# Tables

Table 1: Example phrases per coding dimensions

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| *Coding dimension* | *Coded to the dimension if …* | *Example phrase* |
| Core principles |  |  |
| 4R framework | Explicit reference to the 4R framework/all 4R dimensions (reduce, reuse, recycle, recover)? | “includes the 4Rs” |
| Reduce | Discussion around refusing, rethinking, redesigning (including prolonging the lifespan of products), minimization, reduction and/or prevention of resource use and preserving of natural capital? | "the reduction of resources” |
| Reuse | Discussion around reusing (excluding waste), closing the loop, cycling, repairing and/or refurbishing of resources? | "products could be repaired, reused” |
| Recycle | Discussion around remanufacturing, recycling, closing the loop, cycling and/or reuse of waste? | "where the wastes are reused” "from restoration and recycling"  |
| Recover | Discussion around incineration of materials with energy recovery? | “byproducts, (…), and energy are cycled back into the overall production stream” |
| Waste hierarchy | Indication of an order or ranking of the various Rs mentioned, e.g. via words such as “first”, “alternatively” or “least desirable”? | “if reuse or repairs are not possible, they can be recycled or recovered from the waste stream” |
| Systems perspective |  | Explicit discussion around CE as a system? | “a circular economy is an industrial system”  |
|  | Micro-systems perspective | Discussion around product level changes, firms and/or consumers and their preferences? | “CE will ensure that byproducts are identified in individual enterprises and used effectively either internally through cleaner production (CP)” |
| Meso-systems perspective | Discussion around CE at the regional level and/or eco-industrial parks? | “At the regional level, circular economy emphasizes structuring a substance recycling eco-industrial park” |
| Macro- systems perspective | Discussion around CE at the global and/or national level and/or the overall industry structure? | “the development of a CE emphasizes adjusting industrial composition and structure” |
| Aims |
| Sustainable development |  | Explicit reference to sustainability and/or sustainable development? | "sustainable development created by promoting a circular economy (CE)"  |
| Environmental quality |  | Discussion on how CE aims to maintain, protect and/or restore the environment and/or resource efficiency/enable transition towards low carbon economy? | “environmental conservation” |
| Economic prosperity |  | Discussion on how CE aims to maintain, protect, transform and/or strengthen/make more competitive the economy? | “secure continued economic growth” |
| Social equity |  | Discussion on how CE aims to protect, transform, strengthen and/or develop the society and/or human well-being and create jobs? | “maximize (…) human well-being” |
| Future generations (time dimension) |  | Discussion of future generations and/or the long-term perspective of CE? | “contributing to long-term sustainability”  |
| Enablers |
| Business models |  | Explicit mentioning of business models (including specific type of business model such as product-as-a-service)? | “it is (…) about business models”  |
| Consumers |  | Explicit mentioning of consumption/consumer perspective/consumers as drivers of CE? | “rethinking (…) consumption” |

Table 2: Coding procedure

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| --- | --- |
| Process step | Activity |
| 1 | Development of initial coding framework (including coding rules), based upon coders’ practical knowledge on the topic and preliminary skimming of relevant literature |
| 2 | Independent coding of set of definitions by both coders; searching for additional possible coding dimensions within definitions during coding |
| 3 | Comparison of coding results; discussion of definitions that at least one coder did not find straight-forward to code based on initial coding rules and discussion of diverging results; refinement of coding rules based on this discussion; discussion on and alignment regarding additional coding dimensions for coding framework |
| 4 | Independent coding of set of definitions by both coders based on revised coding framework  |
| 5 | Comparison of coding results; discussion of diverging results; finalization of results (ultimate results can include diverging results) |

Note: The depicted coding procedure is illustrative. Additional definitions were added and coding framework was further revised based upon anonymous feedback on this paper from reviewers at *Resources, Conservation and Recycling.*

Table 3: Definitions of the Circular Economy

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| --- | --- | --- |
| # | Source | Definition |
| 1 | Aldersgate (2012) | A circular economy is a restorative industrial economy in which materials flows are of two types: biological nutrients, designed to re-enter the biosphere safely, and technical nutrients (non-biological materials), which are designed to circulate at high quality, with their economic value preserved or enhanced. |
| 2 | Allwood, Ashby, Gutowski, & Worrell (2011, p. 368) | The UK government has extensively promoted a waste hierarchy of “reduce, re-use, recycle” (DoETR, 1995) now taken up in China as the ‘Circular Economy’ (Yuan et al., 2006), of which the first two options describe material efficiency, but in reality much policy has been oriented towards promoting the third (Bulkeley and Gregson, 2009). |
| 3 | Andersen (2007, p. 133) | The concept of a circular economy – currently widely promoted in Asia – has its conceptual roots in industrial ecology, which envisions a form of material symbiosis between otherwise very different companies and production processes. Industrial ecology emphasises the benefits of recycling residual waste materials and by-products through, for example, the development of complex interlinkages, such as those in the renowned industrial symbiosis projects (see Jacobsen 2006). However, in more general terms, it promotes resource minimisation and the adoption of cleaner technologies (Andersen 1997, 1999). |
| 4 | Augustsson, Sörme, Karlsson, & Amneklev (2017, p. 696) | A circular economy aims to reduce the inﬂow of new re-sources and instead reuse materials from various outﬂow streams, that is, the waste of society (EEA 2016). The high priority of waste recycling is supported by legislation, policies, and directives, for examples, the waste hierarchy in the EU (Directive2008/98/EC). |
| 5 | Bai, Qiao, Yao, Guo, & Xie (2014, p. 6) | In 2006, the style of NDEIPs changed to a ‘circular’, integrated industry design. The Qingdao New World NDEIP is one of the leading examples. The Venous Industry EIPs are based on the concept of circular economy to recycling and reusing waste from existing industrial clusters like the veins in human body. Some industrial parks that were approved for NDEIP construction followed EIP guidance and had several key accomplishments related to NDEIP, including the low carbon development, material reduction and circulation, pollution control and environmental management. |
| 6 | Bakker, Wang, Huisman, & den Hollander (2014, p. 11) | According to Stahel (1998: p 29), the key to product life extension “lies in the transformation of the actual linear production focused industrial economy into a utilization-focused service economy operating in loops”. This is a concise summary of the concept of a circular economy that is at the basis of much current design thinking. McDonough and Braungart (2002, 2013) for instance talk about “waste equals food” and “nutrient management” in their cradle-to-cradle design methodology and the Ellen MacArthur Foundation (2013) argues for “circular products” that complement a circular economy. Stahel (1998) likens the linear economy to a river and the circular economy to a lake, creating a useful metaphor of flow and loss versus retainment and preservation of value. Stahel (1998) likens the linear economy to a river and the circular economy to a lake, creating a useful metaphor of flow and loss versus retainment and reservation of value. This circular thinking underpins the EU Waste Framework Directive (2008/98/EC), which presents a waste management hierarchy of prevention, reuse, recycling, other recovery (i.e. energy recovery) and disposal, with prevention and reuse the preferred waste management approaches. |
| 7 | Baxter, Aurisicchio, & Childs (2017, p. 507) | In a circular economy (CE) solution where cycling of material ﬂows provides repeated value, such impurities pose an implementation challenge and can add cost or complexity to the cycle or may even invalidate it. |
| 8 | Beek, Heijden, Ridley, & Alteren (2016, p. 8) | We believe it does and that the solution lies in the development of a circular economy, where growth is decoupled from the use of scarce resources through disruptive technology, and business models are based on longevity, renewability, reuse, refurbishment, capacity sharing and dematerialisation.  |
| 9 | Bilitewski (2012, p. 1) | The circular economy is a concept which is transforming traditional patterns of economic growth and production. A conventional perception of economic systems is that they are linear. The linear system is converted to a circular system when the connection between resource use and waste residuals is made. |
| 10 | Birat (2015, p. 1) | The rationale is that growth has been based in the past on wasting raw materials and resources (“the linear model") and that a more resource-wary approach would benefit Europe by reducing the depletion of natural resources, whether they are rare or not, and the dependency of the Region on raw development of a circular economy, based on recycling, reuse, reduction – even elimination – of waste (all recyclable waste (plastics, metals, glass, paper, cardboard, biodegradable waste) barred from landfilling by 2025 and all landfill stopped by 2030) and lean-eco design. This is similar to speaking of industrial and urban ecology, of urban metabolism and of exploiting urban or industrial mines. |
| 11 | Blomsma & Brennan (2017, p. 603) | In this article, we examine the circular economy (CE) concept: an emergent framing around waste and resource management that aims to offer an alternative to prevalent linear take-make-dispose practices by promoting the notion of waste and resource cycling. Strategies such as, but not limited to, reuse, recycling, and remanufacturing operationalize this concept. |
| 12 | Bocken, de Pauw, Bakker, & van der Grinten (2016, p. 308) | Design and business model strategies [that are] slowing, closing, and narrowing resource loops*[Also considering figures in this paper]* |
| 13 | Bocken, Olivetti, Cullen, Potting, & Lifset (2017, p. 476) | A CE aims to keep products, components, and materials at their highest utility and value at all times. The value is maintained or extracted though extension of product lifetimes by reuse, refurbishment, and remanufacturing as well as closing of resource cycles—through recycling and related strategies. An alternative strategy for extension of product lifetimes may be to use products more efficiently through sharing them or making them multifunctional. All these strategies may be facilitated through changes in ownership relationships, such as leasing and product service systems (PSSs). |
| 14 | Bocken, Ritala, & Huotari (2017, p. 487) | The basic premises of the CE appear to be closing and slowing loops. Closing loops refers to (post consumer waste) recycling, slowing is about retention of the product value through maintenance, repair and refurbishment, and remanufacturing, and narrowing loops is about efficiency improvements, a notion that already is commonplace in the linear economy |
| 15 | Brown & Ulgiati (2011, p. 6) | *[Circular economy visualized in Figure 1 in this paper]* |
| 16 | Castellani, Sala, & Mirabella (2015, p. 374) | Increasingly, reuse also represents a relevant new niche of business beyond “charity and thrift shops” and a fundamental element of the circular economy. For example, Gelbmann and Hammerl (2014) described an innovative business model based on reuse, considering that ecologically oriented work integration social enterprises focusing on reuse may constitute a novel kind of Sustainable Product–Service System (SPSS). This may also involve international trade (Brooks 2013). |
| 17 | Charonis (2012, p. 2) | Throughout this paper, the circular economy is understood as a system that is designed to be restorative and regenerative; restoration replaces the ‘end-of-life’ concept for products, energy systems are shifted towards renewable technologies, toxic chemicals that impair reuse are eliminated and waste is eliminated to the greatest extent possible through improved materials, products and systems design (Ellen MacArthur Foundation 2012). |
| 18 | Chertow (2012) | If cascading is conceptually stepwise, loop closing is more circular. A general name for many different variations of reuse and recycling of resources, loop closing occurs when a resource has a cyclical flow embedded in the industrial ecosystem and the resource, rather than being used in a degraded form, reappears akin to its original form. |
| 19 | Circular Academy (2017) | A circular economy is a transformative economy redefining production and consumption patterns, inspired by ecosystems principles and restorative by design, which increases resilience, eliminates waste and creates shared value through an enhanced circulation of material and immaterial flows |
| 20 | Conticelli & Tondelli (2014, p. 335) | If we consider, for instance, the Chinese Circular Economy (CE), which was introduced in 1998 as a new sustainable development strategy, which integrates cleaner production and industrial ecology in a broader system encompassing industrial firms, many more planning strategies could be identified in the EIP implementations, such as, for instance, site development preserving local natural features, recruitment of companies committed to high resource efficiency and low pollution, management to support the financial, environmental and social success of EIP companies and a strong linkage to surrounding communities through economic development, social and environmental programs. |
| 21 | Cullen (2017, p. 483) | A circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times |
| 22 | Dajian (2008, p. 4) | Therefore China’s idea of circular economy has its own characteristics. The author believes at least the following characteristics are worth emphasizing. First, China’s circular economy is an idea about the economic pattern in respect of nature rather than an idea about environmental management in some other countries, because China hopes to reduce resource consumption and pollutant production at sources and in the whole process by changing the economic pattern. It also hopes to achieve win-win in both economy and environment by circular economy instead of ‘economy without recycle’ or ‘recycle without economy’; therefore the department proposed for planning circular economy as a whole in China is the State Development and Reform Commission which has a comprehensive nature instead of environmental management departments in some other countries. Second, China’s circular economy not only aims at garbage economy or 3R economy for treating solid waste in respect of objects but at all scarce resources involved in China’s economic development, including water, land, energy, materials and corresponding waste; to a certain extent, it is of more urgent significance for China to develop circular economy which deals with consumption of water, land, energy and other resources and control of related pollutants. Third, China’s circular economy comprises different space levels in respect of scale and includes circular economy of individual enterprises, industrial parks and regions, etc. Fourth, China’s circular economy stresses progressively increased practice forms on the following three levels in respect of pattern and emphasizes the need to develop from low-level recycle of waste based on ecological efficiency (to reduce consumption and pollution) to high-level recycle of products and services based on ecological effects (to prevent consumption and pollution).  |
| 23 | Davis & Hall (2006) | Thinking of the economy as a closed system --- as opposed to a linear system --- has spawned legislation that seeks to hold waste production and energy consumption within acceptable limits. Examples include elaborate recycling and waste management legislation and associated laws and regulations now in effect in Japan and the European Union. Such measures are generically referred to in this paper as “circular economy legislation. |
| 24 | den Hollander, Bakker, & Hultink (2017, p. 517) | In a circular economy (CE), the economic and environmental value of materials is preserved for as long as possible by keeping them in the economic system, either by lengthening the life of the products formed from them or by looping them back in the system to be reused. The notion of waste no longer exists in a CE, because products and materials are,in principle, reused and cycled indeﬁnitely |
| 25 | Dupont-Inglis (2015) | The concept of the circular economy is about decoupling growth from resource consumption and maximizing the positive environmental, economic and social effects. It’s about designing products so that they are easier to reuse or recycle and making sure that every product ingredient is biodegradable or fully recyclable. In short, it’s a concept that is perfectly aligned with the development of the bioeconomy and the transition towards biobased rather than fossil based products. |
| 26 | Dutch House of Representatives (2013)  | A circular economy is an economic system that takes the reusability of products and materials and the conservation of natural resources as starting point. It also strives for value creation for people, nature and the economy in each part of the system |
| 27 | Ellen MacArthur Foundation (2013) | 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 distinguishes between technical and biological cycles. As envisioned by the originators, a circular economy is a continuous positive development cycle that preserves and enhances natural capital, optimises resource yields, and minimises system risks by managing finite stocks and renewable flows. It works effectively at every scale. |
| 28 | Ellen MacArthur Foundation (2014, p. 15) | A circular economy is 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. Such an economy is based on a few simple principles, as shown in Figure 2. First, at its core, a circular economy aims to design out waste. Waste does not exist: products are designed and optimized for a cycle of disassembly and reuse. These tight component and product cycles define the circular economy and set it apart from disposal and even recycling, where large amounts of embedded energy and labour are lost. Second, circularity introduces a strict differentiation between consumable and durable components of a product.  |
| 29 | Ellen MacArthur Foundation (2015, p. 23) | For the purpose of this economic analysis, the circular economy is defined as an economy that provides multiple value-creation mechanisms which are decoupled from the consumption of finite resources (Figure 8). This definition rests on three principles: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows – for example, replacing fossil fuels with renewable energy or returning nutrients to ecosystems. Optimise resource yields by circulating products, components, and materials in use at the highest utility at all times in both technical and biological cycles – for example, sharing or looping products and extending product lifetimes. Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil, and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use. Narrower notions of the circular economy, limited to material reuse and sometimes regeneration, exist. But the modern economy requires applying all three principles to reintegrate the economy into our planet’s system, which is the ultimate ambition of circular thinking. Thus, applying these principles means creating an economy that is restorative and regenerative, that preserves ecosystems and increases their return over time, that creates prosperity, and that fuels growth by capturing more value from existing infrastructure and products. |
| 30 | Ellen MacArthur Foundation (2016, p. 15)  | The circular economy helps decouple economic value creation from resource consumption. Its four value drivers – extending the use cycle length of an asset, increasing utilisation of an asset or resource, looping or cascading an asset through additional use cycles, and regeneration of natural capital – can be combined with one (or several) of the three main intelligent assets value drivers – knowledge of the location, condition, and availability of an asset. The circular economy rests on three key principles, shown in Figure 1.3. –– Principle 1: Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows – for example, replacing fossil fuels with renewable energy or using the maximum sustainable yield method to preserve fish stocks. –– Principle 2: Optimize resource yields by circulating products, components and materials in use at the highest utility at all times in both technical and biological cycles – for example, sharing or looping products and extending product use cycles. –– Principle 3: Foster system effectiveness by revealing and designing out negative externalities, such as water, air, soil and noise pollution; climate change; toxins; congestion; and negative health effects related to resource use.  |
| 31 | EUKN (2015, p. 1) | The circular economy, as defined by the Ellen McArthur Foundation, refers to an industrial economy that is restorative by intention, aims to rely on renewable energy, minimises the use of toxic chemicals, and eradicates waste through careful design. The transition to a circular economy can be understood as the implementation of different business models and technologies in all sectors of production, marketing, consumption and waste management. Companies are the driving force in the shift towards the circular economy. However, governmental support is indispensable for an transition at larger scale. |
| 32 | European Commission (2014) | A development strategy that enables economic growth while optimising consumption of resources, deeply transforms production chains and consumption patterns, and redesigns industrial systems at the system level |
| 33 | European Commission (2015) | The transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimised, is an essential contribution to the EU's efforts to develop a sustainable, low carbon, resource efficient and competitive economy. |
| 34 | Fang, Côté, & Qin (2007, p. 316) | These paths include the following: industrialization pushed forward by information technology; sustainable development created by promoting a circular economy (CE) with optimal utilization of resources and energy; and maximization of integrated community profit. At the macro-level, the development of a CE emphasizes adjusting industrial composition and structure, creating resource recycling systems, and improving these recycling systems. At the meso-level, the will be developed by applying industrial ecology concepts. These concepts include: fostering networks among businesses and communities to optimize the use of resources; and planning of eco-efficient energy cascades. At the micro-level, the CE will ensure that byproducts are identified in individual enterprises and used effectively either internally through cleaner production (CP) or externally by other industries. |
| 35 | Fellner, Lederer, Scharff, & Laner (2017, p. 494) | It foresees a “transition to a more circular economy, where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized, which is seen as an essential contribution to the EU’s efforts to develop a sustainable, low carbon, resource efﬁcient and competitive economy |
| 36 | Geissdoerfer, Savaget, Bocken, & Hultink (2017, p. 759) | A regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling. |
| 37 | Geng & Doberstein (2008, p. 232) | The Chinese people have chosen to use the term ‘circular economy’ as the working language of EID. The terminology may not be very familiar to Western readers, but in China it is understood to mean the realisation of a closed loop of materials flow in the whole economic system. Different from the traditional linear production model, a circular economy approach encourages the organisation of economic activities with feedback processes which mimic natural ecosystems through a process of ‘natural resources→transformation into manufactured products → byproducts of manufacturing used as resources for other industries.’ In essence, the circular economy approach is the same as the more familiar terms EID and ‘industrial ecology’, and fits comfortably within a broad range of ecological modernisation initiatives pioneered around the world. The Chinese circular economy concept comes originally from Germany and Japan, where there was a desire to form a more closed loop society (Wang et al. 2004). It advocates that economic systems could and should operate according to the materials and energy cycling principles that drive natural systems. These include ecosystemic self-sustaining properties, through the recycling of essential materials and energy, the capacity for one organism’s wastes to be used as a resource by another organism, and through self-organisation capacities. |
| 38 | Geng, Fu, Sarkis, & Xue (2012, p. 216) | CE is based on the ‘win-win’ philosophy that a healthy economy and environmental health can co-exist (Geng and Doberstein, 2008; Park et al., 2010). It incorporates myriad strategies to achieve greater efficiency through economies of systems integration. The EID foundation of CE encourages economic activities to mimic the natural ecosystem metaphor, such as a closed loop of material flow within the broader economic system (Geng and Doberstein, 2008).  |
| 39 | Geng, Sarkis, Ulgiati, & Zhang (2013, p. 1256) | A CE is an industrial system focused on closing the loop for material and energy flows and contributing to long-term sustainability. CE incorporates policies and strategies for more efficient energy, materials, and water consumption, while emitting minimal waste into the environment. |
| 40 | Geng, Zhang, Côté, & Fujita (2009, p. 16) | It is believed that such EIP initiatives could bring great environmental, economic, and social benefits as a contribution to ecologically sustainable industrial development and China’s national circular economy program. This program includes initiatives related to cleaner production and ecodesign (at the company level), industrial symbiosis and EIPs (at the industrial cluster lever), and, more broadly, the regional eco-industrial network (at the regional level; Geng and Liu 2006). |
| 41 | Geng, Zhang, Ulgiati, & Sarkis (2010, p. 5278) | China has a number of evolving regulatory policies related to industrial park and regional development programs and their implication on the environment. One of these major policies is the ‘circular economy’. The circular economy policy is meant to encourage resource-use efficiency and integrates cleaner production and industrial ecology in a broader system encompassing industrial firms, networks or chains of firms, eco-industrial parks, and regional infrastructure to support resource optimization (Geng and Doberstein, 2008; Park et al., 2010; Sarkis and Zhu, 2008; Zhu et al., 2010). (page 5278). Just as in natural ecosystems, interconnected entities form symbiotic relationships to assure survival and resource efficiency. For business, value is added as its waste byproducts, water, and energy are cycled back into the overall production stream of local region (Geng and Doberstein, 2008). Such a closing of the loop results into higher conservation of natural resources and lower disposal and production costs. (page 5282) |
| 42 | Ghisellini, Cialani, & Ulgiati (2016, p. 4) | Circular economy mainly emerges in the literature through three main “actions”, i.e. the so called 3R's Principles: Reduction, Reuse and Recycle. The Chinese CE promotion Laws define CE “a generic term for the reducing, reusing and recycling activities conducted in the process of production, circulation and consumption”. |
| 43 | Goldberg (2017, p. 491) | In the inﬂuential Ellen MacArthur Foundation Report, Towards the Circular Economy (EMF 2012, 7), the authors deﬁne the circular economy as an industrial system that is “restorative and regenerative by intention and design . . . It replacesthe ‘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. |
| 44 | Haupt, Vadenbo, & Hellweg (2017, p. 615) | 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 (Ellen MacArthur Foundation 2013; EEA 2014). |
| 45 | Hislop & Hill (2011) | The circular economy represents a development strategy that maximises resource efficiency and minimises waste production, within the context of sustainable economic and social development |
| 46 | Hobson (2016, p. 2) | 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 (Ellen MacArthur Foundation 2013b: 2; see also Aldersgate Group, 2012; Ellen Macarthur Foundation, 2013a, 2014; Lee et al., 2012). |
| 47 | Hultman & Corvellec (2012, p. 2414) | Enabled by the evolution of applied industrial ecology, it is increasingly possible to use waste as input in production processes (Commoner, 1997; Ehrenfeld, 1997; Erkman, 1997; Frosch, 1992; Harper and Graedel, 2004). In such circular material management, recycling is a complement to and even replacement for the extraction of ‘virgin’ materials. European Union policy refl ects the shift from waste as problem to waste as resource (Corvellec and Hultman, 2012; Watson, 2009). EU waste and environmental policy is effected through the European Waste Hierarchy (EWH) (EC, 2008a). |
| 48 | Ellen MacArthur Foundation (2012, p. 7) | A circular economy is 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. |
| 49 | Iung & Levrat (2014, p. 16) | The circular economy is a generic term materializing an economic concept that fits in the context of sustainable development and based on the concepts of green economy, usage (functionality) economy and industrial ecology. In that way, the conventional entire life cycle artefact phases (Beginning-of-Live BOL, Middle-of-Life MOL, End-of-Life EOL) has to be reconsidered for replacing the EOL with restoration, shift towards the use of renewable energy, eliminates the use of toxic chemicals (return to the bio-sphere), and aims for the elimination of waste. In that way, the maximum value could be extracted from restoration and recycling (less energy and cost efficient than producing everything from scratch reused multiple times) [13]. Thus, circular economy implies an extended vision for sustainable manufacturing assuming that sustainability is achieved thanks to the cyclical nature of eco-systems. It leads to rethink how the industrial systems must be designed in order to establish not only interactions between these systems but also with the natural environment (Figure 2). It has to be seen as a concretization of industrial symbiosis (e.g. the symbiosis of Kalundborg [14]). This symbiosis is an illustration of the way from a linear to a circular economy. |
| 50 | Jiao & Boons (2014, p. 21) | In 2009, the Circular Economy Promotion Law was put into effect. In the Law, CE was defined as a holistic concept covering the activities of ‘reduce, reuse, and recycle’ in the process of production, circulation, and consumption. |
| 51 | Jones et al. (2013, p. 1) | As described by Jones et al. (2011), in a circular economy material loops need to be closed by direct recycling of pre-consumer manufacturing scrap/residues (e.g. steel slags), urban mining of post-consumer End-of-Life products (e.g. recovery rare earth metals from electronic waste), and land mining of historic (and future) urban waste streams (Fig. 1). In all three cases the need for energy and carbon intensive mining of primary materials can be reduced (Ayres, 1997). |
| 52 | Lehtoranta, Nissinen, & Mattila (2011, p. 1868) | In 2002, the ‘circular economy’ (CE) concept was accepted as a new development strategy by the central government (Yuan et al., 2006). CE aims at a closed-loop flow of materials, energy, and waste. It relies mostly on the same principles that industrial ecology applies. China launched an industrial park-wide ISO 14001 demonstration programme in 1999 and an EIP demonstration programme in 2000 (Chiu and Yong, 2004; Fang et al., 2007; Shi et al., 2010).  |
| 53 | Li, Bao, Xiu, Zhang, & Xu (2010, p. 4274) | The concept of circular economy broadly accepts that an economic growth and development system to integrate economy with resources and environmental factors is based on the material metabolism mode of ‘‘resource-product-regenerated resource’’, which incorporates a mechanism of efficient resource use and waste stream feedback, while its metabolism is compatible with the whole ecosystem. For the system, the reduction of resources, energy, and waste stream through the lifecycle of products and the increase in economic output and effectiveness can be achieved simultaneously by improving resource productivity (or eco-efficiency). There are three principles of circular economy, namely to reduce, to reuse and to recycle. And it is generally achieved at three levels. At the level of enterprises, circular economy mainly focuses on cleaner production. At the regional level, circular economy emphasizes structuring a substance recycling eco-industrial park. At the national level, circular economy represents a new pattern of economic operation and aims to create a recycling oriented society.  |
| 54 | Lieder & Rashid (2016, p. 37) | In line with eco-industrial development CE is understood as “realization of closed loop material flow in the whole economic system” (Geng and Doberstein, 2008). In association with the so called 3R principles (reduction, reuse and recycling) “the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases” (Yuan et al., 2006). Taking into account economic aspects CE can also be defined as “an economy based on a spiral-loop system” that minimizes matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress” (Stahel, 1982). For this paper, the relevant CE definition is the one of “an industrial economy that is restorative or regenerative by intention and design” (Ellen Macarthur Foundation, 2013). This definition is more comprehensive as it considers both the environmental and economic advantages simultaneously under the notion of regenerative performance requiring high quality circulation of technical nutrients while ensuring safe entry of bio nutrients in the biological sphere.  |
| 55 | Linder, Sarasini, & van Loon (2017, p. 545 ff.) | Circularity metrics are useful for empirically assessing the effects of a circular economy in terms of proﬁtability, job creation, and environmental impacts. The ultimate goal of a circular economy is sustainable development (Bonciu 2014;Kopnina 2014; Mathews et al. 2011; Qiao and Qiao 2013;Lowe 2015). A shift to a circular economy presents the challenge of recirculating direct and indirect material ﬂows in a manner that can promote eco-effectiveness (Webster 2013). The shift requires changes at the micro level (individual companies and consumers), meso level (eco-industrial parks), and macro level (city, province, region, and nation) (Geng et al. 2016a; Ghisellini et al. 2016; Qiao and Qiao 2013; Geng et al. 2009;Geng and Doberstein 2008). Micro-level activities that can support this change include eco-design, waste minimization, cleaner production, environmental management systems, product-life extension, new business models, and new modes of consumption. Three material recirculation strategies (reuse, remanufacture, and recycle) that seek to transform the way manufactured goods are produced and consumed have been identiﬁed. |
| 56 | Liu & Bai (2014, p. 145) | In a circular economy, the waste from factories would become a valuable input to another process—and rather than disposing of defunct products, they could be repaired, reused or upgraded (Preston, 2012). |
| 57 | Liu, Li, Zuo, Zhang, & Wang (2009, p. 265) | China’s leadership, inspired by Japanese and German Recycling Economy Laws, has formed a Circular Economy (CE) initiative in order to decouple the economic growth from environmental degradation, as well as build an environmental-friendly and resource-saving society. ‘‘The CE in practice’’ aims at realizing waste minimization, environmental conservation, energy efficiency and economic development simultaneously, so it equals to a package of the all-round, systematic strategies and tools approaching the goals mentioned above. ‘‘3R’’ principle – reduction, reusing, and recycling of materials and energy – are often cited to describe the three possible approaches in practice. However, ‘‘the CE in theory’’ belongs to the field of ecological economics which owns the theoretical premise that the economic system is an open subsystem of the earth’s ecological system with limited resource and environment capability. As the unbalanced material exchange between the ecosystem and the socioeconomic system have taken place on the stage of industrialization, the circular economy defines its mission as solving the problems from the perspective of reducing the material flux and making the material flow balanced between the ecosystem and the socioeconomic system.  |
| 58 | Mathews & Tan (2011, p. 438) | To achieve those goals, China is specifying a range of means, such as closing down inefficient factories and power plants—but also including the implementation of circular economy measures, through interconnecting the chains of resource and energy utilization. In this approach, wastes from one process can be captured and used as raw material for another, with energy generation being shared along the value chain, as an explicit developmental goal. |
| 59 | McDowall et al. (2017, p. 657-658) | In summary, China’s approach to the CE reﬂects a greater concern with industrial production, water, pollution, and places greater attention to scale (through a multilevel system of experimentation under hierarchy) and place (through incorporation of CE ideas into land-use planning). CE policy is framed as part of a wider response to the environmental challenges created by rapid growth and industrialization. Europe’s conception of the CE has a narrower environmental scope, focusing on waste and resources, with little regard for pollution, and Europe’s view is largely silent on issues of scale or place. Europe’s CE policies are framed in economic as much as environmental terms, focusing on the potential for resource efﬁciency to boost competitiveness. |
| 60 | McKinsey & Company (2015) | If European leaders decided to shift toward a more circular economy, managing the transition would have to be a top priority. A circular economy could greatly benefit the environment and boost competitiveness and resilience. A circular economy would decouple economic growth from resource use. Across the three study sectors, carbon emissions would drop as much as 48 percent by 2030 (31 percent on the current development path) and 83 percent by 2050 (61 percent on the current development path), compared with 2012 levels. Electric, shared, and autonomous vehicles, food-waste reduction, regenerative and healthy food chains, passive houses, urban planning, and renewable energy would be the principal sources of emission reduction across the three sectors. |
| 61 | Mendoza, Sharmina, Gallego-Schmid, Heyes, & Azapagic (2017, p. 526) | The concept of the circular economy (CE) has emerged in recent years in response to the need for decoupling economic growth from resource consumption and environmental impacts (EC 2011; EMF 2014). Aiming to maximize resource efﬁciency, it represents an alternative to the current linear take-make-use-dispose economic model. The CE concept rests on the following three fundamental principles (EMF 2012): (1) preserving and enhancing natural capital by controlling ﬁnite stocks and balancing renewable resource ﬂows; (2) optimizing resource yields by circulating products, components, and materials at the highest utility and value at all times within technical and biological cycles; and (3) fostering system effectiveness by revealing and designing out negative externalities. |
| 62 | Mirabella, Castellani, & Sala (2014, p. 29) | Moreover, industrial ecology concepts such as cradle to cradle and circular economy have been considered leading principle for eco-innovation, aiming at “zero waste” society and economy where wastes are used as raw material for new products and applications. In fact, closed systems are the basis of so-called industrial symbiosis, in which the goal is to use wastes from one sector as an input for other sectors. |
| 63 | Moreau, Sahakian, van Griethuysen, & Vuille (2017, p. 498) | 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, optimises resource yields, and minimises system risks by managing ﬁnite stocks and renewable ﬂows. It works effectively at every scale.In light of the environmental consequences of linear production and consumption processes, the circular economy (CE) is gaining momentum as a concept and practice, promoting closed material cycles by focusing on multiple strategies from material recycling to product reuse, as well as rethinking production and consumption chains toward increased resource efﬁciency. Yet, by considering mainly cost-effective opportunities within the realm of economic competitiveness, it stops short of grappling with the institutional and social predispositions necessary for societal transitions to a CE. |
| 64 | Mulrow, Derrible, Ashton, & Chopra (2017, p. 559) | As a concept, the circular economy (CE) is being discussed and practiced at scales ranging from the individual product or ﬁrm to global supply chains and the entire globalized economy. Moreover, CE practices hold consequence not only for environmental impact, but also for economic performance, human well-being, and cultural shift toward a sustainability paradigm (Geng and Doberstein 2008; Geng et al. 2012, Hobson2016). The Ellen MacArthur Foundation (EMF) (EMF 2013), a UK-based charitable organization, has proposed three principles of a CE: (1) preserve and enhance natural capital; (2) optimize resource yields; and (3) foster system effectiveness. These principles are well deﬁned, but also broad enough for almost any entity to adapt for its own purposes and operations. |
| 65 | Murray, Skene, & Haynes (2017, p. 1) | The circular economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being |
| 66 | Naustdalslid (2014, p. 303) | CE may be seen as a system for production and consumption, which aims at balancing economic growth and development with environmental and resource protection, and has also been explained as a strategy for ‘decoupling economic growth from resource consumption’, and hence secure continued economic growth without destroying the environment (Zhu 2008). The concept is inspired by industrial ecology and practical efforts of resource recovery through recycling and reuse of materials in industrial production. But the concept is also linked to the wider social and economic system by including household and other consumption refuse items in the total recycling system at a local, regional, and finally at a national, levels.  |
| 67 | Ness (2008, p. 291) | By organising economic activities in a closed loop of materials, the CE policy promotes harmony between the economic system and the ecosystem (CCICED 2003). This promotes new types of industrialisation, including ‘product and service design to promote reduce, reuse and recycling of materials’ and ‘sustainable product and service design’. In this regard, Stahel (1982) developed a conceptual and methodological framework of great value to planning and implementing a more CE in China, based on product life extension, the service or functional economy, and the notion of products as service carriers. Thus, improving resource efficiency is an important element of the CE (the subject of research by the China Research Centre for Economic Transition) and of a pilot study to develop and implement the policy within the city of Guiyang (Kuhndt et al. 2007).  |
| 68 | Ness & Xing (2017, p. 572 ff.) | The CE, though, seeks to have no net impact on the environment, by restoring any damage done in resource acquisition while minimizing waste generated during the production and life cycle of products. Moreover, it has been claimed that CE approaches will generate jobs and improve competitiveness, while fostering energy savings and reducing GHG emissions (EC 2015b). The objective of decoupling economic growth from re-source consumption is at the heart of the CE, according to Gregson and colleagues (2015), reﬂected in the emphasis on resource efﬁciency. In the CE, reuse and remanufacture conserve more value than recycling (Stahel and Reday-Mulvey 1981). Most recycling is down cycling, with reduced quality and value (Braungart et al. 2007). It is not only important to use resources and goods more efﬁciently, but also to limit unnecessary demand—reduce or prevent in the 3R’s waste hierarchy (Stahel 1997; Cooper 2005). The circular economy (CE) concept has emerged as a way to obtain more value from resources while reducing material throughput. It involves closed-loop and cooperative approaches, reuse, adaptation, resource stewardship, stock management, sharing, and other new business models. |
| 69 | Niero, Hauschild, Hoffmeyer, & Olsen (2017, p. 743) | The circular economy, deﬁned asa restorative or regenerative industrial system by intention and design (EMF 2013), has recently been proposed as a solution for this challenge by the European Commission (EC) (EC 2015). |
| 70 | OECD (2011, p. 20) | Improving resource productivity through sustainable materials management requires integrated life-cycle based policies for waste, materials and products, such as circular economy or 3R related initiatives, integrated supply chain management, and the use of instruments aimed at stimulating technological change. It also implies internalising the costs of waste management into prices of consumer goods and of waste management services; and ensuring greater cost-effectiveness and full public involvement in designing measures. |
| 71 | OECD (2016) | With an expected global population of 9 billion by 2030, including 3 billion middle-class consumers, future consumption demand will create unprecedented pressure on natural resources. The Forum reflected on the importance of the “circular economy” in decoupling economic growth and job creation from the use of natural resources. Turning the ambition of the SDGs into reality will require robust data to capture progress, ensure effective monitoring and provide evidence to inform decision making. |
| 72 | OPAi & MVO Nederland (2014) | A circular economy is an industrial economy, which has resilience as intention and replaces usage by using. The circular economy is based on closing loops and (where possible, infinitely) extending cycles |
| 73 | Park & Chertow (2014, p. 47) | Along with the notion of a closed-loop system, circular material economies, and sustainable materials management, the resource-based paradigm is based on the view that what we formerly perceived as wastes should instead be considered to be potential resources until determined otherwise. Table 1 summarizes the core idea of the resource-based paradigm as differentiated from the waste-based one. |
| 74 | Pin & Hutao (2007, p. 24) | However, circular economy actually requires organizing economic activities to form a feedback flow of “resources- products-regenerative resources” with the characteristics of low exploitation, high utilization, and low emission. All the substance and energy can be utilized reasonably and enduringly during the incessant economic circulation to reduce the influence on natural environment caused by economic activities as little as possible.  |
| 75 | Pingjing, Fan, Hua, & Liming (2013, p. 147) | The circular economy is a generic term for an industrial economy that is, by design or intention, restorative, and in which material flows are of two types: biological nutrients (which are designed to re-enter the biosphere safely) and technical nutrients (which are designed to circulate at high quality without entering the biosphere). The term encompasses more than the production and consumption of goods and services, including a shift from fossil fuels to the use of renewable energy and the role of diversity as a characteristic of resilient and productive systems.  |
| 76 | PRC (2008, p. 1) | 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. The term “reducing” as mentioned in these Measures refers to reducing the consumption of resources and the production of wastes in the process of production, circulation and consumption. The term “reusing” as mentioned in these Measures refers to using wastes as products directly, using wastes after repair, renewal or reproduction or using part or all wastes as components of other products. The term “recycling” as mentioned in these Measures refers to using wastes as raw materials directly or after regeneration. Developing a circular economy is an important strategy for the economic and social development of the state. The development of a circular economy shall follow the principle of giving priority toreduction under the precondition of being technically feasible, economically rational and good for saving resources. |
| 77 | Prendeville, Sanders, Sherry, & Costa (2014, p. 3) | Circular economy definitions consider economic growth, promote renewable energy, the notion of ‘restoration’ and the ‘replenishing’ of resources. Importantly, the concept of closed loop can also be identified within circular economy definitions. This aligns with the Ecodesign Centre’s view of the circular economy as a broader agenda than that of closing the loop.  |
| 78 | Preston (2012, p. 1) | A ‘circular economy’ (CE) is an approach that would transform the function of resources in the economy. Waste from factories would become a valuable input to another process – and products could be repaired, reused or upgraded instead of thrown away. |
| 79 | Reh (2013, p. 122) | Laws of process integration also apply for the largest scale of possible circular economy, our idealized technically shaped environment with the sectors of industry, transportation and living (Reh, 2006). These laws are mass and energy conservation “more in-more out”, entropy based pinch methods, optimization and resource conservation network (RCN) (Foo, 2012). The more gaseous, liquid and solid resources of any kind are being used, the more off-gas, waste water and solid residues following varying times of use have to be treated to protect the natural environment. The 3R principle: Reduce, Reuse and Recycling, may reduce the stress on different global resources considerably. |
| 80 | Richa, Babbitt, & Gaustad (2017, pp. 715–716) | Such a strategy can be informed by circular economy (CE) principles such as reuse and recycling (Ramoni and Zhang 2013). A circular or closed-loop economy aims to eliminate waste by cycling materials and products within the system to achieve resource and energy efﬁciency as well as proﬁtability (EMF 2013; McKinsey & Company 2014; Allwood et al. 2011, 2012; Gregson et al. 2015; Ghisellini et al. 2016). |
| 81 | Saidani, Yannou, Leroy, & Cluzel (2017, pp. 1–2) | To support both economic growth and sustainable resource management, the circular economy paradigm seems to be a great opportunity for industrial practitioners. Indeed, the promises and benefits from circular practices have been comprehensively discussed in literature (EMF, 2013b; CIRAIG, 2015; MGI, 2015; Lacy, 2015; Ghisellini et al., 2016). The circular economy is seen as a restorative solution with the potential to eliminate waste (EC, 2015a; EEA, 2015; EEA, 2016). Also, it could both secure Europe’s competitiveness and ensure benefits from the three piliars of sustainable development (Banaitė, 2016 Sauvé et al., 2016; Geissdoerfer et al., 2017). Particularly, using closed-loop approaches mitigate manufacturers' dependency on virgin materials and decrease price volatility (Kiser,2016). |
| 82 | Sakai et al. (2011, p. 87) | It is generally recognized that reduce, reuse, and recycle (3R) and waste management policies form the basis of developing a material cycles society. However, 3R and waste management policies differ among countries owing to each country’s particular circumstances or political strategies. |
| 83 | Schut, Crielaard, & Mesman (2015, p. 639) | Foundation, the international think tank that is commonly recognised as being an authoritative source for circular concepts (see ): “The circular economy is an economic and industrial system that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.” This definition indicates that material flows fulfil an important role in the body of thought concerning circular economy. But it is also about a new way of thinking about economic principles including ‘value’ and about business models that give shape to the desired value creation. |
| 84 | Sihvonen & Ritola (2015, p. 639) | In Europe, a new zero-waste program introduces new recycling targets and envisions a circular economy where products and materials serve multiple lifecycles in various formats, and where economic growth is decoupled from the environmental degradation. |
| 85 | Skene (2017, p. 1) | According to the definition in the Law to Promote Circular Economy in the People’s Republic of China, the circular economy is the integration of activities of reduction, reuse and recycling during production, exchange and consumption (Shen and Qi 2012). The Ellen MacArthur Foundation defines the circular economy as an industrial system that is restorative or regenerative by intention and design. It replaces the ‘end of-life’ concept with restoration, moves 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 (EMF 2012). Other authors also observe that the circular economy is not merely a preventative approach, reducing pollution, but also aims to repair previous damage (Cooper 1999; Nakajima 2000). |
| 86 | Song, Li, & Zeng (2015, p. 200) | In a zero waste system, material flow is circular, which means the same materials are used again and again until the optimum level of consumption. No materials are wasted or underused in circular system (Murphy and Pincetl, 2013; Mason et al., 2003; Colon and Fawcett, 2006). Therefore, at the end of their lives products are reused, repaired, sold or redistributed within the system. If reuse or repairs are not possible, they can be recycled or recovered from the waste stream and used as inputs, substituting the demand for the extraction of natural resources.  |
| 87 | Stahel (2013, p. 4) | Turning the linear industrial economy into a loop or circular economy is, by definition, reducing the economic importance of resource extraction and waste management, and also reducing the environmental impairment caused by these industrial sectors. This change of focus from a linear throughput to a stock management opens opportunities in three loops of different characteristics, which are described in this section and shown graphically in figure 1: (i) a reuse and remarketing loop for goods, (ii) a loop of product-life extension activities of goods, and (iii) a recycling loop for molecules (secondary resources). |
| 88 | Stahel (2014) | If we define a circular economy as all economic activities to extend the service-life of goods, components and materials, through reuse and re-marketing, repair, re-manufacturing and technological updating of goods, it has always existed: reusable bottles, second-hand markets, repair and renovation of buildings and infrastructure. Among corporations, the repair and serial re-manufacturing of combustion engines and automotive components, of machine tools and jet turbines, railway rolling stock and aircraft has existed since the early days. |
| 89 | Stahel (2016, p. 6 ff.) | In less-developed countries, the circular economy of reusing goods and recycling materials is commonplace. The Loop Economy starts at the end of a goods' utilisation. The objective of the Loop (or circular) Economy is to bring goods and molecules back into new use in a grave-to-craddle approach. This reduces both 'end of pipe' waste volumes (after utilisation) and the demand for virgin resources at the 'beginning of pipe' (base material production).  |
| 90 | Stahel & Clift (2016, p. 140) | The circular economy is based on value preservation, not value added. The basic elements are shown schematically in Fig. 7.1. The Reuse Loop includes secondhand markets (from garage sales and flea markets to eBay) as well as commercial and private reuse of goods (e.g. refilling of beverage containers, reuse and resale of garments). These activities are usually carried out locally. Loop 1, labelled Remanufacturing, includes repair, remanufacturing and “upgrading” to meet new technological standards or to meet new fashion expectations (Smith and Keoleian 2004). Remanufacturing may be a local activity (e.g. refurbishing of domestic appliances or cars) or may be carried out via regional service centres. Loop 2 represents recycling in which, rather than repairing or re-using manufactured goods and components, the product is reprocessed to recover secondary materials for return to the same use. Reprocessing may be a regional activity or may be part of a global supply system. Reprocessing includes operations such as recycling of paper and plastics, re-refining of fluids such as lubrication oils (Clift 2001) and, where practical, depolymerisation of polymers (Clift 1997). Some end-of-life goods and materials may go to other uses, such as export for re-use in other locations or “cascading” into lower specification applications (downcycling) including energy recovery, or may leak from the economic system as waste |
| 91 | Su, Heshmati, Geng, & Yu (2013, p. 215) | In another word, facing existing environmental problems and resource scarcity, they called for a need to contemplate earth as a closed economic system: one in which the economy and the environment are not regarded by linear inter-linkages, but by a circular relationship (Boulding, 1966). Through an analysis on the relationship between economic and natural systems, they proposed a closed-loop of material flows in the economy, which was named, circular economy.  |
| 92 | Su et al. (2013, p. 69)  | Yet, under the first law of thermodynamics where total energy and matter remains constant in a closed system, the open-ended system could be and should be converted to a circular system when considering the relationship between resource use and waste residuals. In another word, facing existing environmental problems and resource scarcity, they called for a need to contemplate earth as a closed economic system: one in which the economy and the environment are not regarded by linear inter-linkages, but by a circular relationship (Boulding, 1966). In order to implement the CE, the 3R principles (Reduction, Reuse, and Recycle) have been embedded in production and consumption since the flow of materials and energy penetrates in both areas (Zhu and Qiu, 2007).  |
| 93 | Thomas & Birat (2013, p. 5) | Industrial Ecology, 3R’s principles (Reduce, Reuse, Recycle) or Sustainable Design are concepts that should lead to this idea of a “circular or closed loop economy”. It means that production or resource companies should be collaborating together to exchange materials, waste, energy and water so that new products can be designed out of waste. A closed looped economy is defined material by material and process industry by process industry and this controls the extent to which this ideal organization can be achieved and when: practically, for a highly recyclable material like steel, a closed loop economy can be approached only when the production of steel peaks so that the amount of end of life material and the level of demand become close enough.  |
| 94 | Tisserant et al. (2017, p. 628-629) | The circular economy (CE) concept is gaining weight as an alternative to the make-use-dispose paradigm (EC 2011). The CE concept aims at extending the useful life of materials and promotes recycling to maximize material service per resource input while lowering environmental impacts and resource use. The CE concept is closely related to the 3R Principles: Reduce, Reuse, and Recycle (Ghisellini et al. 2016; Lieder and Rashid 2016). |
| 95 | TNO (2013) | A circular economy is an economic and industrial system based on the reuse of products and raw materials, and the restorative capacity of natural resources. It attempts to minimize value destruction in the overall system and to maximize value creation in each link in the system |
| 96 | UNEP (2011, p. 49) | Since 2006, China has run nationwide mandatory energy saving and pollution reduction programmes to address what Chinese researchers refer to as ‘low resource efficiency’ and ‘high pollution levels’. The so-called ‘circular economy’ strategies were implemented to address the linear process from primary resources to products and further to postconsumption wastes. In addition to the key ‘circular economy’ policies such as the Law on Circular Economy Promotion, other measures included the Law on Cleaner Production Promotion, management and taxation policies for comprehensive utilization of wastes and used resources; Assessment Standards to evaluate ecoindustrial parks and set out codes for their establishment; green procurement by governmental agencies and public institutions; and investment policies for piloting the circular economy, including a special fund to support pilot projects. |
| 97 | van Buren, Demmers, van der Heijden, & Witlox (2016, p. 1) | Replacing the linear economy—source, use and waste—with a “circular” economy offers such an alternative. In this circular system materials are applied in products in such a way that they can be recovered and reused almost endlessly. It prevents that “value” (i.e., resources) from just exiting the economy. The circular system can be organized to create sustainable value by minimizing the environmental impact and by inducing new economic activities (labor). Unlike the current economy, which is largely based on the principle “take-make-waste” (linear economy), the focus point in a circular economy is to not unnecessarily destroy resources. This implies far more than the reduction of waste through recycling [2], stresses the following focal points: reducing the consumption of raw materials, designing products in such a manner that they can easily be taken apart and reused after use (eco-design), prolonging the lifespan of products through maintenance and repair, and the use of recyclables in products and recovering raw materials from waste flows. A circular economy aims for the creation of economic value (the economic value of materials or products increases), the creation of social value (minimization of social value destruction throughout the entire system, such as the prevention of unhealthy working conditions in the extraction of raw materials and reuse) as well as value creation in terms of the environment (resilience of natural resources). |
| 98 | Veleva, Todorova, Lowitt, Angus, & Neely (2015, p. 375) | A main goal of industrial ecology is to change the current linear nature of our industrial systems and move to a circular system “where the wastes are reused as energy or raw materials for another product or process.” Within the broader field of industrial ecology, which examines the flow of physical resources through systems at different scales, the sub-field of industrial symbiosis (IS) focuses on these flows at the level of industrial clusters and industrial parks. |
| 99 | Wang, Lassoie, Dong, & Morreale (2013, p. 227) | As to China, Industrial symbiosis is implemented under the philosophy of “circular economy” (CE) (Geng et al., 2009; Li et al., 2010). CE focuses on cleaner production (CP) in enterprise level, industrial substance reuse and recycling in regional level or industrial park level, and creating a recycling oriented society in national level (Li et al., 2010). Iron/steel industry is a key field of circular economy practice, after the cleaner technologies upgrading from the late 1990s to the early 21st century, since 2005, circular economy has been promoted widespread, and by 2009, 10 iron/ steel enterprises had become the national circular economy pilots.  |
| 100 | Wang, Shi, Hu, Xu, & Sun (2010, p. 146) | On that point, the central government has started to give the same priority in policy making on environmental sustainability as on economic viability through a new “circular economy” strategy aimed at transforming the current “linear” economy into a “circular” one (NCPC 2004). |
| 101 | Wen & Meng (2015, p. 211) | In the face of limited resources and high energy consumption, China implemented a new national strategy for CE in 2005, which aimed to obtain high resources and energy efficiency by means of “reduce, reuse and recycle” (Yuan et al., 2006; Zhang et al., 2008). |
| 102 | Wijkman & Skånberg (2016, p. 5) | The proposition is that a circular economy, where products are designed for ease of recycling, reuse, disassembly and remanufacturing should replace the traditional, linear ’take, make & dispose’ model that has dominated the economy so far. This, no doubt, is a major prerequisite to stay within the Planetary Boundaries. |
| 103 | Winkler (2011, p. 243) | Recently, it has become increasingly important to shift businesses from participating in a flow economy (producing high amounts of useless waste) to participating in a circular economy, where most used products, scraps, residual materials, and other waste materials are collected, conditioned, and reused or recycled to improve material efficiency and profitability. |
| 104 | WRF (2012) | The concept “circular economy” describes an industrial economy in which material flows keep circulating at a high rate (in terms of quality, property, function, range of use) without the materials entering the biosphere, unless they are biological nutrients |
| 105 | Xin, Han, & Hu (2014, p. 1) | This paper puts forward an ideology of the recycling of retired or scrap weaponry and equipment based on 3R, by introducing 3R principle which is the core ideology of circular economy. |
| 106 | Yan & Wu (2011) | The circular economy is such kind of economic mode which takes the efficient and circular use of resources as its core , the “3R”( reduce, reuse and recycle) as its principles, is characteristic with closed-loop material cycle and cascade of energy use, and runs according to the way of natural material circulate and the energy flow. |
| 107 | Yap (2005, p. 13) | ‘Circular economy’ (Xunhuan Jingji), also called the ‘recycling economy’, is described as a ‘scientific development model where resources become products, and the products are designed in such a way that they can be fully recycled’. |
| 108 | Yong (2007, p. 126) | With the above understanding, the circular economy defines its mission as resolving the problems from the perspective of reducing the material flux and making the material fl ow balanced between the ecosystem and the socioeconomic system. The approach includes: (1) restructuring the material flow from the linear approach to a circular approach, i.e., from the resources to the products and to the wastes, then further translating the wastes to new resources and (2) raising the efficiency of resource utilization and reducing the intensity of emissions. |
| 109 | Yuan, Bi, & Moriguichi (2006, p. 5) | Although there is no commonly accepted definition of CE so far, the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases. The “3R” principles—reduction, reuse, and recycling of materials and energy—are often cited to describe the three possible approaches in practice (Feng 2004).The approach is expected to achieve an efficient economy while discharging fewer pollutants. The strategy requires complete reform of the whole system of human activity, which includes both production processes and consumption activities. |
| 110 | Zhang et al. (2009, p. 264) | Circular economy is a mode of economic development based on the circulation of resources. CE requires compliance with ecological laws and sound utilization of natural resources to achieve economic development, i.e., it is essentially an ecological economy that follows the principles of ’’reducing resource use, reusing, and recycling’’ (Feng and Yan 2007). |
| 111 | Zhijun & Nailing (2007, p. 95) | The circular economy, which is a mode of economic development based on ecological circulation of natural materials, requires compliance with ecological laws and sound utilization of natural resources to achieve economic development. It is, essentially, an ecological economy that follows the principles of ‘‘reducing resource use, reusing, and recycling’’, with the objectives of reducing the resources that enter the production process, effecting multiple use of the same resources in different ways, and reusing waste from one facility as a resource for other facilities. In this mode, with materials going through a feedback process of ‘‘resource– product–renewed resource’’, the ultimate objective of optimum production, optimized consumption and minimum waste can be achieved in production. |
| 112 | Zhu, Geng, & Lai (2010, p. 1324) | The CE model has been implemented at three levels, namely, eco-regions at the macro-level, eco-industrial parks at the meso-level, and eco-enterprises at the micro-level (Yuan et al., 2006). CE practices encompass environmental protection requirements on reduction, reuse, and recycling (3Rs) with an emphasis on achieving the dual environmental and economic performance goals. |
| 113 | Zhu, Zhou, Cui, & Liu (2010, p. 4821) | Industrial solid waste recycling accords with the 3R rule of circular economy. This indicator reflects the level of material re-used and recycled in an enterprise. The value is a ratio of the total annual industrial solid waste recycled to the total industrial solid waste produced per year. |
| 114 | Zink & Geyer (2017, p. 593) | The concept of the “circular economy” has gained signiﬁcant traction since its introduction a half century ago (Boulding 1966). Scholars, practitioners, governments, and non-governmental organizations have recognized the apparent appeal of closing material loops, reusing and recycling industrial “nutrients” to extract their maximum value with minimum waste (Ellen MacArthur Foundation 2016; Frosch and Gallopoulos 1989; Yuan et al. 2006). There are many “schools of thought” regarding the circular economy that share a central theme, but differ in their intended outcomes and optimal implementations (Ellen MacArthur Foundation 2016). Some of these concentrate on minimizing waste and resource extraction (EC 2016a; Nansai et al. 2014), others focus on economic growth potential (Ellen MacArthur Foundation 2015; McKinsey & Company2014; Morgan and Mitchell 2015), and others on environmental impact reduction (e.g., Allwood 2014). |

Note: Additional information regarding text/visualizations considered for cording available upon request.

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1. These reference list only contains the references from the column ‘Source’ in Table 2. [↑](#footnote-ref-1)