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Circular economy as an essentially contested concept

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ABSTRACT

The Circular Economy (CE) is currently a popular notion within the policy and business advocacy groups. Despite being visionary and provocative in its message, the research on the CE concept is emerging. The two intertwined objectives of the paper are; first to identify, discuss and develop the various definitions provided by the emerging literature. Secondly, to suggest an initial research approach with which research on CE can be conducted. Our analysis shows that the existing CE work is mainly done on the practical and technical levels of the actual physical flows of materials and energy in production-consumption systems. The focus of the extant literature is on concrete metrics, tools, instruments and computations. Therefore, the basic assumptions concerning the values, societal structures, cultures, underlying world-views and the paradigmatic potential of CE remain largely unexplored. We argue that CE has already become what Gallie (1955) more than six decades ago termed as an "essentially contested concept" (ECC). The paper further suggests a model for CE research that helps in the categorization, classification and organization of research and investigation on CE. The model can help in limiting the observed unbalance and enhance the contribution of the CE approach to a more sustainable global society.

1. Introduction

Circular Economy (CE) as an approach to combat environmental challenges and promote sustainable development has recently received increasing attention in the discussions on industrial development. These discussions are primarily led by policy makers such as the European Commission (COM, 2015) and business advocacy bodies such as the Ellen MacArthur Foundation (EMAF, 2015; EMAF, 2013; EMAF, 2012; COM, 2015; COM, 2014). The practitioners view CE as a way to set in motion mechanisms to induce regenerative industrial transformations that will pave the way for achieving sustainable production and consumption. The ambition is that the evolution of CE based industrial production instead of the prevailing linear models will not only have a positive impact on the environment but also contribute to economic growth (COM, 2014; EMAF, 2013; CIRAIG, 2015). At the global level some have even suggested that once CE is fully implemented it would result in economic gains exceeding 1000 billion US dollars annually (FICF and Mckinsey, 2014). CE as a potential future industrial paradigm is not only confined to old industrialised nations. For instance, China, as the first country in the world, has already adopted a law for the implementation of the circular economy in 2008 (CIRAIG, 2015). Since then, others have followed; The European Union, for example, has created a CE package by extending the earlier waste directive (COM, 2015).

In a policy and a business development context, CE is embraced as an approach simply because it is viewed as an important approach to achieving sustainable environmental and economic development (EMAF, 2015; EMAF, 2013; EMAF, 2012; COM, 2015; COM, 2014). This vision is underpinned by dissatisfaction with the prevailing and traditional linear *extract-produce-use-dump* material and energy flow model of the modern economic system which is problematic in terms of economic, social and environmental sustainability (Frosch and Gallopoulos, 1989). Accordingly, CE is expected to provide the impetus for an economic system with an alternative flow model, one that is cyclical and regenerative (see EMAF, 2015; EMAF, 2013; EMAF, 2012; CIRAIG, 2015; Geissdoerfer et al., 2017).

Although the idea of materials cycles has been around since the dawn of industrialization (Desrochers 2002, 2004) it has been given potency by the current day discussions on climate change mitigation and sustainable development. Unlike traditional recycling the

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practical policy and business advocacy orientated CE approach emphasizes product, component and material reuse, remanufacturing, refurbishment, repair, cascading and upgrading as well as the potential of sustainable energy sources such as solar, wind, biomass and waste-derived energy utilization throughout the product value chain using a cradle-to-cradle life cycle approach (EMAF, 2013; Rashid et al., 2013; Mihelcic et al., 2003; Braungart et al., 2007). Subsequently, CE once fully developed will promote high value material cycles instead of recycling only for low value raw materials as in traditional recycling (Ghisellini et al., 2016). Thus, the notion of CE is not only about production but also it aims to develop sustainable consumption alongside sustainable production e.g. by promoting and applying the sharing economy approach (e.g., Naustdalslid, 2017; EMAF, 2013). Groups of consumers share the function and the service provided by the physical product for substituting current individual ownership-based consumption patterns. In such an economy, more value is extracted from the physical resources within the economy.

However, the CE approach has almost exclusively been developed and led by practitioners, i.e., policy-makers and business development agencies such as business consultants, business associations, business foundations etc. (e.g., EMAF, 2013; COM, 2014; CIRAIG, 2015). From a scholarly position, the conceptual discussions on CE are still in their infancy and the literature is only emerging. Consequently, there is a need for deeper analysis of the concept, its units of analysis as well as the theoretical basis that underpins it. In this context, CE might *prima facie* fit what Gallie (1956) in his seminal work called an essentially contested concept (ECC). According to Gallie (1956) a concept becomes essentially contested if there is agreement on the means and goals of a concept but disagreements on how to define it, which units of analyses to use to capture the dynamism, what the conceptual cornerstones are and what methodology of enquiry is appropriate.

In this context, CE shares the characteristics of being an ECC with other concepts such as Corporate Social Responsibility (Okoye, 2009; Choi and Majumdar, 2014), Markets (Rosenbaum, 2000), Ecosystem services (Schröter et al., 2014), resilience of complex adaptive systems (Folke, 2006) or the concept of sustainable development itself (Connelly, 2007). CE and all these other concepts are equipped with positive connotations and noble goals but pose conceptual challenges for researchers. Additionally, the scientific knowledge base of CE remains largely unexplored although the idea dates far back, even to the 18th and 19th centuries (cf. Boulding, 1966; Desrochers 2002, 2004). There are also clear differences and separation between relevant research communities engaged in CE research in addition to the lack of a holistic approach (e.g., Korhonen et al., 2004; Shwom, 2009). For instance, although the natural science and engineering orientated research communities have to a large extent addressed CE using physical materials and energy flow-based models of economic systems, they have not managed to comprehensively connect the knowledge base to business, organizational and management study research communities (Korhonen et al., 2004).

Against this background, this paper has two interdependent research objectives which are motivated by the fact that today the CE concept is, on the one hand, a noble approach to mitigate environmental and economic challenges, while on the other hand, in terms of scientific research, it appears to be vague and needs a critical analysis. The objectives are:

- To analyse the concept of circular economy. We do this by highlighting the extant literature with the goal to identify the main academic bodies of knowledge, definitions and conceptual foundations that lie behind the current policy and business development discourse. We arrive at a suggestion on how to solve the definition issue of CE.
- Second, we develop a tentative framework to guide research on the CE concept. We will consider the different options for the actual unit of analysis and the different methodological approaches suitable to study them from the perspective of sustainable development. What are the complexities, tradeoffs and problem displacement risks involved with the diverging units of analysis and respective methods of investigation?

Our ambition is not to diminish the goals and the ambitious visions of the CE discourse. Rather, our intention is to highlight the variety of delineations in the literature, address how the concept is currently defined and suggest an initial methodological model on how to conduct CE related research considering the definitional challenges of the concept.

Apart from this introduction, the paper is organized as follows. The next section provides a discussion and analysis of some of the CE literature including the variety of definitions that exist and identifies some of the limitations of these. Through a literature review we identify the focus of existing research about CE and pinpoint elements that help us characterise CE. In section three, we work toward a new definition. After this, we arrive at the conclusion that CE should be understood as an essentially contested concept (ECC). We base this argument on the consideration of CE from the perspective of the seven main properties in Gallie's ECC. Section five constructs an initial model for carrying out research on CE. Finally, conclusions are made and their implications are discussed.

2. CE and its many definitions

The notion of CE is loosely based on a fragmented collection of ideas derived from a variety of scientific disciplines and semi-scientific concepts. In the engineering field, in particular in industrial ecology, CE related research has found a home as a point of departure (Frosch and Gallopoulos, 1989; Lifset and Graedel, 2001; Graedel, 1996). Apart from established research fields e.g. ecological economics, which has a long tradition in recycling and its related issues (Georgescu-Roegen, 1971; Daly, 1996; Ring, 1997; Boulding, 1966; Ayres, 1999), CE also provides a natural point of departure in other research streams. These include industrial ecosystems (Jelinski et al., 1992) and industrial symbioses (Chertow and Ehrenfeld, 2012), cleaner production (Ghisellini et al., 2016; Lieder and Rashid, 2016; Stevenson and Evans, 2004), product-service systems (Tukker, 2015), eco-efficiency (Huppes and Ishikawa, 2009; Haas et al., 2015; Welford, 1998), cradle-to-cradle design (Braungart et al., 2007; McDonough and Braungart, 2002, 2003), biomimicry (Benyus, 2002) resilience of social-ecological systems (Folke, 2006; Crépin et al., 2012), the performance economy (Stahel, 2010; EMAF, 2013), natural capitalism (Hawken et al., 2008), the concept of zero emissions (Pauli, 2010) and others.

2.1. Existing knowledge base

An essential first step of capturing the knowledge base of any field or in our case a concept is to conduct a literature review which identifies not only the conceptual aspects but also major channels of publication. In order to increase our knowledge and respond to the aim of the paper, we conducted a two-part literature review. Part one covered the main academic bodies of knowledge, theories and conceptual foundations that constitute the currently popular Ellen MacArthur Foundation (EMAF) discussion and discourse on CE. The business or policy foundation EMAF has been able to attract interest in business communities, policy communities, and also in

Table 1
Publications on CE by journal title.

Source	Count	Percent
Journal of Cleaner Production	13	33%
Resource Conservation & Recycling	5	13%
Journal of Industrial Ecology	3	8%
Environmental Science & Technology	2	5%
Sustainability Science	2	5%
Journal of Material Recycling & Waste Management	2	5%
Other journals (1 paper each)	13	33%
Total	**40**	**100%**

Table 2
Publications on CE by year of publication.

Year	Count	Percent
2007	4	10%
2008	2	5%
2009	3	8%
2010	5	13%
2011	3	8%
2012	3	8%
2013	1	3%
2014	6	15%
2015	8	20%
2016	5	13%
Total	**40**	**100%**

academia and in society at large in CE (Korhonen et al., 2018). In part two of the literature review, using "Circular Economy" as a keyword in titles, abstracts and keywords of journal articles between the years 2000 and 2017 (May, 30th), we obtained[1] 419 entries, of which 407 were in English. We chose Web of Science (WOS) and not the other popular alternatives such as Google Scholar and Scopus because WOS: 1) provided suitable search methods for us, 2) gave this paper the possibility to search and filter search using several bibliographic parameters and 3) provided suitable navigation possibilities and institutional access to the full texts of the searched papers. Despite the limitations of using a single database, the WOS provided sufficient coverage for our purpose.

Further filtering of papers with five or more citations resulted in 108 articles. These were manually checked, first their abstract searching for papers that were relevant for discussing the actual concept of circular economy; we reached 40 shortlisted papers that were read to identify if they provided definitions, descriptions or conceptual debates on the concept of CE. The summary of the identified papers is given in Table 1 and Table 2.

As Table 1 below shows, the papers on CE have been published in journals in the category of green, sustainable and environmental sciences. As can be seen, the *Journal of Cleaner Production* takes the largest count of the relevant articles on CE (33%). On the other hand, several journals with only one relevant article together account for a third of the total reviewed articles.

Table 2 presents a classification of the reviewed articles by year of publication between 2007 and 2016. Not surprisingly, the largest count of articles occurs in the years 2014–2016 (together accounting for about 50% of publications); this coincides with the increasing popularity of CE in different business and policy making communities.

[1] The literature search regarded the period 2000–2017. The search was done on the 30th of May 2017. Later shortlisting with 5 or more citations might have filtered most of the 2017 publications for the obvious time factor to get citations.

2.2. Definitions based on the practical business approach

The current practitioner, policy and business development realm formulated CE concept is given in Fig. 1. This figure is a comprehensive representation of the economic and business logic embedded in the CE concept. The inner circles, product reuse, remanufacturing and refurbishment, demand less resources and energy and are more economic as well than conventional recycling of materials as low-grade raw materials. The time the value in the resources spends/lives within the inner circles should be maximized. Materials should first be recovered for reuse, refurbishment and repair, then for remanufacturing and only later for raw material utilization, which has been the main focus in traditional recycling. According to CE, combustion for energy should be the second to last option while landfill disposal is the last option. In this way, the product value chain and life cycle retain the highest possible value and quality as long as possible and is also as energy efficient as it can be. Once a raw material is extracted, refined and produced with the usual costs, it makes economic and business sense to use the value produced as long as possible, i.e., keep the product function/service and use-value in economic circulation as long as possible.

Although the papers reviewed are on CE, out of the 40 shortlisted papers only 8 have been found to contain a definition of circular economy. 19 more papers provided some sort of description of what was meant by CE. The remaining 13 papers had neither a definition nor description of what CE was supposed to mean in their studies, even though the term has been used at different levels of detail including measurement of practical implementation of CE.

In general, the definitions found in the papers could be sourced to two lines of thoughts: firstly the ones that provide reference to and adopted the definition provided by Ellen MacArthur Foundation (i.e. EMAF, 2012) which is a business development agency, and the ones that defined CE based on relevant research background or adopted a definition from other researchers. As Table 3 below shows even the definitions based on Ellen MacArthur Foundation provide diverse foundations despite their main source being the same.

In order to capture the most recent discussions on CE, we decided to also include a recently published special issue in the *Journal of Industrial Ecology* (vol. 21, issue 3, June 2017). The special issue contained 24 articles (and an editorial) under five categories (column; forum; methods, tools and software; research and analysis; applications and implementation). All the 24 articles have been checked for provision of definition on CE, the unit of analysis applied in the papers, and conceptual abstraction of CE. Only nine

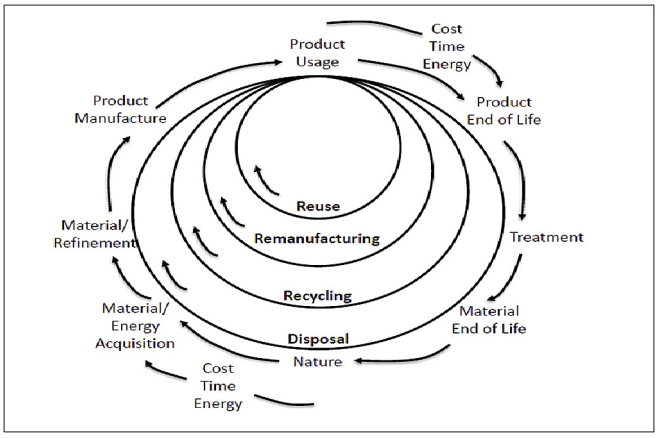

Fig. 1. The current concept of circular economy (for the graph, see Mihelcic et al., 2003). The CE message is that the inner circles demand less resources and energy and are more economic as well. The time the value in the resources spends within the inner circles should be maximized.

Table 3
Definitions of CE in the literature.

Definition	References
A. Based on EMAF definition	
The CE has been defined as an industrial system that is restorative or regenerative by intention and design. It replaces the end-of-life concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse and return to the biosphere, and aims for the elimination of waste through the superior design of materials, products, systems and business models.	Hobson, 2016
CE is an economic strategy that suggests innovative ways to transform the current predominantly linear system of consumption into a circular one, while achieving economic sustainability with much needed material savings.	Singh and Ordonez, 2016
A circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times. The concept [. . .] is a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows.	Moreau et al., 2017
The concept of circular economy conceives of a production and consumption system with minimal losses of materials and energy through extensive reuse, recycling, and recovery.	Haupt et al., 2017
The circular economy, defined as a restorative or regenerative industrial system by intention and design.	Niero et al., 2017
B. Based on own or other researchers' definition	
The circular economy is a simple, but convincing, strategy, which aims at reducing both input of virgin materials and output of wastes by closing economic and ecological loops of resource flows.	Haas et al., 2015
CE aims to achieve optimum production by minimizing natural resource utilization and pollution emission simultaneously, and minimum wastage by reusing the wastes from production and minimum pollution by recycling and restoring the technically useless wastes.	Wu et al., 2014
A circular economy is a mode of economic development that aims to protect the environment and prevent pollution, thereby facilitating sustainable economic development.	Ma et al., 2014
CE is specifically based on both resource efficiency and eco-efficiency, and its purpose is to acquire a set of key measures to move towards a more circular, green, and sustainable economy.	Ma et al., 2015
'The term "circular economy" as mentioned in these measures is a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption'.	Naustdalslid, 2017
Circular economy is a general term covering all activities that reduce, reuse, and recycle materials in production, distribution, and consumption processes.	Blomsma and Brennan, 2017

of these papers provided a clear definition of what they meant by circular economy. Of these, six referred to the EMAF conceptualization and or definition of CE. Considering the excellent discussions in the papers included in the special issue from conceptual analysis (e.g. Moreau et al., 2017) to measurement issues on CE at different levels (e.g. Haupt et al., 2017; Linder et al., 2017), we would have liked to obtain more debates on what CE would and should have constituted in light of its contribution to sustainable development. However, most of the papers (18 of them) were focused on directly observable, practical and technical themes and policy implementation issues of CE only.

3. Towards a new definition of the concept of CE

While some of the approaches and models behind the CE discourse have made important contributions to sustainability science in the past, the theoretical connection is not that clear. The research using solid theoretical foundations is rather scanty. In a recently published paper (Korhonen et al., 2018) showed that there are severe limitations and challenges in the practical application of the concept, in the application of material cycles, renewable and cascading type energy flows in production-consumption systems. These include the limits posed by thermodynamics, spatial and temporal system boundaries as well as the governance and management challenges concerning inter-sectoral and inter-organizational material and energy flows. Therefore, an improved definition is required. The definition that we give here is only a "build-up" for what comes after, i.e. it is not intended as a universal and absolute definition. Rather, it is the best working definition we can come up with. What comes after is the Gallie (1956) discussion in the following section, which is the key message of our paper. It needs a build-up. In other words, here we develop the concept based on current knowledge and then, in the subsequent sections, we use it for its deconstruction and reconstruction toward more sensible pathways to make progress in sustainable development in general through CE work.

From the perspective of sustainable development and its three dimensions, economic, environmental and social, the fundamental features of how the concept is defined ought to include on the one hand, a point of departure in production-consumption systems that maximize the service produced from the linear nature-society-nature material and energy throughput flow. This is done by using cyclical material flows, renewable energy sources and cascading-type energy flows in integrated production – consumptions systems, including their inter-sectoral, inter-organizational and global value chains and life cycles. On the other hand, the successful adoption of CE has a holistic contribution to all the three dimensions of sustainable development. Accordingly, this limits the throughput flow to a level that nature tolerates and utilizes ecosystem cycles in economic cycles by respecting their natural reproduction rates. More economic value is extracted from the existing physical flows and infrastructures of the economy.

Based on the above exploration and discussion we suggest a working definition of the concept of CE. CE is viewed from the production and consumption system perspective and it must be analyzed for its holistic contribution to a more sustainable societal development. The concept should be in line with the current academic, policy and industry consensus that economic systems should utilize nature's cycles for preserving materials, energy and nutrients for sustainable use. CE is defined as:

> CE is a sustainable development initiative with the objective of reducing the societal production-consumption systems' linear material and energy throughput flows by applying materials cycles, renewable and cascade-type energy flows to the linear system. CE promotes high value material cycles alongside more traditional recycling and develops systems approaches to the cooperation of producers, consumers and other societal actors in sustainable development work.

There are several advantages in defining CE from a production-consumption nexus and how its adoption contributes; first, CE can

Table 4
Circular economy as an essentially contested concept. Circular economy too is a cluster concept consisting of several subconcepts. In this table the seven criteria of Gallie are reflected on the concept of circular economy.

1) Potential value in the concept:
- All societal sectors are interested in CE
2) Internal complexity:
- Many arguments for and against of CE
3) Various describability:
- CE has many inter-sectoral and inter-organizational interests and preferences
4) Openness:
- Knowledge on sustainability impacts is continuously evolving
5) Aggressive and defensive use:
- Relatively little critical research available on CE
6) Original exemplar:
- Boulding, 1966; Georgescu-Roegen, 1971; Frosch and Gallopoulos, 1989
7) Progressive competition:
- Various actors, organizations and sectors keep coming up with their respective definitions and applications of CE

only maximize the service produced by the linear flow. Thermodynamics dictates that the overall nature-society-nature flow will always remain linear. Second, the definition takes into account the system boundary challenge by emphasizing production-consumption systems and their integrated flows, e.g. those that cross man-made boundaries and borders. Sustainable consumption is promoted alongside sustainable production e.g. through a move towards a "sharing economy" (see e.g. Welford, 1998; Tukker, 2015). Third, the above definition of CE also acknowledges the governance and management limitations of the physical flows by highlighting the importance of inter-sectoral and inter-organizational management and governance models.

In the idealized vision of a CE, the CE-type arrangements of the physical flows of materials and energy would reduce virgin inputs to the system and waste and emissions outputs from the system (e.g., Korhonen et al. 2004, 2018; Korhonen, 2004). Resource and energy costs would be reduced and also waste and emissions costs, e.g. those arising due to environmental legislation, taxes or waste and landfill management costs, would decrease. New business, market and employment opportunities are created, because the value embedded in materials is used many times (kept in the economic circulation as long as possible) instead of only once as is usually the case in the modern global economic system. An obvious possibility in this vision for business is also the improved image that helps green marketing of products and services.

CE has a multitude of different definitions. Furthermore, different stakeholders are interested in it including policy-makers, businesses, researchers, consumers etc. A single universal definition borders the impossible and should not be attempted, because it will always exclude some interests and because it is dynamic and evolving. However, this should not be used as an excuse to not develop the concept, its methodologies and practices, its policies and strategies. The concepts of Sustainable Development (Connelly, 2007), Entrepreneurship (Choi and Majumdar, 2014) or Democracy (Connolly, 1993) have all faced the notion of being essentially contested concepts.

4. CE as an essentially contested concept: considering Gallie's classic work

According to the policy and business communities the goal of CE is on promoting the inception of a manufacturing paradigm to mitigate the impact of environmental problems and in the extension the realisation of a sustainable society, i.e. it covers the impact of climate change, resource scarcity, depletion of biodiversity etc. and the economic problems of unsustainable development, e.g. rising resource prices etc. It contributes to sustainable development initiatives (WCED, 1987), the framework that was originally defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. There exists a common consensus on this broad qualitative definition of sustainable development. The answer to the question of unsustainable global linear flow economy would seem to come from the physical flow concept in which the flows are reverse; the concept of circular economy (EMAF, 2015; Frosch and Gallopoulos, 1989). There exists economic, ecological and social potential in this new flow model (EMAF, 2015; EMAF, 2013; EMAF, 2012).

Gallie (1956, p.167) defined a concept as essentially contested if it "is liable to be contested for reasons better or worse; but whatever the strength of the reasons they usually carry with them an assumption of agreement, as to the kind of use that is appropriate to the concept in question, between its user and anyone who contests his particular use of it." The lack of clarity surrounding a concept has been argued to be of importance (Gallie, 1956; see also, e.g. Choi and Majumdar, 2014). ECCs are ideas that involve internal complexities, necessitate the involvement of many different schools of thought, actors and interest groups. They can be understood as "cluster concepts" constituting groups of sub-concepts. In this way, Gallie maintains that ECCs can still be used in a systematic manner in making progress in the field/area of concern.

This section analyses CE against the seven criteria of an essentially contested concept (Table 4.). CE too is constructed from several sub-concepts. There are at least four sub-concepts that constitute CE. First, industrial ecology is clearly a part of CE with its basic notion to learn from the cyclical, renewable and cascade-type material and energy flows of nature. Second, industrial symbiosis focuses on this theme in local and regional inter-organizational and inter-sectoral networks of businesses and other societal actors. Third, the cradle-to-cradle design concentrates on the entire value chain and life cycle of a product or service and emphasizes the adaptation of societal flows to those of nature so that society will produce useful sources for nature and *vice versa*. Fourth, the sharing economy is an important part of CE, because it brings consumption systems together with production systems, promotes the shared use of services instead of only individuals who own and consume physical products. It also brings issues relevant for the social dimension of sustainability in the forefront of CE debates. So, it is evident, that like ECCs, CE too is constructed from several sub-concepts. Many more besides these four could be listed.

Gallie (1956) identifies seven specific properties that can be assigned to an ECC. The first attribute is that there needs to be a value accredited to the concept. It is obvious in the discussions on CE that the concept has great potential. The other six are internal complexity, various describability, openness, aggressive and defensive uses, original exemplar and progressive competition. In case of internal complexity, CE is subject to contestability, which is

part of the second criterion in Gallie. The contestability and internal complexity are evident in the earlier parts of our paper. In terms of various describability, the CE concept carries with itself a diversity of descriptions and different types of arguments for what features should be given the highest priority or weight in its applications. CE flows create inter-sectoral and inter-organizational networks and constitute of diverse interests and preferences.

For openness, Gallie notes that an ECC must be open to revision, change and modification when circumstances change. This is relevant for CE as well. For example, our knowledge on our impacts on the natural environment is incomplete and continuously changing. Consider DDTs, which led to Nobel prize upon invention or CFCs that nearly did and paradoxically the only Nobel prize ever related to CFCs was given for work which showed the destructive effects of CFCs on the stratospheric ozone layer some 70 years after invention (Korhonen and Seager, 2008; see also Robért et al., 2013, 2002). In the property of "aggressive and defensive use" it can be noted that CE is a unique concept in terms of how rapidly it has received so much attention. In particular, the Ellen MacArthur Foundation has promoted it intensively although perhaps not aggressively. In any case, when taking into account how little of actual scientific research there exists on the concept, how fragmented and unorganized this research is and the fact that still some 75% of the global energy production rely on linear, throughput-type, non-renewable and emission intensive fossil fuels, it is safe to conclude that the policy community and the business community should at least be aware of this criterion of an ECC in case of CE.

The sixth property or a criterion of an ECC that we use is termed "original exemplar". Here Gallie means that all the users of the concept tend to refer to (historical) an authority, i.e., a single pioneer. The broader authority may be a set of different and independent research traditions that all seem to be in consensus on the importance of the content of the basic message although not necessarily using the same exact concept. In CE, the single authority is Kenneth Boulding's work on the "spaceship earth" (1966), or Georgescu-Roegen's work on thermodynamics in economic systems (1971) or the already now often cited *Scientific American* article "Strategies for Manufacturing" by Frosch and Gallopoulos (1989). The broader reference or authority constitutes from the many traditions discussed earlier in the paper covering, e.g. ecological economics, industrial ecology, cradle-cradle design, restorative economy or performance economy, biomimicry, eco-efficiency, resilience science, natural capitalism, cleaner production etc. All these agree on the importance of material cycles and regenerative use of resources although using different concepts and methodologies. CE meets this criterion of an ECC.

The seventh criterion drawn from Gallie's seven criteria of an ECC is what he calls progressive competition. This means that the original exemplar's work is sustained as different actors that apply the concept compete in their respective achievements. It is clear from our analysis in this paper that this is exactly the case with the current debate on CE. In sum, CE qualifies as an essentially contested concept. This helps in its understanding and provides a possibility to use CE in a constructive manner. The existence of various and conflicting views on CE should, therefore, not be used as an excuse for inaction. The work on CE can improve and make progress in sustainable development.

5. A tentative research framework

5.1. Categories for CE research

The variety of definitions as well as the policy and business discourse underlying the CE approach pose challenges to scholars and practitioners interested in capturing the knowledge base conceptually and empirically. Assuming that measures towards a CE will be ubiquitous in the near future, questions such as: "What is the unit of and level of analysis?", "Where are the system boundaries?", "What is the object of study?" etc. will confront researchers and others working in the field. In this section, therefore, we propose an initial methodological model to conduct scientific enquiry on CE, which is, as above, a cluster concept.

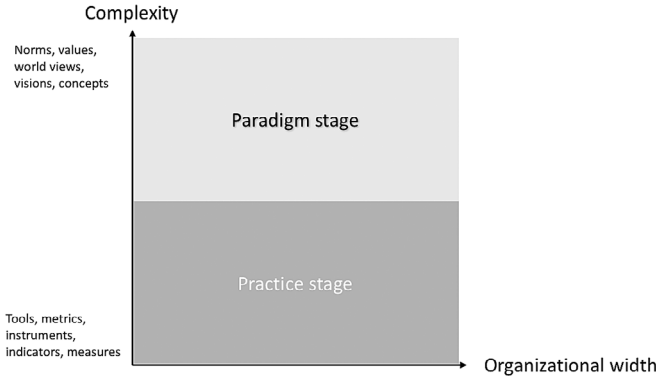

Fig. 2. The context of the unit of analysis, which can be used as a map to navigate inside a complex cluster concept such as circular economy. Together Fig. 2 and 3 constitute the early and tentative research framework for studying CE proposed in this paper.

As a consequence of identifying CE as a cluster concept it is vital that future research is careful with the framing of its studies. We have, in particular, identified the unit of analysis as a critical aspect of capturing CE research, since CE can have a very wide span both in terms of research topics and the scope of the study (c.f. Gronn, 2002). The physical flows of materials and energy exceed process, organizational, sectoral and administrative boundaries and borders and successful CE can only be achieved with an appreciation and understanding of the complexities involved including a diverse set of interests and preferences affecting and affected by the physical fluxes. Diversity of actors, interests and preferences makes the governance, management and decision-making efforts very difficult.

Hence, we consider the different options for the actual unit of analysis and the different methodological approaches suitable to study them from the perspective of sustainable development. Consequently, what are the complexities, tradeoffs and problem displacement risks involved with the diverging units of analysis and respective methods of investigation?

We propose a model for categorization that supports CE researchers in differentiating between different research streams and foci (see Fig. 2). Through better framing of the research it will also be easier to evaluate the quality of the research (Eisenhardt, 1989).

This section identifies two key dimensions in the categorization of the unit of analysis for CE. Firstly, the level of the research, which in practice comes down to the organizational width involved in defining the unit of analysis. E.g. a supply chain consists of a large number of organizations, so any study claiming to study a supply chain should cover a large number of linked organizations. This naturally increases complexity. Similarly, research on networks (Korhonen et al., 2004) involve many organizations, but the boundaries of the studied networks can be difficult to define. Much research on CE is related to policy decisions, which is another level of analysis. Many CE advocates claim that CE is a paradigm shift (e.g. EMAF, 2013). But for a thorough paradigm shift to occur the new paradigm needs to be embedded in everyday life (Kuhn, 1962; Ehrenfeld, 2000). This means that CE research needs to encompass virtually all levels from global down to the individual. Rigorous

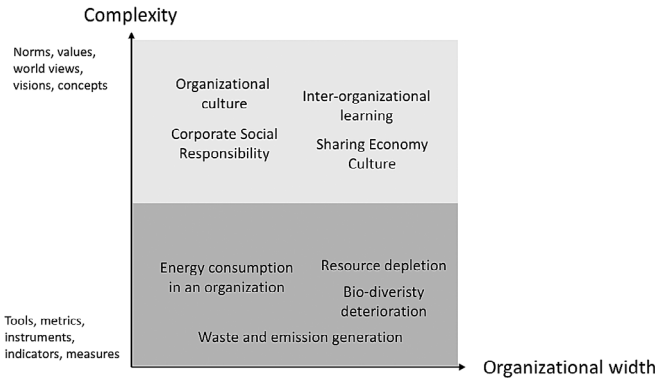

Fig. 3. The context of the unit of analysis, with examples. The message is that Fig. 2 and 3 show that the proposed research framework can help researchers and others to classify, structure and organize the actual study issues, topics, themes and research questions relevant for CE in light of sustainability. On level 1, themes such as organizational culture, learning, responsibility or the overall world-views and visions contributing to the culture of the sharing economy are important. While on the second level, practical and concrete physical flows of materials and energy are important, e.g. fuel, energy and resource inputs and wastes and emission outputs, the physical flows between nature and societal production-consumption systems.

research requires that the conclusions from a study match the level that has been studied, e.g. one should be careful to draw conclusions related to operational aspects from studies of industry clusters. We do not perceive CE as a new paradigm, but we hope it will evolve to become such in the future. Our paper is an attempt to make a contribution to this process by emphasing the scientific and research aspects of the new concept that need to be further explored in the future.

The second aspect relates to the complexity of the questions concerning the *unit of analysis*. Whether it is directly observable, e.g. resource consumption, fuel usage, wastes and emissions generation, loss of jobs etc. or not directly discernible, e.g. a social construct such as a strategy, the underlying world-view of the organization, organizational culture, sense of community in a network of organizations, sense of organizational identity, strategic mindset, awareness of responsibility etc. There are different challenges for the two types. While the former is primarily concerned with reliability, the latter in addition needs to take a particular care with validity in the constructs and their link to the research question (Eisenhardt, 1989).

It has been suggested that CE could be a new paradigm of sustainable development in general (see e.g. Geissdoerfer et al., 2017 etc.). However, we argue that much more work needs to be done before CE can become a new paradigm in the sustainable development of the global society. For Figs. 2 and 3, it is helpful to think the two stages in a societal paradigm change (Ehrenfeld, 2000). Ehrenfeld applied Thomas Kuhn's (1962) definition of a scientific paradigm shift to study dominant societal paradigms in the case of sustainable development and the transition it requires in the global society.

As Ehrenfeld (2000) argues a societal paradigm "… is or contains a set of structures on top of which social action is created." And CE maybe argued to have the potential to become a paradigm in which industrial production and consumption will change in a fundamental manner. A paradigm is our underlying world-view, it is the vocabulary with which we understand and interpret the world and our place in it. It is the basic philosophy of culture and societal development in the global society. A paradigm shift has two interdependent stages. Both of them need to undergo a transition for a paradigm shift to occur. First one is paradigmatic, metaphoric and normative, while the second stage is descriptive, positive and analytic. On the first stage, the paradigm stage, visions, concepts and norms are central while on the second stage, the normal practice stage, metrics, tools, instruments and practical measures are central. Accordingly, the second stage undergoes constant changes, but change is incremental, while the first stage changes only on rare occasions and the change is a radical transition.

Now, the physical flows of materials and energy and tools and models to analyse them such as, life cycle assessment, substance flow analysis, materials flow accounting, material intensity per unit of service, eco-efficiency, ecological and carbon footprints etc. belong to the second stage, the normal practice stage. Vast majority of work published in CE or in its background fields and background concepts address these issues. There are only very few studies available that focus on issues typical to the paradigm stage, the first stage in the shift.

This relates to the fact that the engineering and natural science orientated studies constitute the biggest body of knowledge behind CE and have been developed in isolation from strategic, management and organizational studies or studies typical for social sciences (Broman and Robért, 2017; Ehrenfeld, 2000; Korhonen et al., 2004). A paradigm change toward a sustainable circular economy will not happen if these two communities are not integrated in a more balanced manner and if CE will operate only on the normal practice stage of a societal paradigm shift, the second stage.

Therefore, the prospect here is that scholars interested in conducting scientific research on CE and on its contribution to sustainable development utilize the categorization and classification given earlier in Figs. 2 and 3 when defining the focus of their study, the unit of analysis and methods used to study this unit of analysis. It is also important to acknowledge and communicate transparently what parts of the paradigm change are addressed and what are excluded from the study and why/not. This will help in avoiding scale misperceptions in the interpretation of the applicability of the study results. A good example of a scale misperception is the interpretation of the increase in eco-efficiency of production systems as an indicator of overall sustainability, while issues such as consumption systems's (induced) rebound effects are ignored (Korhonen and Seager, 2008). Furthermore, eco-efficiency as a microeconomic-level success can be falsely understood as a contribution to the overall macroeconomic-level sustainability (Huppes and Ishikawa, 2009).

Examples of themes, topics and units of analysis that can be addressed on the first stage are, e.g. organizational culture, strategic thinking and strategy formulation in an organization, corporate or organizational social responsibility, collaboration culture in a network of processes, companies and sectors, intra-organizational vs. inter-organizational learning, capabilities for radical innovations, organizational inertia or path dependency, organizational transitions, resilience of different organizational types, sense of community in a network of organizations etc. (see Fig. 3). Methods that are needed for such themes should be chosen accordingly. Obviously, more qualitative research methodologies and social science-type constructs can be used when addressing the paradigm stage.

Examples of the themes, topics and units of analysis on the second stage of the circular economy paradigm change include, e.g. resource, raw material, energy, water usage of an organization, wastes and emissions generation of an organization, utilization of waste-derived resources and renewables in a network of organizations or in value chains etc (see Fig. 3). Methods cover materials and energy flow tools, footprints, instruments, metrics and indicators as well as management systems required for such assessments, environmental or sustainability management systems for an individual organization, inter-organizational, value chain, life cycle or supply chain assessments, for regional or national economies etc.

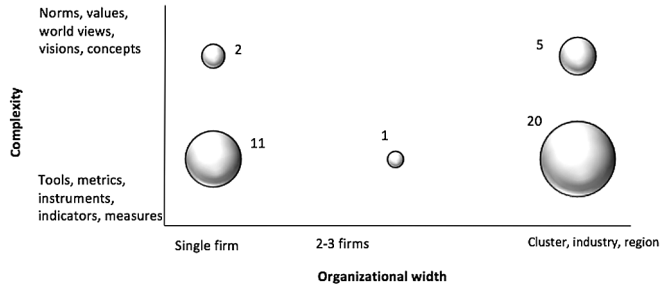

Fig. 4. Complexity and organizational width in the CE papers reviewed.

5.2. Categorization of CE literature according to the unit of analysis

If we look at the 40 shortlisted papers presented and reviewed in terms of the analytical methodology introduced here, most of the papers happen to mainly address practical or low levels of abstraction as in Figs. 3 and 2. In other words, the papers seem to belong to the normal practice stage of a paradigm shift. Large proportion of the papers addressed the physical flows of materials and energy, e.g. in industries, clusters or regional economies as their unit of analysis. This is not surprising as CE is a systems level and inter-organizational approach.

Importantly, the literature reviewed supports the argument that current CE work mainly addresses issues typical for the second stage in the paradigm change discussed above. Therefore, the basic assumptions concerning the values, societal structures, cultures, underlying world-views and the paradigmatic potential of CE remain largely unexplored. The methodology proposed in this section can help in limiting this unbalance as it raises the awareness of this challenge and provides a tool to structure one's research. It also helps in the motivation behind the research work, because the ambition level of the research can be better understood Fig. 4.

6. Discussion and conclusions

This paper has discussed the Circular Economy concept which is now prevalent in the policy and business development debate on sustainable development of industrial production. CE is viewed by policy development agencies and business associations as an important mechanism to promote sustainable production and is viewed as a possible or potential future paradigmatic shift which will consequently result in industrial transformations. The expectation is that the adoption of CE will fundamentally transform economic activities away from reliance on non-renewable and emissions intensive carbon flows towards more sustainable production and consumption.

As the Swedish economist Erik Dahmén (1950) in discussing the mechanisms of industrial transformation wrote more than half a century ago, the transition like this would certainly create transformative pressures in the prevailing systems of production where there will be both opportunities and necessities. Thus, the anticipation is that once a CE approach is in full force, from a business perspective, there will be new business ventures and business models. This transformation will be holistic in nature where all the value chains of the industrial system will be impacted at various levels. In addition, innovations, entrepreneurship and technological development will be key areas that will play important roles.

Although the societal history of CE dates back to the beginning of industrialization and the 19th century (see e.g. Desrochers, 2004; Desrochers, 2002; Boulding, 1966), the academic research on it has just begun to emerge. As a result, it is still fragmented and mainly at the applied levels. Generally in the applied sciences, life-cycle approaches and models such as "closed loops" "remanufacturing", "product reuse", "waste management" have been developed and discussed in the literature without in-depth and critical discussions on the theoretical foundations, system boundary limitations and frameworks for methodological inquiries. A paradigm change needs such considerations.

With this point of departure, in this paper, we have attempted to discuss the two interrelated issues; the actual concept of CE and research methodologies for its investigation. This paper adopted a critical approach to the policy and practice orientated concept of CE. Our argument is that it is not a theory but an emerging approach to industrial production and consumption. As an approach CE has already demonstrated that it has unique power and value in attracting a diversity of sectors and a variety of organizational types to get involved in the work. The logic of turning from linear and wasteful to cyclical, restorative, reproductive and smart physical flow structures is appealing and positively provocative crossing sectoral, organizational, administrative and national boundaries and borders in its message. Sometimes, however, scientific research seems to move more slowly than the practitioner community and its enthusiasm. Scientific research is very important for securing that the actual impacts of CE work toward a more sustainable global society in the short and in the long term. The business and policy communities might find this requirement from the scholars frustrating, but we maintain that the collaboration in this manner and with all of these interest groups jointly involved will yield the best outcome.

Our philosophy of work here has been to initiate a more scientific, research orientated or scholarly discussion on the newly popularized concept of the circular economy. For research objective one, based on a literature review and conceptual exploration, we developed a new scientific working definition of the concept of CE. This was done in terms of the original WCED (1987) notion of sustainable development. Importantly, we finally arrived at a definition of circular economy as an essentially contested concept according to the classic work of Gallie in philosophy of science. For research objective two, the paper provided an early methodological model for investigating the CE concept. The model provides different categories for structuring scientific research on CE. Both of these two broad areas require much further work. We hope that this paper and its way of categorizing research on CE will stimulate further research and scientific investigation.

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References

Ayres, R.U., 1999. The second law, the fourth law, recycling and limits to growth. Ecol. Econ. 29 (3), 473–483.
Benyus, J.M., 2002. Biomimicry: Innovation Inspired by Nature, Perennial.
Blomsma, F., Brennan, G., 2017. The emergence of circular economy: a new framing around prolonging resource productivity. J. Ind. Ecol. 21 (3), 603–614.
Boulding, K.E., 1966. The economics of the coming spaceship earth. In: Jarrett, H. (Ed.), Environmental Quality Issues in a Growing Economy. Johns Hopkins University Press, Baltimore, MD.
Braungart, M., Mcdonough, W., Bollinger, A., 2007. Cradle-to-cradle design: creating healthy emissions e a strategy for eco-effective product and system design. J. Clean. Prod. 15 (13–14), 1337–1348.

Broman, G., Robért, K.H., 2017. A framework for strategic sustainable development. J. Clean. Prod. 140 (1), 17–31.
Chertow, M., Ehrenfeld, J., 2012. Organizing self-organizing systems. J. Ind. Ecol. 16 ((1), 13–27.
Choi, N., Majumdar, S., 2014. Social entrepreneurship as an essentially contested concept: opening a new avenue for systematic future research. J. Bus. Ventur. 29 (3), 363–376.
CIRAIG (International Reference Centre for the Life Cycle of Products Processes and Services), 2015. Circular Economy: a Critical Literature Review of Concepts. Canada, Montreal.
COM (European Commission), 2015. Closing the Loop - an EU Action Plan for the Circular Economy, Brussels.
COM (European Commission), 2014. Towards a Circular Economy: a Zero Waste Programme for Europe, Brussels.
Connelly, S., 2007. Mapping sustainable development as a contested concept. Local Environ. 12 (3), 259–278.
Connolly, W.E., 1993. The Terms of Political Discourse.
Crépin, A.-S., et al., 2012. Regime shifts and management. Ecol. Econ. 84, 15–22.
Dahmén, E., 1950. Svensk Industriell företagarverksamhet: kausalanalys Av Den Industriella utvecklingen 1919-1939 (Entrepreneurial Activity in Swedish Industry in the Period 1919-1939). Industriens Utredningsinstitut, Stockholm.
Daly, H.E., 1996. Beyond Growth: the Economics of Sustainable Development. Beacon Press, Boston.
Desrochers, P., 2004. Industrial symbiosis: the case for market coordination. J. Clean. Prod. 12 (8), 1099–1110.
Desrochers, P., 2002. Regional development and inter-industry recycling linkages: some historical perspectives. Enterpren. Reg. Dev. 14 (1), 49–65.
Ehrenfeld, J.R., 2000. Industrial ecology: paradigm shift or normal science? Am. Behav. Sci. 44 (2), 229–244.
Eisenhardt, K.M., 1989. Building theories from case study research. Acad. Manag. Rev. 14 (4), 532–550.
EMAF (Ellen MacArthur Foundation), 2015. Growth within: a Circular Economy Vision for a Competitive Europe, London. EMAF (Ellen MacArthur Foundation), 2013. Towards the Circular Economy, London.
EMAF (Ellen MacArthur Foundation), 2012. Towards the Circular Economy, London.
FICF (Finland's Independence Celebration Fund) and Mckinsey, 2014. Kiertotalouden mahdollisuudet Suomelle (The Possibilities of Circular Economy for Finland), Helsinki.
Folke, C., 2006. Resilience: the emergence of a perspective for social–ecological systems analyses. Global Environ. Change 16 (3), 253–267.
Frosch, D., Gallopoulos, N., 1989. Strategies for manufacturing. Sci. Am. 261 (3), 94–102.
Gallie, W.B., 1956. Essentially contested concepts. Proc. Aristot. Soc. 55, 167–198.
Geissdoerfer, M., et al., 2017. The circular economy - a new sustainability paradigm? J. Clean. Prod. 143, 757–768.
Georgescu-Roegen, N., 1971. The Entropy Law and the Economic Process. Harvard University Press, Cambridge, MA.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.
Gronn, P., 2002. Distributed leadership as unit of analysis. Leader. Q. 13 (4), 423–451. https://doi.org/10.1016/S1048-9843(02)00120-0.
Graedel, T.E., 1996. On the concept of industrial ecology. Annu. Rev. Energy Environ. 21, 69–98.
Haas, W., et al., 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.
Haupt, M., Vadenbo, C., Hellweg, S., 2017. Do we have the right performance indicators for the circular economy?: insight into the Swiss waste management system. J. Ind. Ecol. 21 (3), 615–627.
Hawken, P., Lovins, A., Lovins, H.L., 2008. Natural Capitalism: Creating the Next Industrial Revolution, BackBay.
Hobson, K., 2016. Closing the loop or squaring the circle? Locating generative spaces for the circular economy. Prog. Human Geogr. 40 (1), 88–104.
Huppes, G., Ishikawa, M., 2009. Eco-efficiency guiding micro-level actions towards sustainability: ten basic steps for analysis. Ecol. Econ. 68, 1687–1700.
Jelinski, L.W., et al., 1992. Industrial ecology: concepts and approaches. In: Proceedings of the National Academy of Sciences, vol. 89, pp. 793–797.
Korhonen, J., 2004. Industrial ecology in the strategic sustainable development model: strategic applications of industrial ecology. J. Clean. Prod. 12, 809–823.
Korhonen, J., et al., 2004. Management and policy aspects of industrial ecology: an emerging research agenda. Bus. Strat. Environ. 13 (5), 289–305.
Korhonen, J., Honkasalo, A., Seppälä, J., 2018. Circular economy: the concept and its limitations. Ecol. Econ. 143, 37–46.
Korhonen, J., Seager, T.P., 2008. Beyond ecoefficiency: a resilience perspective. Bus. Strat. Environ. 17 (7), 411–419.
Kuhn, T., 1962. The Structure of Scientific Revolutions. Chicago University Press, Chicago.
Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51.
Lifset, R., Graedel, T.E., 2001. Industrial ecology: goals and definitions. In: Ayres, R.U., Ayres, L. (Eds.), Handbook for Industrial Ecology. Edward Elgar, Brookfield.
Linder, M., Sarasini, S., van Loon, P., 2017. A metric for quantifying product-level circularity. J. Ind. Ecol. 21 (3), 545–558.
Ma, S., et al., 2015. A case study of a phosphorus chemical firm's application of resource efficiency and eco-efficiency in industrial metabolism under circular economy. J. Clean. Prod. 87, 839–849.
Ma, S., et al., 2014. Mode of circular economy in China's iron and steel industry: a case study in Wu'an city. J. Clean. Prod. 64, 505–512.
McDonough, W., Braungart, M., 2002. Cradle to Cradle: Remaking the Way We Make Things. North Point Press.
McDonough, W., Braungart, M., 2003. Toward a sustaining architecture for the 21st century: the promise of Cradle-to-Cradle design. Ind. Environ. 26 (2–3), 13–16.
Mihelcic, J.R., et al., 2003. Sustainability science and engineering: the emergence of a new metadiscipline. Environ. Sci. Technol. 37, 5314–5324.
Moreau, V., et al., 2017. Coming full circle: why social and institutional dimensions matter for the circular economy. J. Ind. Ecol. 21 (3), 497–506.
Naustdalslid, J., 2017. Circular economy in China – the environmental dimension of the harmonious society. Int. J. Sustain. Dev. World Ecol. 21 (4), 303–313.
Niero, M., et al., 2017. Combining eco-efficiency and eco-effectiveness for continuous loop beverage packaging systems: lessons from the Carlsberg circular community. J. Ind. Ecol. 21 (3), 742–753.
Okoye, A., 2009. Theorising corporate social responsibility as an essentially contested concept: is a definition necessary? J. Bus. Ethics 89 (4), 613–627.
Pauli, G., 2010. Blue Economy: 10 Years, 100 Innovations, 100 Million Jobs. Paradigm Publications.
Rashid, A., et al., 2013. Resource conservative manufacturing. J. Clean. Prod. 57, 166–177.
Ring, I., 1997. Evolutionary strategies in environmental policy. Ecol. Econ. 23 (3), 237–250.
Robért, K.-H., Broman, G., Basile, G., 2013. Analyzing the concept of planetary boundaries from a strategic sustainability perspective: how does humanity avoid tipping the planet? Ecol. Soc. 18 (2), 5. https://doi.org/10.5751/ES-05336-180205.
Robèrt, K.-H., Schmidt-Bleek, B., Aloise de Larderel, J., Basile, G., Jansen, J.L., Kuehr, R., Price Thomas, P., Suzuki, M., Hawken, P., Wackernagel, M., 2002. Strategic sustainable development – selection, design and synergies of applied tools. J. Clean. Prod. 10, 197–214.
Rosenbaum, E.F., 2000. what is a market? on the methodology of a contested concept. Rev. Soc. Econ. 58 (4), 455–482.
Schröter, M., et al., 2014. Ecosystem services as a contested concept: a synthesis of critique and counter-arguments. Conserv. Lett. 7 (6), 514–523.
Shwom, R., 2009. Strengthening sociological perspectives on organizations and the environment. Organ. Environ. 22 (3), 271–292.
Singh, J., Ordonez, I., 2016. Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J. Clean. Prod. 134, 342–353.
Stahel, W.R., 2010. The Performance Economy. Palgrave Macmillan.
Stevenson, R., Evans, J.W., 2004. Editorial to: cutting across interests: cleaner production, the unified force of sustainable development. J. Clean. Prod. 12, 185–187.
Tukker, A., 2015. Product services for a resource-efficient and circular economy — a review. J. Clean. Prod. 97, 76–91.
WCED (World Commision on Environment and Development), 1987. Our Common Future.
Welford, R., 1998. Corporate environmental management, technology and sustainable development: postmodern perspectives and the need for a critical research agenda. Bus. Strat. Environ. 7 (1), 1–12.
Wu, H., et al., 2014. Effectiveness of the policy of circular economy in China: a DEA-based analysis for the period of 11th five-year-plan. Resour. Conserv. Recycl. 83, 163–175.