

The Emergence of Circular Economy

A New Framing Around Prolonging Resource Productivity

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Summary

In this article, we use Hirsch and Levin's notion of *umbrella concepts* as an analytical lens, in order to articulate the valuable catalytic function the circular economy (CE) concept could perform in the waste and resource management debate. We realize this goal by anchoring the CE concept in this broader debate through a narrative approach. This leads to the insight that whereas the various resource strategies grouped under the CE's banner are not new individually, the concept offers a new framing of these strategies by drawing attention to their capacity of prolonging resource use as well as to the relationship between these strategies. As such, the CE offers a new perspective on waste and resource management and provides a new cognitive unit and discursive space for debate. We conclude by discussing research opportunities for the industrial ecology (IE) community relating to the concept's theoretical development and its implementation. Specifically, we pose that reinvigorating and growing the social science aspects of IE is required for both. After all, it is in understanding and facilitating the collective implementation of any idea, also the CE concept, that the potential lies for shaping our material future.

Introduction

In this article, we examine the circular economy (CE) concept: an emergent framing around waste and resource management that aims to offer an alternative to prevalent linear take-make-dispose practices by promoting the notion of waste and resource cycling. Strategies such as, but not limited to, reuse, recycling, and remanufacturing operationalize this concept. The goal of this article is to articulate the potentially catalytic function the CE performs in the waste and resource management debate by creating a cognitive unit and a discursive space that centers around the capacity of a group of waste and resource management strategies to extend the productive life of resources. Through this, the CE concept provides a

service in this debate by addressing a knowledge gap in relation to what constitutes meaningful and actionable waste and resource management.

Our analysis builds on previous work, primarily from sociology and organizational science, which poses that when ideas regarding waste and resources operate at scale and are enacted in value chains, industries, and other networks, they allow particular practices to emerge and become established. This process involves the alignment of decisions and actions such that preferred technologies are adopted and the appropriate executive and supervisory organizations are created (Lounsbury et al. 2003; O'Brien 2008; Corvellec and Hultman 2012; Silva et al. 2016). Given sufficient time and scale, these enactment processes shape and become embedded in industrial systems.

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This phenomenon of shared ideas as a basis for collective action has been theorized through different concepts that offer different analytical possibilities, such as collective action frames (Benford and Snow 2000), field frames (Lounsbury et al. 2003), and institutional logics (Thornton et al. 2012). Here, we discuss this phenomenon as applicable to waste and resource management and use the designation of *frame* and *framing* to mean a set of ideas, or the creation of such a set, with the capacity to be used as a basis for collective action.

Through examining the framing of waste and resource management proposed by the CE, we identify research opportunities that will make a substantial contribution to the development of the concept. Specifically, we highlight two such opportunities for industrial ecology (IE) in particular, the first relating to the concept's theoretical development and the second to its implementation. We pose that reinvigorating and growing the social science aspects of IE is required for both.

Social science has, to the present day, received relatively little attention within IE (Lindkvist and Baumann 2014). Instead, IE's contribution to date has manifested itself, broadly speaking, in three ways (Lifset and Graedel 2002). First, IE has examined what can be learned from nature in a literal sense, such as when artificially creating materials or mimicking processes found in nature on an industrial scale or when applying solutions found in nature to product design (Benyus 1997). The second contribution can be found in the application of ecological principles to industrial systems in a metaphorical sense. This has taken the form of exploring how to impart the industrial system with the efficiency and low waste quality of ecosystems (Lifset 1997; Ehrenfeld 2000; Ayres and Ayres 2002). Last, IE has extensively studied resource flows within industry and society as well as the interaction with the ecosystems that support it, identifying opportunities to improve resource use. This is illustrated through the systematic analysis of material, energy, and substance flows, in various forms and scales ranging from products to processes to industrial sectors to economies (Lifset 1997), at city, national, and regional levels (Kennedy et al. 2007; Patricio et al. 2015) and the globe (Haas et al. 2015).

Through these efforts, much knowledge was acquired with regard to waste and resource management. However, relatively little (recent) attention has been given to what constitutes an effective frame for enabling collective action in this area. This is all the more striking given that IE finds its very origin in the acknowledgment of the role of frames in rethinking industrial practices and systems: The field initially proposed the development of a new framing of industrial systems based on ecological principles. Frosch and Gallopoulos (1989) are attributed with first articulating this in the seminal article that marks the start of IE as an academic field (Clift and Druckman 2015). Frosch and Gallopoulos (1989) understood the importance of the introduction of a new frame, but also the need of such a frame to be widely shared in order to have impact:

Changing the content of technological education [...] will not be enough. The concepts of industrial ecology must be recognized and valued by public officials, industry leaders

and the media. They must be instilled into the social ethos and adopted by government as well as industry. (Frosch and Gallopoulos 1989, 152)

Other early proponents of IE also understood both points, such as Tibbs (1993), White (1994), Graedel and Allenby (1995), and Socolow (1994). This is further reflected in the ongoing debate within IE regarding the role of human actions, values, and social processes in shaping industrial systems (i.e., O'Rourke et al. 1996; Allenby 1999; Boons and Rooome 2000; Cohen-Rosenthal 2000; Allenby 2001; Hoffman 2003; Hermansen 2006; Boons and Howard-Grenville 2009).

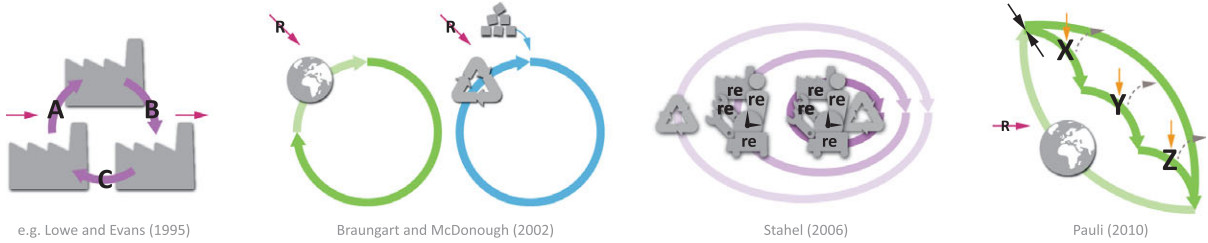
In this article, we use Hirsch and Levin's (1999) notion of *umbrella concepts* as an analytical lens to explore the framing of waste and resource management the CE concept offers in order to understand its role in the waste and resource management debate. We proceed as follows. First, we introduce the notion of umbrella concepts and explain why it is appropriate to conceptualize the CE as an umbrella concept. Next, we introduce two additional aspects of the umbrella concept framework—namely, the catalytic function and the predictable developmental trajectory of umbrella concepts—that prompt our exploration of the knowledge gap the CE attempts to fill. We do this by constructing a narrative that anchors the CE in the broader waste and resource debate as it has developed from the 1960s until the present day. Finally, we discuss the contributions the IE community can make to the theoretical development of the CE concept and its implementation.

Conceptualizing Circular Economy as an Umbrella Concept

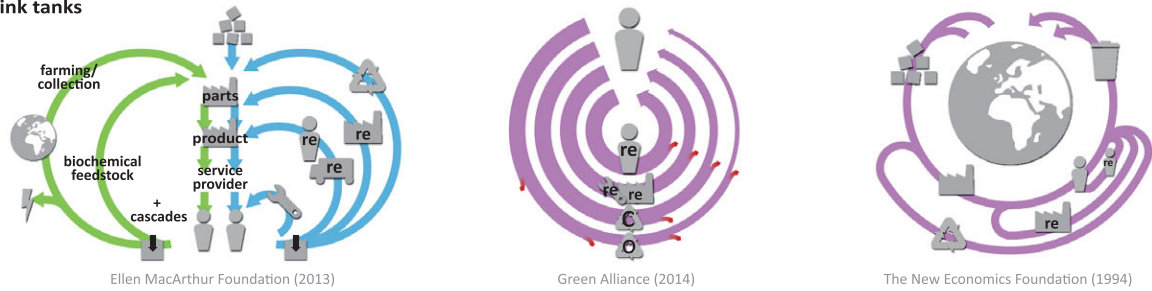
Hirsch and Levin (1999) define an *umbrella concept* as: “a broad concept or idea used loosely to encompass and account for a set of diverse phenomena” (Hirsch and Levin (1999), 200). Umbrella concepts create a relation between pre-existing concepts that were previously unrelated, or not related in the manner the umbrella concept proposes, by focusing the attention on a particular shared quality or characteristic of the concepts it encompasses. Hirsch and Levin offer as examples of umbrella concepts *organizational learning* and *organizational culture*. A second example where the label is invoked is in the case of *social capital* as used by Adler and Kwan (2002). The notion is also widely used outside of organizational science: For example, Klein and colleagues (2003) use it to describe *resilience* and *adaptive capacity* in the field of environmental management.

There is ample ground to conceptualize the CE as an umbrella concept. This becomes evident when comparing and contrasting various frameworks in which circularity plays an important role, see figure 1. Figure 1 presents a selection of interpretations of what a CE could or should look like according to different actors, such as seminal thinkers, think tanks, advisory and legislative institutions, academics, and businesses. For this overview, the original branding and layout is replaced with a uniform visual language that preserves the original strategies and their relationships.¹ What becomes apparent is that,

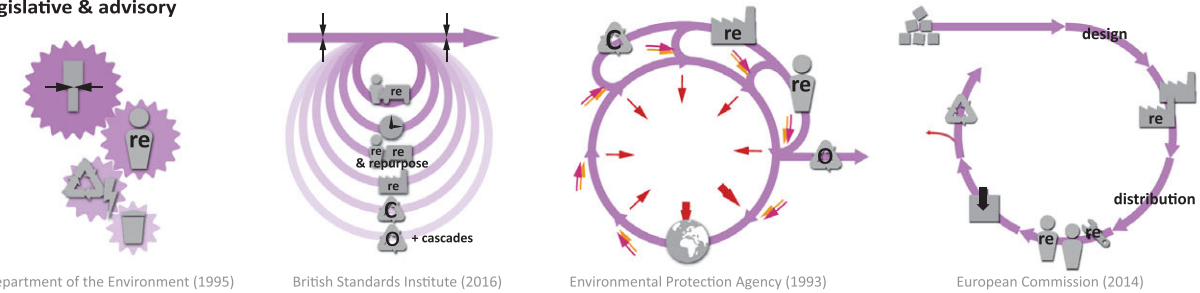
Seminal thinkers/ frameworks



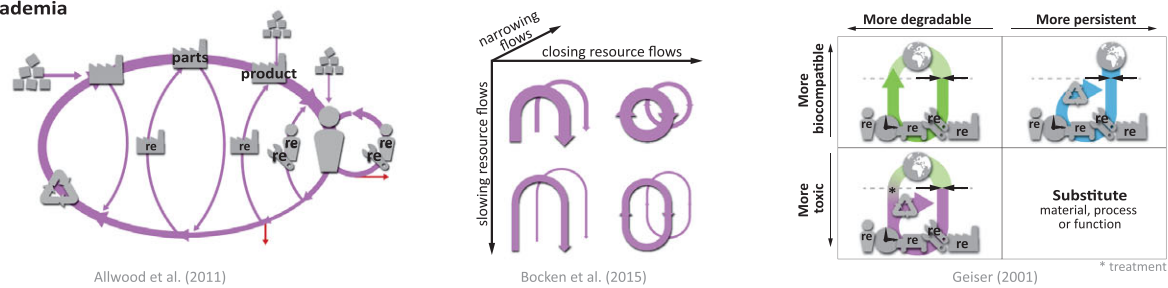
Think tanks



Legislative & advisory



Academia



Business

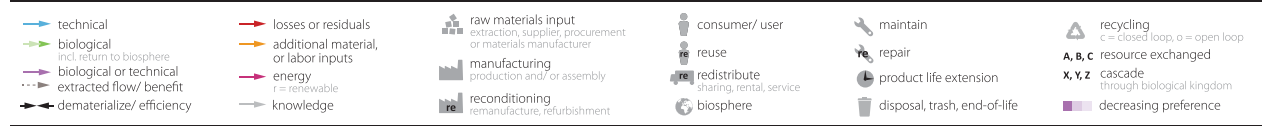
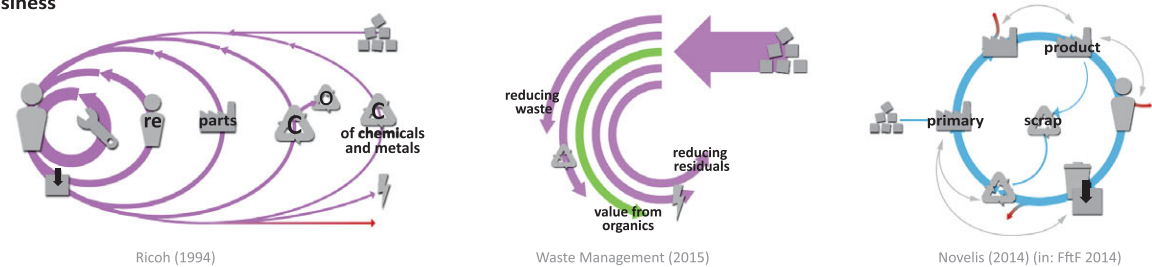


Figure 1 Overview of a selection of interpretations of waste and resource management frameworks. These illustrations purposefully lack some detail so as to draw attention to the underlying structure of these interpretations: that is, the major role that “circular” or resource life-extending strategies play as well as the preoccupation with organizing the relationship between strategies.

whereas preventative strategies such as functional replacement and dematerialization also feature,² the strategies included predominantly and increasingly seek to extend resource life, for example: reuse, recycling, remanufacturing, servitization, repair, waste-to-energy, product longevity approaches, and the cascading of substances (i.e., the transformation of materials through various use phases). The strategies with this capacity will be collectively referred to as resource life-extending strategies (RLEs). Moreover, figure 1 illustrates a preoccupation with assessing and organizing the included resource strategies with regard to what these frameworks consider as their appropriate use. With this, these frameworks attempt to offer insight into the relationships between RLEs.

Viewing the RLEs as the pre-existing concepts that CE groups, their capacity to extend resource life as the shared quality highlighted by their grouping and the appropriate and effective use of these strategies as the phenomenon that it attempts to account for, it becomes apparent that the CE fits the definition of an umbrella concept. Considering the CE an umbrella concept is in line with CIRAIG (2015), who explicitly labels circular economy a *conceptual umbrella* (CIRAIG 2015, xi), and Murray and colleagues (2017), who refer to the circular economy as a “. . . general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes” (Murray et al. 2017, 5).

The Emergence and Development of the Umbrella Concept of Circular Economy

Apart from its capacity to group a collection of concepts two additional aspects of the *umbrella concept* framework are particularly relevant with regard to the CE: the potentially catalytic function an umbrella concept can have within a field or debate as well as the fact that such concepts tend to develop in a predictable manner, respectively.

First, umbrella concepts typically arise when a field or discipline lacks guiding theories or a development paradigm (Hirsch and Levin 1999). In this context, umbrella concepts can act as a catalyst in filling this knowledge gap by creating a new encompassing cognitive unit as well as a new discursive space. The creation of a cognitive unit is accomplished by directing the attention to some shared characteristic of the umbrella concept's constituent elements, thus separating these characteristics out from the background and identifying the core of a phenomenon. This is a simplifying and unifying act that establishes a discursive handle to refer to a particular phenomenon of interest, thus more clearly delineating said phenomenon. This act also creates a discursive space: It generates a (metaphysical) space or platform where the phenomenon can be explored and where that exploration is considered meaningful and valid. The creation of this cognitive unit and a discursive space allows for a discourse to take place as well as the systematic accumulation of knowledge regarding a phenomenon, thus functioning as a catalyst by spurring on a particular field or discipline.

Second, umbrella concepts typically progress along a predictable trajectory. This trajectory starts with the articulation of the umbrella concept by grouping pre-existing concepts. This phase is characterized by excitement and enthusiasm as the concept seemingly resolves the problem of too many unconnected concepts by providing a new framing that binds them together. After this phase, an umbrella concept usually sees its validity challenged when attempts at operationalizing the concept bring to the surface unresolved issues regarding its definition and assessment. A plurality of definitions, a lack of tools, and the existence of different indicators surface during this stage, raising questions regarding the nature of the binding capacity of the umbrella concept. This leads to further work in the form of additional theoretical development, which ultimately causes the concept to either cohere (theoretical challenges are resolved), collapse (construct demise), or persist as a contention (agree to disagree) (Hirsch and Levin 1999).

The catalytic function and the predictable developmental trajectory of umbrella concepts constitute our prompt to explore the knowledge gap the CE attempts to fill and to assess where the concept currently sits within its developmental trajectory. To accomplish this, we proceed to construct a narrative describing the waste and resource management debate from the perspective of the CE as an umbrella concept.

Method for Creating the Narrative

We restrict our narrative to the period from around 1960–present. The reason for this is that the 1960s are generally considered the formative years of the environmental movement, and, as Melosi (2005) observes, this was also when the issue of waste became a national responsibility and hence a truly collective one. This time frame further provides us with a sufficient preamble to the emergence of the CE concept as defined above—which, we argue, takes place from 1985 onward—to clarify the knowledge gap it attempts to fill. For the period pre-1960, we refer the interested reader to the works of Rathje and Murphy (1992), Strasser (1999), Melosi (2005), and O'Brien (2008). The following narrative is an iteration of Blomsma (2015) and Brennan and colleagues (2015).

The starting point for the creation of our narrative were the Boons-Desrochers articles (i.e., Desrochers 2000, 2001, 2012; Boons 2008, 2012). This set of articles illustrate the fact that, in the past, different demands were placed on waste and resource management and were therefore judged an appropriate starting point for understanding the development of this debate.³ We supplemented this set with well-known seminal texts, such as Boulding (1966), Buckminster Fuller (1969), and Commoner (1971), and used this collection as a set to snowball from. We continued through this snowball approach to review academic, gray, and public policy literature, focusing on the period 1960–present, predominantly related to the geographical regions of North America and Europe. We specifically focused on the different RLEs highlighted by thought leaders and other influential publications as well as the different ways the CE has been labeled (e.g., but not limited to, *closed spaceship economy*,

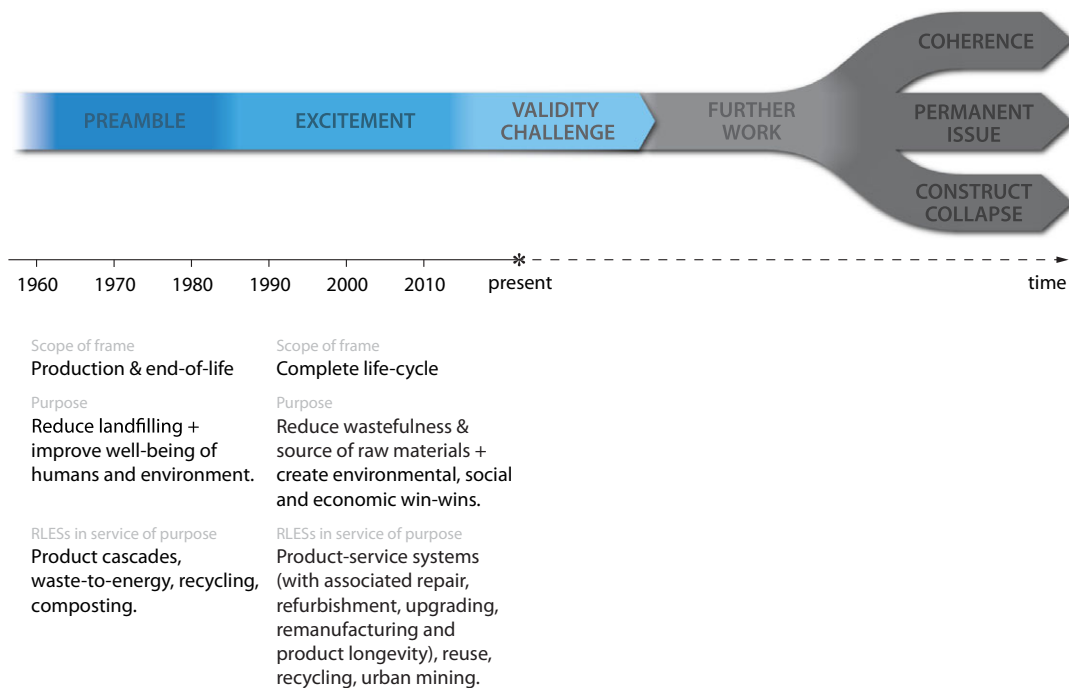


Figure 2 In schematic form, this illustration depicts the stages the circular economy concept has gone through, as well as the stages of development ahead, if the concept were to follow the typical trajectory umbrella concepts develop along. The transition between phases is depicted as a gradient, because no single event can be identified as causing the transition and because exact timings differ for different regions. Included RLESs are those highlighted by thought leaders and in influential publications during the periods in which they feature. RLESs = resource life-extending strategies.

closed-loop economy, cyclic economy, etc.). We proceeded until saturation was reached, meaning that no new sources were uncovered that altered our interpretation of the narrative.

Although narrative reviews can be criticized for not being systematic, their value lies in providing insights into the emergence and trajectory of new concepts, which span multiple fields: By illustrating the succession and the interplay of ideas over time, critical engagement with a concept is promoted (Boell and Cecez-Kecmanovic 2015), beyond the insights that systematic reviews provide. Specifically, we show, in narrative format, how the framing of the waste and resource management debate changed as a result of many different intersecting developments and how this created the conditions for the CE concept to emerge. Through this, our narrative enriches systematic reviews already performed in the area of the CE (e.g., Ghisellini et al. 2016; Lieder and Rashid 2015), given that such reviews tend to not appropriately address the fact that before the emergence of the umbrella concept of the CE, terminology to identify the phenomenon varied enormously as well as failed to articulate the role of the CE concept in the waste and resource debate.

We further limit our narrative to resource and waste management applied at scale within industry and waste management. Moreover, although we acknowledge that RLESs play a role inseparable from preventative strategies, for reasons of brevity, we only include preventative strategies, where necessary, to understand the development of the narrative. The narrative

should not be taken as evidence that the discussed strategies were widely implemented in the periods discussed, but that these strategies were considered well suited to address the issues of the time. It should further not be taken to mean that multiple social narratives regarding waste and resources did not or cannot co-exist (Dryzek 1997; O'Brien 2008), but that we focus on the broad development of the CE as an umbrella concept.

Waste and Resources: An Increasingly Rich and Complex Debate

We have divided our narrative in stages, as in line with the umbrella concept framework, see figure 2. The first period, from 1960 to 1985, we refer to as the *preamble*, because this is the period before the articulation of the CE concept. Featured next is the *excitement* stage, where the concept crystallizes and gains momentum. We also discuss its transition to the *validity challenge* period and go on to draw implications for the *further work* stage. Please note that our periodization is not meant to indicate periods where activities abruptly start or end, but periods characterized by particular developments. To indicate this as well as to acknowledge regional differences, figure 2 uses gradients to depict the transition between periods.

1960–1985 Preamble Period

During this period, the waste and resource debate is preoccupied with the role of waste handling, with special attention

directed at the polluting effects of waste. The set of RLESs highlighted during this period were therefore primarily related to end-of-life (EoL) processes of both industrial and municipal waste, alongside which featured preventative measures focused on the production side of the industrial system. As a result such waste handling strategies as cleaner incineration, waste-to-energy, recycling, and composting were emphasized.

Two developments were key during this period. The first was a reiteration of the idea of responsible management of natural resources earlier put forward by thinkers such as Thomas Malthus, John Stuart Mill, and Hans Carl von Carlowitz (Lacy and Rutqvist 2015). Publications such as *Silent Spring* (Carson 1962), *Tragedy of the Commons* (Hardin 1968), and *Operating Manual for Spaceship Earth* (Buckminster Fuller 1969) drew attention to these ideas by problematizing toxicity and scarcity. During this stage, awareness that the impact of environmental pollution extended beyond the superficial and localized (Commoner 1971) was coupled with the realization that human and environmental well-being are not only linked, but depend on resource use and processing. These ideas were illustrated evocatively by Kenneth Boulding, who described the then current situation as the *open cowboy economy* and contrasted this with the desirable situation that he called the *closed spaceship economy* (Boulding 1966). These ideas were taken up by Stahel and Reday-Mulvey (1981), who formulated the concept of a *closed-loop economy* (Murray et al. 2017). In the latter half of this period, these calls for rethinking economic systems and industrial practices became formal appeals to act directed at industry and governing bodies, evidenced by the appearance of such seminal works as *Limits to Growth* (Meadows et al. 1972).

The second key development contributing to the framing of the waste and resource debate during this period was progress in the academic fields of biology, ecology, physics, systems thinking, and the management and business sciences, as well as the interplay between these fields (see, for relevant reviews, Fischer-Kowalski 2002; Boons 2009; Capra and Luisi 2014). New fields and disciplines were created, such as environmental economics and eco- or green design. Among these, eventually, also the field of IE (Frosch and Gallopoulos 1989), where the concept of loops and cycles was first explored in a systematic manner. These fields generated new insights, attitudes, and ideas, such as a readiness to learn from nature and the use of natural systems as a model for human society, specifically the idea that industrial systems can be imparted with the efficiency and waste-less quality of natural systems. This created the fertile ground for a range of seminal works that attempted to operationalize the call to action and provide practical guidance for change, such as *The Closing Circle* (Commoner 1971), *Small is Beautiful* (Schumacher 1973), and *Design for the Real World* (Papanek 1974). In this tradition also fit such later seminal works as *Biomimicry* (Benyus 1997) and Herman Daly's work on ecological economics (Daly 1991).

During this period, waste was primarily framed as a negative force, attributable to associated environmental, social, and economic costs. Restoration and prevention of (further) damage

to human and environmental health and well-being became central to the waste and resource debate. However, no clear solutions emerged. On the contrary, debates erupted around the appropriateness of waste and resource management strategies: The increasing scarcity of space for landfilling in some places, such as the Netherlands and Japan, and the increasing financial and environmental costs of incineration in others, such as North America, led these practices to fall out of favor in these areas (Murray 1999; Melosi 2005). These discussions brought to the fore the question of what strategies should be applied under what circumstances and turned the attention to what other strategies should be considered.

Under this influence, waste and resource management practices previously wielded were reframed. Take recycling, for example. Initially, this period saw the rise of many nonprofit recycling initiatives that served charitable and community-building purposes, where this practice was cast as a moral duty to the environment. Gradually, however, these small-scale initiatives ceased to exist and recycling became primarily the responsibility of larger organizations, due to solid waste management companies embracing recycling as an opportunity to make profit (Lounsbury et al. 2003). With this, recycling shifted away from being a marginal practice pre-1960s (Hoy and Robinson 1979, in: Lounsbury et al. 2003), to—war efforts aside—becoming a permanent industry in its own right. Interestingly, the primary purpose ascribed to recycling did not change: It continued to primarily be seen as serving to reduce the negative EoL effects of matter that is no longer wanted by its previous owner (see, e.g., RCC 1977). A second example concerns the concept of cascades, which was extended to include product cascades (Stahel and Reday-Mulvey 1981; Stahel 1982), a type of cascade that entails the transfer of a product to a user who is less demanding regarding (a) particular product feature(s) than its previous user.

1985–2013 Excitement Period

From \pm 1985 onward, there is room to view waste as a positive force: as a resource and a source of value (O'Brien 2008), and, for this reason, we start the *excitement* period here. The development of new ways of representing and analyzing social life during the 1970s and 1980s, among which was life cycle thinking (Boons and Howard-Grenville 2009), contributed to this. The strategies for dealing with resources that were highlighted during this period primarily related to extending the use phase of resources and delaying or preventing landfilling or permanent disuse, such as recycling, urban mining, and product-service systems. The latter also renewed the interest in related strategies such as product longevity, repair, refurbishment, upgradeability, and remanufacturing.

During this period, the meaning attributed to several strategies already viewed as important solutions became richer and more complex. Cascading, for example, came to include webs and sequences, and the notion of energetic cascades, such as the use of steam or heat for secondary applications, became prominent again (Chertow 2000; Pauli 2010); product longevity approaches saw the introduction of *optimal product life span* (Bakker et al. 2014); recycling was reframed more explicitly as

a source of raw materials, and waste-to-energy again became an acceptable ‘last resort’ strategy under certain circumstances (EMF 2013).

Another development during this period was the wider discussion regarding sustainable development, sparked by the Brundtland report (WCED 1987). Specifically, during this period sustainable development was framed as an opportunity, and addressing this global challenge became viewed as a means of managing risk, saving costs, and as a means to deliver economic growth and innovation (Hart and Milstein 2003). Moreover, waste and resource strategies were increasingly viewed as intimately intertwined through synergies and trade-offs. An example of synergies is the belief that win-win situations exist where multiple benefits can be generated from a single intervention. This view rose to prominence during the United Nations (UN) Conference on Environment and Development (UNCED 1992) and gained traction as the concept of the triple bottom line, which poses that economic, environmental, and social benefits can simultaneously be generated by means of strategic interventions that take these factors into account (Elkington 1994, 1997). The idea of synergies was taken up by the business community, as evidenced by such works as Porter and van der Linde (1995), Porter and Kramer (2011), and Pfitzer and colleagues (2013). An example of trade-offs is the introduction of the *food-water-energy nexus* (Keairns et al. 2016), which poses that it is difficult to directly replace one resource with another because of their interconnected nature. In short, the waste and resource debate had become increasingly demanding and complex (Hultman and Corvellec 2012; Silva et al. 2016).

Although the complexity of this debate increased, clear answers remained absent, surfacing a knowledge gap in relation to what constitutes meaningful and actionable waste and resource management. In response, such umbrella concepts as zero waste, resource efficiency, extended producer responsibility, sustainable consumption and production, IE, and green economy emerged or were reiterated. Around many of these umbrella concepts, academic communities and research programs coalesced and they were used to direct practical initiatives implementing alternative waste and resource strategies.

A second observation in support of the intensification of the waste and resource debate is the appearance of a multitude of waste and resource management frameworks that take a more prescriptive approach by attempting to codify the relationships between different waste and resource management practices. These frameworks, see figure 1, typically feature one or more strategies that can be designated as circular. Two types of actors in particular took to using these frameworks. The first were policy makers who sought to use circularity as a legislative tool. Yuan and colleagues (2006), Yong (2007), Murray and colleagues (2017), and Ghisellini and colleagues (2016) narrate the spread of policy directed at the extension of resource life around the globe—from Sweden to Germany, from Japan to China—often replacing or reinventing earlier policies. Notable in this regard also is the Dutch National Environmental Policy Plan from 1989 (SG 1989). Moreover, in Europe, the Waste Hierarchy (EC 2008) was introduced as a formal policy

guide, formalized first in 1989. In the United States, guidance was provided by the U.S. Environmental Protection Agency (US EPA) in the form of various documents (US EPA 1993, 2002), among which is *Sustainable Materials Management: The Road Ahead* (US EPA 2009).

The second group that took to using such frameworks was businesses. Various consultancy and support services targeted at businesses were offered by organizations that promoted their respective frameworks, among which were Cradle-to-Cradle™ (Braungart and McDonough 2002; McDonough and Braungart 2013), the Performance Economy (Stahel 2006), the Blue Economy (Pauli 2010), and the Circular Economy (EMF 2013).

Other efforts during this period similarly attempted to make accessible and popularize the idea of pursuing resource life extension through loops and cycles. A well-known contribution in this category is *Factor Four* (Von Weizsäcker et al. 1998), that promotes resource productivity: among the many examples discussed in this text recycling and reuse feature numerous times. *The Ecology of Commerce* (Hawken 1993) and *The Natural Step* (Robèrt 2002) are other examples of works in this category. The latter builds on earlier cooperative work that uses thermodynamic arguments to show that resource cycling is unavoidable if humanity wishes to operate within planetary boundaries, developing the idea of a *cyclic industrial era* (Eriksson and Robèrt 1991). Other less well-known examples popularizing the theme were the report *Industrial Ecology* (Tibbs 1993), which talks of a *cyclic economy*, and the report *Eco-efficiency and Materials* (Young et al. 2001), that speaks of a *cyclical economy*. Alternative terms such as *revalorization* (Parkinson and Thompson 2003) and *closed-loop production* (Abdallah et al. 2012) were also in use. Note the diverse terminology, despite Pearce and Turner having introduced the term *circular economy* in 1990 (Pearce and Turner 1990),⁴ and it having found some adoption (Cooper 1994, 1999).

As such, it can be said that it was the presence of a knowledge gap in the waste and resource management debate combined with the various attempts at making sense of RLESs, often through the metaphor of loops or cycles, that built momentum for the articulation of *circular economy* as an umbrella concept. Although this encompassing label is also associated with the specific interpretation of it by the Ellen MacArthur Foundation (EMF) (EMF 2013), it nevertheless came to stand for the cognitive unit of the wider umbrella concept. Promotional efforts of the EMF in collaboration with the World Economic Forum (WEF) (WEF 2014), made this one of the dominant umbrella concepts in the waste and resource management debate, contributing to the creation of a discursive space, of which this special edition is a part.

Seen in this light, the CE articulates a distinct cognitive unit compared to the other umbrella concepts that also emerged during this period. In contrast to other umbrella concepts, the CE articulates (more clearly) the capacity to extend the productive life of resources as a means to create value and reduce value destruction. This, despite the fact that it encompasses pre-existing concepts that are also encompassed by other umbrella concepts. The role of recycling, for example, when under the zero

waste umbrella, is that of a strategy primarily aimed at reducing landfill and not that of a strategy that can provide resource security. In other words, other umbrella concepts emphasize different use and different outcomes of what the CE identifies as RLEs.

2013–Present: Validity Challenge Period

From 2013 onward, a different type of engagement with the CE concept is also taking place, heralding the validity challenge period. Specifically, the new cognitive unit and discursive space facilitated discussion, allowing for more critical engagement. The current situation can be characterized as one where interpretations abound, as illustrated by figure 1, which implies that theoretical or paradigmatic clarity regarding the CE concept has yet to emerge.

A case in point is distinguishing between recycling, down-cycling, and cascading: There are no well-established means to distinguish between these strategies quantitatively or conceptually, yet circular metrics are already being put forward (i.e., EMF and Granta 2015; Linder et al. 2017), leading different assessments to be incomparable. A second critique, in the context of the emerging European Union (EU) Circular Economy Package (EC 2015), is the lack of clarity regarding resource efficiency targets, which remain focused on (low-grade) recycling. This suggests there is no fundamental shift in policy, which critics argue should also incorporate disassembly and reusability (Edie 2014). Another source of critique is the CE's engagement with other resource flows, namely energy. Allwood (2014), for example, argues that an important dimension regarding whether RLEs can generate the promised benefits relies on considering the negative impact of energy use in their realization, which not all interpretations of the CE engage with.

Equally important, but more abstract, is the CE's relationship to other concepts such as sustainability. Murray and colleagues (2017), Gregson and colleagues (2015), and Geissdoerfer and colleagues (2017), for example, argue whether current interpretations are indeed in line with the creation of both societal and environmental benefits. Observations have also been made regarding the lack of appropriate tools and language, such as in the context of the CE-inspired business model innovation (Antikainen and Valkokari 2016; Bocken et al. 2016; Lewandowski 2016).

These illustrative examples of issues stemming from operationalizing the concept are indicative of an umbrella concept in its validity challenge stage.

Future: Further Work—A Research Agenda for Industrial Ecology to Contribute to the Development of Circular Economy

Given the concept's state of development, it has considerable further development ahead before it can become a robust concept. It thus has its most important stage of development ahead, the *further work* stage as indicated in figure 2, which implies that many opportunities for research exist. We highlight

two such opportunities for IE in particular, the first relating to the concept's theoretical development and the second to its implementation. We discuss these in turn.

First, in order to develop the theoretical underpinning of the CE umbrella concept further, a deeper understanding of the relationship between RLEs is necessary. The CE concept implies, after all, a shift away from implementing and assessing singular strategies, to the assessment of different *circular configurations*: situations where two or more different RLEs work together in sequence or in parallel. Metrics and other assessment methods will play a key role in generating this deeper understanding. This implies that IE's tools (e.g., life cycle assessment, material flow analysis, and input-output) need to be deployed to systematically interrogate different RLE configurations in different contexts in order to learn more about such configurations. Effectively, configurations need to be studied as a unit-of-analysis in their own right. From this, one could identify what makes configurations effective, for example, and how, recycling and reuse could generate synergies.

An important aspect in this is the need for assessment tools to be useful and meaningful to those who use them or their output (O'Rourke et al 1996; Hoffman 2003). As such, due consideration needs to be given to how different RLEs are defined and how the relationships between different RLEs as well as other strategies are conceptualized, quantified, and presented. Specifically, being cognizant of the fact that such tools are to be used by practitioners and decision makers means that it is important to understand what such users consider meaningful and how they handle complexity. Various forms of social embeddedness, such as cognitive, cultural, and political (Hoffman 2003; Boons and Howard-Grenville 2009), play a role in this. For example, different actors in the CE landscape (e.g., academic, policy, business, and nonprofit actors) have different interpretations of the concept and differ with respect to their level of influence. To delegate research into how these interpretations can be meaningfully aligned to others scholars outside the IE field would represent a missed opportunity, given IE's unique access to the policy and industry arenas as well as increase the distance of such work from technical expertise.

Second, transformational change requires socioinstitutional change, as eloquently stated by Hoffman:

Quantitative analysis of technical data alone will not convince a community to accept a new industrial facility in its midst, an environmental group to endorse a corporate initiative, an investor group to invest in a self-professed sustainable company, a government official to rely on promises of environmental stewardship, a consumer to purchase a green product, or a corporate board of directors to invest in a new technology that reduces material or energy use. (2003, 82)

That is: Whereas answers to technical and engineering *what* questions are needed, which IE has traditionally engaged, what is also required if CE strategies are to be implemented are answers to *how* questions regarding accomplishing socioinstitutional change (Boons and Howard-Grenville 2009). This goes for the range of circular strategies. For example, the

implementation of consumer recycling schemes, aimed at a higher degree of source separation, involves a connected set of changes regarding new infrastructure, appropriate product design as well as new disposal habits (Baxter et al. 2016). A second example, concerning reuse and remanufacturing business models, involves changing the relationships within value chains and overcoming uncertainties related to financial risk associated with future customer demand and high capital requirements (Linder and Williander 2017). As such, understanding the role of social embeddedness in all its diverse forms—cognitive, cultural, structural, political, spatial, and temporal embeddedness (Boons and Howard-Grenville 2009)—is crucial to implementing the CE. Or, in the words of O'Brien (2008), the conversation regarding waste is “a social process of valuation and the industrial, political and economic means of its realization” (O'Brien 2008, 5).

To guide the development of the CE concept toward wide implementation and alignment with sustainable development thus suggests that further integration of social theories with IE is required, which, up to the present day, is an underexposed area (Lindkvist and Baumann 2014). This entails incorporating perspectives from other disciplines, such as law, ethics, economics, system dynamics, and sociology and organizational studies, within IE, beyond superficial linking (Hoffman 2003).

Discussion and Conclusion

In this article, we have shown that the waste and resource debate is currently framed in a different manner compared to the period 1960–1985, with respect to the outcomes waste and resource management is expected to generate. RLESs were previously not (primarily) framed, and certainly not collectively, as extending the productive life of resources. The CE's reframing casts RLESs in a way that more clearly delineates the role they could play in managing waste and resources. Thus, the CE's service to the waste and resource debate is having articulated the capacity of a group of strategies to extend resource life as a means to facilitate additional value extraction and reduce value loss and destruction. Effectively, the CE umbrella concept names and delineates a new phenomenon and, through this, gives it the substance of a unit that can be discussed, thus creating a cognitive unit. This also creates a platform where a discussion dedicated to the appropriate application of RLESs can be held, thus generating a discursive space. Thanks to this service, it is now possible to engage in a conversation as well as accumulate and compile knowledge in a systematic manner. It is in this capacity that the concept's catalytic function lies and it is in this sense the CE could contribute to filling the knowledge gap with regard to what constitutes meaningful and actionable waste and resource management practices.

The narrative as presented in this article is limited in scope, time frame, and geographical location as well as overlooks details regarding the distinct, but co-evolving, scientific, policy, and practice discourses. Although greater detail with regard to these aspects may yield additional insights, we have neverthe-

less shown that, similar to other concepts (Sepulveda 2015), the CE's core ideas had emerged before clarity was generated regarding the encompassing label. In other words, we have brought to the fore that the idea of resource life extension central to the CE concept was gestating before the EMF and WEF articulated the encompassing label and started promoting it (EMF 2013; WEF 2014). This is something not previously acknowledged explicitly by systematic reviews.

We have further argued that our understanding of what aids or inhibits socioinstitutional change in waste and resource management can be enriched by paying attention to how material flows are shaped by, and interact with, nonmaterial flows, that is, the different forms of social embeddedness. Moreover, we have indicated a number of ways IE can contribute to the development of the CE concept. If IE engages these opportunities, then IE can truly become—to quote Tom Graedel—“the science of the circular economy” (Tom Graedel, keynote ISIE Conference 2015, Surrey, UK), where we hope *science* comes to include both the physical and social sciences.

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Notes

1. The exception to this is the diagram for the Blue Economy: Gunter Pauli does not provide a general conceptual diagram in *The Blue Economy* (Pauli 2010). Instead, the conceptual diagram here is based on the diagrams that accompany the case descriptions in this text as well as his description of the Blue Economy that invokes the metaphor of a waterfall.
2. By preventative strategies, we refer to strategies that prevent the use of a resource in the first place, such as sufficiency (doing without), functional replacement (doing different, such as the waterless dyeing processes described in Heida [2014]), dematerialization, and efficiency measures (using less). However, these do not include sharing or co-use, which we regard to be circular strategies because they rely on redistribution and can involve repair or remanufacturing practices.

3. Initially, we explored the period from around mid-nineteenth century onward because this marks the beginning of a period where new technologies, such as electricity, railroads, chemical and engineering expertise, and a more centralized industrial infrastructure, sparked many innovations and previously unseen quantities and types of industrial substances were generated (Boons 2008). For the purposes of this article, such a broad historical perspective is not required and therefore the limit our narrative to the period 1960–present.
4. Perhaps not such a curious fact after all, given that Pearce and Turner merely use the CE to refer to the feedback loops that exist between natural stocks and the use of nature as a sink for wastes, and do not invoke it in the modern sense, that is, to extend the productive life of resources.

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