Circular Economy

Practices, knowledgebases and novelty

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Circular Economy: Practices, Knowledge Bases and Novelty

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Abstract: *The aim of this article is to provide a critical theoretical discussion of the knowledge basis for the concept of the circular economy (CE), drawing on examples from emerging practices and existing knowledge and discussions. The analysis includes examples from three fields of application: (1) the macro level, where the CE concept is used as a basis for the formulation of general policies, with examples from the EU; (2) the meso level, where the concept is applied to inform businesses and policymakers on how to design industrial systems in order to create closed-loop production and consumption systems, with examples from interactions between the agriculture and the energy sectors in Denmark, using a biogas case, and; (3) the micro level, where the CE concept is deployed to assist individual companies in the design of products and manufacturing processes. Based upon a detailed discussion of decades of research and the practical experiences with three other fields of environmental research, the novelty of the CE concept is critically evaluated against three main academic schools of thought, as outlined in the: (1) cleaner production literature, (2) industrial ecology literature and (3) cradle-to-cradle literature. The paper concludes that the CE concept revitalizes existing concepts rather than bringing essentially new tools, strategies and knowledge to the table. Finally, the paper elaborates on the knowledge gaps and future use of the CE concept, with special attention to stakeholder involvement, co-innovation and transdisciplinary research.*

Keywords: circular economy, closed-loop, cleaner production, industrial ecology, cradle-to-cradle

1. Introduction

As the global population continues to grow and is expected to reach 9 billion by 2050, humanity needs to balance the ever-increasing demand for food, fibre, energy and natural resources (Riding et al. 2015). This is regarded as a primary driver for the development of new business models, including in the design and organizational principles applied to industrial systems, in order to create sustainable production and consumption systems. Increasing resource consumption, as stated by the United Nations Environment Programme (UNEP 2011), the fear of supply disruption and increasing raw material prices (McKinsey 2011, EC 2014b) and growing awareness of the negative environmental impacts from the current production and consumption system (UNEP 2011) have led researchers, policymakers and companies to search for new ways of organizing industrial systems.

Over the last 30 years, a large number of concepts and strategies have been developed and implemented aimed at creating zero-emission and closed-loop production and consumption systems; for example, Cleaner Production (UNEP 1998), Industrial Ecology (Ayres and Ayres 2002) and Cradle-to-Cradle (McDonough and Braungart 2002). Such concepts emphasize various aspects of the development of resource-efficient and circular economies (Lieder and Rashid 2016) and are holistic and multi-disciplinary by nature (Sauvé et al. 2016).

The Circular Economy (CE) concept replicates many of the ideas in these concepts and strategies but also reformulates them, adds new insights and conveys the ideas into the decision-making arenas of businesses and political institutions. In China, the CE has been used as a development model for a wide range of policies since the adoption of the "Circular Economy Promotion Law of the Republic of China" in 2008 (Su et al 2013, Geng and Doberstein 2008). The EU used the concept as a basis for the formulation of a circular economy action plan and as an important source of inspiration for the revision of a collection of waste-oriented directives (EC 2014a) and has allocated funds through its Horizon 2020 research programme since 2014 to support research and innovation into the circular economy. Global multinational companies, like IKEA, Hennes & Mauritz (H&M), Cisco and Renault, have applied the CE concept as a basis for the formulation of integrated product design and waste management strategies. Further, many research articles (Stahel 2016, Suavé et al. 2016), review articles (Tukker 2015, Lieder and Rashid 2016, Ghisellini et al. 2016) and consultant reports (EMF 2013a[1], World Economic Forum 2014) have been published in order to define the concept.

The aim of the present article is to expand the existing knowledge base by providing a critical theoretical analysis of the novelty of the CE concept. Similarities and differences between the CE and existing concepts and strategies are clarified and the praxis discussed. The article discusses the novelty of the CE concept by comparing it to the existing body of knowledge in the field, thereby identifying elements that have been abandoned, maintained or added.

2. The Circular Economy Framework

The "circular economy" is a term used to characterize an industrial system in which production processes and products are designed to allow the flows of materials (biological as well as technical) to recycle without creating waste of any kind (Hollander et al. 2017). The idea has attracted increasing attention in recent years (Ghisellini et al. 2016), but in itself it is not new (Murray et al. 2017). Several schools of thought have been analyzing, developing and describing industrial systems with such features for many years, from Boulding's spaceship economy in the 1960s (e.g. Boulding 1966), to the discussions following the Club of Rome's report on limits to growth (Meadows et al. 1972), Robert Ayres' industrial metabolism (Ayres 1989) in the 1980s and to discussions on industrial ecology in the 1990s (Erkman 1997). Several reviews (Lieder and Rashid 2016, Ghisellini et al. 2016) have concluded that the use of the CE term for such industrial systems is a phenomenon that has primarily been used since around 2010.

The CE can be characterized as an "umbrella concept" (Blomsma and Brennan 2017) and is used variously as a broad term to describe macro policies, to describe industrial systems on a meso level and as a framework for environmental strategies within private companies on the micro level. Kirchherr et al. (2017) found more than 114 different definitions of the CE concept. Furthermore, based on their review, Kirchherr et al. (2017) defined 10 strategies to increase circularity, where extended product durability counted for five of those strategies. A central point here is that strategies oriented towards extending the lifespan of products and their parts are given high priority, featuring in 5 out of the 10 strategies. Due to the many different definitions, it is difficult to point to an authoritative definition of the concept. However, frequently cited reports published by the EMF (2013a, 2013b, 2014) and the CE report published by the European Commission (2004a) represent two attempts to present a definition. The European Commission report (EC 2014a) defines

1 Ellen MacArthur Foundation

CE systems in this way:

> *"Circular economy systems keep the added value in products for as long as possible and eliminate waste. They keep resources within the economy when a product has reached the end of its life, so that they can be productively used again and again and hence create further value."*

In Europe, the Ellen MacArthur Foundation has been a pioneer in popularizing the concept of the CE, in close collaboration with the consultancy firm McKinsey & Company. A series of joint reports (EMF 2013a, 2013b, 2014), in which they unfold the CE concept as they see it, has been used to popularize the thinking behind this concept. They characterize conventional industrial systems as linear, where resources and energy are consumed during production and consumption. Ultimately, the resources consumed are transformed into waste without considering potential recycling options cascading for new products and services. Conversely, CE systems are industrial systems intentionally designed to recover all materials, for the production of, for example, new products (the technosphere) and/or services, such as alternative and renewable nutrients for agroecosystems (the biosphere). The EMF (2013a) defines the CE 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 aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models."*

The EMF has very successfully conveyed its knowledge of closed-loop industrial systems into the political decision-making process, as well as into businesses. For example, through its creation of the CE100 network, a large group of multinational enterprises that now exchange knowledge and experience of CE activities and strategies.

As there is no authoritative definition of the CE concept, it is fruitful to explore how the concept is deployed in praxis to arrive at a definition. The following three sections look at three selected areas of application. The first is at the macro level of analysis, where the CE concept is used as a foundation for the design of macro policies. The second is at the meso level, where the CE concept is used for the creation of closed-loop production and consumption systems and at a regional level, and the third is at the micro level, where the CE concept is used at a company level as a basis for the formulation of corporate product design and recycling strategies.

2.1 The Macro Level

The CE concept has been used as a basis for the formulation of general policies in a number of countries, such as China (Su et al. 2013, Geng and Doberstein 2008) and in the EU (EU 2014a, McDowall et al. 2017). Other countries, such as Japan, Germany, the USA, Korea and Vietnam, have also implemented some elements of CE thinking into sectoral policies and strategies, mainly targeting the waste sector (Ghisellini et al. 2016).

Whereas most countries have used the CE concept as a framework for the formulation of waste-oriented sectoral policies aimed at the incremental reductions of waste volumes, China has used the CE framework as a broad, macro-level model for sustainable and economic development (McDowall et al. 2017, Su et al. 2013). The Chinese CE model, originally adopted in 2002, was based on a national top-down approach relying mainly on command-and-control regulation that, according to Ghisellini et al. (2016), differentiates the Chinese approach from the rest of the world's bottom-up approach that emphasizes stakeholder involvement, including from NGOs, industry, civil society and the research community.

In Europe, developing the CE and resource efficiency are a top priority in the European Union (McDowall et al. 2017). In July 2014, the European Commission published the report "Towards a circular economy: A zero waste programme for Europe" (EC 2014a) in order to establish a policy framework for a resource-efficient CE. The report addresses three main aspects: first of all, the aim to "design out waste", supported by work undertaken as part of the EU Research and Innovation Programme, Horizon 2020; partnerships; the eco-design directive (EC 2014a) and strategies for biomass cascading. Second, the aim to stimulate investment by means of green public procurement and by encouraging Member States to integrate CE priorities into the funding activities under the European Structural and Investment Funds. Third, by redefining waste policy and targets. By July 2014, the European Commission had adopted a legislative proposal for revised waste policies that aimed to increase the CE.

The so-called CE Package included proposals for 2025 and 2030 targets for a range of waste streams under the EU Waste Framework Directive 2008/98/EC, the Landfill Directive 1999/31/EC and the Packaging and Packaging Waste Directive 94/62/EC. The CE Package was pulled back in December 2014 from the co-decision procedure and relaunched in a revised version in December 2015, with a stronger focus on the full economic circle, before being finally adopted in 2018. The revised package includes an action plan for the CE (EC 2015) that addresses the full cycle, from product design to production processes, consumption, waste management and recycling. It is framed as a holistic macro-level strategy for economic growth and job creation, climate and energy, industrial innovation and sustainable development (EC 2015). It, to some extent, builds on ideas that can be traced back to the cleaner production concept (when, for example, it addresses environmental management and resource efficiency) and industrial ecology (for example, when addressing industrial symbiosis) but also with direct references to the work carried out by the EMF on the CE (mainly when addressing the general framework for the action plan).

However, despite clear references to cleaner production, industrial ecology and the circular economy, the foundation of the package remains a waste-focused strategy and the core political aims remain as recycling targets for selected waste streams. As such, it still appears mainly as a sectoral strategy for waste and resources covering the four central EU directives on waste, regardless of the intention of building a holistic action plan that covers the full economic cycle.

2.2 The Meso Level

The cycling of matter is fundamental in all ecosystems, but in the modern urbanized society, such cycles are often broken, and carbon and valuable nutrients are often not returned to the soil, from where the original biomass was exported. Closing the cycles again is especially important since society has to adapt to increasing limitations in fossil fuel supply and increasing issues with climate change. A shift towards a more optimized use of biomass for food, fibre and energy purposes in the coming decades is required. To illustrate the possibilities of implementing changes at the meso level in practical use, the following case study of a biogas plant is provided.

Solrød Biogas Case Study

The municipality of Solrød is located 20 km south of central Copenhagen, Denmark. The plant was constructed in summer 2015 and has a raw material capacity of 200,000 tonnes per year, producing 4.0–6.3 million m3 of biogas. This is supplied to a gas engine to produce electricity, which is supplied to the grid and consumed within the extensive district heating system in greater Copenhagen (Fredenslund et al. 2014). The by-product of the fermentation process is used as agricultural fertilizer, creating a closed-loop system in which all the nutrients contained in the raw material are returned to the soil (Fredenslund et al. 2014).

The feedstock is generated from three main sources: industrial waste from two large food ingredients producers; livestock manure, mainly from pig production; and seaweed. The municipality had for many years been suffering from malodour caused by seaweed washing up on the shores of its bay. The municipality was therefore searching for a solution, just like in many other coastal areas where decomposing seaweed was harming the recreational value of the otherwise attractive coastline. Now, 4,000 tons of seaweed is removed annually from the 3.7 km of coastline in Solrød municipality and used in the biogas plant.

The Solrød case demonstrates multiple benefits:

- reduction of GHG by substituting fossil fuel with renewable energy;
- production of renewable energy sources, which thus increases energy security;
- production of renewable fertilizers with improved use efficiency, and the possible redistribution of valuable nutrients from animal farms to other farm types without livestock production;
- reduction of unpleasant odours in the coastal area;
- contribution to solving marine pollution by removing nutrients from the aquatic environment in Køge Bay (which was suffering from

eutrophication problems caused by a surplus of nutrients in the aquatic environment, originating primarily from agriculture); improved use of industrial biomass waste, and;

- benefits to companies in the food industries and to VEKS (a district heating company) that can benefit from the increased use of renewable energy sources.

The biogas plant is illustrative as a case study on the CE as it brings together traditionally separate stakeholders from industry, agriculture and public authorities, and is closing a loop in the material flow of biological material, from agricultural soil → food industry → biogas → back to the agriculture as fertilizer for new generations of agricultural products. Modern agricultural systems are often disconnected and linear, in the sense that nutrients embedded in the products provided to urban societies are often flushed away through the sewerage systems and the solid fractions mixed (and often contaminated) with other waste fractions in the waste-handling systems. This prevents the pure biological material lines from flowing back to the agricultural soils and thereby creating a CE. The linear production and consumption system thus leaves agriculture with a deficit of nutrients.

This is especially crucial for those nutrients produced from essentially non-renewable resources, such as phosphorous (P), for which, the global commercially available stocks will become scarce in the next 50–100 years and are possibly depleted already (Cordell and Drangert 2009). Depletion is also likely to increase phosphate production costs by a factor 3 to 5 in this century (van Vuuren et al. 2010). These challenges may be beyond comparison because, unlike for fossil fuel energy, there is no biological or technological substitute for P (Childers and Corman 2011). Since only about one-quarter of the P applied to agricultural fields is actually recycled today (Childers and Corman 2011), innovative recycling and re-use concepts need to be urgently developed (Dawson and Hilton 2011).

The biogas system can be seen as a fully functional CE system that enables the flows of biological materials to return to the agricultural soils in a closed loop.

2.3 The Micro Level

At the micro level, the CE deals with strategies for the design of products and manufacturing processes for individual companies, organizations and their suppliers (Witjes and Lozano 2016). A number of larger companies, including IKEA, Hennes & Mauritz (H&M), Cisco and Renault, have applied the CE concept as a basis for the formulation of integrated product design and waste management strategies. In a study among S&P 500 companies, Bocken et al. (2017) found evidence for widespread circular economy practices linked to issues such as recycling. The EMF created a platform for large-scale companies involved with CE called "The Circular Economy 100". The platform brings together 100 companies with an aim to accelerate transition to a CE by the means of best-practice sharing, workshops, educational programmes and annual summits (EMF, undated).

Small and medium-sized companies, such as the Dutch cell phone producer Fairphone (Page 2015), Danish textile company Vigga and the Norwegian reseller of household equipment Norsk Ombruk, are further examples of companies that are basing their business models on CE thinking (Kiørboe et al. 2015). The key areas of attention for business models within the CE framework are the prevention of waste and/or the circulation of by-products and waste streams into production and consumption systems, thereby closing the material loops and contributing to the creation of circular economies (Kiørboe et al. 2015). Bocken et al. (2016) distinguish between three strategies for business models to support CE: (1) slowing the resource loop by increasing product durability; (2) closing the resource loop through recycling-oriented activities, and; (3) reducing the resources needed to produce a given product. The three strategies, leaning on ideas from industrial ecology and cleaner production, aim at closing the loops in production and consumption systems and are often applied to existing companies operating with traditional business models.

Another approach to the CE is being made by companies with business models based on the so-called product service system (PSS) (Tukker and Tischner 2006, Planning 2015). The PSS framework aims to reduce environmental harm through transforming product ownership relations that incentivize extended product durability, enhanced recycling, reuse and a range of other potential benefits to both consumers and producers (Mont 2002).

One company that has been using the CE strategy is the major global household equipment company IKEA. IKEA strategically addresses resource efficiency and energy independence in its product development and waste strategies (IKEA 2015). The IKEA group has defined 2020 targets for resource consumption, energy efficiency, renewable energy consumption and the sustainable raw material sourcing of wood, cotton, palm oil and seafood (IKEA 2015). IKEA aims to produce as much renewable energy as it consumes at a group level (mainly by the ownership of wind turbine farms) by 2020, to increase its energy efficiency by 30% by 2020, relative to 2010, and to source 100% of its wood from sustainable sources (FSC certified) by 2020 (IKEA 2015). Downstream in the supply chain, IKEA aims to produce more efficient and sustainable products that consume less energy and water in use. In terms of product development, IKEA has introduced a product sustainability scorecard framework as a tool to integrate sustainability considerations into product design.

Specifically addressing the CE agenda, IKEA has launched mattress take-back systems in 20 countries and other related systems in targeted countries, such as Norway and Australia. Looking at the full portfolio of initiatives launched by the IKEA group, one could argue that its central business model of producing low-cost household equipment for mass market consumption still contributes to increased resource use and environmental strain; however, the rather impressive number of ambitious targets it has set for the group as a whole, and its suppliers, indicate its strong willingness to act, albeit within the boundaries of its existing (linear) business model. IKEA has been working for years with traditional environmental management, eco-design and supply chain management, but has lately added aspects focusing on by-products and take-back systems, all of which contribute to reducing resource consumption and creating closed-loop consumption and production systems in line with the philosophy within the CE framework.

3. Analysis of the Cultural Economy and Its Knowledge Base

This vision of the CE aims at transforming linear industrial systems (take, make, dispose systems) into closed-loop systems that hold resources (biological as well as technical) within the production and consumption system for as long as possible, without creating waste (Stahel 2016). Creating such systems requires changes to technology, product design and production processes in individual companies, often drawing on knowledge from lifecycle analysis, an eco-design philosophy that is traditionally a part of the cleaner production concept (van Berkel 2007, Baas 2007). It also implies changes to business models and value chains (EC 2014a), which can be traced back to the literature on product service systems (Tukker and Tischner 2006).

Further, the CE concept is based on a system perspective that is aimed at creating changes not only to individual companies but to industrial systems. It therefore implies systemic innovation to the ways that companies interact between and within value chains while exchanging intermediate products, resources, by-products and waste, but also the ways in which value is created and distributed across agents in the industrial systems. Such a strategy to industrial transformation draws heavily on knowledge and experience that can be traced back to the industrial ecology (Ehrenfield 2004, Chertow 2007) and cradle-to-cradle literature (McDonough and Braungart 2002). The relationship to the industrial ecology literature is furthermore underpinned by the extensive use of analogies between industrial systems and natural systems. The link between the CE and the cradle-to-cradle literature can be found, for example, in the conceptual division between durable and consumable components of industrial systems (EMF 2013a).

3.1 The Company Approach – Cleaner Production

Manufacturing companies are the key stakeholders in the design of products and services and are consequently key stakeholders when aiming to transform linear production and consumption systems into circular production and consumption systems. A common denominator in the CE literature is a focus on innovation in private enterprises, and more specifically, how environmental constraints can be turned into opportunities for innovative businesses

(Stahel 2016). Using examples and case studies, the CE literature focuses on how companies can profit from the reinvention of business models, increased efficiency in their use of resources and improved environmental innovation (Stahel 2016, Webster et al. 2013). This strategy is not new. Stahel (1982) had argued in the early 1980s that private companies could find business opportunities in product innovation (especially product-life extensions). Also, the cleaner production literature has for three decades discussed the same issues, focusing on the development of tools and management systems to eliminate waste through integrated preventative strategies for manufacturing companies. The business community has even implemented the strategy in practice, and the political systems in Europe, the USA and elsewhere have supported that implementation through policies and legislation; for example, the IPPC directive in the EU adopted in 1996 (EC 1996).

The cleaner production strategy was developed during the late 1980s and 1990s, when huge effort was made to develop tools, strategies, systems and concepts that could reduce the environmental impact of manufacturing processes (Baas 2007). These efforts were labelled "waste minimization" (US EPA 1988), "pollution prevention" (US EPA 1992) and "cleaner production" (UNEP 1998). Cleaner production is defined by UNEP (1998) as the

> *"continuous application of an integrated, preventive strategy applied to processes, products and services in pursuit of economic, social, health, safety and environmental benefits".*

The focus was on manufacturing activities in broad terms and the aim was to develop pro-active, integrated and preventative strategies to eliminate environmental impacts at the source (UNEP 1998).

The tools for cleaner production were developed in institutions such as the Organization for Economic Cooperation and Development (OECD), the United Nations Industrial Development Organization (UNIDO), and by a group of national governments (Baas 2005). The initial work was followed by further elaboration by the International Standardization Organization (ISO), which led to the launch of the ISO environmental management series (ISO 14001), the World Business Council for Sustainable Development (WBCSD) that developed the so-called eco-efficiency concept (WBCSD 2000), and the development of the Eco-Management and Audit Scheme (EMAS) by the European Commission. The common denominator for these systems was a focus on the reduction of environmental impacts at the source, rather than clean-up and post-treatment (Thrane and Remmen 2007).

An institutional framework for the diffusion of cleaner production practices was also established under UNIDO and UNEP (Luken et al. 2015, van Berkel 2010). The first years of cleaner production practice largely focused on the implementation of systems and procedures at single sites and within single companies; while the involvement of other actors in the value chain, such as suppliers, was emphasized in later revisions of the standards. The concept of cleaner production systems has proved rather successful, if measured by the number of companies using the concepts. Indeed, by May 2016, more than 9,200 sites and 4,000 organizations had been certified under the EMAS system (EC 2016), and in 2014, more than 320,000 organizations were certified under ISO 14001 (ISO 2014).

The measures to be implemented as a result of such systems typically include: improving energy efficiency, de-materialization, waste minimization, raw material substitution and changing organizational structures and procedures (UNEP 2000, Christensen and Kjær 2012). Cleaner production is a preventative strategy to environmental management. The central idea in the cleaner production philosophy is to analyze root causes to identify the sources of the environmental impacts, and then to eliminate the problem through changes to products, production processes, working procedures or by recycling (internal or external). It is therefore a zero-waste strategy, like CE, but most often limited to the boundaries of a manufacturing site or within an individual company (although the involvement of suppliers was integrated into later revisions of ISO14001 and EMAS). Compared to the CE literature, the work on cleaner production is rich in details of its implementation, with several practical guidelines developed for specific industries (UNEP 2000). There is additionally a clear line between eco-design initiatives that can be found in cleaner production (Brezet and Hemel 1997) and the "design out waste" philosophy that can be found in the CE literature (EMF 2014, Hollander et al. 2017, Mendoza et al. 2017).

3.2 The System Approach - Industrial Ecology

The CE concept is a systemic approach to industrial transformation. The systemic approach can be found in most definitions used by both researchers (Webster et al. 2013) and policymakers (EC 2014a). Industrial ecology is a branch of environmental research that deals with the design of circular industrial systems (Erkman 1997). This field of research was formed in the early 1990s, based on the work of Frosch and Gallopoulos (1989) and Robert Ayres (Ayres 1989), and has gained increasing attention since then (e.g. Deutz et al. 2015, Clift and Druckman 2016). The literature in the field has emphasized the creation of industrial systems where by-products from one company are used as an input by another company (Chertow 2007), often using the Kalundborg Industrial Symbiosis system as a model (Jacobsen 2006).

A large number of research articles have reported how such systems can contribute to substantial reductions in raw material and energy consumption by redesigning linear production and consumption as circular, closed-loop systems, where waste, by-products and end-of-life products are re-recycled, thereby substituting for virgin raw materials (Ehrenfield 2004, Jacobsen 2006, Altham and van Berkel 2004, Chertow 2007). The literature on industrial ecology is often based on case studies that illustrate the wide applicability of the concept and the vast potential associated with the optimized use of waste and by-products across multiple companies (Kohornen 2001, van Berkel 2007, Mirata and Emtairah 2007, Yang and Feng 2008, Sokka et al. 2011, Martin and Eklund 2011).

The primary focus in the industrial ecology literature is on the recirculation of industrial waste and by-products and, when compared to cleaner production, less on pollution prevention and source reduction (Baas 2008). The industrial ecology literature has a broader scope than cleaner production, analyzing industrial systems with multiple production sites rather than single companies in isolated studies. Compared to the CE literature, industrial ecology studies tend to focus on industrial systems, giving less attention to the use phase and less emphasis to new business models, even though business model strategies in recent years have been given increased attention. For example, a special issue of the Journal of Industrial Ecology in 2014 focused on industrial ecology as a source of competitive advantage (Hoffman et al. 2014).

Many of the ideas in the CE concept can also be found in the industrial ecology literature. The distinction between linear and circular industrial systems was discussed by Lifset and Graedel (2002), who define a typology of ecosystems with three systems: linear material flows, quasi-cyclic material flows and cyclic material flows. Such cyclic material flow systems resemble a CE and are characterized by industrial systems in which all the resources are recycled and zero waste is created.

3.3 Cradle-to-Cradle

Core elements of the CE concept can be traced directly back to the cradle-to-cradle concept coined in the 1990s by William McDonough and Michael Braungart, with the central idea of developing tools and strategies for a radical redesign of products. The cradle-to-cradle metaphor paraphrased the lifecycle assessment "cradle-to-grave" catchphrase that was developed during the same period by organizations such as the Society of Environmental Toxicology and Chemistry (SETAC), UNEP (UNEP-SETAC 2005) and ISO. The cradle-to-cradle concept was developed to motivate designers to redesign products in order to eliminate waste (McDonough and Braungart 2002). Cradle-to-cradle design intentionally focuses on recycling so that end-of-life products can be returned as nutrients (technically or biologically) for new generations of products (McDonough and Braungart 2002). In order to accommodate such product features, a distinction between technical nutrients (covering metals, plastics and other processed materials) and biological nutrients (covering organic materials) was suggested (McDonough and Braungart 2002). This distinction was later adopted and integrated as an essential element in the CE concept (EMF 2013a).

The cradle-to-cradle literature included a new design framework aimed at eco-effectiveness, where products were to be radically redesigned to incorporate environmental, social and economic benefits (McDonough and Braungart 2002). This design framework distinguishes cradle-to-cradle from cleaner production, and especially from the so-called eco-efficiency framework developed by WBCSD, where the philosophy was to produce more value with fewer inputs. Braungart et al. (2007) argued that this strategy is linear, reactionary and ultimately insufficient, as it only reduces environmental impacts but fails to support the design of products that ultimately eliminate environmental impacts and waste.

The cradle-to-cradle concept was registered as a trademark of the McDonough Braungart Design Chemistry consultancy, which offered cradle-to-cradle certification to products. This concept was deployed by many major companies, such as the Ford Motor Company, Herman Miller, Nike and SC Johnson among others (McDonough and Braungart 2002). The certification was turned over to the non-profit institute, Cradle to Cradle Products Innovation in 2012.

Both the cradle-to-cradle and CE concepts apply a proactive and solution-oriented strategy that emphasizes possibilities and options for companies. The data and documentation on which the concepts are based on are often (hypothetical) case studies (McDonough and Braungart 2002, EMF 2013a) and the style they use to describe the concepts is often popular rather than scientific, as opposed, for example, to the lifecycle assessment concept, which emphasizes scientific rigour in methods and procedures (Christensen et al. 2014). Both concepts emphasize the distinction between technical and biological materials, although the cradle-to-cradle term is "nutrients" (McDonough and Braungart 2002) and the CE term is "material" (EMF 2013a). Furthermore, they highlight the need for both closed-loop production and the radical redesign of existing products. The general design philosophy is based upon the concept of eco-effectiveness, which seeks to design out waste through radical design changes, instead of making incremental modifications and improvements to existing designs (Braungart et al. 2007).

4. Discussion

As a theoretical and practical approach to reducing or eliminating man-made pressure on ecosystems, the CE concept can be placed within a broader field that covers a range of overlapping strategies, such as cleaner production, cradle-to-cradle and industrial ecology. A common denominator in these strategies is that they are solution-oriented, emphasizing the development of practical tools, strategies, design principles, business models, etc., to create sustainable production and consumption systems. Another common aspect is that companies are viewed as the central agents, who by their use of innovation and technology can contribute to a sustainable development without damage to their own material and economic foundation; this view is supported in the literature (e.g. EMF 2013a, EMF 2015).

Cradle-to-cradle and the CE both have their point of departure in a simple model over industrial systems that distinguishes between biological components and technical components (EMF 2013a, McDonough and Braungart 2002). Both also emphasize design changes to products and production systems as the preferred strategy to eliminating waste and emissions.

The industrial ecology and cleaner production strategies have many similarities, with (i) industrial ecology focusing on the linkages between multiple industries, often with an emphasis on waste and by-product utilization (Chertow 2007, Ayres and Ayres 2002, Ehrenfield 2004), and (ii) cleaner production focusing on activities and procedures within individual companies (Baas 2008). Industrial ecology tends to focus on the relations between manufacturing companies (Jackson 2002). Both industrial ecology and cleaner production tend to focus more on incremental improvements (eco-efficiency and a continuous improvement philosophy) with regard to product and process improvements, rather than the radical redesign of production and consumption systems (eco-effectiveness), and can thereby be differentiated from the CE and the cradle-to-cradle strategies. Braungart et al. (2007) and the EMF (2013a) argue that the eco-effectiveness approach is known from the cradle-to-cradle and CE literature and represents an approach to managing environmental problems that is fundamentally different to the eco-efficiency strategy.

However, despite conceptual differences between the eco-effectiveness and the eco-efficiency strategies, some researchers point at common grounds as well. In a study of beverage packaging systems, Niero et al. (2017), for example, suggested a framework that integrated the eco-efficiency and eco-effectiveness strategies and combined advantages of the two strategies. Environmental management systems based on cleaner production, such as EMAS and ISO14001,

	Cleaner production	Industrial ecology	Cradle-to-cradle	Circular economy
Scope	Industrial production sites	Industrial systems (often manufacturing systems)	Production and consumption systems	Production and consumption systems
Actors	Environmental managers; plant managers, institutional support, policymakers	Companies, suppliers, consumers, symbiosis centres, public–private partnership consortia	Consultants, manufacturing companies	Consultants, companies, suppliers, consumers, waste treatment companies, policymakers
Focus	Pollution prevention, source reduction, integrated measures, production processes, eco-efficiency	By-product exchange and waste utilization, industry focus	Technical and biological nutrients, "waste equals food" philosophy, eco-effectiveness, product certification	Durable and consumable components, closed-loop systems, eco-effectiveness
Innovation perspective	Continuous improvements, organizational learning, product and process modifications, Best Available Technology	Closed-loop systems, waste and by-product utilization, exploitation of multiple benefits	Design out waste, redesigned products, new business models	Redesigned products, closed-loop systems, new business models

Table 1. Actors, focus and innovation in four different strategies for sustainable production and consumption systems (inspired by Baas 2008).

both explicitly encourage and motivate companies to incrementally reduce their environmental impacts. The practices that have been developed by the many thousands of companies that have been certified to ISO14001 and EMAS standards have therefore primarily resulted in incremental, step-by-step reductions of their environmental impacts (Ganzleben et al. 2009).

In order to realize concepts including zero-emission objectives and closed-loop production and consumption visions, co-innovation through the involvement of multiple actors is important. Mendoza et al. (2017) found that the implementation of CE necessitates systemic innovation of both a technical and non-technical nature across value chains. Actor networks to foster such systemic changes may include companies, users, policymakers, scientists and other relevant bodies, depending on the specific case. Facilitation through regular interactions between the actors is needed to ensure early confrontation with, and integration of, a diversity of perspectives, insights, experiences and ideas. Such integration of the knowledge of academic and non-academic actors (technical as well as non-technical), through a facilitated transdisciplinary research process (Regeer et al. 2009a), can lead to socially robust knowledge that is both scientifically credible and socially valuable (Gibbons et al. 1994, Regeer et al. 2009b).

Another core element is the alignment of the proposed innovation with prevailing systems (e.g. legal, technical or financial) and institutions (e.g. the market place, knowledge infrastructure, modes of governance) as well as with a growing group of relevant actors (e.g. consumers, retailers, inhabitants). The goal is a process of broad and reflexive learning focusing on the technical as well as the social aspects of CE solutions. Acknowledging that different actors may have different ideas and expectations, making explicit the differences without forcing consensus, and using the differences constructively, are essential elements of the facilitation. Trade-offs can be identified and utilized between (for example) generating jobs, economic performance and environmental impacts in the short and longer term. The latter also points to a general weakness in the literature on the CE and related concepts concerning the lack of attention to the institutional, organizational and cultural bases for change. The majority of the CE literature is based on techno-environmental knowledge concerned with, for example, resource flows, production and consumption systems, business models and company strategies and policy, whereas less attention is paid to study how institutional arrangements and culturally based values and practices may hinder or stimulate the transition to a circular economy

5. Conclusion

It can be concluded that the CE concept as a platform for the transition to sustainable production and consumption systems revitalizes existing concepts rather than bringing fundamentally new tools, strategies and knowledge to the table. The CE concept and its current application in policies and business strategies builds on years of accumulated knowledge from various research fields, such as cleaner production, industrial ecology and cradle-to-cradle. From these research fields, the CE concept defines solution-oriented strategies, with companies as the central change agents, focusing on both technical material flows and biological material flows (the material aspect of the circular economy) and with the economy that is associated with these flows (the economic aspect of the circular economy). The effort put in by organizations such as the EMF has managed to reinvigorate the knowledge about pollution prevention, zero emissions and closed-loop production and consumption systems, and has managed to convey this huge body of existing knowledge into high-level policy processes as well as into the business strategies of a considerable number of large corporations. Further development and adoption of the CE strategy would require a research agenda focusing on co-innovation and transdisciplinarity, bringing research across disciplines together with businesses and other stakeholders, to facilitate co-innovation for the transition to circular and sustainable production and consumption systems.

6. References

Altham, J. and van Berkel, R. (2004). Industrial Symbiosis for Regional Sustainability: An Update on Australian Initiatives, 11th International Sustainable Development Research Conference, 2004

Ayres, R., and Ayres, L., (edited), (2002). A Handbook of Industrial Ecology, Edward Elgar, Cheltenham, UK, Northampton MA, USA

Ayres, R. (1989). Industrial Metabolism, Technology and Environment, p.23-39, National Academy Press, Washington DC

Baas, L. (2005). Cleaner production and industrial ecology, Dynamic Aspects of the introduction and dissemination of new concepts in industrial practice, Eburon Academic Publishers, Delft, The Nederland's

Baas, L. (2007). To make zero emissions technologies and strategies become a reality, the lessons learned of cleaner production dissemination have to be known, Journal of Cleaner Production 15 (2007) 1205-1216

Baas, L. (2008). Cleaner Production and Industrial Ecology: A Dire Need for 21st Century Manufacturing, chapter 11 in Handbook of Performability Engineering, edited by Krishna B. Misra, 2008 Springer-Verlag London Limited,

Blomsma, F., and Brennan, G. (2017). The Emergence of Circular Economy - A New Framing Around Prolonging Resource Productivity. Journal of Industrial Ecology, Volume 21, Number 3, DOI: 10.1111/jiec.12603

Bocken, N.M.P., de Pauw, I, de Bakker, C., and van der Grinten, B. (2016). Product design and business model strategies for a circular economy, Journal of Industrial and Production Engineering, 33:5, 308-320, DOI: 10.1080/21681015.2016.1172124

Bocken, N.M.P., Ritala, P., and Houtari, P. (2017). The Circular Economy - Exploring the Introduction of the Concept Among S&P 500 Firms, Journal of Industrial Ecology, Volume 21, Number 3, p.487-490

Boulding, K. E. (1966). The economics of the coming Spaceship Earth. Environmental Quality in a Growing Economy: Essays from the Sixth RFF Forum. H. Jarrett. Baltimore, John Hopkins University Press: 3-14.

Braungart, M., McDonough, W., Bollinger, A., (2007). Cradle-to-cradle design: creating healthy emissions e a strategy for eco-effective product and system design, Journal of Cleaner Production 15 (2007) 1337-1348

Brezet, H. and Carolien van, H. (1997). Ecodesign: A Promising Approach to Sustainable Production and Consumption, Paris, France: United Nations Environment Programme, Industry and Environment, Cleaner Production; The Hague: Rathenau Institute; Delft, Netherlands: Delft University of Technology, 1997

Chertow, M. R. (2007). "Uncovering" Industrial Symbiosis, Journal of Industrial Ecology, 2007, Childers, D.L. and Corman, J. (2011). Sustainability challenges of phosphorus and food: solutions from closing the human phosphorus cycle. BioScience 61, 117-124.

Christensen, T.B., Lybæk R and Kjær, T. (2014). Methods for Prevention of Environmental Impacts. in J Simonsen, C Svabo, SM Strandvad, K Samson, M Hertzum & OE Hansen (red), Situated Design Methods. MIT Press, s. 339-356. Design thinking, design theory

Christensen, T.B. and Kjær, T. (2012). What is Cleantech – Unraveling the buzzword, in Rethinking, Climate Change Research edited by Almlund, Jespersen and Riis, Ashgate Studies in Environmental Policy and Practice, Ashgate: UK, 2012: 21-43

Clift, R. and Druckman, A. (2016). Taking Stock of Industrial Ecology, Springer International Publishing, AG Switzerland, DOI 10.1007/978-3-319-20571-7_1

Cordell, D. and Drangert, J.O. (2009). The story of phosphorus: global food security and food for thought. Global Environmental Change 19, 292-305.

Dawson, C.J. and Hilton, J. (2011). Fertilizer availability in a resource-limited world: Production and recycling of nitrogen and phosphorus. Food Policy 36, 14-22.

Deutz, P., Lyons, D.I., and Bi, J. (2015). International Perspectives on Industrial Ecology, Studies on the Social Dimensions of Industrial Ecology series, Edward Elgar Publishing Ltd, UK.

EC, (2016). Website European Commission, DG Environment, accessed on the 15th of September 2016 http://ec.europa.eu/environment/emas/emas_registrations/statistics_graphs_en.htm

EC, (1996). Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control, Official Journal of the European Communities, No L 257/26

EC, (2014a). Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions - Towards a circular economy: A zero waste programme for Europe, COM(2014) 398 final/2, Brussels, Belgium

EC, (2014b). Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions On the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative, COM(2014) 297, Brussels, Belgium

EC, (2015). Communication from the Commission to the European Parliament, The Council, the European Economic and Social Committee and the Committee of the Regions, Closing the loop – An EU action plan for the circular economy, European Commission COM(2015) 614 final, Brussels, Belgium

Ehrenfeld, J. (2004). Industrial ecology: a new field or only a metaphor? Journal of Cleaner Production 2004, vol 12 p.825–831

EMF, (2013a). Towards the Circular Economy – economic and business rationale for an accelerated transition, Ellen McArthur Foundation, 2013, Cowes, United Kingdom

EMF, (2013b) Towards the Circular Economy - Opportunities for the consumer goods sector", Ellen McArthur Foundation, 2013, Cowes, United Kingdom

EMF, (2014). Towards the Circular Economy - Economic and business rationale for an accelerated transition, Ellen McArthur Foundation, 2013, Cowes, United Kingdom

EMF, undated, The circular economy 100 – A platform to rethink the future, Ellen McArthur Foundation, Cowes, United Kingdom

EMF, (2015) Growth within: a circular economy vision for a competitive Europe, Ellen McArthur Foundation, Cowes, United Kingdom

Erkman, S. (1997). Industrial Ecology: An Historical View, Journal of cleaner production, 1997, 5(1-2), pp. l-10

Fredenslund, A., Nielsen, K.J., Paamand, K., Kjær, L., Busck, M. and Kjær T. (2014). Solrød Biogas - Conception, project development and realisation, Solrød Municipality, Solrød, Denmark

Frosch, R.A. and Gallopoulos, N. (1989). Strategies for manufacturing. Scientific American 261(3):144-152

Ganzleben, C., Vernon, J., Peacock, M., Belin, A., Candell, M. (2009). Study on the Costs and Benefits of EMAS to Registered Organisations, Report prepared by Milieu Ltd and Risk and Policy Analysis Ltd for DG Environment of the European Commission, Milieu Ltd, Brussels, Belgium

Geng, Y., Doberstein, B. (2008). Developing the circular economy in China: challenges and opportunities for achieving "leapfrog development". Int. J. Sustain. Dev. World Ecol. 37e41 (February 2014). Available at: http://www.tandfonline.com/doi/abs/10.3843/SusDev.15.3:6

Ghisellini, P., Cialani, C., and Ulgiati, S. (2016). A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, Journal of Cleaner Production, Volume 114, 15 February 2016, Pages 11–32. http://dx.doi.org/10.1016/j.jclepro.2015.09.007

Gibbons M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., Trow, M. (1994). The New production of knowledge – The dynamics of Science and research in contemporary societies, SAGE Publications, London, UK

Hoffman A.J., Corbett, CJ., Joglekar, N., Wells, P. (2014). Industrial Ecology as a Source of Competitive Advantage. Journal of Industrial Ecology, Volume 18, Number 5, DOI: 10.1111/jiec.12196

Hollander, M.C. den Bakker, C.A.; Hultink, E.J. (2017). Product Design in a Circular Economy - Development of a Typology of Key Concepts and Terms, Journal of Industrial Ecology, Volume 21, Number 3, DOI: 10.1111/jiec.12610

IKEA, (2015). IKEA Group Sustainability Report, FY15, Accessed from the internet 22. September 2016, http://www.ikea.com/ms/en_US/img/ad_content/2015_IKEA_sustainability_report.pdf

ISO. (2014). The ISO Survey of Management System Standard Certifications – 2014 Executive summary, accessed online on the 15 of September 2016: http://www.iso.org/iso/iso_survey_executive-summary.pdf?v2014

Jackson, T. (2002). Industrial ecology and cleaner production. in Ayres, Robert and Ayres, Leslie (edited), A Handbook of Industrial Ecology, Edward Elgar, Cheltenham, UK, Northampton MA, USA

Jacobsen, N. B., Industrial Symbiosis in Kalundborg, Denmark - A Quantitative Assessment of Economdic and Environmental Aspects, Journal of Industrial Ecology, (2006). 10(1–2)

Kirchherr, J., Reike, D., and Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions, Resources, Conservation & Recycling 127 (2017) 221–232

Kiørboe, N., Sramkova, H. and Krarup, M. (2015). Moving towards a circular economy – successful Nordic business models, Nordic Council of Ministers, Copenhagen, Denmark, http://dx.doi.org/10.6027/ANP2015-771

Korhonen, J. (2001). Co-production of heat and power: an anchor tenant of a regional industrial ecosystem, Journal of Cleaner Production, 2001, 9:509–517

Lieder, M., and Rashid, A. (2016). Towards circular economy implementation: a comprehensive review in context of manufacturing industry, Volume 115, 1 March 2016, Pages 36–51. http://dx.doi.org/10.1016/j.jclepro.2015.12.042

Lifset, R. and Graedel T.E. (2002). Industrial ecology: goals and definitions, in Ayres, Robert and Ayres, Leslie (edited), A Handbook of Industrial Ecology, Edward Elgar, Cheltenham, UK, Northampton MA, USA

Luken, R.A., Van Berkel, R., Leuenberger, H., Schwager, P. (2015). A 20-year retrospective of the National Cleaner Production Centres programme, Journal of Cleaner Production article in press (2015)

1-10

Martin, M. and Eklund, M, Improving the environmental performance of biofuels with industrial symbiosis, Biomass and Bioenergy 35. (2011). 1747-1755

McDonough, W. and Braungart, M. (2002). "Cradle to Cradle – Remaking the Way We Make Things", North Point Press: New York, first edition.

McDowall, W., Geng, Y., Huang, B., Bartekov, E., Bleischwitz, R., Türkeli, S., Kemp, R., Domenech, T. (2017). Circular Economy Policies in China and Europe, Journal of Industrial Ecology, Volume 21, Number 3, DOI: 10.1111/jiec.12597

McKinsey (2011). Resource Revolution: Meeting the world's energy, materials, food, and water needs, McKinsey & Company 2011, McKinsey Global Institute,

Meadows, D. H., Meadows, D.L., Randers, J., Behrens, W.W. (1972). The Limits to Growth – A report for the Club of Rome's project on the predicament of mankind, Earth Island Limited, London, 1972.

Mendoza, J.M.F., Sharmina, M., Gallego-Schmid, A., Heyes, G., Azapagic, A. (2017). Integrating Backcasting and Eco-Design for the Circular Economy - The BECE Framework. Journal of Industrial Ecology, Volume 21, Number 3, DOI: 10.1111/jiec.12590

Mirata, M. and Emtairah, T. (2005). Industrial symbiosis networks and the contribution to environmental innovation: The case of the Landskrona industrial symbiosis programme, Journal of Cleaner Production 13 (2005) 993-1002

Mont, O.K. (2002). Clarifying the concept of product–service system, Journal of Cleaner Production 10 (2002) 237–245

Murray, A., Skeme, K. and Haynes, K. (2017). The Circular Economy: An interdisciplinary exploration of the concept and application in a global context, Journal of Business Ethics (2017) 140: 369-380

Niero, M., Hauschild, M.Z.; Hoffmeyer, S.B. and Olsen, S.I. (2017). Combining Eco-Efficiency and Eco-Effectiveness for Continuous Loop Beverage Packaging Systems - Lessons from the Carlsberg Circular Community, Journal of Industrial Ecology, Volume 21, Number 3, DOI: 10.1111/jiec.12554

Page, T. (2015). An Approach to the Management of the Sustainable Issues in Mobile Phone Design and Manufacturing, i-Manager's Journal on Management 10.2 (Sep-Nov 2015): 12-23.

Planning, P. (2015). Business Model Innovation in a Circular Economy - reasons for non-acceptance of Circular Economy business models, Open Journal of Business Model Innovation, in press

Regeer, B.J. and Bunders, J. (2009a). Knowledge co-creation: Interaction between science and society – A transdisciplinary approach to complex societal issues, VU University Amsterdam, Athena Institute, Preliminary studies and background studies, number V.10e (2009)

Regeer, B.J., Hoes, A.C. , van Amstel-van, Saane, M., Caron-Flinterman, F.F. and Bunders, J.F.G. (2009b). Six Guiding Principles for Evaluating Mode-2 Strategies for Sustainable Development, American Journal of Evaluation, 30(4) 515-537

Riding, M., Herbert, B., Ricketts, L., Dodd, I., Ostle, N., Semple, K. (2015). Harmonising conflicts between science, regulation, perception and environmental impact: The case of soil conditioners from bioenergy, Environment International 75 (2015) 52–67

Sauvé, S., Sophie B. and Pamela, S. (2016). Environmental sciences, sustainable development and circular economy: Alternative concepts for transdisciplinary research, Environmental Development 17 (2016) 48–56. http://dx.doi.org/10.1016/j.envdev.2015.09.002

Sokka, L., Pakarinen, S. and Melanen, M. (2011). Industrial symbiosis contributing to more sustainable energy use – an examplefrom the forest industry in Kymenlaakso, Finland, Journal of Cleaner Production 19 (2011) 285–293

Stahel, W. (1982). The product-life factor. In: Orr, G.S. (Ed.), An Inquiry into the Nature of Sustainable Societies. The Role of the Private Sector. Houston Area Research Centre, Houston

Stahel, W. (2016). The circular economy: A new relationship with our goods and materials would save resources and energy and create local jobs. Nature 531(2016) 435–438, doi:10.1038/531435a

Su, B., Heshmati, A., Geng, Y., Yu, X. (2013). A review of the circular economy in China: moving from rhetoric to implementation, Journal of Cleaner Production 42 (2013) 215-227

Thrane, M. and Remme, A. (2007). Cleaner Production, in Tools for Sustainable Development, edited by L. Kørnøv, M., Thrane, A. Remmen and H. Lund, Aalborg Universitetsforlag 2007, Aalborg Denmark

Tukker A., and Ursula T. (2006). New Business for Old Europe – Product-Service development, competitiveness and Sustainability, Greenleaf Publishing 2006: Sheffield, UK

Tukker, A. (2015). Product services for a resource-efficient and circular economy – a review, Journal of Cleaner Production 97 (2015) 76-91

UNEP, (2011). GREENeconomy – Pathways to Sustainable Development and Poverty Eradication, United Nations Environment Programme, St-Martin-Bellevue, France

UNEP, (2000). Cleaner Production Assessment in Dairy Processing. Prepared by COWI Consulting Engineers and Planners AS, Denmark for United Nations Environment Programme; Division of Technology, Industry and Economic; April 2000, Paris France

UNEP, (1998). International Declaration on Cleaner Production, UNEP Division of Technology, Industry and Economics, Paris, France

UNEP-SETAC, (2005). "Life Cycle Approaches-The road from analysis to practice". published by the United Nations Environment Programme (UNEP) and Society of Environmental Toxicology and Chemistry (SETAC), 2005. Paris, France

US EPA, (1988). Waste Minimization Opportunity Assessment Manual, Hazardous Waste Engineering Research Laboratory Office of Research and Development US Environmental Protection Agency Performance, United States Environmental Protection Agency, USA

US EPA, (1992). EPA Definition of "Pollution Prevention" Memorandum, United States Environmental Protection Agency, Washington, USA

Van Berkel, R. (2007). Cleaner production and eco-efficiency initiatives in Western Australia 1996-2004, Journal of Cleaner Production 15 (2007) 741e755

Van Berkel, R. (2010). Evolution and diversification of National Cleaner Production Centres (NCPCs), Journal of Environmental Management 91 (2010) 1556-1565

Van Vuuren, D.P, Bouwman, A.F and Beusen, A.H.W. (2010). Phosphorus demand for the 1970–2100 period: A scenario analysis of resource depletion. Global Environmental Change 20, 428-439.

WBCSD, (2000). "Eco-efficiency – Creating more value with less impact", World Business Council for Sustainable Development, 2000, Geneva, Switzerland

Webster, K., Blériot, J. and Johnson, C. (2013). A new dynamic – effective business in a circular economy, Ellen MacArthur Foundation Publishing, Cowes, United Kingdom

Witjes, S. and Lozano, R. (2016). Towards a more Circular Economy: Proposing a framework linking sustainable public procurement and sustainable business models, Resources, Conservation and Recycling, Volume 112, September 2016, Pages 37-44

World Economic Forum, (2014). Towards the Circular Economy: Accelerating the scale-up across global supply chains, Prepared in collaboration with the Ellen MacArthur Foundation and McKinsey & Company, Published by World Economic Forum, Geneva, Switzerland

Yang, S. and Feng, N. (2008). A case study of industrial symbiosis: Nanning Sugar Co., Ltd. in China, Resources, Conservation and Recycling 52 (2008) 813–820