Resources, Conservation & Recycling 153 (2020) 104553

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec

Full length article

Targets for a circular economy

Piero Morseletto

Institute for Environmental Studies (IVM), Faculty of Earth and Life Sciences, VU University Amsterdam, De Boelelaan 1087, HV, Amsterdam, the Netherlands

ARTICLE INFO

Keywords:
Targets
Circular economy targets
Circular economy governance
Circular economy strategies
Resource efficiency

ABSTRACT

The transition to a circular economy requires actions and policies. In the praxis of governance, a common way to steer the transition to a different state proceeds through the setting of targets. Thus far, no study has investigated circular economy targets in a systematic way. To bridge this gap, this study examines which targets can facilitate the transition towards a circular economy. The analysis focuses both on existing and new targets; the latter complement existing targets which are limited to a few discrete cases addressing only partially the goal of a more circular economy. A framework based on 10 common circular economy strategies (i.e. recover, recycling, repurpose, remanufacture, refurbish, repair, re-use, reduce, rethink, refuse) is applied to scrutinise the selected targets. The study clarifies that existing targets for recovery and recycling do not necessarily promote a circular economy, though they are the most commonly applied targets so far. Because of lack of efficacy of recovery and recycling, targets should instead favour other more powerful circular economy strategies. In relation to these, the study looks into new and existing targets showing how they can reduce waste, increase efficiency, close production loops, and maximise retention of the economic value of materials and products. In particular, the study proposes an expanded set of brand new targets for the transition to a circular economy together with a fresh view on targets aimed at scholars and decision-makers alike.

1. Introduction

A circular economy (CE) can be defined as an economic model aimed at the efficient use of resources through waste minimisation, long-term value retention, reduction of primary resources, and closed loops of products, product parts, and materials within the boundaries of environmental protection and socioeconomic benefits. A CE has the potential to lead to sustainable development, while decoupling economic growth from the negative consequences of resource depletion and environmental degradation (Murray et al., 2017; Babbitt et al., 2018; Hofmann, 2019).

Despite the relevance of CE in the current policy and economic debate, the concept of a CE remains open to interpretations (Ghisellini et al., 2016; Kalmykova et al., 2018; Laurenti et al., 2018; Reike et al., 2018). Scholars have classified and synthesised scattered theoretical and empirical studies along various criteria: by origins, principles, and models/implementations (e.g. Ghisellini et al., 2016; Kirchherr et al., 2017; Kalmykova et al., 2018; Prieto-Sandoval et al., 2018; Homrich et al., 2018); by CE business models (e.g. Lewandowski, 2016; Nußholz, 2017; Lüdeke-Freund et al., 2019; Manninen et al., 2018; Hofmann, 2019); by drivers and barriers (e.g. Ranta et al., 2018; De Jesus and Mendonça, 2018; Sousa-Zomer et al., 2018); and by methods of implementation (e.g. Lieder and Rashid, 2016; Masi et al., 2017; Reike et al., 2018). These meta-studies show that the governance of the transition to a CE is an emerging field of research, wherein governance can be defined as an ensemble of programmatic and decision-making activities guiding organisations towards desired aims and objectives.

This study focuses on targets because of their relevance in governance. Targets play a fundamental role in steering transitions from one state to another (Parris and Kates, 2003; Becker et al., 2013; Rotmans et al., 2001). An example is targets for the transition from a low to a high level of recycling in the economy. Thus far, no study has investigated CE targets in a broad and systematic way, at least in the literature available in English. Studies on CE targets predominantly focus on existing targets (i.e. those adopted by governments and organisations), look at specific solutions (e.g. targets on recovery materials), have a specific geographical focus (e.g. in countries or regions), and refer to sectors or industries (e.g. energy or waste management), often for comparative purposes (e.g. Bahn-Walkowiak and Steger, 2015; McDowall et al., 2017; see also Table 1). Furthermore, targets are rarely analysed from a governance perspective. Consequently, the role of targets in supporting the implementation of CE is here investigated by asking: which targets can facilitate a transition towards a CE, and how do these targets achieve this?

This question has three methodological implications for this study. First, the necessity of investigating not only existing CE targets but also

E-mail addresses: piero.morseletto@vu.nl, piero.morseletto@gmail.com.

https://doi.org/10.1016/j.resconrec.2019.104553
Received 2 October 2018; Received in revised form 13 October 2019; Accepted 20 October 2019
0921-3449/ © 2019 Elsevier B.V. All rights reserved.

Table 1
Main studies on CE targets by main area/purpose of analysis (Bahn-Walkowiak and Steger, 2015; BioIS, 2013; Bjørn et al., 2017; De los Rios and Charnley, 2017; EEA, 2016; McDowall et al., 2017; Qi et al., 2016; Repo et al., 2018; Smol et al., 2015; Sakai et al., 2011; Su et al., 2013).

study ▼ / area/ object of the targets ▶	recycling	resources efficiency	waste recovery/reduction	energy recovery	water recovery	emission reduction	design	context / purpose of analysis
Bahn-Walkowiak & Steger (2015)	●	●	●	●	●	●		Sectors and countries (USA, Japan, South Korea, Europe)
BioIS (2013)	●	●	●	●				Sectors and material (plastic in the EU)
Bjørn et al. (2017)	●	●			●	●		Corporations (in several countries)
De los Rios, I. C., & Charnley, F. J. (2017).	●	●	●	●		●	●	Corporations (in several countries)
EEA (2016)	●	●	●	●	●	●	●	Sectors and countries (EU and European countries)
McDowall et al. (2017)	●	●	●	●	●	●	●	Sectors and countries (China and EU)
Qi et al. (2016)	●	●	●	●	●	●		Sectors and countries (China)
Repo et al. (2018)	●	●	●	●	●		●	Sectors and countries (EU)
Smol et al. (2015)	●	●	●	●	●			Sector: Building/constructions
Sakai et al. (2011)	●	●	●	●		●		Sectors and countries (Japan, South Korea, USA, EU)
Su et al. (2013)	●	●				●		Sectors (pilot cities in China)

possible or advisable targets – here called new targets. Existing targets are observable in the economy; in this study, they are analysed through a review of the academic and grey literature. Instead, new targets are not yet applied in the economy; they can be divided among those already proposed by scholars and experts (and thereby become available in the literature), or brand new ones, as I propose in the present study. New targets are needed because existing are limited to a few issues (e.g. recycling, efficiency improvement) and only cover limited arrays of CE solutions, such as recyclying or efficiency (Ranta et al., 2018; Bjørn et al., 2017; Milios, 2016). However, CE goes beyond these solutions; it involves aspects like closed loops or value retention at higher levels (e.g. long-life, remanufacturing, etc.), which should be considered in a systematic analysis. In this regard, new targets are developed taking into account needs and problems in the economy, and are elaborated for reaching the attention of scholars and decision-makers.

The second implication of the research question is the need to examine targets beyond specific solutions, economic sectors, or geographical characteristics. In this sense, this study examines targets in a holistic way (i.e. in overarching terms and in a broad economic context) for assessing the role of targets in the transition to a CE in general.

The third implication is considering targets from a governance viewpoint. CE targets can be examined from many angles such as resources, business models, sectors/industries, or CE strategies. To examine targets, this study adopts this last perspective because strategies can incorporate new and existing targets regardless economic compartments or geographical connotations. Moreover, in governance terms, strategies are paths through which organisations and economic systems can guide their transformations (Nelson, 1991; Lafferty and Meadowcroft, 2000; Voss et al., 2006). Among the many CE-strategies frameworks, this study employs the framework devised by Potting et al. (2017) because it encompasses a comprehensive collection of strategies.

The remainder of the paper is structured as follows. Section 2 presents the background information on targets and the framework adopted for the analysis. Section 3 presents the methodology and Section 4 presents the results. Finally, Section 5 summarises the findings and proposes suggestions for research advancement and policy advice.

2. Background information on targets and strategies

2.1. Targets and CE targets

Although targets are omnipresent in governance, there are not many definitions of what constitutes a target. I have previously defined targets as meaningful reference values that express a desired operational policy outcome in a synthetic (often numerical) manner (Morseletto et al., 2017). Targets differ from goals. Goals are open-ended statements of what to be accomplished with no or little reference to schedules and deadlines of completion (Wheelen and Hunger, 2004). Goals tend to be broad, non-operational aims towards a desired condition, whereas targets denote operational outcomes that realise that condition. Targets play a pivotal role in governance because they provide specific direction and require a commitment to reach predetermined outcomes (Lester and Neuhoff, 2009; Boswell, 2015; Akenji et al., 2016). In addition, targets are used to motivate actors to strive for results (Hood and Lodge, 2006), and monitor advancements by providing guidance for measurement (Milios, 2016).

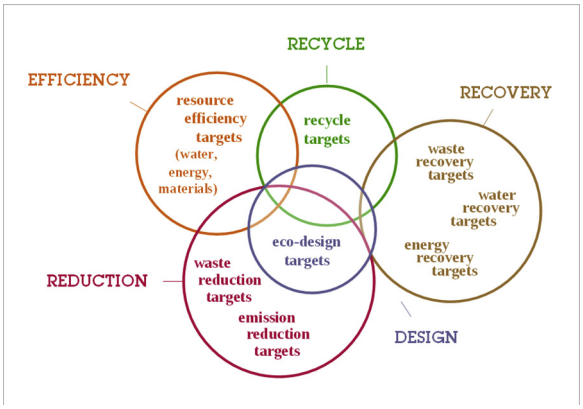

Fig. 1. Main existing CE targets by areas of application.

Governance targets help actors move forward from an existing state, while promoting a pragmatic view on what to reach. Targets are popular because they are practical, measurable, and focused on delivery (see Bevan and Hood, 2006; Lester and Neuhoff, 2009). Furthermore, targets are valued for their ability to strongly affect efficiency, which is one of the ways they can help drive the CE (Milios, 2016; Akenji et al., 2016).

There are many existing targets set by organisations to achieve a CE. These targets have been analysed in various studies, albeit rarely with a wide CE or governance perspective. Table 1 displays the main studies on CE targets (published in English) by area/object of target and context of application.

Fig. 1 provides a visual representation of the CE targets summarised in Table 1, which are also the most commonly applied targets in the economic systems. These targets can be grouped into five main areas of application: efficiency, recycle, recovery, reduction and design. In the contingent world of governance, these areas are not distinct. Overlaps occur because of their high level of interconnections, for instance, waste reduction targets can relate to material efficiency while design can have consequences for all other areas. In a heuristic spirit, this aspect is conveyed in the figure by the overlaps among the cycles that represent the areas of application of targets.

Fig. 1 and Table 1 highlight the observation that currently existing targets are concentrated in a few areas, notably, recycling, recovery, and resource efficiency. Nonetheless, a CE encompasses a wider range of strategies than recycling and recovery (e.g. reusing or refurbishing) and more possible solutions beyond efficiency (e.g. Product–Service Systems – PSS) (see Reike et al., 2018; Tukker, 2015). The narrowness of the existing targets implies that new targets are urgently required to better reflect the multifaceted reality of a CE. This suggests a differentiated approach to the analysis of existing and new targets. Existing targets can be scrutinised by examining the grey and academic literature in relation to targets and CE. Instead, new targets can be divided among those already proposed but not yet implemented (i.e. advanced by scholars and experts), and brand new ones as I propose in the present study. These targets are required to fully strengthen a CE. Proposed targets can be analysed but also re-elaborated or expanded if required; brand new targets can augment existing ones, and need to be developed by assessing the needs, benefits, problems and possible solutions of any economy striving to be circular.

2.2. CE strategies and the framework of analysis

CE targets can be examined in different ways, including the following: economic sectors, business models, material flows, (e.g. input-output across sectors), material categories (e.g. biotic materials, non-metallic minerals), typology of targets (e.g. threshold, intensity, reduction targets), long-term CE goals/outcomes (e.g. value retention, waste elimination), lifecycle areas (e.g. eco-design, material inputs), CE metrics/indicators (e.g. material flow accounting, resource duration), and CE strategies (e.g. the 3Rs: Reduce/Reuse/Recycle). From a governance perspective, this last approach is appropriate for conducting a thorough analysis of targets for several reasons. First, strategies are bundles of actions aimed at implementing CE solutions in economic systems. Second, being cross-sectoral, and involving all actors and products, strategies capture the multifaceted aspects of a CE at the macro, meso, and micro levels (i.e. global and national levels, regional and industrial parks levels, and consumers and corporations levels respectively – Zhu et al., 2010; Ghisellini et al., 2016; Kirchherr et al., 2017; Kalmykova et al., 2018). Third, multiple strategies apply targets in different governance contexts and conditions; this aspect enables verification of the transformative nature of targets in policy and organisational praxis (Tuominen and Himanen, 2007; Akenji et al., 2016).

Various studies identified CE strategies and provided useful schemes and visualisations (e.g. King et al., 2006; Jawahir and Dillon, 2007; Allwood et al., 2011; EMF, 2013; Bakker et al., 2014; Sihvonen and Ritola, 2015; Willskytt et al., 2016; Reike et al., 2018). To analyse CE targets, this study adopts the framework presented by Potting et al. (2017) because it contains a well-defined, almost complete set of 10 existing CE strategies. Other frameworks contain similar sets of strategies (i.e. Reike et al., 2018; Allwood et al., 2011; Bakker et al., 2014). In particular, the framework of Reike et al. (2018) selected identical strategies as Potting et al., with the exception of 'Re-mine' (i.e. retrieval of materials after the landfilling), instead of Rethink as used by Potting et al. (R1 in Fig. 1). Rethink seems a more relevant strategy in terms of CE (see 4.3.1) while 'Re-mine' is unusual and has been seldom applied or studied (see Reike et al., 2018; Haas et al., 2015). The other frameworks focus on material efficiency (Allwood et al., 2011) or life extension through design (specifically of laptops and refrigerators) (Bakker et al., 2014). Potting and et al.'s framework refers to products, therefore excluding materials and compounds or social aspect of CE. Nonetheless, products cover a good deal of an economy and many of the strategies can refer to materials and compounds as well (e.g. from dismissed products).

Finally, the framework by Potting et al. orders the strategies in terms of increasingly power to achieve circularity (increasing from high to low number i.e. from R9 to R0). The authors are cautious on this point and propose the hierarchy as a 'rule of thumb' because the order is not always consistent. This underlines the existence of exceptions and secondary or rebound effects, which means that the R-order is not appropriate for certain products and under certain conditions. For these reasons, the hierarchy among strategies has to be taken *cum grano salis* (i.e. with wisdom, according to the original meaning of the expression by Pliny the Elder), but still can provide a useful orientation when examining CE strategies.

In this study, the framework by Potting et al. is used to identify and systematise CE targets according to each strategy. I show how foundational CE elements such as closed loops, value retention and waste minimisation can be realized when the targets are appropriately designed.

3. Material and methods

No previous studies have examined CE targets systematically and – in particular – from a governance perspective. The first step of this research is to review the literature discussing targets and strategies to obtain an overview of existing and new targets.

The data were collected at the end of 2017 and in 2018, primarily by searching Google, Google Scholar, and Scopus databases for a combination of 'circular economy' and each of 'target/targets' and 'solutions' keywords. 'Zero waste' was also searched in combination with 'targets', having found evidence of an interaction of the two terms. The search was repeated for all possible strategies (e.g. recycle/recycling, reuse, etc.).

Because 'target' and 'strategy' are specific words in the governance lexicon and common words with multiple nuances in the English language, the preliminary results needed to do be distilled through an attentive reading of the text. The search resulted in a collection of 59 academic and 13 non-academic works (policy documents, research institute reports, etc.) in which targets were purposefully mentioned or discussed.

Next, 10 CE strategies that are or could be associated with targets were searched using Google, Google Scholar, and Scopus databases. This provided secondary data on strategies and, specifically, on targets that potentially address the qualitative and quantitative aspects of each strategy. Previous research and other material on targets collected by the author complemented the analysis; this allowed the elaboration of brand new targets on the basis of the information on different CE strategies confronted with the aims and objectives of CE and current problems in the economy.

A keywords search inevitably delineates the boundaries of an investigation. As Kalmykova et al. (2018) underline, terminologies such as 'closed-loop economy' or 'green supply chain management', 'cradle to cradle', and 'industrial symbiosis' all describe concepts that overlap with CE; not searching specifically for these terms in the main data collection phase is a limitation of this study. To compensate for this limitation, a 25 snowball sampling was used to expand the list of documents for the analysis. The data was organized according to the framework by Potting et al., in which the 10R are structured into three groups: a) useful application of materials; b) extend lifespan of products and their parts; and c) smarter product manufacturing and use (see Fig. 2).

In the following section, each group is analysed in separate subsections and targets are scrutinised in relation to every strategy. Strategies are explained starting with the original definition by Potting et al. (see Fig. 2). Owing to the numerous definitions of the Rs that exist within the discipline (see e.g. Reike et al., 2018) – where required – supplementary meanings are provided. In contrast to the original scheme by Potting et al., the analysis follows the reverse R numbering (i.e. strategies from a low to a high level of circularity). This allows the initial analysis of most diffused targets, while better emphasising the connections between strategies and targets.

4. Results and discussion

This section considers the three groups of targets in the framework: useful application of materials, extend lifespan of products and their parts, and smarter product manufacturing and use. Each group is presented in distinct subsections. These scrutinise the R-strategies that belong to each group following this scheme: first, the subsection provides a short description of a strategy; then, the subsection analyses the related targets. A brief presentation introduces each group.

4.1. Useful application of materials (R9–R8)

This group of strategies (Recovery and Recycle) relates to solid waste otherwise destined for landfill, or burned without heat recovery.

Waste is composed of organic and inorganic materials, which are also classified as biological and technical nutrients (EMF, 2013). From processing nutrients, R9-R8 strategies obtain energy (R9-Recovery) or materials (R8-Recycle). Nonetheless, energy and conversion yields rates can vary enormously according to material type and processing (BIS, 2013; EPRS, 2017); for R9-R8, yield rates are often extremely low, treatment expensive, and products' integrity destroyed. Moreover, governing waste relates to end-of-life products, and R9-R8 strategies have relatively little influence on the system of production and consumption (Potting et al., 2017). Despite this, R9-R8 is where most circular policies (and targets) are currently concentrated (Ghisellini et al., 2016; EPRS, 2017).

4.1.1. Recovery (R9)

4.1.1.1. Description. Potting et al. (2017) defines Recovery as incineration of material with energy recovery. More broadly, Recovery refers to waste that is not recycled, but that is used as a

Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	Rethink	Make product use more intensive (e.g. through sharing products or by putting multi-functional products on market).
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources
Extend lifespan of product and its parts	R3	Reuse	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date
	R6	Remanufacture	Use parts of discarded product in a new product with the same function
	R7	Repurpose	Use discarded products or its part in a new product with a different function
Useful application of materials	R8	Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	Recovery	Incineration of material with energy recovery

Fig. 2. CE strategies, from Potting et al. (2017) – colours modified.

source of energy or valuable biochemical compounds. Recovery includes several conversion processes mainly related to organic waste (see Demirbas, 2009). Following Potting et al., this study looks at incineration, which is the most diffused form of recovery for size and source range (Astrup et al., 2015).

Aside from energy recovery, the positive aspect of incineration is its complementarity to recycling, which is not always possible (see, R8 below). The downside is that incineration destroys materials/products forever (except for carbon and low-bottom ashes, which are barely usable) and encourages material wastefulness (Clark et al., 2016). Incineration requires cheap and abundant waste to ensure the return of investment of its facilities, which means that it competes for resources with other R strategies.

4.1.1.2. Analysis. A few countries have established targets to reduce municipal solid waste (MSW) through incineration – e.g., China – or targets to reduce incineration – e.g., Denmark in the 90s (Lauber and Ingram, 2000). However, a perfectly circular economy should tend to zero incineration. Strict interpretations of 'zero-waste' – a whole-system approach to reduce waste – preclude waste-to-energy (WTE) practices (Zaman, 2015). In a perfect system, waste does not exist. Zero percent is only an ideal, asymptotic value; even zero-waste approaches recognise that there is a percentage (up to 10%) of discards made of mixed materials, which are non-recyclable/non-compostable/non-reusable (ZeroWin, 2010). Most life-cycle-assessment (LCA) studies show that WTE is preferable to landfilling (Astrup et al., 2015). Thus, a feasible target-range for waste-to-incineration might be between zero and 10% with a preference for lower values. In addition, further sets of targets can be devised as incentives to reduce incineration overcapacity (e.g. those on waste transport/importing) or to penalize it, thereby removing incineration as competition for resources for other R strategies. However, incineration targets should be defined at the lowest unavoidable/physiological level of waste, which is waste not otherwise usable in other CE strategies. Under these terms, incineration can contribute positively to the transition to a CE.

4.1.2. Recycle (R8)

4.1.2.1. Description. Recycling is the processing of materials to obtain the same (high-grade), or lower (low-grade), quality of recycled materials. Recycle extracts materials (called secondary materials) from discarded material/products (Worrell and Reuter, 2014). Secondary materials may be subjected to upcycling, a process that converts them into materials of higher quality and equal/increased functionality (as in the case of bio-refined extract), or, in the opposite direction, to downcycling (as it is for most materials). Intuitively, upcycling should be the preferable solution because of its higher value and quality; however, upcycling is not often possible.

Different considerations are necessary for closed-loop/open-loop recycling that is when recycling occurs within the same (closed) or a different (open) product system. Closed-loop recycling takes place when a "secondary good is shunted back to an earlier process in the same system where it directly replaces ("supersedes") input from primary production of the same e.g. material" (ILCD, 2010, 346). Instead, open-loop recycling occurs "where at least a share of the secondary good is used in different systems (ILCD, 2010, 346). Adopting these definitions, closed-loop solutions should be privileged (then object of a target) over open-loops ones because transport and third-party collection is avoided (and if the production process can handle the recycled input without extra use of e.g. energy or additives). However, Geyer et al. (2016) prove that closed-loop recycling is not necessarily better than open-loop recycling (see also Haupt et al., 2017). In fact, recycling depends on many factors, including uses, prices, type/properties of materials, displacements, and losses/impurities connected with recycling (see Geyer et al., 2016; Niero and Olsen, 2016). A better principle for guiding recycling targets is the potential for environmental impact reduction (see Geyer et al., 2016). Following this principle, targets need to be specifically defined for different products/materials/industries.

4.1.2.2. Analysis. In CE governance, Recycle is the first area of development for targets in different parts of the world (Turner and Pierce, 1994). However, Recycle is energy intensive, and not free from environmental impact. It requires transportation, as well as physical, chemical, and/or mechanical treatments (Cullen, 2017; Jensen et al., 2011). Above all, recycling destroys a product's integrity and market value, degrades the quality of materials, and does not lead to substantial changes in the designing/making of products (Allwood, 2014). Additionally, as anticipated, Recycle is not always feasible or convenient. For instance, composite materials are difficult and/or expensive to be recycled, metals are susceptible to corrosion, polymers can be recycled seven to nine times, and cellulose fibers four to six times (Haupt et al., 2017; Allwood et al., 2012; Blichert-Toft, 2017). Even recycling glass (theoretically, endlessly recyclable) can be impractical or expensive when waste glass is broken, contaminated, or different in colours (Jani and Hogland, 2014).

Although less attractive than other superior strategies (i.e. R > 8), Recycle remains the most prominent strategy worldwide (Potting et al., 2017a; Bahn-Walkowiak and Steger, 2015; Milios, 2018). For example, the EU defined a target for recycling 65% of MSW by 2030 (EC, 2015), similar to a previous construction/demolition-waste target (EC, 2008). China, Korea and Japan have variable targets (from 80% to 95%) for recycling automotive products (Wang and Chen, 2013). Volume-based targets of these kinds can have the positive effect of diverting waste streams away from incineration and landfill. Conversely, they can encourage low-quality recycling, because yield rates are typically higher, owing to a higher tolerance of impurities or contaminants (Allwood et al., 2012; Pacheco-Torgal, 2013). These targets reflect a culture oriented towards waste management and "are not oriented towards the societal change necessary to move towards circular economy" (Haupt and Zschokke, 2017, 836).

For an easier transition to a CE, however, targets should initially be aimed at improving environmental performance (see Geyer et al., 2016; Haupt and Zschokke, 2017; Morseletto, 2019). They should encourage high-quality recycling, with materials easily recyclable, preferably using a closed-loop recycling approach within the same industry or within the same product and/or usage categories. Targets for Recycle should be incorporated in the initial conception and design of products (see R0–R2). Instead of defining targets on Recycle, an opposing view is to include targets for recycled content in products. Interestingly, the association Carpet Recycling UK defines targets on landfill diversion, thus promoting closed-loop recycling, together with the Reuse, Repurpose and Rethinking strategies (Bird, 2014). In the same vein, from a governance perspective, targets for Recycle can better contribute to the transition to a CE if they are devised to encourage inherent self-destruction in the design of products. This will reduce recycling in favour of superior circular strategies, (i.e. R0–R7). For these reasons, I proffer the terms 'antithetic targets' and 'antagonist targets' combining high-quality recycling targets with ambitious targets for waste reduction (in absolute terms, and for waste to be recycled). In addition, CE (as the zero-waste approach) is based on the concept of designing-out waste (Murray et al., 2017). At the industrial level, waste should be eliminated at the source, or be directly recycled on-site, as much as possible (Zaman, 2015). Under these terms, antithetic and antagonist targets for Recycle would be more beneficial for a CE and social/economic/environmental factors than existing targets.

4.2. Extend lifespan of products and its parts (R3–R7)

This group (Reuse/Repair/Refurbish/Remanufacture/Repurpose) devises strategies to retain finished goods and their parts in the economy for longer, while maintaining or improving their value. To work, R3–R7 strategies require market receptivity, well-functioning

reverse logistics, profitability for the parties involved, and the deployment of these strategies by varying business models. Products related to R3–R7 are stochastically uncertain in terms of their quantity/quality conditions (Guide, 2000). For CE governance, this poses challenges in innovation and requires adjustments to the revenue models and socio-economic patterns. When defining targets, these elements need to be considered together, with caveats against R3–R7. For example, prolonging the lifespan of product in certain cases can slow down innovation or prevent the development of new/evolved products that are more environmentally friendly (see Bressanelli et al., 2018). In other cases, regulations can impede R3–R7, imposing a phase-out of products or higher standards (e.g. for safety, energy efficiency).

4.2.1. Repurpose (R7)

4.2.1.1. Description. Repurpose – also referred to as recontextualising – is the use of discarded products or their parts in the formation of a new product with a different function. It is also denotes the reusing a product for an alternative purpose. This is called open-loop reuse (Willskytt et al., 2016). In Repurpose, original products/parts acquire different identities and functions; thus, Repurpose differs from the other strategies in the group (R3–R6).

4.2.1.2. Analysis. It is difficult to define targets for Repurpose, for the following reasons: 1) many parts can be repurposed in a wide variety of separate products; 2) not many products can be repurposed, with this often depending on the creativity of the 'repurposer'; 3) the 'repurposer' is not connected to the originator of the product/components; 4) the scale of production is small, often artisan; and 5) the traceability of products/components can be lost. Consequently, targets should be considered as a residual complement to the other R3–R6 targets, for products or their parts that cannot be re-manufactured/refurbished/repaired/re-used. These targets would work only on the small proportion of products that can be repurposed.

Buildings represent a separate case (see Leising et al., 2018). The so-called repurposed-architecture/adaptive-building-reuse can be considered a Repurpose strategy if, for instance, the transformation from home to office is considered a different function for the building. Nonetheless, defining targets for building-repurpose might not be realistic, because decisions to repurpose depend on many factors, such as costs, permissions, city planning, and so on.

4.2.2. Remanufacture (R6), Refurbish (R5), Repair (R4)

This subsection considers Remanufacture, Refurbish, and Repair together as they occur within the boundaries encompassing a producer and its affiliated companies (e.g. contracted or licensed third parties) or within the boundary of private consumers. A product can be re-manufactured, refurbished, or repaired, but cannot be subject to these treatments simultaneously. Furthermore, R4–R6 all aim at reversing/postponing obsolescence.

4.2.2.1. Description. Remanufacture – also called second-life production – implies using parts of discarded products in a new product with the same function. A remanufactured product should have the quality of a brand new one even when retrieving/reclaiming components from other products (used as spare parts) (see Reike et al., 2018 for details). Traditionally, Remanufacture – also named rebuilt/remould/rewound – is industry specific and involves durable assemblies (Charter and Gray, 2007).

Refurbish, or its equivalent reconditioning, means restoring an old product and bringing it up to date. Refurbishing is about upgrading/modernising the function of a product. Typically, it does not involve disassembly but the replacement of parts; for this reason, it is also called "light" remanufacturing (Ferguson and Souza, 2010). In general, refurbished products are upgraded and brought back to specified quality standards or satisfactory working and/or cosmetic conditions (Jayaraman, 2006; den Hollander et al., 2017d).

Repair is defined by Potting et al. (2017) as repair and maintenance of defective product so it can be used with its original function. Repair is also making a broken product operational again through fixing/replacing failed parts (Jayaraman, 2006; Charter and Gray, 2007). Repair is a common practice if the owner decides reparation whether a product is under guarantee or not. Corrective maintenance is usually equated with Repair (den Hollander et al., 2017d).

In the framework adopted in this study, maintenance (i.e. keeping a product in good working condition for durability/serviceability) is not a CE strategy as instead considered elsewhere (e.g. EMF, 2013). Maintenance is a sophisticated activity that takes different forms (e.g. preventive, predictive, preventive, etc.) (Mobley, 2002), Maintenance can require R6-R4 Remanufacture-Refurbish-Repair, to which it could be considered connected or contiguous. In fact, maintenance can include repair, replacement, adjustment, lubrication, and/or modification activities (Parida and Kumar, 2006; Willskytt et al., 2016). For aircrafts or heavy machinery, so-called Maintenance-Repair-Overhaul (MRO) services are common, underlining the interconnection between maintenance and Repair (see Romero and Vieira, 2014). For simplicity and congruence with the 10R framework adopted, this paper interprets maintenance as a form of soft Repair. Instead, Updating or Upgrading can be considered life extension strategies, but also remedial actions in the forms of Refurbish/Remanufacture.

4.2.2.2. Analysis. In the world economy, targets for R6-R4 are rare. For example, there are no specific targets at the country level (see Karvonen et al., 2017; Wang and Chen, 2013; Bahn-Walkowiak and Steger, 2015), while at the corporate level, there are only a handful of cases of targets, mainly connected to cost and emission reduction or energy efficiency (Sihvonen and Partanen, 2017). For example, a company can have Repair targets connected to reducing transport costs.

Defining specific targets for strategies that keep an original product functioning is not straightforward. A possible target for extending lifespan might be – as discussed in the European context (EESC, 2013) – a total ban on planned obsolescence (i.e. the deliberate decision by producers that a product no longer works or is desirable after a predetermined period – Cooper, 2010). However, demonstrating planned obsolescence is complicated, and sometimes difficult to detect. Planned obsolescence occasionally emerges unpredictably, such as in the commercial practice of mobile phone replacements according to contracted periodicity (Wieser, 2016). This encourages high replacement rates – induced and integrated in a look-alike circular strategy – providing that a target on planned obsolescence can be easily bypassed unless well framed and fine-tuned.

An ideal target for life extension strategies should be aimed at using products for their (entire) technical life (i.e. the physical capacity of a product to function), or bringing service life closer to technical life. However, temporal targets remain difficult to set. Accurate data on product lifespans are complex to obtain (Cooper, 2010). Moreover, lifespan varies according to contextual factors (e.g. typology of use/product), users' expectations/requirements, evolution rate (i.e. upgradability, technological changes, legislative restrictions), and product performance in time (Wieser, 2016; Bakker et al., 2014).

From a different viewpoint, the warranty for purchased goods works towards serviceability; in these terms, it might be equated to a temporal target set at the very minimum level. In contrast, lifetime or long-term maintenance contracts could represent the signal of maximum durability. Conceptually, a target closer to a lifetime-warranty time limit would better represent the objective of desired life extensions. Longer mandatory-guarantees might be the object of a target for encouraging the production of more durable products. This might facilitate defining reliability targets for products (because companies should be interested in minimising returns/complaints), while setting ambitious Repair targets. In these terms, targets of this kind could greatly favour the transition to a CE.

Targets on loop-efficiency (i.e. targets quantifying the degree at

which materials are efficiently preserved in the system) also require considering time as a reference. Instead, targets to reverse or at least postpone obsolescence could be reached using different measures that facilitate not only Repair/Refurbish/Remanufacture, but also Maintenance/Updating/Upgrading. Primarily, these measures are linked to a) costs/availability, b) design, and c) culture, which all have implications in the transition to a CE.

Measures on costs/availability can imply having, for example, targets on costs of spare parts. Often, spare parts are unavailable or prohibitively costly, while fixing products can be expensive in comparison owing to technical difficulties and associated time/labour. In addition, reparability can be limited by the absence of repair information, incompatibilities between spare parts, or difficulties in disassembly (Milios, 2016). Eliminating these bottlenecks might be the object of targets to make the economy more circular. The structure of costs depends on many social and economic factors; however, costs are not rigid, and there are several instruments (e.g. incentives/deterrents, allowances), which can rectify unbalances and disadvantages (Vedung, 2010). The same instruments can promote improvements in organisation, engineering, supply-chain, and business processes, which can reduce costs (Bressanelli et al., 2018). The outcomes of engineering, organisation, and business processes can be measured, therefore the object of specific targets. For instance, IT innovations in reverse logistics can drastically reduce time and procedural costs of returning products.

The second set of measures relates to design. There are designs for longevity, reliability, durability, and disassembly (Cooper, 2005; Vezzoli and Manzini, 2008; Cooper, 2010). These favour the extension of products' lifetimes and facilitate the transition to a CE. Other solutions deriving from design (e.g. modularity/standardisation/interchangeability in parts, simplification of products, repair-friendly features – see Lund, 1998; Vezzoli and Manzini, 2008) can get similar effects. These solutions can also contrasts different forms of obsolescence (aesthetic, social, technological, economical i.e. when products have become respectively outmoded, outlawed, outdated, and too costly – Burns, 2010). Therefore, products can have long lifecycles, high utilisation, and multiple uses. A preliminary analysis can be anticipated here, although design precedes production, thus ideally belonging to Rethink/Reduce/Refuse (see R0–R2 below). It is possible to establish targets for different types of design (for longevity, reliability, durability, and disassembly) according to quality protocols and certifications, physical parameters (e.g. stress test), simplicity (assembly/disassembly/repair), and compatibility (for spare parts). Defining protocols and compliance systems can require a long time to be defined, and accepted by corporations and consumers. A gradual approach in using targets is advisable to allow companies adapting, supporting CE design, and evolve business models (Despeisse et al., 2017; Santini et al., 2010; Lewandowski, 2016). However, as Tecchio et al. (2017) evidence, ecodesign requires metrics and resource-efficiency standards that are missing. These would facilitate the definition of related (and shared) resource-efficiency targets, which could be beneficial in relation to CE.

The third set of measures relates to culture. Shorter innovation cycles, and increasing product complexity tend to rapidly decrease the value of products, therefore favouring a throwaway/fast-consumption mentality (Burns, 2010; EPRS, 2017). In the first place, consumers are not concerned about a product's lifespan (Cooper, 2010). A cultural change is required on both the supply and demand sides (see Laurenti et al., 2018). CE governance entails radical recasting of the consumption and production systems (Gregson et al., 2015) and targets for cultural attitudes makes little sense. Desirable behaviours can be encouraged in different ways, such as introducing durability criteria, extending warranty time, enforcing the producers' responsibility, or abolishing (i.e. zero target) disposable products whenever possible. On this, specific targets can be applied also in conjunction with market-based (e.g. taxes, liabilities), and non-market-based instruments (e.g. reporting, voluntary approaches), or by legislative (e.g. laws, regulations) and semi-legislative (e.g. standards guidance, recommendations).

It is important to underline that setting targets requires the consideration of the socioeconomic context to which a culture is linked. Otherwise, targets are likely to be ineffective. Moreover, target setting needs to avoid rebound effects. For example, Zink and Geyer (2017) demonstrate the importance of supply/demand responses of price to an increased supply of repaired/refurbished goods, the pricing response of sellers to lowered demand attributed to reused goods, and buyers' willingness to substitute between new and secondary good. These factors are difficult to predict; nevertheless, targets can aim at correcting the rebound effects.

4.2.3. Reuse (R3)

4.2.3.1. Description. Reuse can be defined as the second or further use (by another user/owner) of a product that is still in good condition and manages to fulfil its original function. A reused product retains its function and identity (Jayaraman, 2006). Although Reuse is a common practice across the world, targets on Reuse are scarce (Sihvonen and Partanen, 2017). Example of this kind are: targets on reuse and part recovery in the EU Directive on end-of-life vehicles (Wang and Chen, 2013); targets on waste-management/reuse as defined by the EU Waste Framework Directive (Hogg et al., 2014), or Spain for furniture, textiles and electrical items (McDowall, 2016, quoted in Chapman, 2017). The scarcity of targets on Reuse may reflect a culture attentive to the production of new goods, but it can also due to the difficulties in framing the problem.

4.2.3.2. Analysis. There are different types of Reuse (e.g. relocation, resale – see Cooper and Gutowski, 2017; Allwood et al., 2011; Reike et al., 2018); however, for defining CE targets, it is useful to distinguish between products that change ownership and products that retain their ownership, but have different users.

The first category relates to relocated (gifted, discarded) or (re)sold products. In this case, Reuse depends on the predisposition of individuals to use second-hand products, and the existence of second-hand markets (Allwood, 2014; Singh and Ordonez, 2016). There are several marketplaces (pawn, charity, second-hand shops, e-commerce platforms) for a vast variety of goods. Should targets for Reuse align with the diffusion and efficiency of these marketplaces, then a target might be lower transaction costs (particularly relevant for low-value goods). This can be linked to an expected percentage increase of reused products, which can be monitored through sales in different marketplaces.

The second macro category includes hired/shared/refunded-deposit products. Product service systems (PSS) (i.e. the mix of products and services that business offers to clients, see Tukker, 2015) belong to this category. Here, products are generally owned by a subject that contracts them to different users. Targets can aim to increase the number of products falling into the PSS category using incentives/favourable taxation while avoiding perverse rebound effects (e.g. those in the mobile phones in subsection 4.2.2; see also Zink and Geyer, 2017). The shifting from ownership to access alters the entire business process and supply chain and may have significant implications for the transition to a CE.

A special target can be devised for primary packaging (e.g. even a radical zero-dismiss target) and the reuse of certain secondary packaging. However, this would require major modifications to the conception of products and logistics (see R1-Rethink below).

Targets should also increase modularity and standardisation to increase Reuse (e.g. pallets, containers, rail tracks, but also equipment). This is strongly related to design (of products and related products/facilities). For example, in Sweden and Denmark, beer manufacturers have agreed on a standard glass container to facilitate the sorting and collection of discarded bottles (ADEME, 2009). These are more robust and designed for reuse. In addition to modularity/standardisation, if a

product changes over time, a target for designers might be (predictive) efficiency improvements (see Cooper and Gutowski, 2017). However, this type of targets is industry specific.

As mentioned previously, an alternative target could be related to the reduction/elimination of disposable products, which represent the antithesis of Reuse.

Reuse should include 'parts harvesting', which is the practice of recovering selected from discarded products to be reused (Ferguson and Souza, 2010). In general, spare parts suit R4-R6 strategies. Some of these can be the object of specific targets. Allwood et al. (2011) argue that steel used in construction (structural sections, reinforcing bars, and sheet steel for cladding and 'purlins') can be reused by 40%. This could be a feasible industry target; it could also be a paradigmatic target for other products/industries. It is relevant emphasising that, to facilitate the reuse of parts, products need to a) be built with disassembly in mind, b) expressly allow disassembly, c) reduce disassembly time (disassembly is an expensive and labour-intensive operation). This is particularly important in a CE perspective.

Reuse can also be associated with Repair/Maintenance in a way to perpetuate the purpose of a product, which means keeping a product within 'inner cycles' (EMF, 2013). Targets on inner cycles can be obtained for specific categories of products. For example, pallets or containers are always reused, regardless of the goods they carry. Again, Reuse should prevent fast consumption of products (e.g. mobile phones) to be reused (e.g. in less developed countries), thus avoiding the rich-poor dualism, with both sides equally eager for new/reused products.

4.3. Smarter product use and manufacture (R0–R2)

This group encompasses Refuse, Rethink, and Reduce, which take place when products are conceived, designed, and developed. These strategies are precursory, enabling, and transformative. Precursory, because they occur before other CE strategies. Enabling, because they favour all other strategies. Transformative, because they can make the economic system a truly circular one if applied extensively. Accordingly, R0–R2 can lead the transition to a CE before production takes place.

R0–R2 are closely connected to design. Design was previously mentioned as an ex ante activity that can enhances for example, to reuse or disassembly of a product. A broad definition of design can refer to designing production processes, logistics systems, patterns of consumption and lifestyles as well (Jayaraman, 2006; Despeisse et al., 2017). In other words, design can relate to any situation that relies on schemes, connections, or sequences. In the same way, Rethink – i.e. proposing new ideas and solutions to provide certain product functions – can embrace the reframing and regenerating of potentially every aspect of CE systems. By adopting such a wide definition of Rethink, design can be traced back to this strategy, as can (potentially) Refuse and Reduce. To do so, the analysis of the strategies and targets starts with Rethink.

4.3.1. Rethink (R1)

4.3.1.1. Description. According to Potting et al. (2017), Rethink refers to making a product use-intensive (e.g. through sharing products or by putting multi-functional products on market). However, Rethink has a wider connotation, because it includes the re-elaboration/re-conceptualisation of ideas, dynamics, processes, concepts, uses, and post uses of a product (e.g. Clift and Allwood, 2011; Andrews, 2015; Kristensen et al., 2016; Linder, 2017). This allows including dematerialisation (i.e. the substitution of a product by a nonmaterial alternative with the same utility for users), which is an integral part of CE (Andrews, 2015; Allwood et al., 2011; Milios, 2016).

Rethink may always have characterised CE, because to make something more circular requires rethinking it, to some extents.

4.3.1.2. Analysis. In the economy, there are no targets for Rethink; however, many targets are possible. For the sake of conciseness', three main categories of targets are presented: 1) circularity; 2) constitutive elements of CE; and 3) enforcing/making possible other CE strategies.

Targets for Rethink should consider an overall target for CE in relation to the level of circularity as defined by several scholars (see Elia et al., 2017 for a review). For instance, Haas et al. (2015), using material flows as a proxy, calculate that only 7% of all materials entering the global economy are in closed loops. Multiple targets for rethinking materials/products can be devised at the corporate/sector/regional/national scales. These targets can set ambitious levels of circularity (also using different metrics, e.g. Linder et al., 2017; Haupt et al., 2017; Mayer et al., 2019) for products and materials (and to favour the other R strategies). In addition, an overall/aggregate target on circularity (e.g. a percentage of the economy to be circular) could have a mobilising role in society.

Similarly, Rethinking can point to the constitutive elements of CE. There could be percentage targets on the employment of virgin and/or recycled materials, or on the number of recycling loops with an optimum performance and lifespan (Clark et al., 2016). In the same vein, there could be targets for zero waste or the totality of by-products being reused/recycled. Targets should include an explicitly environmental component, such as the reduction of emissions, toxicity, or negative environmental impacts among others (Allwood et al., 2012; EMF, 2013; Leslie et al., 2016). In addition, targets for closed loops in operations, according to product typologies or sectors, could increase the level of circularity in the system.

In relation to enforcing/making possible other R strategies, a first set of targets should focus on design and engineering, which can facilitate other CE strategies. For example, in specific commodity-related categories, there can be a percentage of new products that can be easily (and cheaply) disassembled, repaired, or upgraded. As mentioned earlier, this requires protocols and compliance systems. Other targets can be devised for reusing transit and secondary packaging or for refilling primary ones. Such targets cover not only redesigning packages, but can also require the reorganisation of several logistics operations (possibly including the entire business model). Furthermore, targets can be devised for designing products that ease Repair, including arranging support within an efficient supply chain. Finally, targets can provide new benefits to products and services, predisposing them to different CE strategies (e.g. Reuse, sharing, PSS, multiple uses). Here, targets can incentivise intensity of use or the more efficient use of products. For example, a 20% intensity of use of a product like a lawn mower (a product used sporadically, for a short time but own by many) could favour new business models or organisational patterns.

These few examples of targets show how Rethink lies at the nexus of future CE developments and represent the most relevant strategy for promoting a transition to truly CE.

4.3.2. Refuse (R0)

4.3.2.1. Description. Refuse refers to making a product redundant by abandoning its function or offering the same function with a radically different product. Refuse can also extend to the use of certain materials or production processes to make the economy more circular.

4.3.2.2. Analysis. Countries have different phase-out targets, for instance, on plastic bags (Lewis et al., 2010) or incandescent lamps (Waide, 2010). Similar targets can be devised for single-use products, disposable straws, useless secondary packages, or even for some products that can be substituted by nonmaterial ones (e.g. digital). These targets are product-specific and need to be defined, negotiated, and decided on a product-by-product/category-by-category basis. Conversely, targets on materials relate to any product using certain material that has to be refused (e.g. virgin materials) to impose it Recycle or Reuse. For the same reason, a ban might be possible on specific materials in relation to products for instance, plastic for packaging. Furthermore, a production process can be refused when

closed loops that are environmentally beneficial are impossible or difficult to obtain. An ideal target could be refusing all open-loop processes that are detrimental to the environment (see Geyer et al., 2016; Haupt et al., 2017 for a thorough analysis). However, a more practical solution is to define targets that minimise such processes (which technically, is Reduce). Note that having a target on Reduce can correspond to having a target on Rethink.

4.3.3. Reduce (R2)

4.3.3.1. Description. Reduce implies using fewer natural resources, and therefore fewer inputs of energy, raw materials, and waste. This definition can be extended to reducing of the number of products, tout court (see Reike et al., 2018), such as decreasing the number of owned cars in a way to incentivise Reuse. In these terms, Reduce can be linked to Reuse. To some extent, Reduce can be also interpreted as a less drastic form of Refuse.

4.3.3.2. Analysis. Targets for Reduce can also mirror targets for Rethink because – as Reike et al. (2018) underline – Reduce is linked to the Concept/Design (using less material per unit of production), or to 'dematerialization' (see also Lieder and Rashid, 2016; Sihvonen and Ritola, 2015; Worrell and Reuter, 2014). There do exist efficiency targets that address Reduce, but they focus on reducing resources. For example, in the EU, there are reduction targets for water extraction and targets addressing material inputs in Italy, Austria, Sweden, Switzerland, and Hungary (Bahn-Walkowiak and Steger, 2015). Similarly to countries, several companies have adopted waste and resources reduction targets. Although these targets allow meeting wider environmental objectives, they are not necessarily entrenched within a CE perspective. For the transition to a CE, Reduce targets should embrace every aspect of production and consumption. A few examples of possible targets are presented here.

Akenji et al. (2016) note that most estimations show the need to reduce the global material footprints by as much as 80% before the middle of this century. Therefore, Reduce targets need to be devised in association with a lightweight design. This can be defined as a conceptual approach aimed at using a minimal quantity of materials while retaining the aesthetical or practical function of an object. Historically, lightweight design was employed in construction (possibly, since the conception of the Pantheon in Rome) and engineering (e.g. the aerospace industry – Otto, 2005), but can be applied to any product. Lightweight-design targets can be defined for weight reduction (e.g. as a percentage) or the reduction of a certain material making up a product. However, these targets have to agree with targets for durability.

A special set of Reduce targets should tackle scrap that represents a less-known side of production. For example, Allwood (2014) shows that approximately 25% of all steel and 50% aluminium annually made are converted into scrap. Scrap exists in most industry and conversion rates of purchased materials into scrap could be minimised through employing bold targets with consequent material savings and reduction of product costs.

Another relevant, but hidden aspect of production is dissipative uses, which absorb a large share of the economy's throughput (Moreau et al., 2017). These uses, as is the case of anthropogenic carbon (e.g. from combustion engines) and nitrogen (e.g. from fertilisers), result in large material and energy flows being dispersed. Reducing these can be the object of targets that close material cycles.

4.4. Targets for the 10R

As a synthesis of the previous subsections, Fig. 3 summarises the main new and existing targets as proposed for each R-strategy.

Fig. 4 shows the correlation among targets for different R-strategies.

5. Conclusion

This study has investigated both existing and new CE targets to provide a broad and systematic analysis for the consideration of scholars and decision makers. The analysis was based on a systematic review of the literature related to existing targets supplemented by the elaboration of new targets. The study has used CE strategies as a lens to look at targets in a holistic way. Ten comprehensive strategies – as summarised by the 10R framework by Potting et al. (2017) – have been scrutinized systematically in this investigation.

Targets can facilitate a transition towards a CE in several ways, for example, by reducing waste, closing production loops, using resources more efficiently, or maximising the retention of the economic value of materials and products. Most of the existing targets relate to waste management, resource conservation (mostly for R9-Recovery and R8-Recycle), or are combined with different environmental objectives (e.g. emission reduction). However, R8–R9 targets do not necessarily promote a CE because recovery and recycling activities destroy products' integrity and do not help products remain in the economy. Recycle and Recovery have limited benefits in terms of the (partial) reclamation of materials and energy recovery. Therefore, R8–R9 targets should point at minimal/physiological levels also to favour more powerful CE strategies (R0–R7). In relation to these, the study has investigated new and existing targets showing how they better address the goal of a more circular economy. Except for Repurpose (for which it is difficult to define targets), the study has illustrated how targets for Reuse, Repair, Refurbish, Remanufacture – if well devised – can effectively extend the lifespan of products. In particular this study has proposed an expanded set of brand new targets in relation to Remanufacture, Refurbish, Repair, Re-use, but also for Refuse, Rethink and Reduce. These new targets are powerful governance elements that – if applied – can increase the circularity in economic systems and accelerate the transition to a CE for each strategy.

This study has also evidenced that targets can address one or multiple R-strategies. However, targets can lead to trade-offs, synergies, or complementarities, which need to be considered for the realisation of a CE. For example, targets Recycle or Recovery can be minimised by using targets from other strategies (namely, Reuse, Repair, Refurbish, Remanufacture, Refuse, Rethink and Reduce). Instead, targets for Reduce-Rethink-Refuse can facilitate every CE strategies, while targets on design/Rethink alone can help deploying every other strategy. Not all targets can be met at the same time (e.g. Repurpose-Remanufacture-Refurbish-Repair). Nonetheless, the R-strategies together define a system in which multiple options and targets can be applied to promote CE implementation.

Future research should consider deepening the scope of studying targets, offering further theoretical and disciplinary insights, for example, investigating specific products/industries, product-categories, and business processes. Empirical cases can verify targets in more detail, or assess the necessity of their adjustments, fine-tuning, and re-elaboration. Further research should also study targets in relation to the innovations required to implement CE strategies, for instance, linking targets to the current researches on policy design for product life extension, or effective and well-designed policy mix for CE. Finally, from a specific policy/decision making perspective, targets can be used to define a roadmap to implement CE successfully.

As with every transformative process, CE needs targets to guide change towards sought-after outcomes. However, target setting requires the careful application of programmatic and decision-making activities to achieve the goal of having an effective circular economy.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

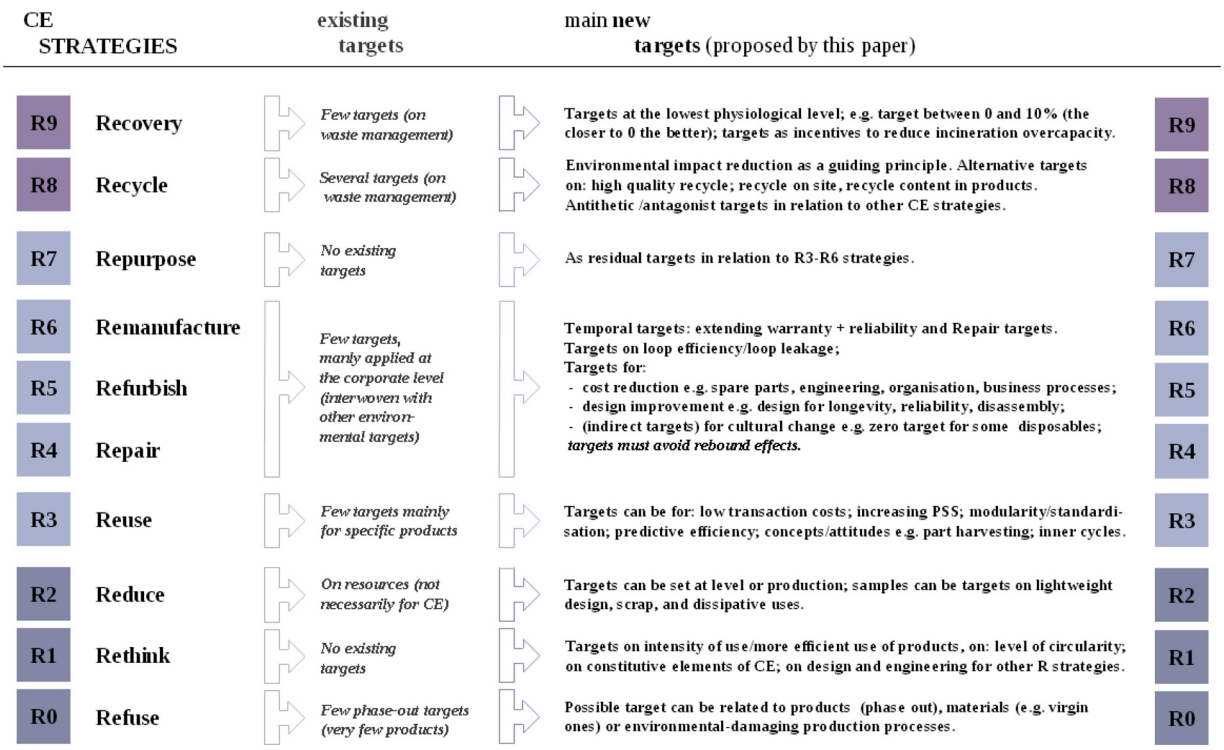

Fig. 3. Targets for R-strategies.

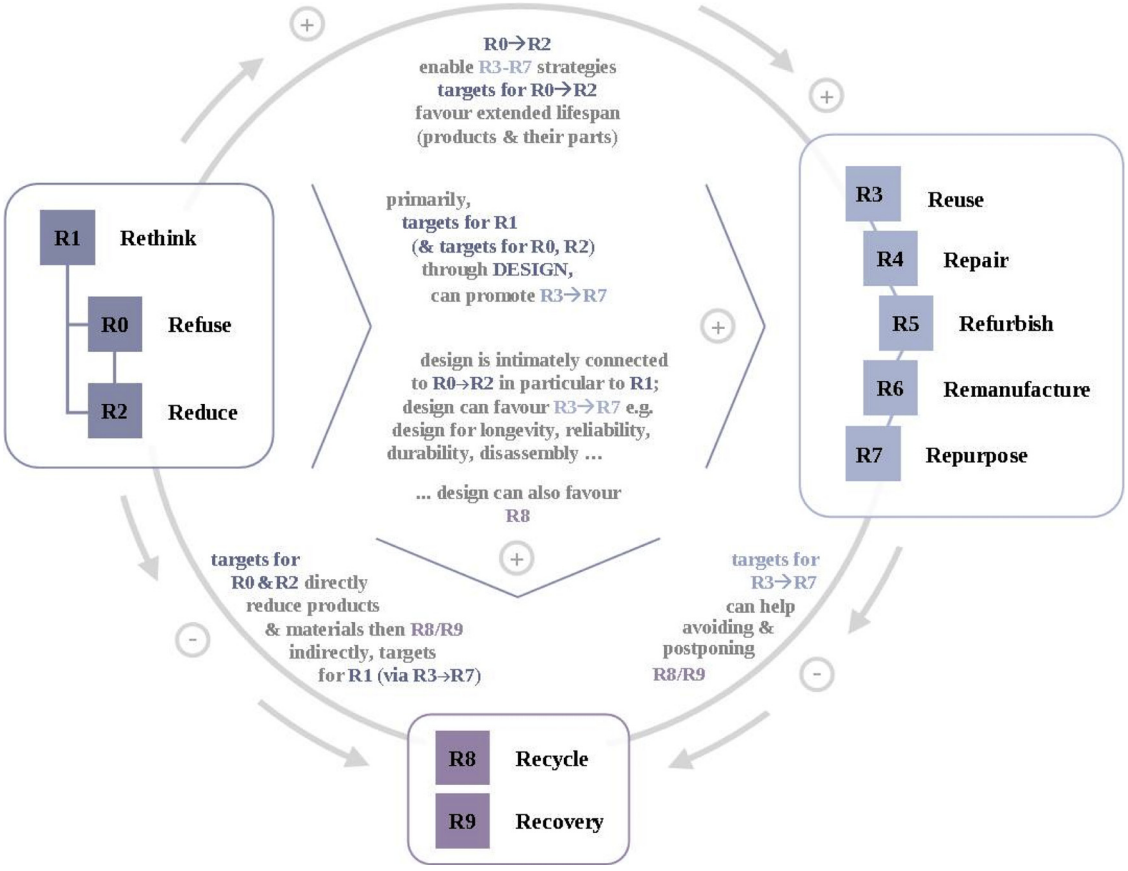

Fig. 4. Correlations among targets.

Declaration of Competing Interest

No conflict of interest.

Acknowledgements

I am very grateful to Josepha (Josè) Potting, Heather Leslie, Stefano Pascucci, and Philipp Pattberg for their precious comments and insights. A special thank you goes to Marko Hekkert, Gianmarco Bressanelli, and Ton Bastein for the talks and fruitful discussions. I also thank Aldert Hanemaaijer and Harald Wieser for the documents provided. The paper was improved markedly by the comments and suggestions of the anonymous reviewers.

References

ADEME, 2009. Assessment of Results on the Reuse and Recycling of Packaging in Europe. http://www.ademe.fr/evaluation-resultats-reutilisation-recyclage-emballages-europe.
Akenji, L., Bengtsson, M., Bleischwitz, R., Tukker, A., Schandl, H., 2016. Ossified materialism: introduction to the special volume on absolute reductions in materials throughput and emissions. J. Clean. Prod. 132, 1–12.
Allwood, J.M., Ashby, M.F., Gutowski, T.G., Worrell, E., 2011. Material efficiency: a white paper. Resour. Conserv. Recycl. 55 (3), 362–381.
Allwood, J.M., Cullen, J.M., Carruth, M.A., Cooper, D.R., McBrien, M., Milford, R.L., et al., 2012. Sustainable Materials: with Both Eyes Open. UIT Cambridge, Cambridge, UK p. 384.
Allwood, J.M., 2014. Squaring the circular economy: the role of recycling within a hierarchy of material management strategies. Handbook of Recycling. Elsevier, pp. 445–477.
Andrews, D., 2015. The circular economy, design thinking and education for sustainability. Local Econ. 30 (3), 305–315.
Astrup, T.F., Tonini, D., Turconi, R., Boldrin, A., 2015. Life cycle assessment of thermal waste-to-energy technologies: review and recommendations. Waste Manag. 37, 104–115.
Babbitt, C.W., Gaustad, G., Fisher, A., Chen, W.Q., Liu, G., 2018. Closing the loop on circular economy research: from theory to practice and back again. Resour. Conserv. Recycl. 135, 1–2.
Bahn-Walkowiak, B., Steger, S., 2015. Resource targets in Europe and worldwide: an overview. Resources 4 (3), 597–620.
Bakker, C., den Hollander, M., Van Hinte, E., Zljlstra, Y., 2014. Products That Last – Product Design for Circular Business Models. TU Delft Library.
Becker, J., Kugeler, M., Rosemann, M., 2013. Process Management: A Guide for the Design of Business Processes. Springer-Verlag, Berlin.
Bevan, G., Hood, C., 2006. What's measured is what matters: targets and gaming in the English public health care system. Publ. Adm. 84 (3), 517–538.
Bird, L., 2014. Opening Remarks, Carpet Recycling UK-Conference. http://www.carpetrecyclinguk.com/downloads/27_percent_landfil_diversion_how_the_UK_exceeded_its_targets_two_years_early_Laurance_Bird_and_Jane_Gardner_Carpet_Recycling_UK.pdf.
BioIS-Bio-Intelligence Service, 2013. Study on an Increased Mechanical Recycling Target for Plastics. Plastic Recyclers Europe, Parice.
Bjørn, A., Bey, N., Georg, S., Røpke, I., Hauschild, M.Z., 2017. Is Earth recognized as a finite system in corporate responsibility reporting? J. Clean. Prod. 163, 106–117.
Blichert-Toft, J., 2017. Geochemical perspectives. Future Glob. Miner. Resour. 6, 1.
Boswell, C., 2015. The double life of targets in public policy: disciplining and signalling in UK Asylum policy. Publ. Adm. 93 (2), 490–505.
Bressanelli, G., Perona, M., Saccani, N., 2018. Challenges in supply chain redesign for the circular economy: a literature review and a multiple case study. Int. J. Prod. Res. 1–28.
Burns, B., 2010. Re-evaluating obsolescence and planning for it. Longer Lasting Products—Alternatives to the Throwaway Society. Gower, pp. 39–60.
Chapman, J., 2017. Routledge Handbook of Sustainable Product Design. Taylor & Francis, Abingdon.
Charter, M., Gray, C., 2007. Remanufacturing and Product Design: Designing for the 7th Generation. CfSD.
Clark, J.H., Farmer, T.J., Herrero-Davila, L., Sherwood, J., 2016. Circular economy design considerations for research and process development in the chemical sciences. Green Chem. 18 (14), 3914–3934.
Clift, R., Allwood, J., 2011. Rethinking the economy. Chem. Eng. 837, 30–31.
Cooper, T., 2005. Slower consumption reflections on product life spans and the "throwaway society". J. Ind. Ecol. 9 (1–2), 51–67.
Cooper, T., 2010. The significance of product longevity. Longer Lasting Products: Alternatives to the Throwaway Society. Gower, pp. 3–37.
Cooper, D.R., Gutowski, T.G., 2017. The environmental impacts of reuse: a review. J. Ind. Ecol. 21 (1), 38–56.
Cullen, J.M., 2017. Circular economy: theoretical benchmark or perpetual motion machine? J. Ind. Ecol. 21 (3), 483–486.
De Jesus, A., Mendonça, S., 2018. Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. Ecol. Econ. 145, 75–89.
De los Rios, I.C., Charnley, F.J., 2017. Skills and capabilities for a sustainable and circular economy: the changing role of design. J. Clean. Prod. 160, 109–122.
Demirbas, A., 2009. Biofuels securing the planet's future energy needs. Energy Convers. Manage. 50 (9), 2239–2249.
den Hollander, M.C., Bakker, C.A., Hultink, E.J., 2017d. Product design in a circular economy: development of a typology of key concepts and terms. J. Ind. Ecol. 21 (3), 517–525.
Despeisse, M., Baumers, M., Brown, P., Charnley, F., Ford, S.J., Garmulewicz, A., et al., 2017. Unlocking value for a circular economy through 3D printing: a research agenda. Technol. Forecast. Soc. Change 115, 75–84.
EEA - European Environment Agency, 2016. More from Less – Material Resource Efficiency in Europe. 2015 Overview of Policies, Instruments and Targets in 31 Countries. EEA, Luxembourg.
EC-European Commission, 2008. Directive 2008/98/EC. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0098.
EC-European Commission, 2015. Closing the Loop – an EU Action Plan for the Circular Economy. http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF.
Elia, V., Gnoni, M.G., Tornese, F., 2017. Measuring circular economy strategies through index methods: a critical analysis. J. Clean. Prod. 142, 2741–2751.
EESC-European Economic and Social Committee, 2013. Calls for a Total Ban on Planned Obsolescence. http://www.eesc.europa.eu/en/news-media/press-releases/eesc-calls-total-ban-planned-obsolescence#downloads.
EMF-Ellen MacArthur Foundation, 2013. Towards the Circular Economy. https://www.ellenmacarthurfoundation.org/assets/downloads/publications/Ellen-MacArthur-Foundation-Towards-the-Circular-Economy-vol.1.pdf.
EPRS-European-Parliamentary-Research-Service-Scientific-Foresight-Unit (STOA), 2017. Towards a Circular Economy–Waste Management in the EU. http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_STU(2017)581913.
Ferguson, M.E., Souza, G.C., 2010. Commentary on closed-loop supply chains. Closed-Loop Supply Chains: New Developments to Improve the Sustainability of Business Practices. CRC-Press, pp. 1–8.
Geyer, R., Kuczenski, B., Zink, T., Henderson, A., 2016. Common misconceptions about recycling. J. Ind. Ecol. 20 (5), 1010–1017.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32.
Gregson, N., Crang, M., Fuller, S., Holmes, H., 2015. Interrogating the circular economy: the moral economy of resource recovery in the EU. Econ. Soc. 44 (2), 218–243.
Guide, V.D.R., 2000. Production planning and control for remanufacturing: industry practice and research needs. J. Oper. Manag. 18 (4), 467–483.
Haas, W., Krausmann, F., Wiedenhofer, D., Heinz, M., 2015. How circular is the global economy?: An assessment of material flows, waste production, and recycling in the European Union and the world in 2005. J. Ind. Ecol. 19 (5), 765–777.
Haupt, M., Vadenbo, C., Zeltner, C., Hellweg, S., 2017. Influence of input scrap quality on the environmental impact of secondary steel production. J. Ind. Ecol. 21 (2), 391–401.
Haupt, M., Zschokke, M., 2017. How can LCA support the circular economy?—63rd discussion forum on life cycle assessment, Zurich, Switzerland, November 30, 2016. Int. J. Life Cycle Assess. 22 (5), 832–837.
Hofmann, F., 2019. Circular business models: business approach as driver or obstructer of sustainability transitions? J. Clean. Prod. 224, 361–374.
Hood, C., Lodge, M., 2006. The Politics of Public Service Bargains: Reward, Competency, Loyalty-and Blame. Oxford University Press, Oxford.
Hogg, D., Vergunst, T., Elliot, T., Elliot, L., Fischer, C., Kjær, B., Mehlhart, G., Küchen, V., 2014. Impact Assessment on Options Reviewing Targets in the Waste Framework Directive, Landfill Directive and Packaging and Packaging Waste Directive" Final Report. Eunomia Research & Consulting Ltd., Bristol.
Homrich, A.S., Galvão, G., Abadia, L.G., Carvalho, M.M., 2018. The circular economy umbrella: trends and gaps on integrating pathways. J. Clean. Prod. 175, 525–543.
Jani, Y., Hogland, W., 2014. Waste glass in the production of cement and concrete–a review. J. Environ. Chem. Eng. 2 (3), 1767–1775.
Jawahir, I.S., Dillon, O.W., 2007. Sustainable manufacturing processes: new challenges for developing predictive models and optimization techniques. Proc. 1st-International Conference on Sustainable Manufacturing, 18–19/10/2007 1–19.
Jayaraman, V., 2006. Production planning for closed-loop supply chains with product recovery and reuse: an analytical approach. Int. J. Prod. Res. 44 (5), 981–998.
Jensen, P.D., Basson, L., Hellawell, E.E., Bailey, M.R., Leach, M., 2011. Quantifying 'geographic proximity': experiences from the United Kingdom's national industrial symbiosis programme. Resour. Conserv. Recycl. 55 (7), 703–712.
Kalmykova, Y., Sadagopan, M., Rosado, L., 2018. Circular economy – from review of theories and practices to development of implementation tools. Resour. Conserv. Recycl. 135, 190–201.
Karvonen, I., Jansson, K., Behm, K., Vatanen, S., Parker, D., 2017. Identifying recommendations to promote remanufacturing in Europe. J. Remanufact. 7 (2–3), 159–179.
King, A.M., Burgess, S.C., Ijomah, W., McMahon, C.A., 2006. Reducing waste: repair, recondition, remanufacture or recycle? Sustain. Dev. 14 (4), 257–267.
Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. 127, 221–232.
Kristensen, D.K., Kjeldsen, C., Thorsøe, M.H., 2016. Enabling sustainable agro-food futures: exploring fault lines and synergies between the integrated territorial paradigm, rural eco-economy and circular economy. J. Agric. Environ. Ethics 29 (5), 749–765.
ILCD - Institute for Environment and Sustainability: International Reference Life Cycle Data System, 2010. Handbook – General Guide for Life Cycle Assessment – Detailed Guidance. March 2010. EUR 24708 EN. first edition. Publications Office of the European Union, Luxembourg. https://ec.europa.eu/jrc/en/publication/eur-

scientific-and-technical-research-reports/international-reference-life-cycle-data-system-ilcd-handbook-general-guide-life-cycle.
Lafferty, W., Meadowcroft, J., 2000. Patterns of governmental engagement. In: Lafferty, W., Meadowcroft, J. (Eds.), Implementing Sustainable Development: Strategies and Initiatives in High Consumption Societies. Oxford University Press, pp. 337–421.
Lauber, V., Ingram, V., et al., 2000. Packaging waste. In: Arthur, P. (Ed.), The Voluntary Approach to Environmental Policy. Oxford University Press, Oxford, pp. 104–155.
Laurenti, R., Singh, J., Frostell, B., Sinha, R., Binder, C., 2018. The socio-economic embeddedness of the circular economy: an integrative framework. Sustainability 10 (7), 2129.
Leising, E., Quist, J., Bocken, N., 2018. Circular economy in the building sector: three cases and a collaboration tool. J. Clean. Prod. 176, 976–989.
Leslie, H.A., Leonards, P.E.G., Brandsma, S.H., de Boer, J., Jonkers, N., 2016. Propelling plastics into the circular economy—weeding out the toxics first. Environ. Int. 94, 230–234.
Lester, S., Neuhoff, K., 2009. Understanding the role of policy targets in National and International Governance. EPRG Working Paper 0909. University of Cambridge, Cambridge.
Lewandowski, M., 2016. Designing the business models for circular economy–towards the conceptual framework. Sustainability 8 (1), 43.
Lewis, H., Verghese, K., Fitzpatrick, L., 2010. Evaluating the sustainability impacts of packaging: the plastic carry bag dilemma. Packag. Technol. Sci. 23 (3), 145–160.
Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51.
Linder, M., 2017. Ripe for disruption: reimagining the role of green chemistry in a circular economy. Green Chem. Lett. Rev. 10 (4), 428–435.
Linder, M., Sarasini, S., Loon, P., 2017. A metric for quantifying product-level circularity. J. Ind. Ecol. 21 (3), 545–558.
Lüdeke-Freund, F., Gold, S., Bocken, N.M., 2019. A review and typology of circular economy business model patterns. J. Ind. Ecol. 23 (1), 36–61. https://doi.org/10.1111/jiec.12763.
Lund, R., 1998. Remanufacturing: an American resource. Proceedings of the Fifth International Congress Environmentally Conscious Design and Manufacturing.
Manninen, K., Koskela, S., Antikainen, R., Bocken, N., Dahlbo, H., Aminoff, A., 2018. Do circular economy business models capture intended environmental value propositions? J. Clean. Prod. 171, 413–422.
Masi, D., Day, S., Godsell, J., 2017. Supply chain configurations in the circular economy: a systematic literature review. Sustainability 9 (9), 1602.
Mayer, A., Haas, W., Wiedenhofer, D., Krausmann, F., Nuss, P., Blengini, G.A., 2019. Measuring progress towards a circular economy: a monitoring framework for economy-wide material loop closing in the EU28. J. Ind. Ecol. 23 (1), 62–76.
McDowall, J., 2016. Spain becomes first EU country to set target for reuse – https://resource.co/article/spain-becomes-first-eu-country-set-target-reuse-11038 – quoted in Chapman, J. (2017).
McDowall, W., Geng, Y., Huang, B., Barteková, E., Bleischwitz, R., Türkeli, S., et al., 2017. Circular economy policies in China and Europe. J. Ind. Ecol. 21 (3), 651–661.
Milios, L., 2016. Policies for Resource Efficient and Effective Solutions: A Review of Concepts, Current Policy Landscape and Future Policy Considerations for the Transition to a Circular Economy. Mistra REES Report. .
Milios, L., 2018. Advancing to a Circular Economy: three essential ingredients for a comprehensive policy mix. Sustain. Sci. 13 (3), 861–878.
Mobley, R.K., 2002. An Introduction to Predictive Maintenance. Butterworth-Heinemann.
Moreau, V., Sahakian, M., Griethuysen, P., Vuille, F., 2017. Coming full circle: why social and institutional dimensions matter for the circular economy. J. Ind. Ecol. 21 (3), 497–506.
Morseletto, P., Biermann, F., Pattberg, P., 2017. Governing by targets: reductio ad unum and evolution of the two-degree climate target. Int. Environ. Agreem.: Polit. Law Econ. 17 (5), 655–676.
Morseletto, P., 2019. Restorative and regenerative: exploring the concepts in the circular economy. J. Ind. Ecol forthcoming.
Murray, A., Skene, K., Haynes, K., 2017. The circular economy: an interdisciplinary exploration of the concept and application in a global context. J. Bus. Ethics 140 (3), 369–380.
Nelson, R.R., 1991. Why do firms differ, and how does it matter? Strateg. Manage. J. 12 (S2), 61–74.
Niero, M., Olsen, S.I., 2016. Circular economy: to be or not to be in a closed product loop? A life cycle assessment of aluminium cans with inclusion of alloying elements. Resour. Conserv. Recycl. 114, 18–31.
Nußholz, J., 2017. Circular business models: defining a concept and framing an emerging research field. Sustainability 9 (10), 1810.
Otto, F., 2005. Frei Otto: Complete Works: Lightweight Construction, Natural Design. Birkhäuser.
Pacheco-Torgal, F., 2013. Introduction to the recycling of construction and demolition waste (CDW). Handbook of Recycled Concrete and Demolition Waste. Woodhead-Publishing, pp. 1–6.
Parida, A., Kumar, U., 2006. Maintenance performance measurement (MPM): issues and challenges. J. Qual. Maint. Eng. 12 (3), 239–251.
Parris, T.M., Kates, R.W., 2003. Characterizing and measuring sustainable development. Annu. Rev. Environ. Resour. 28 (1), 559–586.
Potting, J., Hekkert, M., Worrell, E., Hanemaaijer, A., 2017. Circular Economy: Measuring Innovation in the Product Chain. PBL–Netherlands Environmental Assessment Agency.
Prieto-Sandoval, V., Jaca, C., Ormazabal, M., 2018. Towards a consensus on the circular economy. J. Clean. Prod. 179, 605–615.
Qi, J., Zhao, J., Li, W., Peng, X., Wu, B., Wang, H., 2016. Development of Circular Economy in China. Springer, Singapore.
Ranta, V., Aarikka-Stenroos, L., Ritala, P., Mäkinen, S.J., 2018. Exploring institutional drivers and barriers of the circular economy: a cross-regional comparison of China, the US, and Europe. Resour. Conserv. Recycl. 135, 70–82.
Reike, D., Vermeulen, W.J., Witjes, S., 2018. The circular economy: new or refurbished as CE 3.0?—exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resour. Conserv. Recycl. 135, 246–264.
Repo, P., Anttonen, M., Mykkänen, J., Lammi, M., 2018. Lack of congruence between European citizen perspectives and policies on circular economy. Eur. J. Sustain. Dev. 7 (1), 249–264.
Romero, A., Vieira, D.R., 2014. Using the product lifecycle management systems to improve maintenance, repair and overhaul practices: the case of aeronautical industry. In: IFIP International Conference on Product Lifecycle Management. Springer, Berlin, Heidelberg. pp. 159–168.
Rotmans, J., Kemp, R., Van Asselt, M., 2001. More evolution than revolution: transition management in public policy. Foresight 3 (1), 15–31.
Sakai, S.I., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., et al., 2011. International comparative study of 3R and waste management policy developments. J. Mater. Cycles Waste Manag. 13 (2), 86–102.
Santini, A., Herrmann, C., Passarini, F., Vassura, I., Luger, T., Morselli, L., 2010. Assessment of Ecodesign potential in reaching new recycling targets. Resour. Conserv. Recycl. 54 (12), 1128–1134.
Sihvonen, S., Ritola, T., 2015. Conceptualizing ReX for aggregating end-of-life strategies in product development. Procedia CIRP 29, 639–644.
Sihvonen, S., Partanen, J., 2017. Eco-design practices with a focus on quantitative environmental targets: an exploratory content analysis within ICT sector. J. Clean. Prod. 143, 769–783.
Singh, J., Ordonez, I., 2016. Resource recovery from post-consumer waste: important lessons for the upcoming circular economy. J. Clean. Prod. 134, 342–353.
Smol, M., Kulczycka, J., Henclik, A., Gorazda, K., Wzorek, Z., 2015. The possible use of sewage sludge ash (SSA) in the construction industry as a way towards a circular economy. J. Clean. Prod. 95, 45–54.
Sousa-Zomer, T.T., Magalhães, L., Zancul, E., Cauchick-Miguel, P.A., 2018. Exploring the challenges for circular business implementation in manufacturing companies: an empirical investigation of a pay-per-use service provider. Resour. Conserv. Recycl. 135, 3–13.
Su, B., Heshmati, A., Geng, Y., Yu, X., 2013. A review of the circular economy in China: moving from rhetoric to implementation. J. Clean. Prod. 42, 215–227.
Tukker, A., 2015. Product services for a resource-efficient and circular economy–a review. J. Clean. Prod. 97, 76–91.
Tuominen, A., Himanen, V., 2007. Assessing the interaction between transport policy targets and policy implementation—a Finnish case study. Transp. Policy 14 (5), 388–398.
Tecchio, P., McAlister, C., Mathieux, F., Ardente, F., 2017. In search of standards to support circularity in product policies: a systematic approach. J. Clean. Prod. 168, 1533–1546.
Turner, R.K., Pierce, D., 1994. The role of economic instruments. Economic Incentives and Environmental Policies: Principles and Practice. Kluwer, pp. 251–273.
Vedung, E., 2010. Policy instruments: typologies and theories. Carrots, Sticks, and Sermons: Policy Instruments and Their Evaluation. Transaction, pp. 21–58.
Vezzoli, C.A., Manzini, E., 2008. Design for Environmental Sustainability. Springer-Verlag.
Voss, J.P., Bauknecht, D., Kemp, R. (Eds.), 2006. Reflexive Governance for Sustainable Development. Edward Elgar Publishing.
Waide, P., 2010. Phase Out of Incandescent Lamps. OECD/IEA Series. International Energy Agency, Paris.
Wang, L., Chen, M., 2013. Policies and perspective on end-of-life vehicles in China. J. Clean. Prod. 44, 168–176.
Wheelen, T.L., Hunger, J.D., 2004. Strategic Management and Business Policy, 9th ed. Prentice Hall, Englewood Cliffs, NJ.
Willskytt, S., Böckin, D., André, H., Ljunggren Söderman, M., Tillman, A.M., 2016. Framework for analysing resource-efficient solutions. EcoBalance Conference 2016.
Wieser, H., 2016. Beyond planned obsolescence: product lifespans and the challenges to a circular economy. GAIA-Ecol. Perspect. Sci. Soc. 25 (3), 156–160.
Worrell, E., Reuter, M.A., 2014. Recycling in Context Handbook of Recycling. Elsevier, pp. 1–61.
Zaman, A.U., 2015. A comprehensive review of the development of zero waste management: lessons learned and guidelines. J. Clean. Prod. 91, 12–25.
ZeroWIN, 2010. Towards Zero Waste in Industrial Networks. Literature Review "Approaches to Zero Waste". www.zerowin.eu.
Zink, T., Geyer, R., 2017. Circular economy rebound. J. Ind. Ecol. 21 (3), 593–602.
Zhu, Q., Geng, Y., Lai, K., 2010. Circular economy practices among Chinese manufacturers varying in environmental-oriented supply chain cooperation and the performance implications. J. Environ. Manage. 91 (6), 1324–1331.