CIRCULAR ECONOMY 3.0: GETTING BEYOND THE MESSY CONCEPTUALIZATION OF CIRCULARITY AND THE 3R'S, 4R'S AND MORE …

W.J.V. VERMEULEN, D. REIKE[1] and S. WITJES[2]

[1] *Copernicus Institute of Sustainable Development, Utrecht University, Netherlands*
[2] *Radboud University Nijmegen, Netherlands*

In recent years the concept of Circular Economy has received growing attention, both in the worlds of science and of policy making. Some scholars and practitioners present it as a novelty, but we have to acknowledge that it builds on the legacy of predecessors, like waste recycling and separation, industrial ecology, eco-industrial parks and industrial symbiosis. Various concepts go back to the 1980's, such as the concepts of waste hierarchies (3R's, 4R's etc.) and cascading. The 3R's concept has become commonplace in many national waste regulations all over the world.

At best, we can frame the renewed attention as '***Circular Economy 3.0***'. By doing so, questions arise concerning what it takes from versions 1.0 and 2.0 and what is new. Most important may be the 'action imperatives' suggested by scientists: what should producers actually do to achieve the best impact. These have traditionally been expressed as the various R's, complemented with expressions of preference and priority.

In an extensive review of academic literature, we have analysed the various perceptions of this. We analysed inputs from a range of academic disciplines in these discourses. We identified 69 scientific articles that explicitly referred to a waste hierarchy in terms of a 3R, 4R or more. We examined articles from various disciplinary backgrounds (including environmental sciences, engineering, logistics, policy studies and more).

A remarkable finding is that in the literature there is a messy cacophony around the 3 or more R's as value retention imperatives (we would prefer not to use the word 'recycling' anymore as an overarching concept, as can be seen in the article). In explaining what to do, these authors present a range from 3Rs to 10R's, with the 5R's version being the most frequently suggested. In a similar analysis of 114 definitions we also illustrated the confusion around the conceptualisation of circular economy (Kirchherr et al. 2017).

We see the same confusion also in policy documents: both the EU and the UN suggest a 3R's approach, but the R's have different meanings. This links to a more serious issue in the scientific literature on circular economy: when using a 3R's to 10R's waste hierarchy, scientists are further messing up because they use 38 different 're-'-words in these hierarchies[1], even the one's using 3R's or 4R's do not refer to the same R's.

In our article, we intend to clean up this conceptual confusion as well as we can. Synthesizing the many contributions, we present a final 10R's hierarchy (starting with the R0, being 'refuse' from the consumer perspective, and ending up with R9, the re-mining from old land-fills). By means of a

[1] In alphabetic order these are: re-assembly, re-capture, reconditioning, recollect, recover, recreate, rectify, recycle, redesign, redistribute, reduce, re-envision, refit, refurbish, refuse, remarket, re-manufacture, renovate, repair, replacement, reprocess, reproduce, repurpose, resale, resell, re-service, restoration, resynthesize, rethink, retrieve, retrofit, retrograde, return, reuse, reutilise, revenue, reverse and revitalize.

thorough comparison, we sketch the variation of definitions of the 10 R's and come to the best available, come to the best available among the more various definitions given.

2 distinct product life cycles: Value retention options R0 – R9:	***Life Cycle 1:*** *Product Produce and Use Life Cycle*		***Life cycle 2:*** *Product Concept and Design Life Cycle*	unspecified general word use *(to be further avoided)*
	consumers	producers/retailers	designers	
Short loops: R0-3				
Refuse: R0	- choice to buy less, or use less; - reject packaging waste and shopping bags	n.a.	- refuse the use of specific hazardous materials or any virgin material; - design production processes to avoid waste	
Reduce: R1	- using purchased products less frequently; - use them with more care and longer.	n.a.	- as explicit steps in product design: - using less material per unit of production; - or 'dematerialization'	*'eliminating waste, not dispose anymore'* *'as for all user steps'*
Resell/Re-use: R2	- buying second hand, or finding a buyer for a product that was not or hardly in use, possibly after some cleaning or minor adaptations restoration; - use online consumer-to-consumer auctions for used products	- 'direct re-use' as economic activity via collectors and retailers, possibly with quality inspections, cleaning and small repairs; (commercial and non-commercial); - 'direct re-use' of unsold returns or products with damaged packaging; - multiple re-uses of (transport) packaging	- 're-use in fabrication' - apply recycled materials	
Repair: R3	- by the consumer in their vicinity, or at their location, or through a repair company; - or at a 'repair café'	- send recollected products to their one's own repair centers, to manufacturer-controlled, or to third party repair centers; - distinguish 'planned repair' as part of a longer lasting maintenance plan from 'ad-hoc' repairs	- enable easy repairing	*confused with 'refurbishment'*
Medium Long Loops: R4-6				
Refurbish: R4	n.a.	- overall structure of large multi-component product remains intact, while many components are replaced or repaired, resulting in an overall 'upgrade' of quality of product - Examples: buildings, airplanes, trains, mining shovels		
Remanufacture: R5	n.a.	- full structure of a multi-component product is disassembled, checked, cleaned and when necessary replaced or repaired in an industrial process, recycled parts may be used - expected retained quality more tempered: 'up to original state, like new'		*some also refer to this as 'reconditioning', 'reprocessing' or 'restoration': better avoid*
Repurpose: R6	n.a.		- reusing discarded goods or components adapted for another function:	*some use: 'rethink' or 'fashion upgrading': better avoid*
Long Loops R7-9				
Recycle Materials: R7	- give back as separate waste streams	- processing of mixed streams of post-consumer products or post-producer waste streams using expensive technological equipment, including shredding, melting and other processes to capture (nearly) pure materials;	- apply recycled materials	*'recycle' is frequently and confusingly use to cover all alternatives: better avoid*
Recover (energy): R8	n.a.	capturing energy embodied in waste, linking it to incineration in combination with producing energy, distilled water or use of biomass	n.a.	'recover' often used as equivalent for general recycling: better avoid
Re-mine (R9)	n.a.	- retrieval of materials after the landfilling phase: - 'cannibalization'; - hi-tech landfill mining or urban mining	- apply recycled materials	

Table 1: Most commonly used descriptions of value retention options and word to better be avoided (Reike et al. 2018)

Table 1 (see also page 5) provides the main lessons from this analysis, which we suggest using as a guide for the future. In doing so, we need to distinguish between two types of product life cycles: we need to distinguish between the product life cycles of 'Produce and Use' and of 'Concept and

Design'. Not doing so leads to part of the confusion as they refer to different actors and options. In Figure 1 we show the synthesis as the comprehensive Product Produce and Use Life Cycle (the second product life cycle is shown in Reike et al. 2018).

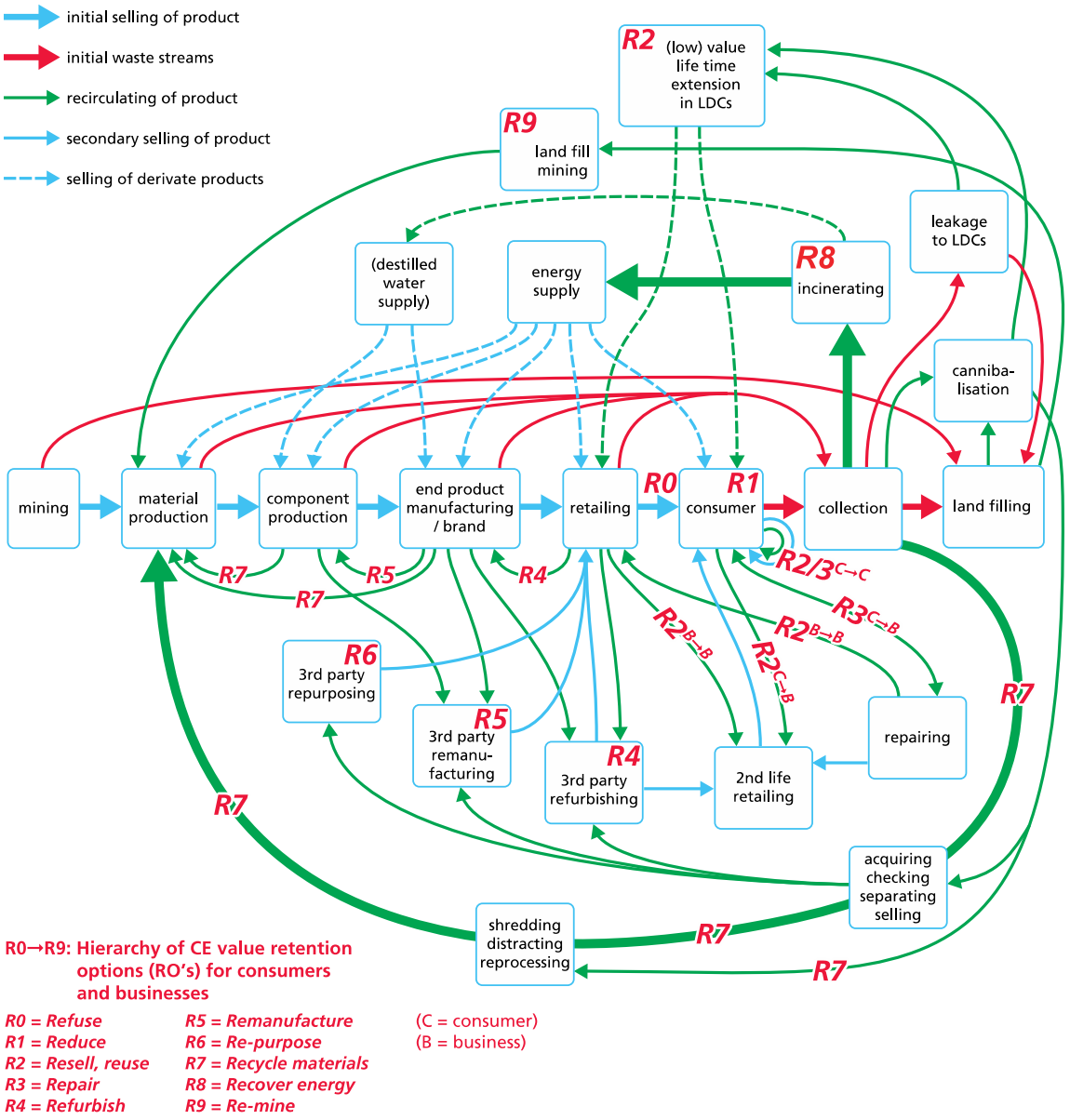

Figure 1 Mapping Circular Economy Retention Options: The Product Produce and Use Life Cycle (Reike et al. 2018).

With this, we present an integrated version of value retention options mapping, including some of the loops that are often ignored (like the substantial leakages to less developed countries) and highlight the role of new economic actors in the repairing, refurnishing and remarketing of products. The figure allows balanced attention to be given to the (in many places already well-organized) longer-value retention loops, the middle long loops (where we now see many new business models initiated) and the short loops (with a key role for consumers and non-commercial activities). This analysis stresses the distinction between the short loops, the middle-long loops and the long loops.

The first four short loops (R0-3) exist close to the consumer, and can be linked to commercial or non-commercial actors engaged in extending the life span of the product. Scholars applying a clear hierarchy characterize these as the most preferable R's in the circular economy. In our historic overview in the article, we argue that the varying emphasis on the R0 and R1 in the literature may be evidence of a paradigmatic division with respect to the issue of the perceived necessity of absolute reduction of inputs and consumption, and may hence also be related to the different motives of different groups in promoting circular economy. This may conflict with a current popular focus on business opportunities in the circular economy.

The second group of three medium-long loops (R4-6) includes refurbish, remanufacture and repurpose, often confused with each other and some other concepts. For these loops commercial business activity is the main driving force, with frequently specialized 3rd actors with high levels of expertise as stakeholders.

The third group of three long loops (R7-9) refer to traditional waste management activities, including recycling, different forms of energy recovery and, more recently, re-mining. Many scholars applying clear hierarchies with their R's agree that these options are the least desirable. Still, materials or particles obtained through longer loop recycling can serve as input for shorter loop R's (see 'remanufacture'). This is also the area which government policies in the circular economy 1.0 and 2.0 have been focusing on. Here a key challenge is how higher-value application of recycled materials can be achieved, especially in the countries where mass recycling is already well organized (mostly in North-west and central Europe).

We hope researchers and policy makers will benefit from our efforts to synthesize the formerly messy discourse. For the more detailed discussion, we refer to the background articles:

Reike, D., Vermeulen, W.J.V. & 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. *Resources, Conservation and Recycling*, 135, pp.246–264. Available at: https://doi.org/10.1016/j.resconrec.2017.08.027.

Kirchherr, J., Reike, D. & Hekkert, M., 2017. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling*, 127, pp.221–232. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0921344917302835.

2 distinct product life cycles: Value retention options R0 – R9:	***Life Cycle 1:*** *Product Produce and Use Life Cycle*		***Life cycle 2:*** *Product Concept and Design Life Cycle*	unspecified general word use *(to be further avoided)*
	consumers	producers/retailers	designers	
Short loops: R0-3				
Refuse: R0	- choice to buy less, or use less; - reject packaging waste and shopping bags	n.a.	- refuse the use of specific hazardous materials or any virgin material; - design production processes to avoid waste	
Reduce: R1	- using purchased products less frequently; - use them with more care and longer.	n.a.	- as explicit steps in product design: - using less material per unit of production; - or 'dematerialization'	*'eliminating waste, not dispose anymore'* *'as for all user steps'*
Resell/Re-use: R2	- buying second hand, or finding a buyer for a product that was not or hardly in use, possibly after some cleaning or minor adaptations restoration; - use online consumer-to-consumer auctions for used products	- 'direct re-use' as economic activity via collectors and retailers, possibly with quality inspections, cleaning and small repairs; (commercial and non-commercial); - 'direct re-use' of unsold returns or products with damaged packaging; - multiple re-uses of (transport) packaging	- 're-use in fabrication' - apply recycled materials	
Repair: R3	- by the consumer in their vicinity, or at their location, or through a repair company; - or at a 'repair café'	- send recollected products to their one's own repair centers, to manufacturer-controlled, or to third party repair centers; - distinguish 'planned repair' as part of a longer lasting maintenance plan from 'ad-hoc' repairs	- enable easy repairing	*confused with 'refurbishment'*
Medium Long Loops: R4-6				
Refurbish: R4	n.a.	- overall structure of large multi-component product remains intact, while many components are replaced or repaired, resulting in an overall 'upgrade' of quality of product - Examples: buildings, airplanes, trains, mining shovels		
Remanufacture: R5	n.a.	- full structure of a multi-component product is disassembled, checked, cleaned and when necessary replaced or repaired in an industrial process, recycled parts may be used - expected retained quality more tempered: 'up to original state, like new'		*some also refer to this as 'reconditioning', 'reprocessing' or 'restoration': better avoid*
Repurpose: R6	n.a.		- reusing discarded goods or components adapted for another function:	*some use: 'rethink' or 'fashion upgrading': better avoid*
Long Loops R7-9				
Recycle Materials: R7	- give back as separate waste streams	- processing of mixed streams of post-consumer products or post-producer waste streams using expensive technological equipment, including shredding, melting and other processes to capture (nearly) pure materials;	- apply recycled materials	*'recycle' is frequently and confusingly use to cover all alternatives: better avoid*
Recover (energy): R8	n.a.	capturing energy embodied in waste, linking it to incineration in combination with producing energy, distilled water or use of biomass	n.a.	'recover' often used as equivalent for general recycling: better avoid
Re-mine (R9)	n.a.	- retrieval of materials after the landfilling phase: - 'cannibalization'; - hi-tech landfill mining or urban mining	- apply recycled materials	