken et al., 2017) – hence CE 3.0 goes further than predecessors like IE and CP in recognizing that implementation of preventive measures and circularity decisively hinges on organizational aspects rather than technical matters of realization only.

The elements above are referred to by different parties contributing to CE conceptualization, even though this paper first condensed how these elements recombine in CE 3.0. There are, however, at least three related elements on which CE literature is fundamentally divided and which we argue are essential to clear conceptualization (Table 1). Linked to these, we can distinguish two schools of thought.

The first two elements are very much related. There is a small group of scholars which places the idea of 'refusing' and 'reducing' absolute resource inputs at center (see Naustdalslid, 2014). Typically, this group also refers to attaining eco-effectiveness with increased efficiencies constituting a necessary but insufficient component of CE.[2] Most scholars, however, relate CE to eco-efficiency, some are referring to effectiveness as sub-concepts of the former (Li et al., 2010; OECD, 2011), hence revealing a lack of reflection in employing these notions. This issue is closely linked to idea of CE denoting an alternative economic system. As Cox (1999) outlined, the dominant logic in the capitalist economy is seeking "a position where neither customers, employees, competitors or suppliers can leverage value from you, while putting yourself in a position to leverage all of them" (p.171). System thinking being an essence of CE seems to deny this logic of optimizing for oneself. Nevertheless, it is apparent that especially consultancies and policy documents embed CE into the current economic paradigm and a rhetoric of healthy growth, rather than using it as a vehicle for modification of the capitalist system into one where value is distributed more fairly and equally. For example, the EMAF, a consultancy that has been influential in framing CE over the past years, holds that CE is about "a shift to a new economic model" (EMAF and McKinsey & Company, 2014, p.3) assuring simultaneously that it entails "exploit[ing] new opportunities for innovation, growth and resilience" by gradual decoupling only and underscoring that up to additional 7% GDP growth can be attained until 2025 through CE (Ellen MacArthur Foundation, 2017, para. 3). Somewhat similar, the EU, OECD and WEF link CE to increased global competitiveness and economic growth - hence to resource efficiency rather than to eco-effectiveness (OECD, 2011; WEF, 2014). At the other side of the spectrum, stand a handful of critical scholars. Gregson et al. (2015) questioned whether our economic system can deliver optimal circularity. The authors argue that high value preservation of resources throughout multiple circular loops would require "radical transformations to the economic order, including fundamental recasting of manufacture, retail, consumption and property rights" (p. 235). In the same vain, Lazarevic and Valve (2017) hold that CE is far from new and radical, if it is simply embedded into the current institutional set-up as a market driven approach that embraces rather than rejects the Western patterns of production and consumption.

The final controversy regards the link of CE to sustainability. Many authors view it as a concept uniting economic and environmental sustainability, but there are also a few examples following another interpretation. The Dutch government (2013) defines CE as "economic system that takes the reusability of products and materials and the conservation of natural resources as starting point. It also strives for value creation for people, nature and the economy in each part of the system" (Circular Academy, 2016, para. 4). This definition includes the social dimensions of sustainability and rather points to a need of balance among the three dimensions. Similarly, Dupont-Iglis (2015) argues that CE is about "maximizing the positive environmental, economic and social effects" (para. 3; see also Yong, 2007; Liu et al., 2009; Conticelli and Tondelli, 2014; Lieder and Rashid, 2015). Van Buren et al. (2016) are most explicit on the social dimension noting that CE entails "creation of social value (minimization of social value destruction throughout the entire system, such as the prevention of unhealthy working conditions in the extraction of raw materials and reuse)" (p.3).

Taking these controversies in CE into account, it is apparent that there are still fundamental paradigmatic divides in conceptualization. Arguably, the reformist school copies the more general 'win-win' framing of sustainability which emerged during the 1990s and which was indeed successful at encouraging sustainability efforts of businesses. In that sense, it is understandable why scholars have claimed the good fit between CE and other approaches for ecological modernization. Still, writings stressing the easy fit or embedding it in a healthy growth rhetoric for persuasion, and failing to point out the new elements of CE, hardly carry legitimacy in calling CE new and transformational, instead rendering it merely a refurbished concept to be placed – also evolutionary speaking – among other sustainability initiatives. Conversely, if creation of circular systems implies clear recombination of the established teachings, as to imply major institutional changes or even modifications to our economic model, then CE can legitimately be termed a new approach with potential for transformative impact.

4. CE in Practice – Geographical Perspectives on 'Where We Are Now'

Insights on the history of CE have shown that CE is not per se a new or transformative concept. On the contrary, if we interpret it in line with the ideas of the reformist school of thought, placing it among other

[2] For a definition of eco-efficiency vs. eco-effectiveness in the context of ecological sustainability, we recommend Dyllick and Hockerts (2001). They emphasise non-substitutability of natural capital, i.e. absolute limits to resource use, and hence seem to apply the notion even stricter than most cradle-to-cradle scholars who typically refer to the interpretation provided by McDonough and Braungart (2002).

sustainability initiatives and within the current economic paradigm, we can argue that certain levels of circularity have already been institutionalized in different forms across various geographies. Overall, a very mixed picture of success emerges with diverse modes and speeds of implementation with policies and measurements focused on capturing 'recycling' rates rather than 'reuse', 'reduction' or recovery rates of products and materials linked to other R-imperatives.

Sakai et al. (2011) provide a good overview with a wide geo-political comparison of Asian countries, Europe and the USA, describing waste management and recycling policies, set *targets* and actual recovery and recycling rates. For the USA, they give a 44% recovery *target* for municipal wastes (2001) and an ambition to raise this to 51%, in 2008. According to Kollikkathara et al. (2009), recycling of US municipal solid waste grew from 16% to 33% between 1990 and 2006, while landfilling was reduced from 70% to 55%. However, Chowdhury argues that reliable data is hardly available on recycling rates in the USA (Chowdhury 2009). The most recent data available in the online US-Environmental Protection Agency (EPA) Report on the Environment shows that recycling has slightly gone up to 34% in 2013, while 53% of municipal solid waste was still landfilled (EPA, 2016). In a detailed study including uncertainty estimates, Chen (2013) showed that in the period of 1980s–2010s, the aluminium end-of-life recovery rate lay between 38% and 65% and actual recycling varied between 34% and 61% with an increasing trend and the peak occurring in 2008.

For Japan, the municipal waste recycling was reported at 20%, in 2006, with a *target* of 24% for 2015 (Sakai et al., 2011). However, some of the Japanese 2010 recycling *targets* for specific materials are far higher: 91% for glass, 62% for paper, 50–70% for various home appliances, and 40–85% for various forms of food waste. Most ambitious in Japan was the construction waste *target*: 95–98% for the various materials in 2012. Even more ambitious policies can be found in Korea, with an overall reduction *target* for municipal waste recycling of 61% in 2012. China has set various efficiency and waste management targets as part of its 12th five-year plan (2011–2015) and its CE policies. Su et al. (2013) report of the four major cities, Beijing, Shanghai, Tianjin and Dalian to have achieved remarkable increases in waste reclamation rates in the period of 2005–2010. Industrial solid waste recovery increased between 16 and 34% and safe disposal of municipal solid waste in landfills by 10–20%. In the municipality of Dalian this means attainment of overall rates as high as 96% and 100% in the two respective categories. However, data on actual reuse are scarce. Ghosh et al. (2016) find that China officially reports to recycle 28% of its e-waste, yet it is burdened by an equally large illegal import of e-waste from elsewhere.

In the first decade of the 21st century, the overall EU ambition is somewhere in between Korea and the other countries mentioned. The 2008 EU Waste Framework Directive (EC, 2008) included a 50% *target* for recycling household waste (2020), 70% recycling of demolition waste (2020), and 85% recycling of cars (2015), to mention a few elements (Sakai et al., 2011). However, within the EU, there are clearly different histories and speeds. First movers were mostly mid and Northwestern European countries, among them Denmark, Germany, the Netherlands, and the UK (EUKN 2015). In the Netherlands, for example, waste prevention and recycling of waste received extensive attention in policymaking, since the beginning of the 1990s, and yielded substantial results. For a large number of product groups this policy developed 'recycling arrangements' (Vermeulen, 2002; Vermeulen and Weterings, 1997). In a paper to the European Environment Agency (EEA), Milios reports about the Netherlands achieving the 50% recycling of municipal waste in 2010, with the share of landfilling getting close to 0% (Milios, 2013). In a more recent evaluation of the national waste management plans (2003–2009 and 2009–2015) for the Dutch government, Bergsma et al. show that domestic waste in 2010 was for 79% recycled, 20% incinerated and 2% landfilled, while construction waste was recycled for 98%, and 2% landfilled (see also Schut et al., 2015).

It is important to note here that household waste and other municipal waste are only a small portion of all waste generated (resp. 16,6% and 10% in 2010 in NL), compared to construction waste (44,7% in 2010) and industrial waste (28,6% in 2010) (Bergsma et al., 2014). For industrial waste the recycling rates are at 88,6%, with 7% incineration and 4% landfilling. This indicates that consumer waste behavior is the weaker link in the chain (Bergsma et al., 2014; Goorhuis et al., 2012). More recently, efforts have been made to further increase the recovery rates from households.

The Dutch policies resulted in recycling rates, in 2015, for various waste streams of 85–97% (83% of glass, 85% of paper, 97% of cars, > 95% of tyres, 95% of (domestic) metal, 97% of construction waste), and lower rates for some other material flows (around 45% in timber, around 51% of household plastic waste), but in all cases significantly higher than 25 years ago (ARN, 2016; Nedvang, 2015; Schut et al., 2015; Vereniging Band en Milieu, 2016). However, these high circularity rates disguise that downcycling is still the rule rather than upgrading (see Blomsma and Brennan, 2017). While Dutch policy documents explicitly call for shorter loop options, national *targets* beyond 'recycling' and 'recovery' are still missing.

The Dutch case is an example from the front running group of countries with proactive policies and recovery *targets*. A recent review by the EEA on municipal waste management in 32 European countries clearly illustrates the divide (2013). Consumers in the wealthier mid and Northwestern European countries generate twice as much waste as in Eastern European countries. Yet, overall recycling rates for municipal waste, in 2010, in the mid and Northwestern European countries, are beyond the 50% *target*, like in Austria, Germany, Belgium, Netherlands and Switzerland, with regions even reaching 80–90%, while Rumania, Turkey, Bulgaria remain close to 0% recycling. The landfilling practices are mirroring this: Switzerland and Netherlands reaching close to 0% landfilling, while Bulgaria, Croatia, Latvia, Lithuania and Turkey still landfill 80–100% of their municipal waste (EEA, 2013).

With the recent EU ambitions for a CE (EU, 2016), the European divide poses a double challenge for policymaking: supporting the laggards to catch up, and challenging the frontrunners to make next steps to fully closing loops and moving towards shorter loop R-imperatives. Another recent review by the EEA of the material resource efficiency policies in 32 countries suggests that the frontrunner countries explicitly promote steps towards CE with higher ambitions like 75% recovery of all domestic waste, in 2020, and 90% of glass, in 2015 (Netherlands). Laggard examples include the municipal waste-recycling *target* of 2020 in Lithuania, Poland, Serbia and Slovakia set at 50% and to be reached by 2020 or 2030 (Serbia) (see also the list of different recycling targets in: EEA, 2016a,b).

With these national differences in Europe, the average recovery and recycling rate for all forms of waste sums up to 46% in the period 2012–2014 (EEA, 2016a,b), which can be viewed as being half way on the road towards circularity. The numbers above clearly suggest a strong divide within Europe, in terms of ambition and actual reuse rates. However, a recent study of Van Eygen et al. (2016) shows that also mid-European countries have not come far in establishing structures that would enable viability of longer loop R-imperatives for their key materials – downcycling rather than upgrading or reducing amounts used is still the rule. In Austria, in 2010, the vast majority of all plastic waste was incinerated for energy recovery or in the cement industry (46%, 21%) and at best mechanically recycled into granulate or chemically into feedstock used in other production processes (21%, 10%). Moreover, a report by Zero Waste Europe (ZWE, 2015) shows that an EU wide a decrease of landfilling by 8% achieved by national landfilling ban policies in 2009–2013 was coupled with a substantial increase in incineration. Germany, Denmark, the Netherlands and Sweden all built incinerators with over-capacity which the ZWE argues caused adverse effects with doubling or tripling of incineration, a decrease in recycling rates (Austria, Norway), and a lower focus on prevention and other more desirable R-imperatives as a result of needing

Table 2
Overview of R-Imperatives According to Hierarchy and Discipline.
(Amelia et al., 2009; Badurdeen et al., 2009; Geng et al., 2012; Gerrard and Kandlikar, 2007; Govindan et al., 2014; Graedel and Allenby, 1995; Guide et al., 2003; Ingarao et al., 2011; Kazazian, 2003; Kazerooni Sadi et al., 2012; Peng et al., 1997; Price and Joseph, 2000; Rahman et al., 2009; Rahman and Subramanian, 2012; Rusjanto et al., 2011; Sinha et al., 2016; Xin et al., 2014; Xing and Luong, 2009; Yan and Wu, 2011) (For interpretation of the references to colour in the table legend, the reader is referred to the web version of this article).

Scholarly Discipline	#	Rs clearly ranked	Suggests Rank	Rs not ranked	Author Contribution
1. Waste Management and Environmental Sciences (incl. end-of-life treatment)	14	8	3	3	**Peng et al. 1997**; Price & Joseph 2000; Tyler Miller & Spoolman 2002; **King 2006**; Gerrard & Kandlikar 2007; Yoshida et al. 2007; Rusjanto 2010; **Allwood et al. 2011**; Kazerooni Sadi et al. 2011; Hultman & Corvellec 2012; Jones et al. 2013; Worrell & Reuter 2014; Xin et al. 2014; Diener & Tillmann 2015
2. Reverse Logistics and Closed-Loop Supply Chain Management (incl. green/lean/sustainable supply chain management)	28	19	6	3	**Thierry 1995**; **Fleischmann et al. 1997**; De Brito & Dekker 2003; **Guide et al. 2003**; **Blackburn et al. 2004**; Fernandez & Kekaele 2005; **Mitra 2007**; **Srivastava 2008**; Amelia et al. 2009; Badurdeen et al. (2009); **Defee et al. 2009**; **Jayal et al. 2010**; **Wang & Hsu 2010**; Kuik et al. 2011; Hazen et al. 2012; **Hassini 2012;** Loomba & Nakkashimi 2012; Rahman & Subramanian 2012; García-Rodriguez et al 2013; Nagalingam et al. 2013; Romero & Molina 2013; Silva et al. 2013; **Govindan et al. 2014**; Agrawal et al. 2015; Sihvonen & Ritola 2015; van Buren et al. 2016; Fercoq et al. 2016; Sinha et al. 2016
3. Product Design and Cleaner Production (incl. other preventive and design approaches)	10	4	4	2	**Jawahir et al. 2006**; **Gehin et al. 2008**; Rahman et al. 2009; Xing & Luong 2009; Ingarao et al. 2011; Yan & Wu 2011; Den Hollander & Bakker 2012; Bakker et al. 2014; Yan & Feng 2014; Go et al. 2015
4. Industrial Ecology	12	7	2	3	Graedel & Allenby 1995; **Ayres & Ayres 1996**; Cohen-Rosenthal & Musnikow 2003; Kazazian 2003; Roine & Brattebo 2003; Francis 2003; Stahel 2003; Stahel **2010**; **Graedel et al. 2011**; Li 2011; Liu et al. 2016; Stahel & Clift 2016
5. Circular Economy 2010+	5	3	0	2	Biliteweski 2012; **Geng et al. 2012**; **Su et al. 2013**; **Ghisellini et al.** 2014; Lieder & Rashid 2016
Total #	69	41	15	13	
% (~)	100	59	22	19	

Author names in bold print: Key author (50+ citations) and highly cited by other authors addressing.
Green color = "Rs clearly ranked": Ranking of R-imperatives explicit through text, figures or tables; in most cases, definitions of Rs and a reasoning for the ranking is provided.
Yellow color = "Suggests Rank": Listing order of R-imperatives in text, figures or tables suggests a ranking, yet not explicit.
Orange color = "Rs not ranked": No clear ranking of R-imperatives through text, figures or tables, no explanations.

sufficient throughput for viability of the newly built, high capacity incinerations (ZWE, 2015).

Insights on circularity on recycling and recovery in developing countries are difficult to obtain as little aggregate information exists. According to Diaz (2017), the root causes for low CE in developing countries are a lack of political will, lack of a national waste management policies, rules and regulations, insufficient funds dedicated to CE, and the absence of expertise and education at all levels. This void of policies and formal structures led to the emergence of an informal recovery, recycling and reuse markets. Diaz estimates that 'informal recycling' efforts amount to 10% to 15% of total municipal and commercial wastes generated in developing countries. Official numbers are available only for the BRIC countries, a review of formal sector e-waste recycling finds very low recycling rates for India (3%), a marginal fraction in Russia (less than 1%), and only informal structures in Brazil and South Africa (Ghosh et al., 2016).

This brings us to the issue of leakages from CE: despite a 40-years history of recycling preferences in Europe (Williams 2015), we still face illicit and illegal exports of waste towards developing countries with weak regulations and enforcement capacities (Crang et al., 2013; Gregson et al., 2015; Lepawsky et al., 2015; Lepawsky and Billah, 2011). Breivik et al. (2014) recently produced a global e-waste mass balance showing a substantial flow of e-waste from OECD countries to China and West-Africa, which represents ~23% of the amounts of e-waste generated domestically within the OECD. This implies a different CE challenge in these countries.

The first study that tries to measure global circularity comes from Haas et al. (2015) and takes 2005 as a reference year. If total material input is considered, the aggregate global recycling rate is as low as 6%, only if biological flows are included (as demanded by CE) the recycling rates is as high as 37%. In line with our findings, the authors assess recycling in Europe (EU-27) as advanced (41% average) compared to the rest of the globe (28%), with a higher share of material recycling but lower biomass reuse than in other parts of the world. Critically, they also note that Europe consumes more materials compared to the global average and that non-circular flows are much higher at 6.4 t/cap/yr (3.4 t/cap/yr globally).

Overall, recycling rates are high for several bulk materials, but low for many high value materials (OECD, 2015). Although there is a global move away from landfilling as the least desirable waste management option, the recent circularity rates in Europe result of policies where incineration and long loop recycling are main R-imperatives. It seems crucial not to try and eliminate longer loop options at all costs – a thorough upfront evaluation of the system effects is decisive to avoid adverse effects and regression. We acknowledge that recycling is a valid form of reuse and currently the optimal treatment for some materials, yet there is a danger that attaining high recycling rates become a synonym for a high level of circularity which can lead to ‘convenient stagnation’ on longer loop R-imperatives.

5. Value Retention Options in CE Literature: From Confusions in Conceptualization Towards a Synthesis

As outlined in the previous sections, CE3.0 is often characterized with reference to hierarchically ranked R-imperatives as an important operationalization principle. In practice, recycling and incineration, lower forms of value retention of materials, still dominate policies and scientists often have to rely on public datasets on ‘recollection and recycling rates’ as data on reuse or resource input reduction is yet difficult to obtain. This section examines the use of R-imperatives in the literature and finds limited consensus among scholars from diverse disciplines relevant to CE.

5.1. R-Imperatives for Circular Economy in the Literature

Our second literature review (see Section 2) is based on 69 contributions. We found these to originate from diverse disciplines which we grouped into the following five: Waste Management and Environmental Sciences (WM), Reverse Logistics and Closed-Loop Supply Chain Management (RL/CLSC) Product Design and Cleaner Production (CDCP), Industrial Ecology (IE) and Circular Economy 2010+ (CE2010 +). An overview of contributions and authors per discipline is found in Table 2.

The 69 peer-reviewed contributions all summarized imperatives for reuse as a certain number of Rs. It seems obvious why this is popular: The ‘re-’ in Latin means ‘again’, ‘back’, but also ‘afresh’, ‘anew’, fairly well expressing the essence of CE (Sihvonen and Ritola, 2015). However, the simplicity that makes such terminology attractive may simultaneously have contributed to confusions in CE literature and its related literature strands. Looking at the myriad of words which appear as R-imperatives in these articles, we note the use of 38 different ‘re-’ words in varying combinations. In alphabetic order these are: *re-assembly, recapture, reconditioning, recollect, recover, recreate, rectify, recycle, redesign, redistribute, reduce, re-envision, refit, refurbish, refuse, remarket, remanufacture, renovate, repair, replacement, reprocess, reproduce, repurpose, resale, resell, re-service, restoration, resynthesize, rethink, retrieve, retrofit, retrograde, return, reuse, reutilise, revenue, reverse and revitalize*.

As Table 2 shows, almost 60% of the authors writing on R-imperatives apply a clear hierarchy, in many cases including definitions of the terms used. Still, about 40% apply no clear hierarchy and remain suggestive or vague on the meaning of the concepts used – this opacity seems concerning, given the variety of terms appearing and since our review entailed a directed search for articles in which R-imperatives are key concepts.

As regards the number of R-imperatives (#Rs) distinguished, these range from 3Rs to 10Rs as can be seen in Table 3. Surprisingly, 3Rs are most used as a typology in the CE2010+ literature, while in WM, 5Rs clearly dominate. Contributions in RL/CLSC frequently use 4Rs, 5Rs or 6Rs. Altogether, a 5R typology is most common, and looking at the color coding, it can be seen that this one is also commonly given with a clear hierarchy and best defined. Typologies of 4Rs and 6Rs typologies are nearly as popular, whereas the more nuanced typologies with 7Rs-10Rs are far less used. It is notable that about ¾ of the latter category are recent contributions, published after 2010. Nevertheless, there is no clear trend visible from use of more simple towards more nuanced typologies over the years (see Table 3).

Most importantly, our comparative analysis revealed the extensive variety and confusion found with the different R-imperatives. Scholars, in combining R-words, present fundamentally different orders and hierarchies some of which lack an obvious logic. As the most simple, the 3Rs distinction serves well to illustrate that authors remain far from applying the same concepts and meaning. For example, 3R can refer to *‘reduce, reuse, recycle’* – this is a well-known waste management principle and dominant with Chinese scholars as the Chinese national CE policies are based on 3Rs. Yet, it is also found with many other scholars (e.g. Lieder and Rashid 2015; Diener and Tillman, 2015; Ghisellini et al., 2014; Yoshida et al., 2007) and can also mean *‘reuse, remanufacture, recycle’* (Gehin et al., 2008; Nagalingam et al., 2013); *‘reduce, recovery, reuse’* (Wang and Hsu, 2010); *‘reuse, recycle, return’* (Hassini et al., 2012); *‘recycling, reuse, revenue’* (Larsen and Taylor, 2000); and *‘reuse, recycle, reduce’* (Yan and Feng, 2014). Finally, one of the most confusing variants is *reuse, recover* and *recycle* (Wang and Hsu, 2010) as the authors use the concepts as an aggregate as well as in a ranked order of activities.

This example could be extended for higher #R typologies and points to a wider cacophony regarding the use of R-words in the literature. This all prompts the question why scientists – despite a growing body of CE literature – have not focused on clearly defining this key concept related to CE operationalization along with an accepted set of definitions. A number of possible explanations can be given:

- The field of CE is not a clearly defined academic discipline with paradigmatic features; instead it is addressed by scholars rooted in various schools of thought, each with their specific focus and disciplinary framings;
- The field of CE is not one of perfect academic isolation, instead it emerged and developed in close symbiosis with policymaking, advocacy and consultancy, where the use of concepts also serves other interests such as persuasion, reducing complexity for communication purposes, and building a business case with alternative concepts. As a result of this the R-words can be used either as general common sense language or as specific disciplinary vocabulary, referring to specific given definitions;
- There is a permanent entry and growing number of new academic actors from different countries and continents, for whom the history of earlier publications in other countries and other disciplines may not be very accessible. With this the focus of the contributions may also be affected by the level of progress in recycling policies and practices in the respective countries, and by nationally defined terminology related to government policies;
- Apart from scientists, governments in different countries use diverse phrasings and supranational organisations, like the EU (3R as: reuse, recycle, recover), UN and OECD (3R as: reduce, reuse, recycle) create their own contradictory syntheses of these in their complex political decision making processes (EC, 2008; Hultman and Corvellec 2012; OECD, 2011; UNEP, 2012).

Next to these more sociological explanations, there are explanations more closely linked to the complex nature of the concept of CE itself:

- It is relevant on various scales: global economy, national economy, value chains of interlinked companies, ‘material flows’ or ‘waste streams’, single business and finally the specific product scale. The key academic disciplines reflecting on CE each link to particular scales thus each addresses specific elements rather than the full system;
- In this context, the unit of analysis is often the ‘product level’, where some address products as generalized term, while others analyze specific products, produced by a specific company in its specific value chain;
- The concept of the product life cycle can actually denote two entirely different cycles: firstly, the full route of resources used for a produced and consumed product via its consumption to its after-use recycling or disposal; secondly the lifecycle from original design to an optimized design including prototyping and adjustments through application over a span of years (Kuik et al., 2011; Nagalingam et al., 2013)

5.2. Making Sense of Value Retention Options: Comparing and Synthesizing Definitions

Exploring the confusion created is one thing, trying to get beyond it is another challenge. Some efforts have been made, based on a limited

Table 3
Representation of R-imperatives for circular economy in academic literature.
(Amelia et al., 2009; Badurdeen et al., 2009; Geng et al., 2012; Gerrard and Kandlikar, 2007; Guide et al., 2003; Ingarao et al., 2011; Kazazian, 2003; Kazerooni Sadi et al., 2012; Peng et al., 1997; Price and Joseph, 2000; Rahman et al., 2009; Rahman and Subramanian, 2012; Rusjanto et al., 2011; Sinha et al., 2016; Xin et al., 2014; Xing and Luong, 2009; Yan and Wu, 2011; Govindan et al., 2014) (For interpretation of the references to colour in the table legend, the reader is referred to the web version of this article).

#Rs	Count (Total/#R)	WM	RL/CLSC	CDCP	IE	CE2010+	Author Contribution
3R's	13 6 Green 2 Yellow 5 Orange	4	3	2	0	4	Yoshida et al. 2007; Amelia et al. 2009*; Xing & Luong 2009; Wang & Hsu 2010; Geng et al. 2012; Hassini et al. 2012; Jones et al. 2013*; Su et al. 2013; Bakker et al. 2014*; Ghisellini et al. 2014; Lieder & Rashid 2016*; Xin 2014; Diener & Tillmann 2015*
4R's	14 9 Green 4 Yellow 1 Orange	2	6	0	6	0	Greadel & Allenby 1995*; Ayres & Ayres 1996*; Cohen-Rosenthal & Musnikow 2003*; Guide et al. 2003*; Kazazian 2003*; Blackburn et al. 2004*; King et al. 2006*; Defee et al. 2009; Graedel et al. 2011*; Kazerooni Sadi et al. 2011; Hazen et al. 2012*; Loomba & Nakkashimi 2012; Rahman & Subramanian 2012; Stahel & Clift 2016*
5R's	19 13 Green 3 Yellow 3 Orange	6	6	3	4	0	Fleischmann et al. 1997*; Price & Joseph 2000; Tyler Miller & Spoolman 2002; Roine & Brattebo 2003*; Stahel 2003*;Fernández & Kekäle 2005; Gerrard & Kandlikar 2007*; Mitra 2007; Gehin et al. 2008; Rahman et al. 2009; Rusjanto 2010; Stahel 2010*; Li 2011; Yan & Wu 2011; Hultman & Corvellec 2012; Romero & Molina 2013*; Worrell & Reuter 2014*; Agrawal et al. 2015; Sinha et al. 2016*
6R's	12 5 Green 5 Yellow 2 Orange	1	7	4	0	0	Peng et al. 1997; Jawahir et al. 2006; Srivastava 2008*; Badurdeen et al. 2009; Jayal et al. 2010; Ingarao et al. 2011; Kuik et al. 2011; García Rodriguez et al 2013; Nagalingam et al. 2013; Yan & Feng 2014; Go et al. 2015; Govindan et al. 2015
7R's	4 3 Green 1 Yellow	0	2	0	2	0	De Brito & Dekker 2003*; Francis 2003; Liu et al. 2016*; Fercoq et al. 2016
8R's	2 1 Green 1 Orange	0	1	0	0	1	Thierry et al. 1995; Bilitewski 2012*
9R's	3 3 Green	0	3	0	0	0	Silva et al. 2013; Sihvonen & Ritola 2015; van Buren et al. 2016
10R's	2 1 Green 1 Orange	1	0	1	0	0	Allwood et al. 2011; Den Hollander & Bakker 2012
Total	69	14	28	10	12	5	

Author names with *: This/these author(s) use(s) a different terminology than 3Rs/4Rs or other units than products and materials, e.g. Ayres and Ayres (1996) 'strategies for raising productivity', Liu et al. (2016) 'repair companies, reuse companies'.
Color Coding: Refers to Clarity on Ranking of R-imperatives, see legend of Table 2

literature review, mostly writing from one of the specific disciplinary confines we discussed above (see for example Sihvonen and Ritola, 2015). A broader and more systematic attempt at creating clarity is relevant as different strands of literature propose that a common language and understanding are crucial for successful implementation of any concept, especially where this involves innovation and learning across multiple groups of stakeholders, as can be assumed to occur in CE. Sharing an understanding of key notions seems critical, especially, where different languages and professional jargon are used by stakeholders possessing different underlying paradigms (Section 3.2), possibly causing mixed views on visions and ambitions, misunderstandings, and consequently inhibiting learning processes.

Based on the interdisciplinary literature review discussed here we synthesize the literature and propose a 10R typology, diversified for the two product life cycles of *'Produce and Use'* and of *'Concept and Design'*. The typology consists of eight reutilization options and two preventive options, most importantly the R0 –denoting zero use and impact, wherefore we use the term resource value retention options (ROs) in order to best cover these altogether. As shown, the meaning of other, common terms (various R-words) can be viewed as eroded and unsuited as umbrella notion. Moreover, the term 'value retention' was not found among the reviewed articles, it is not afflicted by the existing confusion. As a newly introduced term, it must be clear that it shall refer to the idea of resources carrying an intrinsic value – as applied in the sustainability discourse – as opposed to economic notions of value. Hence the retention of resource value means conservation of resources closest to their original state, and in the case of finished goods retaining their state or reusing them with a minimum of entropy as to be able to give them consecutive lives.[3]

We present the various ROs by distinguishing short loops (where

[3] Please note that we put forward the new term resource value retention options for covering due to the high inconsistencies of terminology in the literature. Here, a new umbrella term can add to clarification. Still, we present these options as a number of Rs rather than ROs, as this form of listing is consistently used across all disciplines.

product remains close to its user and function), medium long loops (where products are upgraded and producers are again involved) and long loops (where products lose their original function). We support the comparative analysis and synthesis with Table 4 and Figs. 3 and 4 which show the ROs linked to the two distinct product life cycles.

5.2.1. Shortest Loops: R0-R3 (Refuse, Reduce, Resell/reuse)

The first four loops exist close to the consumer, and can be linked to a commercial or non-commercial actors engaged in extending the life span of the product. Scholars applying a clear hierarchy characterize these as the most preferable ROs in CE. As the historic overview and the previous section argued, the varying emphasis on the R0 and R1 in the literature may be evidence of a paradigmatic division – regarding the issue of the perceived necessity of absolute reduction of inputs and consumption – hence also relating to different motives of different groups in promoting CE.

5.2.2. Refuse: R0

The concept 'refuse' is both used in the context of the consumer and the producer. In the *consumer* case, scholars stress the choice to buy less, or use less, which may apply to any consumption article aiming at prevention of waste creation (Allwood et al., 2011; Black and Cherrier, 2010; Tyler Miller and Spoolman, 2002). It refers to a critical position of consumers, shifting towards a post-material lifestyle (Hedlund-de Witt, 2012; Spaargaren, 2003). Refuse is also often used in the context of rejection of packaging waste and shopping bags (Clapp and Swanston, 2009; Kasidoni et al., 2015). Applied to *producers,* refuse refers rather to the *Concept and Design* Life Cycle where product designers can refuse the use of specific hazardous materials, design production processes to avoid waste (Bilitewski, 2012) or more broadly speaking, any virgin material. Surprisingly, only eight contributions incorporate 'refuse' or 'prevention' in their retention hierarchies (Bilitewski, 2012; Hultman and Corvellec, 2012; Tyler Miller and Spoolman, 2002; Allwood et al., 2011; Cohen-Rosenthal and Musnikow, 2003; Bakker et al., 2014; van Buren et al., 2016; Fercoq et al., 2016) which is possibly explained by the focus on 'reuse' in most articles rather than on explaining all possible ROs.

5.2.3. Reduce: R1

The concept 'reduce' is used in three ways: consumer oriented, producer oriented or as a generic term. Francis (2003) provides such a generic description stating that it is about "eliminat[ing] the production of waste rather than the disposal of waste itself after it has been created" (p.121), while others stress that it refers to all life cycle stages, including the use phase, yet without specifying what the consumer action imperatives in the use phase should be (Ghisellini et al., 2014; Yan and Feng, 2014).

We found some hints on desired *consumer* behaviors, such as using purchased products less frequently, use them with more care and longer, or making repairs for life extension, for example with consumer-to-consumer support (repair shops). Den Hollander and Bakker (2012) included participation in the 'sharing economy' through pooling (simultaneous use) and sharing of products (sequential use) in this category, as they expect more effective product use over time. In most cases, however, 'reduce' is explicitly linked to *producers* and their role in the pre-market stages of the *Concept and Design* Life Cycle, stressing using less material per unit of production, or referring to 'dematerialization' as explicit steps in product design (Jayal et al., 2010; Lieder and Rashid, 2015; Roine & Brattebo, 2003; Sihvonen and Ritola, 2015; Worrell and Reuter, 2014).

5.2.4. Resell/Re-Use: R2

The concepts 'resell' (or 'resale') and 're-use' are closely linked, expressing two sides of the market transaction needed to bring products back into the economy after initial use: the offering side and the taking side. Also in this category, the various explanations of these concepts refer to different positions: consumers, collectors, retailers and producers. There is a strong preference for linking the concept of 're-use' to the 'use'-phase of the Product *Produce and Use* Life Cycle. Still, quite a few scholars (Jayal et al., 2010; King et al., 2006; Wang and Hsu, 2010; Yan and Feng, 2014) apply this concept in the context of only reusing parts or components which is most commonly termed refurbishment and remanufacturing (see below). Other authors explicitly distinguish this as 're-use in fabrication' (Graedel et al., 2011) or mention both options distinctively (Kuik et al., 2011).

Overall, most commonly 'reuse' applies to a second consumer of a product that hardly needs any adaptions and works 'as new' (De Brito and Dekker, 2003), 'with the same purpose' (Bakker et al., 2014; Ghisellini et al., 2014), 'without refurbishment' (Silva et al., 2013), and 'without rework' (Srivastava, 2008) or 'without repair' (Fleischmann et al., 1997). From the consumer perspective, this implies buying second hand, or finding a buyer for a product that was not or hardly in use, possibly after some cleaning or minor adaptations for quality restoration by the consumer. In this context, online consumer-to-consumer auctions for used products are increasingly important, like e-bay and national equivalents (Worrell and Reuter, 2014). Such 'direct re-use' (Agrawal et al., 2015; Loomba and Nakashima, 2012) can also take place as an economic activity via collectors and retailers. Literature suggests that quality inspections, cleaning and small repairs are common here (García-Rodríguez et al., 2013; Hazen et al., 2012; Stahel 2010). Yet also direct re-use of unsold returns or products with damaged packaging belong to this category and producer initiatives that enable multiple re-uses of packaging (Agrawal et al., 2015; Romero and Molina, 2013).

5.2.5. Repair: R3

The meaning of repair may seem to defy misinterpretation. Its common purpose is to extend the lifetime of the product (King et al., 2006). It is described as 'bringing back to working order' (Fernández and Kekäle, 2005; Fleischmann et al., 1997), 'making it as good as new' (Srivastava, 2008), 'recreating its original function after minor defects' (Stahel, 2010), 'replacing broken parts' (Thierry et al., 1995). Despite this apparent clarity, the concept was found to be used in different contexts, for example, denoting what other authors call 'refurbishment', like in an article describing military closed-loop-systems (Wilhite et al., 2014). An important distinction is that repairing can be done by different actors and with or without change of ownership. Repair operations can be performed by the customer or people in their vicinity, at the customer's location, and through a repair company. More recently, peer-to-peer non-commercial repair workshops have become a trend (Ecoinnovators, 2015; Hultman and Corvellec, 2012). Businesses may send recollected products to their own repair centers, to manufacturer-controlled (Thierry et al., 1995), or to third party repair centers (Sherwood et al., 2000). Finally, we can distinguish 'planned repair' as part of a longer lasting maintenance plan (García-Rodríguez et al., 2013; Den Hollander and Bakker, 2012) or 'ad-hoc' repairs.

5.2.6. Medium Long Loops R4-6

The next two concepts, refurbish and remanufacture, resemble another. Therefore some authors seem to use them as synonyms (Blackburn et al., 2004; Defee et al., 2009), yet others mix up the concepts (Mitra, 2007). If we found them both listed among ROs, *refurbish* appeared as superior or more desirable option mentioned prior to remanufacture. However, only few scholars provide explicit definitions. It is important to note that the medium long loops are largely conceived as business activities with indirect links to the consumer, for example, as commissioner or recipient of refurbished, remanufactured or repurposed products.

5.2.7. Refurbish: R4

The use of the concept 'refurbish' seems to be most adequate in cases where the overall structure of a large multi-component product

Table 4
10 Value Retention Options in CE as a Synthesis of Literature.

	R #	CE concept	Object	Owner	Function	Key activity customer	Key activity market actor
Downcycling	R9	Re-mine	Landfilled material	Local authorities; Land owner	New	Buy and use secondary materials	Grubbing, cannibalizing, selling (South)/ high-tech extracting, reprocessing (North)
	R8	Recover (Energy)	Energy content	Collector, municipality, energy company, waste mgt. company	New	Buy and use energy (and/or distilled water)	Energy production as by-product of waste treatment
	R7	Re-cycle	Materials	Collector, processor, waste mgt. company	Original or new	Dispose separately; buy and use secondary materials	Acquire, check, separate, shred, distribute, sell
	R6	Re-purpose (ReThink)	Components in composite products (new product with old parts)	New user	New	Buy new product with new function	Design, develop, reproduce, sell
Product upgrade	R5	Re-manufacture	Components in composite products (old product with new parts)	Original or new customer	Original, upgraded	Return for service under contract or dispose	Replacement of key modules or components if necessary, decompose, recompose
	R4	Re-furbish	Components of composite products (old product with new parts)	Original or new customer	Original, upgraded (large complex products)	Return for service under contract or dispose	Replacement of key modules or components if necessary
	R3	Repair	Components of composite products (old product with new parts)	1st or 2nd consumer	Original	Making the product work again by repairing or replacing deteriorated parts	Making the product work again by repairing or replacing deteriorated parts
Client/user choices	R2	Re-sell/Re-use	Product	Consumer	Original	Buy 2nd hand, or find buyer for your non-used produced/possibly some cleaning, minor repairs	Buy, collect, inspect, clean, sell
	R1	Reduce	Product	Consumer	N.a.	Use less, use longer; recently: share the use of products	See 2nd life cycle Redesign
	R0	Refuse	Product	Potential consumer	N.a.	Refrain from buying	See 2nd life cycle Redesign

remains intact, while many components are replaced or repaired, resulting in an overall 'upgrade' of the product (Brito & Dekker 2003; Fernández and Kekäle, 2005). Applied in this way, the concept refurbish is also known from common language in the context of an overhaul of buildings, while in CE literature airplanes, trains, mining shovels, or engines and machinery are among the examples. The result should be a specified quality (Loomba and Nakashima, 2012; Thierry et al., 1995), bringing the product 'up to the state-of-art' due to the use of newer more advanced components (Stahel 2010). In this category we also find some confusion, for example Srivastava (2008) speaks of 'almost as good as', yet others mention repairing components which better matches the dominant description of remanufacturing.

5.2.8. *Remanufacture: R5*

'Remanufacture' applies where the full structure of a multi-component product is disassembled, checked, cleaned and when necessary replaced or repaired in an industrial process (Gehin et al., 2008; Lieder and Rashid, 2015). Some scholars also refer to this as reconditioning, reprocessing or restoration (Den Hollander and Bakker, 2012; Jayal et al., 2010). Compared to refurbishing, the references on retained quality are more tempered, expressed as 'up to original state, like new' (Go et al., 2015; Loomba and Nakashima, 2012), partly because the remaining life span is expected to be shorter than for new products and because recycled components are used in the remanufactured product. Gehin et al. (2008) propose if new parts were to be added, the resulting product might be an upgrade viewed against the original. Another interpretation found in literature is that remanufactured products would fully consist of recycled components (Badurdeen et al., 2015; Jawahir et al., 2006).

5.2.9. *Repurpose: R6*

The concept of 'repurpose' is used to a lesser extent, in total, only three articles included the concept among the ROs (van Buren et al., 2016; Sihvonen and Ritola 2015; Tyler Miller and Spoolman, 2002), seven other authors seem to mean the same using the concepts 'rethink' (Li, 2011) or 'fashion upgrading' (Stahel, 2010) or 'part reuse' (Den Hollander and Bakker, 2012). Repurposing is popular in industrial design and artists communities. By reusing discarded goods or components adapted for another function, the material gets a distinct new life cycle. This seems to denote both low and high value end-products. Stahel (2010) gives the example of unemployed workers becoming entrepreneurs by transforming defective microchips into jewellery, glass bottles into mugs, textile waste into quilts or plastic sheeting into handbags.

5.2.10. *Long Loops R7-9*

At first view, the long loops are purely denoting traditional waste management activities as this category includes recycling, different forms of energy recovery, and re-mining – which could be viewed as an 'upgrade to landfill management'. All scholars applying clear hierarchies with their ROs agree that these options are the least desirable. Still, materials or particles obtained through longer loop recycling can serve as input for shorter loop ROs (see 'remanufacture'). We added 're-mining'; despite a sheer lack of attention to this RO in the analyzed contributions, a growing body of literature emerges on this subject. We view it as important addition to the RO hierarchy as it is directed at obtaining a use for existing waste stock and materials and flows that seemed irreversibly lost as untreated waste.

5.2.11. *Recycle Materials: R7*

The concept 'recycling' is in the bottom of ROs but at the top when it comes to frequency of use and confusing use. It is either used for any form of avoiding the use of newly mining materials or resources (Ayres and Ayres, 1996; Ghisellini et al., 2014): 'any recovery for any purpose' (Bakker et al., 2014), or it explicitly described as option beyond the shorter routes of R0-R6. Commonly, it means processing of mixed streams of post-consumer products or post-producer waste streams using expensive technological equipment (Yan and Feng, 2014), including shredding, melting and other processes to capture (nearly) pure materials (Graedel et al., 2011). A clear difference with the higher ROs is that recycled materials do not maintain any of the original product structure and can be re-applied anywhere (Graedel et al., 2011; Jawahir et al., 2006; King et al., 2006), wherefore recycled materials are also called 'secondary' materials (Worrell and Reuter, 2014).

In the process of separation and selection of collected waste, various quality levels may be used (Brito & Dekker 2003)which also coincides with low value for these materials and a difficult position on the market, competing with pure virgin materials (Agrawal et al., 2015; Blackburn et al., 2004). Only for relatively few materials, among them metals, recycling has as little quality loss as to enable competition with virgin material. Finally, recycling typically requires high energy inputs for collection and re-processing which may supersede the retained value (Ghisellini et al., 2014; King et al., 2006; Reh, 2013; Stahel, 2010). As we saw with high ROs, also here an important distinction concerns agency. Stahel (2010) stresses that recycling takes place also in business-to-business relations when production wastes from end producers or component producers are being recycled (described as 'primary recycling'). This is advantageous, because materials are not yet mixed, as opposite to 'secondary recycling', where used end-of-life products get collected by municipal waste collectors. We have accordingly included shorter and longer R7-loops in our synthesis (see Fig. 3).

5.2.12. Recover (energy): R8

Like some of the other ROs, 'recover' has a mixed use with three types dominating. First, it is used to describe 'collecting used products at the end-of-life, and then disassembly, sorting and cleaning for utilization (Yan and Feng, 2014). Elsewhere, we found it mentioned as second R in a 3Rs ranking: reduce, recover, reuse (Wang and Hsu, 2010). This use is especially common in the reverse logistics literature (Brito & Dekker 2003). It may also mean the extraction of elements or materials from end-of-life composites (Stahel, 2010). In Worrell and Reuter's "Handbook of Recycling" we see a mixed use of the word, both in connection to collection of recyclable products and materials and in relation to the 'energy recovery' from waste streams (Worrell and Reuter, 2014). However, in 20 of the analyzed articles, recovery means capturing energy embodied in waste, linking it to incineration in combination with producing energy (Hultman and Corvellec, 2012; Sihvonen and Ritola, 2015) or use of biomass (Stahel, 2010). In Fig. 3, we placed it among the lower value ROs referring to its dominant use.

5.2.13. Re-mine (R9)

A RO that is mostly forgotten or ignored in operationalizing CE is the retrieval of materials after the landfilling phase. Both in the North and the South, taking valuable parts from disposed products forms a more or less informal sector which emerged under very different conditions. In developing countries, people try to earn a living by scrapping valuable materials and items from landfills. This often involves freeing hazardous substances thereby posing significant health risks for the 'scavengers'. Focusing on the most valuable parts is named 'cannibalisation' (Fernández and Kekäle, 2005; Fleischmann et al., 1997; Masoumik et al., 2014; Schenkel et al., 2015; Thierry et al., 1995) although the concept is also used more generally to denote selective retrieval of parts (De Brito and Dekker, 2003) which can be used in other products or components (García-Rodríguez et al., 2013).

In developed countries, with a long history of controlled landfilling recently entrepreneurs started to 'mine' the valuable resources stored in old landfills and other waste plants which is called *landfill mining* or *urban mining* (Cossu and Williams 2015; Frändegård et al., 2013; Johansson et al., 2012; Jones et al., 2013; Van Passel et al., 2013; Quaghebeur et al., 2013). It has been argued that the concentration of various minerals is nowadays higher in landfills than in original mines. In this context, Westerhoff et al. (2015) received much attention with their work on turning 'faeces into gold'. They estimated that annually up to 13 million dollars' worth of metals could be extracted from chemically re-mined sludge per city of one million inhabitants. Finally, in strongly urbanized regions, the price of new land is as high as to justify investment in full clean-up of old landfills and restoration of the area for urban development constituting an 'area re-mine'. Together with the medium long loops of refurbish and repurpose, this RO receives least attention in policymaking and business. It may change status in the decades to come, from an unpopular 'R' towards a widely known and practiced activity, once technological progress allows for lucrative re-mining. With a view on this, we have included it as R9 activity in Table 4 and Fig. 3.

A final 'potential RO' is 're-servitization'. We chose not include it as a separate RO because it seems highly interrelated with other ROs such as 'reuse' and was not listed by the analyzed authors. Given centrality of 'functionality' in CE, latest articles stress the importance of 're-servitization' – rethinking and adapting services and the development of product service systems (PSS) – as part of CE business models. For example, Pialot (2017) proposes that shorter loop options can be promoted through linking these with services for the creation of 'hybrid' business models with higher value retention over lifecycles.

With this exposé, mapping of CE options in the Product *Produce and Use* Life Cycle is complete. We identified the contradictory use of concepts, and found that the ROs can be categorized into 10 main options. Three clusters can be formed: ROs closely related to consumer/customer alternatives (R0-R3), ROs referring to various forms of upgrading of used products on the side of users but dominantly carried out by business actors (R4-R6) and the options referring to aggregate material flows, often resulting in down-cycling, hence lower value re-applications (R7-R9). Moving along the options, up to the higher numbered ROs, we also see changes in ownership and changes in function. The three categories can also be labelled 'down-cycling', 'product upgrading' and 'user choices recycling'. This is shortly summarized in Table 4.

5.3. Systematic Integration of Value Retention Options: A Visualization

Above we have indicated that shorter and longer loops can be distinguished among the value retaining activities in CE. Taking the insights from the various scholarly contributions together, a depiction of the RO loops and flows is possible through integration into a synthesized visualization (Fig. 3). These type of visualizations are frequent in the literature and interestingly, those of scholars publishing on CE and related fields for more than three decades, have undergone substantial evolution (compare for example: Stahel 1976 in Stahel, 2003) and Stahel and Clift, 2016; for more examples see Thierry et al., 1995; Jawahir et al., 2006; King et al., 2006; Srivastava 2008; Nagalingam et al., 2015). At the basis of many visualizations in the literature, stands a construct of the production chain, the linear 'produce, use and landfilling' lifecycle which is complemented by 're-directing arrows', loops which signal that the products or parts are brought back to a certain stage of the production chain (Gehin et al., 2008; Go et al., 2015).

As we argued, comprehensive visualizations that are closer to depicting complexities of CE need to distinguish various shorter loops between stages, for example links between retailers and end producers or between the end producer and component manufacturers. This also means that a variety of new stakeholder groups need to be acknowledged, for example third parties (profit or non-profit organisations) engaged in specific recirculation activities (repairing, re-retailing, refurbishment, ...). In the shorter loops some of the R-activities may be either consumer-to-consumer, consumer-to-business, or business-to-business activities. Many of the 3R, 4R, 5R, 6R (...), descriptions and visualizations do not take these differences into account. They are essential, because in all cases, they refer to interactions between different social actors, each of them dealing with their own interpretations, abilities, limitations and contextual situations.

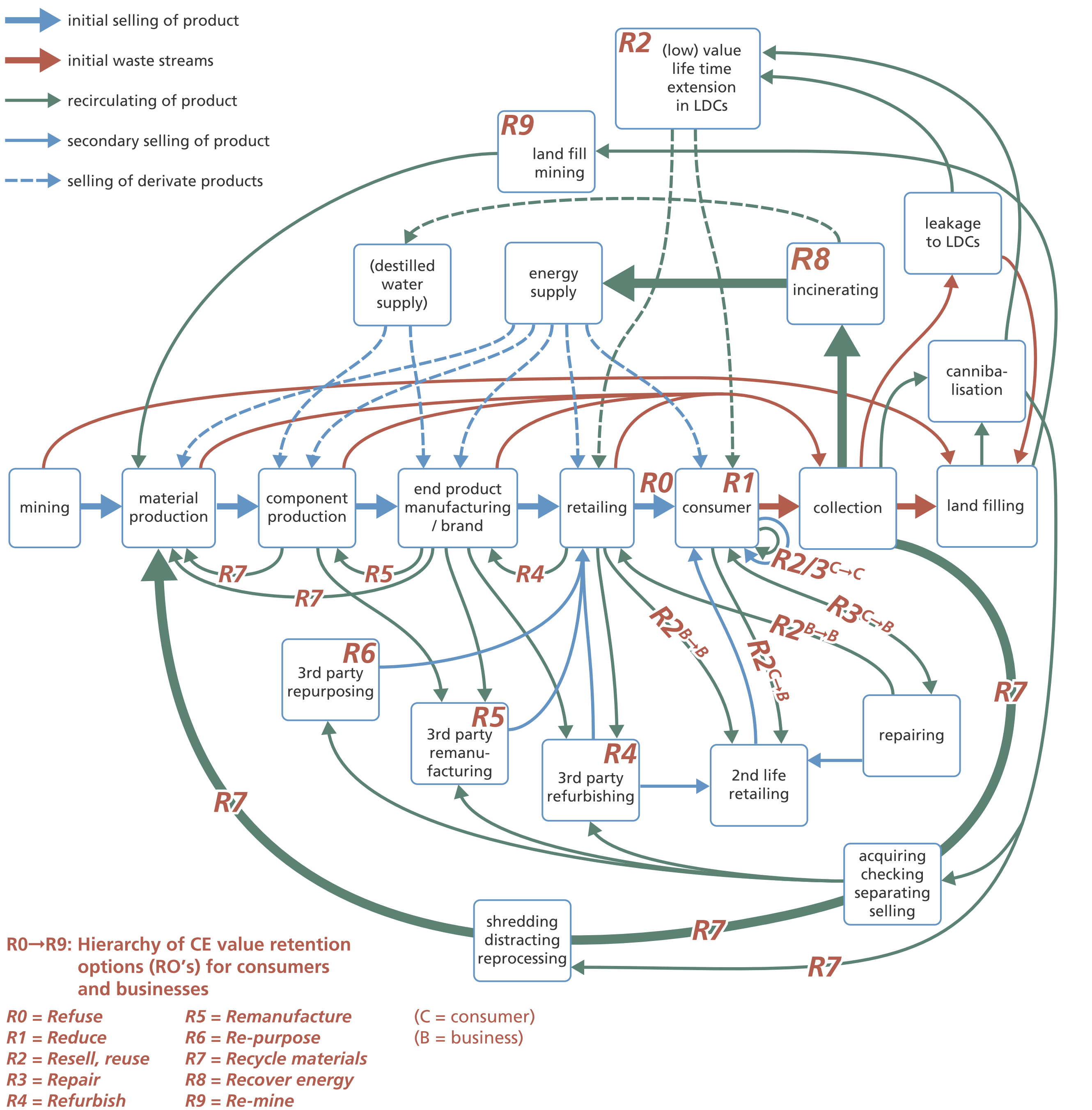

Fig. 3. Mapping Circular Economy Retention Options: The Product *Produce* and Use Life Cycle.

In our discussion of the ROs, we briefly referred to the second type of product cycle: the Product *Concept and Design* Life Cycle. Ideas on prevention, and prolonging product life through design relate to much older approaches (see Section 3). In the 1990s, material choices and improving recyclability represented 3 out of 7 elements in the EcoDesign Strategy Wheel (Brezet and Hemel, 1997; see also Tukker et al., 2001). The same premises can be found in 'Design for Environment' approaches (Ehrenfeld, 1997; Kurk and Eagan, 2008). In later years, the scope of these methods has been widened to include social sustainability, renaming it as 'Design for Sustainability'. In these approaches recycling challenges have also systematically been included (Arnette et al., 2014; Crul et al., 2009; Jawahir et al., 2006; Kuik et al., 2011; Ramani et al., 2010; Yan and Feng 2014). Some of these alternative strategies for 'redesign' received considerable attention, like 'Design for Remanufacturing' (Sherwood et al., 2000) and 'Design for Disassembly' (Boothroyd and Alting, 1992), the latter is found often in relation to the automotive industry. Notably, since the early days of industrial designer's attention to environment and sustainability, ROs founded on material choices and prevention have been at the heart of their conceptual and methodological contributions.

As we stated earlier, the idea to 'design out waste' is crucial in CE. In the articles analyzed, we saw that authors used different ideas to denote ROs as part of the (re-)design of products. Particularly, 'refuse', reduce' and 're-purpose' represent different ideas in different contributions. Mapping CE options as industrial designer requires a perspective where all the RO steps are considered long before a product is first mass produced. This distinctive life cycle aims at prevention and starts with the design process, resulting into a realization of the design which entails all the ROs in Fig. 3. Design is also aimed at long-lasting economic lifespan and the most effective, repeated production and sale of a successful product concept. Industrial design scholars vary in their descriptions of the design process, but commonly it includes: design task definition – function analysis and module structure configuration – material selection and part design – preliminary evaluation (Xing et al., 2003). In the most recent UNEP "Handbook for Design for Sustainability", steps for redesigning, new product development, and for the creation of product service systems, are included (Crul et al., 2009).

The various steps in the literature can be summarized as five core activities in the Product *Concept and Design* Life Cycle to which the different ROs can be attached: policy (strategy formulation), idea generation (using creativity), the strict designing (see steps given above by Xing et al., 2003), realization (which is the timespan of producing the product) and evaluation and reconsideration. The last two steps directly link to the Product *Produce and Use* Life Cycle as shown in Fig. 3. In Fig. 4, we linked R2 and R6 to conceptual ideas of design; the other ROs have been found to be traditionally related to strict designing in the literature, for example Design for Remanufacturing relates to R5. *The Product Concept and Design* Life Cycle can hence be mapped on top of the first figure, as shown in Fig. 4, taking the role of (re-)designers in the lifespan of a product concept as the focus.

Taking insights on the ROs together, it becomes clear that we need to think in terms of two related life cycles, the Product *Produce and Use* Life Cycle (Fig. 3) and the Product *Concept and Design* Life Cycle (Fig. 4). This is a fundamental insight which has so far only been stressed by a particular author group within RL/CLSC (see Kuik et al., 2011; Nagalingam et al., 2013). Another important consideration we point to regards agency and ownership. Most scholars lack attention to the role of consumers in refusing, reducing, and consumer-to-consumer arrangements for re-selling goods. Although firms remain the central actor in our visualization, the connection to government, consumers, and other parties for a functioning system, becomes more explicit. We also show that even a more circular economy will have low value life extension and leakages, which adversely affect developing countries.

Finally, we give attention to neglected or under-addressed ROs through inclusion of 'Refuse' and 'Re-mine' among the ROs. 'Refuse' is critical to include because prevention is always more desirable than minimizing. Overall, merging 'stocks and flows' perspectives as known from IE visualizations, and complementing it with established ideas of value retention of goods and materials found in RL/CLSC, CP and in the design and waste management literature, results in a more complete and systemic picture of ROs in CE.

6. Implications of This Study for Policymakers, Businesses and Academics

With our work on the history and the operationalization principle of ROs in CE, we have shown that a shared understanding of the concept has yet to be established.

Our historic review reflected on the paradigmatic divides in CE and the framing paradox of CE as new and transformational, yet compatible with existing environmental initatives. We distinguished three phases from CE 1.0-3.0 and put forward that CE should be viewed as an evolving concept wherein the new and transformational elements should be clearly defined. Depending on what academics − and other stakeholders − make of it, CE can be understood as new. Yet its dominant framing and implementation efforts so far, place it on one line with other strategies for sustainability, rendering CE a concept complementing other approaches rather than it being the first sustainability concept which would induce transformative change. CE 3.0 as a transformative concept would also demand a more critical perspective on approaches and methods for analysis used in connection with CE (Gregson et al., 2015). The view of CE as an easy fit with existing modernization initiatives may also be related to the slow advancements in the development of systematic approaches for analysis specifically tailored to CE (Blomsma and Brennan, 2017).

We focused on the use of one of the key CE concepts, the R-hierarchies or imperatives in order to point out existing confusions in conceptualizing CE. In an effort to contribute to a clearer idea of this operationalization principle of CE, we proposed the term resource value retention options (ROs) and translated the most common perspectives found on these options among different academic disciplines into a 10R typology along with visualizations. These specifically stress the need for attention to shorter loops, stakeholders, and leakages that will occur even in a more circular economy − with some of the latter being a natural result of physical laws whereas others can be linked to the dominant economic paradigm in which developing countries tend to lose out rather than leapfrog.

There are a number of implications that can be derived from our review. Specifically, we suggest implications and roles for three different groups: government, business and academia.

We advance that government and policymakers have a key role in enabling mechanisms for shorter loop value retention options, setting targets, and in directing economic activities towards more circularity. Our brief overview of the level of measured circularity has largely ignored the multitude of CE pilot case examples where shorter loop value retention options are attained. In Europe, many companies have been founded explicitly to assist businesses in the implementation of these types of circular business models. With help of incentives like funds, subsidies, but also through activities with more indirect effects like knowledge provision, tool development, engagement, events (...), government can ensure a way forward for these frontrunners in society. In particular SMEs with innovative business models and high expertise often require support, in order to make their far-reaching ideas a reality, to link with larger business players or to assess the impacts of their work. Above all, the state has a crucial role as role model and through its public procurement (~16% GDP in EU) should be first in going beyond low hanging fruits and incur more efforts to seriously measure the sustainability impacts to demonstrate viability, increase legitimacy and thereby scalability of CE. With a view on global developments, we follow the call of Diaz (2017) for an integration of informal recyclers into formal structures along with educational efforts by professionals from CE lead countries in order to enable these countries to leapfrog steps in CE development.

Businesses we ask to embrace "simplicity in complexity" through using such heuristics as the synthesized typology of ROs as a starting point for evaluating their own possibilities to engage in CE and to form business models around feasible ROs. A number of scholars have stressed the lack of appropriate CE tools and a shared language, such as in the context of CE-inspired business model innovation (Antikainen and Valkokari, 2016; Bocken et al., 2017; Lewandowski, 2016). In order to profit from CE, businesses can analyze what their own supply chain position means for participation and application of feasible ROs. In addition, businesses have a stake in limiting the confusion around CE. If businesses seek to work together successfully with diverse stakeholder groups in CE, ensuring a common understand of CE among the collaborators at the outset of projects is vital. As Blomsma and Brennan (2017) remarked, CE is not limited to technical implementation but it has fundamental organizational implications which makes alignment on what CE means for one's business or organization an essential component of success. More research should look into these organizational relationships and check the 10R typology put forward against those used by others actors in the CE landscape such as policymakers, business and consultancy to further synthesize meaningful tools for all stakeholder groups.

We call on academics to show the way towards consensus in conceptualizing CE. Definitions, degrees of circularity, its normative character, the relation to other sustainability concepts – and to sustainability itself as a concept – all of this is still far from being clear. Especially proponents of CE have to realize that the time to form the field is now or CE may fall to victim to dissonant views and consequently behind the potential attributed to it. In 1996, Ayres & Ayres noted that IE as a concept has some well-defined relationships but

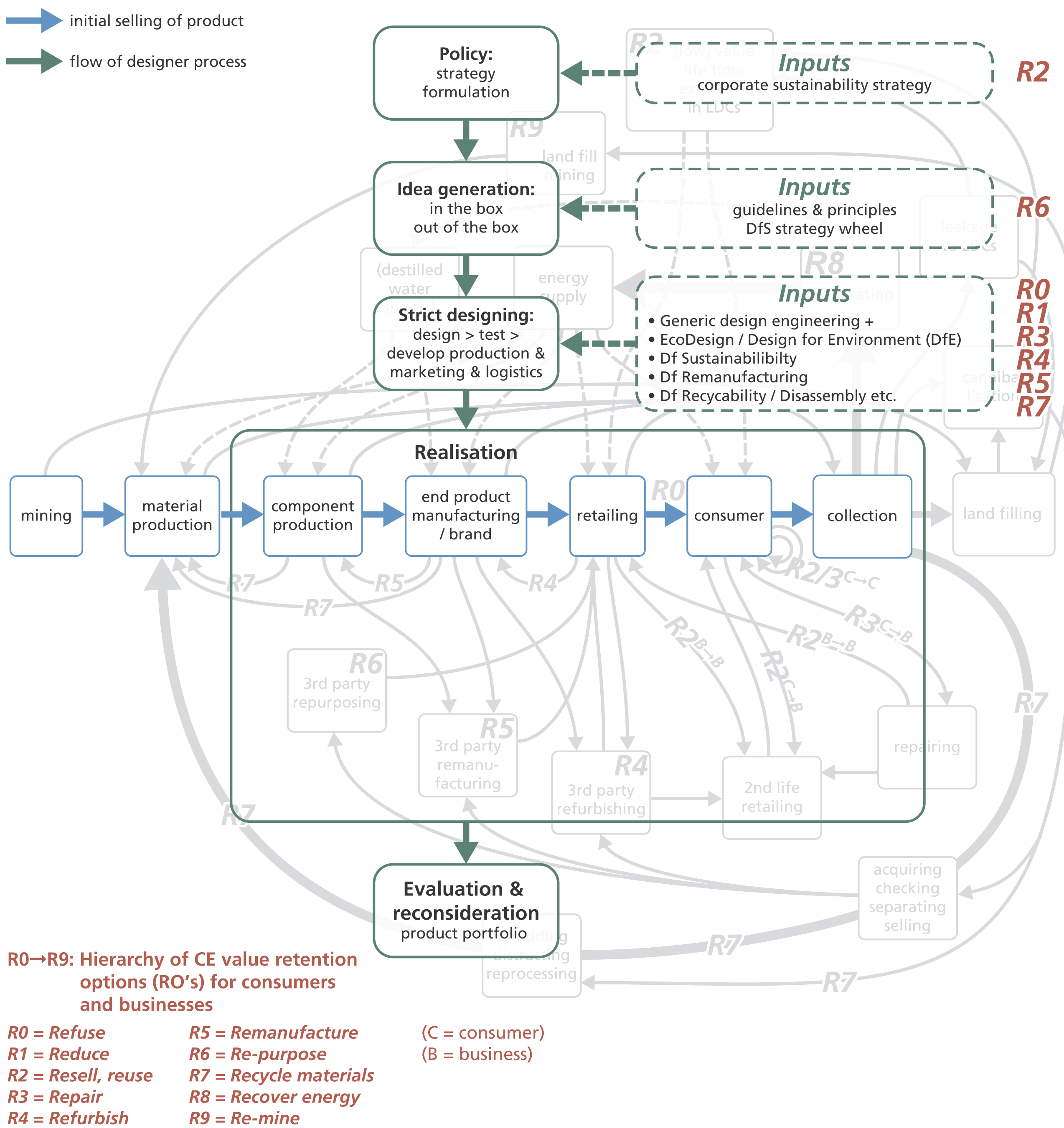

Fig. 4. Mapping Circular Economy Retention Options: The Product Concept and Design Life Cycle.

others are being loosely grouped together by the enthusiasms of the proponents. This shows that like CE these days, IE faced a challenge of interdisciplinarity and arguably has not overcome it. Else celebration of an allegedly new concept of CE may not have resonated as strong in science, politics and business.

We acknowledge that the focus on ROs as key principle of CE is certainly an oversimplified representation and 'embodiment' of CE. First, ROs focus on the technical flows leaving out services and the biological flows, the latter are only addressed through R0, R1, R2 and R8. Moreover, the concept of 'functionality' rather than ownership is of high importance in CE which we have only addressed indirectly by referring to the development of circular business models and product service systems. Other key CE concepts like 'entropy' and rebound effects from reutilization of resources should be taken into account when deciding about application of ROs.

A final issue is that ROs cannot be separated as neatly in reality. A product made of multiple components frequently requires the combination of several ROs. Moreover, measurements of impacts of ROs, and more importantly of trade-offs among the options for different product categories, are still scarce. Therefore, in practice the optimal ROs are often difficult to delineate. Academics and other stakeholders have a role in advancing practice by assisting in the development in systematic measurement of retention options so that hierarchies of preference can be established for different materials and product groups. Many academic contributions are either empirical, quantitative and highly technical, or largely conceptual and qualitative in nature. We believe that more mixed methods research uniting these two worlds is paramount for a better understanding of CE. Our critical and interdisciplinary review and the synthesized R typology serve as a simple but necessary first step towards a more comprehensive and systematic understanding of CE among various academic disciplines and across different stakeholder groups. With our critical review, we hope to contribute to the more coherent use of key concepts relating to CE required for CE to be implemented at full potential.

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Appendix A

See Table A1

Table A1
Combinations of keywords used for the search on value retention options

	Main search term				
1.	Reduce, OR reuse, re-use, repair, remanufacture, re-maufacture, recycle, recover, redesign	And	Reduce, reuse, re-use, repair, remanufacture, re-maufacture, recycle, recover, redesign	And	Reduce, reuse, re-use, repair, remanufacture, re-maufacture, recycle, recover, redesign
2.	Circular economy OR Industrial ecology, reverse logistics, closed-loop, waste management	And	Reduce, Reuse, reus*, repair, remanufacture, re-manufactur*, recycle, recyc*, re-cyc*, refurbish, re-furbish, reduce, reduc*, repurpose, re-purpose, epurpose*, re-purpos*, recover, redesign, re-design	Or	Reduce, Reuse, reus*, repair, remanufacture, re-manufactur*, recycle, recyc*, re-cyc*, refurbish, re-furbish, reduce, reduc*, repurpose, re-purpose, repurpos*, re-purpos*, recover, redesign, re-design
3.	Circular economy	Or	Industrial ecology, reverse logistics, closed-loop, waste management	And	hierarchy, cascading, cascad*,
4.	Circular economy			And	Europe, EU, China, papers from year: 2010 +
5.	Circular economy	Or	Industrial ecology, reverse logistics, closed-loop, waste management	And	3Rs, 4Rs, 5Rs, 6Rs, 7Rs, 8Rs, 9Rs, 10Rs

References

ARN, 2016. ARN Sustaibaility Report 2015. Retrieved from. https://issuu.com/arnbv/docs/arn_duurzaamheidverslag_2015_engels.

Accenture & Circle Economy, 2016. From Rhetoric to Reality – The Circular Economy Index of Dutch Businesses, vol. 1 Amsterdam.

Agrawal, S., Singh, R.K., Murtaza, Q., 2015. A literature review and perspectives in reverse logistics. Resour. Conserv. Recycl. 97, 76–92. http://dx.doi.org/10.1016/j.resconrec.2015.02.009.

Allwood, J.M., Ashby, M.F., Gutowski, T.G., Worrell, E., 2011. Material efficiency: a white paper resources. Conserv. Recycl. 55 (3), 362–381. http://dx.doi.org/10.1016/j.resconrec.2010.11.002.

Amelia, L., Wahab, D.A., Che Haron, C.H., Muhamad, N., Azhari, C.H., 2009. Initiating automotive component reuse in Malaysia. J. Clean. Prod. 17 (17), 1572–1579. http://dx.doi.org/10.1016/j.jclepro.2009.06.011.

Antikainen, M., Valkokari, K., 2016. A Framework for Sustainable Circular Business Model Innovation. Technol. Innovation Manage. Rev. 6 (7), 5–12.

Arnette, A.N., Brewer, B.L., Choal, T., 2014. Design for sustainability (DFS): the intersection of supply chain and environment. J. Clean. Prod. 83, 374–390. http://dx.doi.org/10.1016/j.jclepro.2014.07.021.

Ayres, R.U., Ayres, W.L., 1996. Industrial Ecology. Edward Elgar Publishing Limited, Cheltenham, UK.

Badurdeen, F., Iyengar, D., Goldsby, T.J., Metta, H., Gupta, S., Jawahir, I.S., 2009. Extending total life-cycle thinking to sustainable supply chain design. Int. J. Product Lifecycle Manag. 4 (1–3), 49. http://dx.doi.org/10.1504/ijplm.2009.031666.

Badurdeen, F., Shuaib, M.A., Lu, T., Jawahir, I.S., 2015. Sustainable value creation in manufacturing at product and process levels: metrics-based evaluation. Handbook of Manufacturing Engineering and Technology. Springer, London.

Bakker, C., Wang, F., Huisman, J., Den Hollander, M., 2014. Products that go round: exploring product life extension through design. J. Clean. Prod. 69, 10–16. http://dx.doi.org/10.1016/j.jclepro.2014.01.028.

Bergsma, G.C., Vroonhof, J., Blom, M.J., Odegard, I.Y.R., 2014. Evaluatie Landelijk Afvalbeheerplan (LAP) 1 En 2 (Evaluation of Dutch National Waste Management Plans 1 and 2). Delft, the Netherlands.

Bilitewski, B., 2012. The circular economy and its risks. Waste Manage. (New York, N.Y.) 32 (1), 1–2. http://dx.doi.org/10.1016/j.wasman.2011.10.004.

Black, I., Cherrier, H., 2010. Anti-consumption as part of living a sustainable lifestyle: daily practices, contextual motivations and subjective values. J. Consum. Behav. 453, 437–453. http://dx.doi.org/10.1002/cb.

Blackburn, J.D., Guide, V.D.R., Souza, G.C., Van Wassenhove, L.N., 2004. Reverse supply chains for commercial returns. Calif. Manage. Rev. 46 (2), 6–23.

Blomsma, F., Brennan, G., 2017. The emergence of circular economy: a new framing around prolonging resource productivity. J. Ind. Ecol. 21 (3), 603–614. http://dx.doi.org/10.1111/jiec.12603.

Bocken, N.M.P., Olivetti, E.A., Cullen, J.M., Potting, J., Lifset, R., 2017. Taking the circularity to the next level: a special issue on the circular economy. J. Ind. Ecol. 21 (3), 476–482. http://dx.doi.org/10.1111/jiec.12606.

Bonciu, F., 2014. The European economy: from a linear to a circular economy. Roman. J. Eur. Affairs 14 (4), 78–91.

Boothroyd, G., Alting, L., 1992. Design for assembly and disassembly. CIRP Ann. – Manuf. Technol. 41 (2), 625–636. http://dx.doi.org/10.1016/S0007-8506(07)63249-1.

Boulding, K.E., 1966. The economics of the coming spaceship earth. In: Jarrett, H. (Ed.), Environmental Quality in a Growing Economy: Essays from the Sixth RFF Forum. Johns Hopkins University Press, Baltimore, pp. 1–20.

Bourg, D., Erkman, S., 2003. Perspectives on Industrial Ecology. Greenleaf Publishing Limited, Sheffield. UK.

Breivik, K., Armitage, J.M., Wania, F., Jones, K.C., 2014. Tracking the global generation and exports of e-Waste. do existing estimates add up? Environ. Sci. Technol. 48 (15), 8735–8743. http://dx.doi.org/10.1021/es5021313.

Brezet, J.C., van Heme, C.G., 1997. EcoDesign: A Promising Approach to Sustainable Production and Consumption.

Carter, N., 2001. The Politics of the Environment: Ideas, Activism, Policy. Cambridge University Press, UK.

Chen, W.-Q., 2013. Recycling rates of aluminum in the United States. J. Ind. Ecol. 17 (6), 926–938.

Chowdhury, M., 2009. Searching quality data for municipal solid waste planning. Waste Manage. 29 (8), 2240–2247. http://dx.doi.org/10.1016/j.wasman.2009.04.005.

Circular Academy, Circular economy: some definitions, Retrieved from http://www.circular.academy/circular-economy-some-definitions/.

Clapp, J., Swanston, L., 2009. Doing away with plastic shopping bags: international patterns of norm emergence and policy implementation. Environ. Politics 18 (3), 315–332. http://dx.doi.org/10.1080/09644010902823717.

Cohen-Rosenthal, E., Musnikow, J., 2003. Eco-Industrial Strategies: Unleashing Synergy between Economic Development and the Environment. Greenleaf Publishing.

Conticelli, E., Tondelli, S., 2014. Eco-industrial parks and sustainable spatial planning: a possible contradiction? Admin. Sci. 4 (4), 331–349. http://dx.doi.org/10.3390/admsci4030331.

Cooper, T. Peter, 2011. Lund Simmonds and the Political Ecology of “Waste Utilisation” in Victorian Britain. Technol. Cult. 52 (1), 21–44.

Cossu, R., Williams, I.D., 2015. Urban mining: concepts, terminology, challenges. Waste Manag. 45, 1–3. http://dx.doi.org/10.1016/j.wasman.2015.09.040.

Crang, M., Hughes, A., Gregson, N., Norris, L., Ahamed, F., 2013. Rethinking governance and value in commodity chains through global recycling networks. Trans. Institute British Geogr. 38 (1), 12–24. http://dx.doi.org/10.1111/j.1475-5661.2012.00515.x.

Crul, M., Diehl, J., Ryan, C., 2009. Design for Sustainability-A Step-by-step Approach. UNEP, Paris, France.

De Brito, M.P., Dekker, R., 2003. A Framework for Reverse Logistics. Erasmus Research Institute of Management, Rotterdam, The Netherlands.

Defee, C.C., Esper, T., Mollenkopf, D., 2009. Leveraging closed-loop orientation and leadership for environmental sustainability. Supply Chain Manage.: Int. J. http://dx.doi.org/10.1108/13598540910941957.

Den Hollander, M.C., Bakker, C., 2012. A business model framework for product life extension. Proceedings of Sustainable Innovation 2012, Resource Efficiency, Innovation and Lifestyles 110–118.

Diaz, L.F., 2017. Waste management in developing countries and the circular economy.

Waste Manage. Res. 35 (1), 1–2. http://dx.doi.org/10.1177/0734242x16681406.
Diener, D.L., Tillman, A.-M., 2015. Component end-of-life management: exploring opportunities and related benefits of remanufacturing and functional recycling. Resour. Conserv. Recycl. 102, 80–93.
Dyllick, T., Hockerts, K., Beyond the Business Case for Corporate Sustainability, 2001, 11, 130–141. http://doi.org/10.1002/bse.323.
Ecoinnovators, 2015. The Repair Workshops – giving Light to the Age Old Art of Repair. Retrieved from. http://ecoinnovators.blogspot.com.es/2011/08/repair-workshops-giving-light-to-age.html.
European Commission (EC), 2008. Directive 2008/98/EC of the European Parliament and the Council of 19 November on Waste and Repealing Certain Directives. OJ L 312 22.11. Retrieved from. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098.
European Commission (EC), 2015. Communication From the Commission To The Parliament, The Council, The European Economic and Social Committee of the Regions. Closing the Loop – An EU Action Plan for the Circular Economy (COM/2015/0614 Final). Retrieved from. http://ec.europa.eu/environment/circular-economy/index_en.htm.
European Environment Agency. (EEA), 2013. Managing Municipal Solid Waste – a Review of Achievements in 32 European Counties. Publications Office of the European Unionhttp://dx.doi.org/10.2800/71424.
European Environment Agency (EEA), 2016a. Circular Economy in Europe Developing the Knowledge Base. http://dx.doi.org/10.2800/51444.
European Environment Agency. (EEA), 2016b. More from Less – Material Resource Efficiency in Europe. 2015 Overview of Policies, Instruments and Targets in 31 Countries. http://dx.doi.org/10.2800/240736.
Ellen MacArthur Foundation, McKinsey & Company, 2014. Towards the Circular Economy: accelerating the scale-up across global supply chains. World Econ. Forum 1–64.
Ellen MacArthur Foundation, 2013. Towards the circular economy. J. Ind. Ecol. 1 (1), 4–8. http://dx.doi.org/10.1162/108819806775545321.
Ellen Mac Arthur Foundation, Systemiq and Sun Institute, Growth Within: Achieving Growth Within: A €320-Billion Circular Economy Investment Opportunity Available to Europe up to 2025, 2017, Retrieved from https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Achieving-Growth-Within-20-01-17.pdf.
European Urban Knowledge Network (EUKN), 2015. The Circular City. Lessons From Europe. Factsheet for Policy Lab Netherlands. EUKN, The Hague, The Netherlands Retrieved from. www.eukn.eu/fileadmin/Brief_factsheet_final_version.docx.
Ehrenfeld, J.R., 1997. Industrial ecology: a framework for product and process design. J. Clean. Prod. 5 (1–2), 87–95. http://dx.doi.org/10.1016/S0959-6526(97)00015-2.
Fercoq, A., Lamouri, S., Carbone, V., 2016. Lean/Green integration focused on waste reduction techniques. J. Clean. Prod. 137, 567–578. http://dx.doi.org/10.1016/j.jclepro.2016.07.107.
Fernández, I., Kekäle, T., 2005. The influence of modularity and industry clockspeed on reverse logistics strategy: implications for the purchasing function. J. Purch. Supply Manage. 11 (4), 193–205. http://dx.doi.org/10.1016/j.pursup.2006.01.005.
Fleischmann, M., Bloemhof-Ruwaard, J.M., Dekker, R., van der Laan, E., van Nunen, J.a.E.E., Van Wassenhove, L.N., 1997. Quantitative models for reverse logistics: a review. Eur. J. Oper. Res. 103 (1), 1–17. http://dx.doi.org/10.1016/S0377-2217(97)00230-0.
Frändegård, P., Krook, J., Svensson, N., Eklund, M., 2013. A novel approach for environmental evaluation of landfill mining. J. Clean. Prod. 55, 24–34. http://dx.doi.org/10.1016/j.jclepro.2012.05.045.
Francis, C.G., 2003. The chemical industry from an industrial ecology perspective. In: Bourg, D., Erkman, S. (Eds.), Perspectives on Industrial Ecology. Greenleaf Publishing Limited, Sheffield, UK, pp. 120–135.
García-Rodríguez, F.J., Castilla-Gutiérrez, C., Bustos-Flores, C., 2013. Implementation of reverse logistics as a sustainable tool for raw material purchasing in developing countries: the case of Venezuela. Int. J. Prod. Econ. 141 (2), 582–592. http://dx.doi.org/10.1016/j.ijpe.2012.09.015.
Gehin, A., Zwolinski, P., Brissaud, D., 2008. A tool to implement sustainable end-of-life strategies in the product development phase. J. Clean. Prod. 16 (5), 566–576. http://dx.doi.org/10.1016/j.jclepro.2007.02.012.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The circular economy – a new sustainability paradigm? J. Clean. Prod. 143, 757–768. http://dx.doi.org/10.1016/j.jclepro.2016.12.048.
Geng, Y., Doberstein, B., 2008. Developing the circular economy in China: challenges and opportunities for achieving 'leapfrog development'. Int. J. Sustain. Dev. World Ecol. 15 (April), 231–239. http://dx.doi.org/10.3843/SusDev.15.3.
Geng, Y., Fu, J., Sarkis, J., Xue, B., 2012. Towards a national circular economy indicator system in China: an evaluation and critical analysis. J. Clean. Prod. 23 (1), 216–224. http://dx.doi.org/10.1016/j.jclepro.2011.07.005.
Gerrard, J., Kandlikar, M., 2007. Is European end-of-life vehicle legislation living up to expectations? Assessing the impact of the ELV Directive on green innovation and vehicle recovery. J. Clean. Prod. 15 (1), 17–27. http://dx.doi.org/10.1016/j.jclepro.2005.06.004.
Gertsakis, J., Lewis, H., 2003. Sustainability and the Waste Management Hierarchy. A Discussion Paper on the Waste Management Hierarchy and Its Relationship to Sustainability. Retrieved from. http://www.ecorecycle.vic.gov.au/resources/documents/TZW_-_Sustainability_and_the_Waste_Hierarchy_(2003).pdf.
Ghisellini, P., Cialani, C., Ulgiati, S., 2014. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. http://dx.doi.org/10.1016/j.jclepro.2015.09.007.
Ghosh, S.K., Debnath, B., Baidya, R., De, D., Li, J., Ghosh, S.K., et al., 2016. Waste electrical and electronic equipment management and basel convention compliance in Brazil, Russia, India, China and South Africa (BRICS) nations. Waste Manage. Res. 34 (8), 693–707. http://dx.doi.org/10.1177/0734242x16652956.
Go, T.F., Wahab, D.A., Hishamuddin, H., 2015. Multiple generation life-cycles for product sustainability: the way forward. J. Clean. Prod. 95, 16–29. http://dx.doi.org/10.1016/j.jclepro.2015.02.065.
Goorhuis, M., Reus, P., Nieuwenhuis, E., Spanbroek, N., Sol, M., van Rijn, J., 2012. New developments in waste management in the Netherlands. Waste Manage. Res. 30 (9), 67–77. http://dx.doi.org/10.1177/0734242x12455089.
Govindan, K., Soleimani, H., Kannan, D., 2014. Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future. Eur. J. Oper. Res. 240 (3), 603–626. http://dx.doi.org/10.1016/j.ejor.2014.07.012.
Graedel, T.E., Allenby, B.R., 1995. Industrial Ecology. Prentice Hall, Englewood Cliffs, New Jersey.
Graedel, T.E., Allwood, J., Birat, J.P., Buchert, M., Hagelüken, C., Reck, B.K., et al., 2011. What do we know about metal recycling rates? J. Ind. Ecol. 15 (3), 355–366. http://dx.doi.org/10.1111/j.1530-9290.2011.00342.x.
Gregson, N., Crang, M., Fuller, S., Holmes, H., 2015. Interrogating the circular economy: the moral economy of resource recovery in the EU. Econ. Soc. 44 (2), 218–243. http://dx.doi.org/10.1080/03085147.2015.1013353.
Gu, Y., Wu, Y., Xu, M., Wang, H., Zuo, T., 2016. The stability and profitability of the informal WEEE collector in developing countries: a case study of China. Resour. Conserv. Recycl. 107, 18–26.
Guide Jr., V.D.R., Jayaraman, V., Linton, J.D., 2003. Building contingency planning for closed-loop supply chains with product recovery. J. Oper. Manage. 21 (3), 259–279. http://dx.doi.org/10.1016/S0272-6963(02)00110-9.
Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., 2015. How circular is the global economy? An assessment of material flows, waste production, and recycling in the European union and the world in 2005. J. Ind. Ecol. 19 (5), 765–777. http://dx.doi.org/10.1111/jiec.12244.
Hassini, E., Surti, C., Searcy, C., 2012. A literature review and a case study of sustainable supply chains with a focus on metrics. Int. J. Prod. Econ. 140 (1), 69–82. http://dx.doi.org/10.1016/j.ijpe.2012.01.042.
Hazen, B.T., Wu, Y., Cegielski, C.G., Jones-Farmer, L.A., Hall, D.J., 2012. Consumer reactions to the adoption of green reverse logistics The International Review of Retail. Distrib. Consum. Res. 22 (4), 417–434. http://dx.doi.org/10.1080/09593969.2012.690777.
Hedlund-de Witt, A., 2012. Exploring worldviews and their relationships to sustainable lifestyles: towards a new conceptual and methodological approach. Ecol. Econ. 84, 74–83. http://dx.doi.org/10.1016/j.ecolecon.2012.09.009.
Hobson, K., 2015. Closing the loop or squaring the circle? Locating generative spaces for the circular economy. Progr. Hum. Geogr. 40 (1). http://dx.doi.org/10.1177/0309132514566342.
Hultman, J., Corvellec, H., 2012. The European waste hierarchy: from the socio-materiality of waste to a politics of consumption. Environ. Plan. A 44 (10), 2413–2427. http://dx.doi.org/10.1068/a44668.
Ingarao, G., Di Lorenzo, R., Micari, F., 2011. Sustainability issues in sheet metal forming processes: an overview. J. Clean. Prod. 19 (4), 337–347. http://dx.doi.org/10.1016/j.jclepro.2010.10.005.
Iung, B., Levrat, E., 2014. Advanced maintenance services for promoting sustainability. Procedia CIRP 22 (1), 15–22. http://dx.doi.org/10.1016/j.procir.2014.07.018.
Jawahir, I.S., Dillon, O.W., Rouch, K.E., Joshi, K.J., Jaafar, I.H., 2006. Total life-Cycle considerations in product design for sustainability: a framework for comprehensive evaluation. In: 10th International Research/Expert Conference Trends in the Development of Machinery and Associated Technology. University of Kentucky,. pp. 11–15.
Jayal, A.D., Badurdeen, F., Dillon, O.W., Jawahir, I.S., 2010. Sustainable manufacturing: modeling and optimization challenges at the product, process and system levels. CIRP J. Manuf. Sci. Technol. 2 (3), 144–152. http://dx.doi.org/10.1016/j.cirpj.2010.03.006.
Johansson, N., Krook, J., Eklund, M., 2012. Transforming dumps into gold mines. Experiences from Swedish case studies. Environ. Innov. Soc. Transit. 5, 33–48. http://dx.doi.org/10.1016/j.eist.2012.10.004.
Jones, P.T., Geysen, D., Tielemans, Y., Van Passel, S., Pontikes, Y., Blanpain, B., et al., 2013. Enhanced Landfill Mining in view of multiple resource recovery: a critical review. J. Clean. Prod. 55, 45–55. http://dx.doi.org/10.1016/j.jclepro.2012.05.021.
Kasidoni, M., Moustakas, K., Malamis, D., 2015. The existing situation and challenges regarding the use of plastic carrier bags in Europe. Waste Manage. Res. 33 (5), 419–428. http://dx.doi.org/10.1177/0734242x15577858.
Kazazian, T., 2003. In: Bourg, D., Erkman, S. (Eds.), The Ecodesign Process. Perspectives on Industrial Ecology. Greenfield Publishing Limited, Sheffield, UK, pp. 82–91.
Kazerooni Sadi, M.A., Abdullah, A., Sajoudi, M.N., Bin Mustaffa Kamal, M.F., Torshizi, F., Taherkhani, R., 2012. Reduce, reuse, recycle and recovery in sustainable construction waste management. Adv. Mater. Res. 446–449, 937. http://dx.doi.org/10.4028/www.scientific.net/AMR.
King, A.M., Burgess, S.C., Ijomah, W., Mcmahon, C.A., King, A.M., 2006. Reducing waste: repair, recondition, remanufacture or recycle? Sustain. Dev. 14, 257–267. http://dx.doi.org/10.1002/sd.271.
Kollikkathara, N., Feng, H., Stern, E., 2009. A purview of waste management evolution: special emphasis on USA. Waste Manage. 29 (2), 974–985. http://dx.doi.org/10.1016/j.wasman.2008.06.032.
Kuik, S.S., Nagalingam, S.V., Amer, Y., 2011. Sustainable supply chain for collaborative manufacturing. J. Manuf. Technol. Manage. 22 (8), 984–1001. http://dx.doi.org/10.1108/17410381111177449.
Kurk, F., Eagan, P., 2008. The value of adding design-for-the-environment to pollution prevention assistance options. J. Clean. Prod. 16 (6), 722–726. http://dx.doi.org/10.1016/j.jclepro.2007.02.022.
Larsen, B.R., Taylor, W.R., 2000. 3R's: recycling, reuse and revenue. Pollut. Eng. 32 (10),

29–30.
Lazarevic, D., Valve, H., 2017. Narrating expectations for the circular economy: towards a common and contested European transition. Energy Res. Soc. Sci. http://dx.doi.org/10.1016/j.erss.2017.05.006.
Lepawsky, J., Billah, M., 2011. Making chains that (un)make things: waste–value relations and the Bangladeshi rubbish electronics industry. Geogr. Ann.: Ser. B Hum. Geogr. 93 (2), 121–139.
Lepawsky, J., Akese, G., Billah, M., Conolly, C., McNabb, C., 2015. Composing urban orders from rubbish electronics: cityness and the site multiple. Int. J. Urban Reg. Res. 39 (2), 185–199. http://dx.doi.org/10.1111/1468-2427.12142.
Lewandowski, M., 2016. Designing the Business Models for Circular Economy—Towards the Conceptual Framework. Sustainability 8, 43.
Li, H., Bao, W., Xiu, C., Zhang, Y., Xu, H., 2010. Energy conservation and circular economy in China's process industries. Energy 35 (11), 4273–4281. http://dx.doi.org/10.1016/j.energy.2009.04.021.
Li, W., 2011. Comprehensive evaluation research on circular economic performance of eco-industrial parks. Energy Procedia 5, 1682–1688. http://dx.doi.org/10.1016/j.egypro.2011.03.287.
Lieder, M., Rashid, A., 2015. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51. http://dx.doi.org/10.1016/j.jclepro.2015.12.042.
Liu, Q., Li, H., Zuo, X., Zhang, F., Wang, L., 2009. A survey and analysis on public awareness and performance for promoting circular economy in China: a case study from Tianjin. J. Clean. Prod. 17 (2), 265–270. http://dx.doi.org/10.1016/j.jclepro.2008.06.003.
Liu, Z., Adams, M., Cote, R.P., Geng, Y., Li, Y., 2016. Comparative study on the pathways of industrial parks towards sustainable development between China and Canada. Resour. Conserv. Recycl. http://dx.doi.org/10.1016/j.resconrec.2016.06.012. RECYCL-3289.
Loomba, A.P.S., Nakashima, K., 2012. Enhancing value in reverse supply chains by sorting before product recovery. Prod. Plan. Control 23 (2–3), 205–215. http://dx.doi.org/10.1080/09537287.2011.591652.
Masoumik, S.M., Abdul-Rashid, S.H., Olugu, E.U., Raja Ghazilla, R.A., 2014. Sustainable supply chain design: a configurational approach. Sci. World J. 2014, 897121. http://dx.doi.org/10.1155/2014/897121.
McDonough, W., Braungart, M., 2002. Cradle to Cradle. North Point Press, New York.
McKinsey & Company, 2015. Europe's Circular Economy Opportunity. Retrieved from. http://www.mckinsey.com/business-functions/sustainability-and-resource-productivity/our-insights/europes-circular-economy-opportunity.
Milios, L., 2013. Municipal Waste Management in the Netherlands. European Environmental Agency.
Mitra, S., 2007. Revenue management for remanufactured products. Omega 35 (5), 553–562. http://dx.doi.org/10.1016/j.omega.2005.10.003.
Moyers, B., The Center for Investigative Reporting, 1991. Global Dumping Ground: the International Traffic Intoxic Waste. The Lutterworth Press, Cambridge.
Murray, A., Skene, K., Haynes, K., 2015. The circular economy: an interdisciplinary exploration of the concept and application in a global context. J. Bus. Ethics. http://dx.doi.org/10.1007/s10551-015-2693-2.
Nagalingam, S.V., Kuik, S.S., Amer, Y., 2013. Performance measurement of product returns with recovery for sustainable manufacturing. Rob. Comput. Integr. Manuf. 29 (6), 473–483. http://dx.doi.org/10.1016/j.rcim.2013.05.005.
Nedvang, 2015. Monitoring Verpakkingen Resultaten Inzameling En Recycling 2015. Leidschendam, the Netherlands.
OECD, 2011. Resource Productivity in the G8 and the OECD. A Report in the Framework of the Kobe 3R Action Plan. Paris. Retrieved from. https://www.oecd.org/env/waste/47944428.pdf.
OECD, 2016. Forum 2016 Issues: International Collaboration. Retrieved from. https://www.oecd.org/forum/issues/forum-2016-issues-international-collaboration.htm.
Ochsner, M., Chess, C., Greenberg, M., 1995. Pollution prevention at the 3 M corporation: case study insights into organizational incentives, resources, and strategies. Waste Manage. 15, 663–672. http://dx.doi.org/10.1016/0956-053X(96)00047-5.
Otis, L., Graham Jr., , 2000. Environmental Politics and Policy, 1960–1990s. Pennsylvania State University Press, Pennsylvania, PA.
Peng, C., Scorpio, D.E., Kibert, C.J., 1997. Strategies for successful construction and demolition waste recycling operations. Constr. Manage. Econ. 15 (1), 49–58. http://web.a.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=b88a64e6-6d21-4cc8-b263-ea798d91b1f7@sessionmgr4001&vid=1&hid=4214.
Pitt, J., Heinemeyer, C., 2015. Introducing ideas of a circular economy. Environment, Ethics and Cultures: Design and Technology Education's Contribution to Sustainable Global Futures. pp. 245–260. http://dx.doi.org/10.1007/978-94-6209-938-8_16.
Preston, F., 2012. A global redesign? Shaping the circular economy. Energy Environ. Resour. Govern. 1–20. http://dx.doi.org/10.1080/0034676042000253936.
Price, J.L., Joseph, J.B., 2000. Demand management – a basis for waste policy: a critical review of the applicability of the waste hierarchy in terms of achieving sustainable waste management. Sustain. Dev. 8, 96–105.
Quaghebeur, M., Laenen, B., Geysen, D., Nielsen, P., Pontikes, Y., Van Gerven, T., Spooren, J., 2013. Characterization of landfilled materials: screening of the enhanced landfill mining potential. J. Clean. Prod. 55, 72–83. http://dx.doi.org/10.1016/j.jclepro.2012.06.012.
Røine, K., Brattebø, H., 2003. Towards a methodology for assessing effectiveness of recovery systems: a process system approach. In: Bourg, D., Erkman, S. (Eds.), Perspectives on Industrial Ecology. Greenleaf Publishing Limited, Sheffield, UK.
Rahman, S., Subramanian, N., 2012. Factors for implementing end-of-life computer recycling operations in reverse supply chains. Int. J. Prod. Econ. 140 (1), 239–248. http://dx.doi.org/10.1016/j.ijpe.2011.07.019.
Rahman, M.N.A., Hernadewita, B., Deros, M.D., Ismail, A.R., 2009. Cleaner production implementation towards environmental quality improvement. Eur. J. Sci. Res. 30 (2), 187–194.
Ramani, K., Ramanujan, D., Bernstein, W.Z., Zhao, F., Sutherland, J., Handwerker, C., et al., 2010. Integrated sustainable life cycle design: a review. J. Mech. Des. 132 (9), 91004. http://dx.doi.org/10.1115/1.4002308.
Reh, L., 2013. Process engineering in circular economy. Particuology 11 (2), 119–133. http://dx.doi.org/10.1016/j.partic.2012.11.001.
Romero, D., Molina, A., 2013. Reverse – green virtual enterprises and their breeding environments: closed-loop networks. IFIP Adv. Inf. Commun. Technol. 408, 589–598. http://dx.doi.org/10.1007/978-3-642-40543-3_62.
Rusjanto, J., Hartoyo, O., Qory, F., Aripin, A., Saroso, R., Rohman, K., 2011. A new way to waste recording, waste tracking: and waste reporting to improve waste management. Proceedings – SPE Annual Technical Conference and Exhibition 4, 3319–3327.
Sakai, S., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., et al., 2011. International comparative study of 3R and waste management policy developments. J. Mater. Cycles Waste Manage. 13 (2), 86–102. http://dx.doi.org/10.1007/s10163-011-0009-x.
Schenkel, M., Krikke, H., Caniëls, M.C.J., van der Laan, E., 2015. Creating integral value for stakeholders in closed loop supply chains. J. Purch. Supply Manage. 21 (3), 155–166. http://dx.doi.org/10.1016/j.pursup.2015.04.003.
Schivelbusch, W., 2015. Das verzehrende Leben der Dinge: Versuch über die Konsumption. Carl Hanser Verlag GmbH & Co., München.
Schut, E., Crielaard, M., Mesman, M., 2015. Circular Economy in the Dutch Construction Sector. Den Haag.
Sherwood, M., Shu, L.H., Fenton, R.G., 2000. Supporting design for remanufacture through waste-Stream analysis of automotive remanufacturers. CIRP Ann. – Manuf. Technol. 49, 87–90. http://dx.doi.org/10.1016/S0007-8506(07)62902-3.
Sihvonen, S., Ritola, T., 2015. Conceptualizing ReX for aggregating end-of-life strategies in product development. Procedia CIRP 29, 639–644. http://dx.doi.org/10.1016/j.procir.2015.01.026.
Silva, D.A.L., Renó, G.W.S., Sevegnani, G., Sevegnani, T.B., Truzzi, O.M.S., 2013. Comparison of disposable and returnable packaging: a case study of reverse logistics in Brazil. J. Clean. Prod. 47, 377–387. http://dx.doi.org/10.1016/j.jclepro.2012.07.057.
Sinha, R., Laurenti, R., Singh, J., Malmström, M.E., Frostell, B., 2016. Identifying ways of closing the metal flow loop in the global mobile phone product system: a system dynamics modeling approach. Resour. Conserv. Recycl. 113, 65–76. http://dx.doi.org/10.1016/j.resconrec.2016.05.010.
Spaargaren, G., 2003. Sustainable consumption: a theoretical and environmental policy perspective. Soc. Nat. Resour. 16 (8), 687–701. http://dx.doi.org/10.1080/08941920309192.
Srivastava, S.K., 2008. Network design for reverse logistics. Omega 36 (4), 535–548. http://dx.doi.org/10.1016/j.omega.2006.11.012.
Stahel, W.R., Clift, R., 2016. Stocks and flows in the performance economy. In: Clift, R., Druckman, A. (Eds.), Taking Stock of Industrial Ecology. Springer, pp. 137–158. http://dx.doi.org/10.1007/978-3-319-20571-7. ebook.
Stahel, W.R., 2003. The functional society: the service economy. In: Bourg, D., Erkman, S. (Eds.), Perspectives on Industrial Ecology. Greenleaf Publishing Limited, Sheffield, UK, pp. 264–283.
Stahel, W.R., 2010. The Performance Economy, 2nd ed. Palgrave Macmillan, New York.
Su, B., Heshmati, A., Geng, Y., Yu, X., 2013. A review of the circular economy in China: moving from rhetoric to implementation. J. Clean. Prod. 42, 215–227. http://dx.doi.org/10.1016/j.jclepro.2012.11.020.
Thierry, M., Salomon, M., Van Nunen, J., Van Wassenhove, L., 1995. Strategic issues in product recovery management. Calif. Manage. Rev. 37 (2), 114–135. http://dx.doi.org/10.1016/0024-6301(95)91628-8.
Tukker, A., Eder Ipts, P., Charter, M., Haag, E., Vercalsteren, A., Wiedmann, T., 2001. Eco-design: the state of implementation in europe conclusions of a state of the art study for IPTS. J. Sustain. Prod. Des. 1 (3), 147–161. http://dx.doi.org/10.1023/A:1020564820675.
Miller, Tyler, Spoolman, G.S., 2002. Environmental Science, 9th ed. Brooks/Cole Pub Co.
UNEP, 2011. In: Fischer-Kowalski, M., Swilling, M., von Weizsäcker, E.U., Ren, Y., Moriguchi, Y., Crane, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A. (Eds.), Decoupling Natural Resource Use and Environmental Impacts from Economic Growth, A Report of the Working Group on Decoupling to the International Resource Panel, Retrieved from. http://www.gci.org.uk/Documents/Decoupling_Report_English.pdf.
UNEP, 2012. The Global Outlook on Sustainable Consumption and Production Policies: Taking Action Together. United Nations Environmental Program.
U.S. EPA, 2016. EPA's Report on the Environment, Quantity of Municipal Solid Waste Generated and Managed. Retrieved from. https://cfpub.epa.gov/roe/indicator.cfm?i=53.
van Buren, N., Demmers, M., van der Heijden, R., Witlox, F., 2016. Towards a Circular Economy: The Role of Dutch Logistics Industries and Governments. Sustainability (Switzerland) 8 (7), 1–17.
Van Eygen, E., Feketitsch, J., Laner, D., Rechberger, H., Fellner, J., 2016. Comprehensive analysis and quantification of national plastic flows: the case of Austria. Resour. Conserv. Recycl. 117, 183–194. http://dx.doi.org/10.1016/j.resconrec.2016.10.017.
Van Passel, S., Dubois, M., Eyckmans, J., De Gheldere, S., Ang, F., Tom Jones, P., Van Acker, K., 2013. The economics of enhanced landfill mining: private and societal performance drivers. J. Clean. Prod. 55, 92–102. http://dx.doi.org/10.1016/j.jclepro.2012.03.024.
Vereniging Band en Milieu, 2016. Doel & resultaat Inzameling oude banden voor een schoner milieu.
Vermeulen, W.J.V., Weterings, R.P.M., 1997. Extended producer responsibility. J. Clean Technol. Environ. Toxicol. Occup. Med. 6, 283–298.

Vermeulen, W.J.V., 2002. Greening production as co-responsibility. In: Driessen, P.P.J., Glasbergen, P. (Eds.), Greening Society. The Paradigm Shift in Dutch Environmental Politics. Kluwer Academic Publishers, Dordrecht, pp. 67–90.
Vermeulen, W.J.V.V., 2006. The social dimension of industrial ecology: on the implications of the inherent nature of social phenomena. Prog. Ind. Ecol. 3 (6), 574. http://dx.doi.org/10.1504/pie.2006.012754.
WCED, 1987. Report of the World Commission on Environment and Development: Our Common Future. Oxford University Press, Oxford.
World Economic Forum, 2014. Towards the Circular Economy: Accelerating the Scale-up Aross Global Supply Chains. Retrieved from. http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf.
World Economic Forum, 2016. Intelligent Assets Unlocking the Circular Economy Potential. Retrieved from. http://reports.weforum.org/.
Wang, H.F., Hsu, H.W., 2010. A closed-loop logistic model with a spanning-tree based genetic algorithm. Comput. Oper. Res. 37 (2), 376–389. http://dx.doi.org/10.1016/j.cor.2009.06.001.
Westerhoff, P., Lee, S., Yang, Y., Gordon, G.W., Hristovski, K., Halden, R.U., Herckes, P., 2015. Characterization, recovery opportunities, and valuation of metals in municipal sludges from U.S. wastewater treatment plants nationwide. Environ. Sci. Technol. 49 (16), 9479–9488. http://dx.doi.org/10.1021/es505329q.
Wilhite, A., Burns, L., Patnayakuni, R., Tseng, F., 2014. Military supply chains and closed-loop systems: resource allocation and incentives in supply sourcing and supply chain design. Int. J. Prod. Res. 52 (7), 1926–1939. http://dx.doi.org/10.1080/00207543.2013.787173.
Williams, I.D., 2015. Forty years of the waste hierarchy. Waste Manage. 40, 1–2. http://dx.doi.org/10.1016/j.wasman.2015.03.014.
Worrell, E., Reuter, M.A., 2014. Handbook of Recycling: State-of-the-art for Practitioners, Analysts, and Scientists. Elsevier, Oxford.
Xiao, S., Huang, Y., 2010. The research of the development principles and development model of circular economy. Paper Presented at the International Conference on Challenges in Environmental Science and Computer Engineering, CESCE 2010 1, 97–100. http://dx.doi.org/10.1109/CESCE.2010.141.
Xin, T., Han, Y.Y., Hu, K.K., 2014. Research on system planning of retired or scrap weaponry and equipment recycling. Adv. Mater. Res. 1010–1012, 979–983. http://dx.doi.org/10.4028/www.scientific.net/AMR.1010-1012.979.
Xing, K., Luong, L., 2009. Modelling and evaluation of product fitness for service life extension. J. Eng. Des. 20 (3), 243–263. http://dx.doi.org/10.1080/09544820701834512.
Xing, K., Abhary, K., Luong, L., 2003. IREDA: an integrated methodology for product recyclability and end-of-life design. J. Sustain. Prod. Des. 3 (3–4), 149–171. http://dx.doi.org/10.1007/s10970-005-3925-9.
Yan, J., Feng, C., 2014. Sustainable design-oriented product modularity combined with 6R concept: a case study of rotor laboratory bench. Clean Technol. Environ. Policy 16 (1), 95–109. http://dx.doi.org/10.1007/s10098-013-0597-3.
Yan, J., Wu, N., 2011. Technology supporting system of circular economy of mining cities. 2011 Asia-Pacific Power and Energy Engineering Conference 1–5. http://dx.doi.org/10.1109/APPEEC.2011.5749062.
Yong, R., 2007. The circular economy in China. J. Mater. Cycles Waste Manage. 9 (2), 121–129.
Yoshida, H., Shimamura, K., Aizawa, H., 2007. 3R strategies for the establishment of an international sound material-cycle society. J. Mater. Cycles Waste Manage. 9 (2), 101–111. http://dx.doi.org/10.1007/s10163-007-0177-x.
Yuan, Z., Bi, J., Moriguichi, Y., 2008. The circular economy: a new development strategy in China. J. Ind. Ecol. 10 (1-2), 4–8. http://dx.doi.org/10.1162/108819806775545321.
Zhu, Q., Geng, Y., Lai, K. hung, 2010. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. J. Environ. Manage. 91 (6), 1324–1331. http://dx.doi.org/10.1016/j.jenvman.2010.02.013.
Zero Waste Europe., Policy Paper, November 2015, Zero Waste to Landfill and/or landfill bans: false paths to a Circular Economy, Retrieved January 2016, from https://www.zerowasteeurope.eu.