Restorative and regenerative
Exploring the concepts in the circular economy

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Abstract
The most recognized definition of the circular economy is that it is a restorative and regenerative economy. Despite the wide use and importance attributed to the concepts of “restoration” and “regeneration,” they are rarely defined or explained in the circular economy literature. In this context, this study critically examines the two terms, while providing guidance on their future utilization and development. Specifically, the study investigates the origin of the concepts, their adoption in frameworks that anticipated the idea of the circular economy, and their connotations in the circular economy literature. The examination supports the need for clear and distinct definitions, combined with precision in usage. From a review of the literature, restoration is a better-defined concept than regeneration, although it needs conceptual reinforcement relative to the biological/ecological aspects of the circular economy. This study suggests looking in the direction of restoration ecology, a well-established branch of ecological research. Conversely, regeneration is a symbolic/evocative term with little practical application in the context of circular systems except in the case of certain agricultural practices. Until new conceptual developments intervene, regeneration does not seem to be applicable to the economy as a whole and because of this, might be abandoned as a guiding principle of the circular economy. Unlike regeneration, restoration can be considered a core principle because it has widespread application and can be a point of reference for circular applications. This does not preclude the possibility that other concepts may be needed to augment restoration.

KEYWORDS
biological and technical cycles, circular economy, circular economy guiding principles, industrial ecology, restorative and regenerative concepts

1 | INTRODUCTION

In 2012, the Ellen MacArthur Foundation (EMF) introduced the concept of a circular economy (CE) as “an industrial economy that is restorative or regenerative by intention and design” (EMF, 2013, 7), and later as “restorative and regenerative by design and aims” (EMF, 2015a, 2). Since then, the definition of the CE as restorative and regenerative has come into common use, or at least has reverberated thousands of times throughout both academic and non-academic literature. This definition is by far the most employed one in CE studies (Kirchherr, Reike, & Hekkert, 2017). To give a flavor of this, up to the end of 2019, Google Scholar counts over 700 entries for the combination of “circular economy” and “restorative and regenerative” and almost 400 for “circular economy” and “restorative or regenerative.” The majority of quotations are verbatim from EMF sources, although some authors provide a modified or slightly expanded version of the EMF definition (e.g., Bressanelli, Perona, & Saccani, 2018; Geissdoerfer, Savaget, Bocken, & Hultink, 2017; Heyes, Sharmina, Mendoza, Gallego-Schmid, & Azapagic, 2018—see also Korhonen, Nuur, Feldmann, &
Birkie, 2018). Notably, numerous researchers underscore that the concepts of “restoration” and “regeneration” are central tenets of a CE (Jawahir & Bradley, 2016; Korhonen et al., 2018; Lieder & Rashid, 2016; Murray, Skene, & Haynes, 2017; Reike, Vermeulen, & Witjes, 2018). In the paper, the nouns “restoration” and “regeneration” are used to describe the concepts, while the adjectives “restorative” and “regenerative” are used as modifiers that ascribe attributes to specific things, for example, “restorative agriculture.”

Despite the wide use and importance attributed to “restoration” and “regeneration,” the concepts are rarely defined or explained in the CE literature. Instead, the terms are subject to a range of nuances and interpretations. This study analyzes the different connotations in the literature, while critically investigating the two concepts. With this purpose, the study answers some broad questions: What are the current interpretations of “restoration” and “regeneration”? Is it possible to have useful and mutually exclusive definitions? And, are these concepts necessary as well as applicable for defining a circular economy?

Descriptions of a CE as restorative and regenerative may mislead readers without deep knowledge of the underlying concepts of restoration and regeneration. Understanding the meaning of these terms is essential to describe current reality and a future state that addresses identified problems of the moment (Berger & Luckmann, 1991; Newell & Simon, 1972). Thus, the understanding of what are viewed as foundational CE concepts is essential for elaborating sound and coherent CE solutions by practitioners and scholars. This clarification can be useful as well in other research areas such as industrial ecology, the Green New Deal, and urban metabolism, where these concepts appear repeatedly.

2 | ROOTS AND BONES OF RESTORATION AND REGENERATION

These two words have traveled through centuries and multiple languages; both originate from Latin. The (Latin) prefix “re” indicates repetition. Restoration is from (re)staurare, meaning to repair/give back/build up again. Regeneration is from generare, which means to give birth/generate. Restorative is commonly used for describing aspects related to individuals; it is employed in social disciplines such as healthcare (e.g., restorative medicine), education (e.g., restorative school practices), and philosophy (e.g., restorative justice) to express forms of repair of the self/person. By contrast, regenerative is frequently employed in sciences—such as ecology, biology, and medicine—to indicate a functional self-renewal or—more often—a morphogenic replacement of lost or damaged parts or structures in organisms or ecosystems.

Restoration and regeneration are also associated with ideas and frameworks that have influenced or flowed into the CE proposition (see Craft, Ding, Prasad, Partridge, & Else, 2017; EMF, 2013; Geisenendorf & Pietrulla, 2018; Ghisellini, Cialani, & Ulgiati, 2016; pane Haden, Oyler, & Humphreys, 2009; Jawahir & Bradley, 2016; Lieder & Rashid, 2016; Torres & Parini, 2019; Yudelson, 2010). These ideas and frameworks include regenerative agriculture, restorative economy, regenerative development and design, restorative environmental design, regenerative building, and Cradle to Cradle.

Regenerative agriculture—so-named (and promoted since the late 1970s) by the agriculturalist and publisher Rodale (1983)—is a concept that describes maintaining and improving resources through continuous organic renewal of the complex living system (see Dahlberg, 1991). Rodale later applied the principle of ongoing renewal to a framework he called “regenerative economic development” (Mang & Reed, 2012; see also Medard, Pahl, Shegda, & Rodale, 1985).

The ecologist and entrepreneur Hawken (1993) used the term regenerative economy to describe an economy that combines business activities with environmental (restorative) practices. Hawken (1993, 58) argued that “to restore is to make something well again,” which needs to be applied by the economy to ecosystems. This idea was also employed by the entrepreneur Anderson, who transformed his company (Interface, a prominent carpet tile manufacturer) into a self-described restorative enterprise (see Anderson, 2004; Pane Haden et al., 2009).

Regenerative development and design, advanced by the architect Lyle (1994), reflects his case for a convergence of disciplines including architecture, landscape ecology, land-use planning, permaculture, and regenerative agriculture (see Mang & Reed, 2012). According to Lyle (1994, 10), “in order to be sustainable, the supply systems for energy and materials must be continually self-renewing, or regenerative, in their operation.” Lyle (1994) set the framework, principles, and strategies for reversing environmental damage, conceptualizing regenerative design and circular flows as a replacement for linear systems.

Lyle’s work inspired additional ideas connected to the concepts of restoration and regeneration. Advocates of restorative environmental design (e.g., Kellert, 2004; Reed, 2007) propose to return degraded or damaged sites to a state of acceptable ecosystem health through human intervention. Others promote regenerative building (e.g., Leadership in Energy and Environmental Design [LEED]), which is intended as a holistic approach for constructing human settlements (and nearly all other human activities). These examples reflect the intentional design of human systems that are capable of co-evolving with natural systems (Mang & Reed, 2012; Reed, 2007), and improving the health and vitality of a geographically specific location (anthropic or natural) over time (Yudelson, 2010).

The last framework considered here is Cradle to Cradle, which aims at designing products and manufacturing processes where material flows are safe, restorative, regenerative, and based on closed-loop cycles. This concept derives from the works of the architect Stahel, the chemist Braungart, and the environmental expert Engelfried, and was formalized by Braungart and the architect McDonough (see Braungart & Engelfried, 1992; Braungart & McDonough, 1998; McDonough & Braungart, 2000, 2010; Stahel, 2016). Here, as Hofstra and Huisingh (2014, 464) summarize,
regenerative means to “restore, renew, revitalize and ensure rebirth to […] sources of energy and materials by taking into account future needs, wants and desires of society and nature.”

These ideas and frameworks do not always define a clear distinction between restoration and regeneration. Roughly, restoration focuses on reversing damage caused by human intervention that requires returning to an unspecified origin condition. The proponents of the restorative view demonstrate a practical approach to problem-solving and look at specific cases from the economic domain, for example, fertility/productivity, repair, remanufacture, waste management, and production cycles.

Regeneration represents a form of upgrade from restoration. If restoration means “to make something well again,” regeneration, for some authors, means “to make it better” than a (supposed) origin condition. Advocates of regeneration approaches in the 1990s tended to focus on a vision that may have reflected an optimistic view of social change prevalent during that period (see Ferguson, 2002; Park, Conca, & Finger, 2008). Mang and Reed (2012, 8862) pointed out that there is “a tendency to blur or confuse regenerative approaches with the range of other design systems that emerged in pursuit of ecological sustainability in the 1990s.”

The multiplicity of definitions of the concept of “regeneration” echoed the cacophony of frameworks surrounding the idea (see Mang & Reed, 2012).

3 | RESTORATION AND REGENERATION IN TECHNICAL AND BIOLOGICAL CYCLES

Concurrent with the definition of a CE as restorative and regenerative is the distinction made by EMF (drawn from the Cradle to Cradle literature) between cycling of materials that are predominant in the technosphere and those materials that are predominant in the biosphere (Braungart & McDonough, 1998; Braungart, McDonough, & Bollinger, 2007; McDonough & Braungart, 2010). Furthermore, EMF articulates a dual cycle structure for a circular economy (2015a, 7) where: “The technical cycle involves the management of stocks of finite materials … Technical materials are recovered and mostly restored in the technical cycle… The biological cycle encompasses the flows of renewable materials…. Renewable (biological) nutrients are mostly regenerated in the biological cycle.” Many CE researchers follow EMF in using separate cycles for technical and biological materials (nutrients in Cradle to Cradle language).

From the EMF descriptions, it would seem that the concept of restoration is particularly applicable to the technical cycle and regeneration concept is limited to the biological cycle. However, in other documents by the EMF and elsewhere in the CE literature, restorative and regenerative are viewed as belonging to both cycles. This article uses this dual technical/biological structure to evaluate potential definitions of restoration and regeneration and the usefulness of the concepts in a CE.

3.1 | Restoration and regeneration in the CE literature

To evaluate the use of the restoration and regeneration concepts in the CE literature, data were collected in 2018 from the academic and non-academic literature beginning with the EMF publications by searching the Google Scholar and Scopus databases for “circular economy,” “restoration,” “regeneration,” “restorative,” “regenerative,” and variants including “restore,” and “regenerate.” In addition to the EMF definitions, the searches identified a variety of uses and meanings associated with the restoration and regeneration concepts. These are summarized in Figure 1.

From the literature search, only two documents provided simultaneous definitions of restorative and regenerative. First, in a discussion of sustainability, Brown and colleagues (2018, 8) referred to restorative as “restoring social and ecological systems to a healthy state,” and regenerative as “enabling social and ecological systems to maintain a healthy state and to evolve.” Both concepts relate to a “healthy state,” which is left as an undefined desired condition to reach or retain. To be useful, “healthy state” needs parameters that are quantifiable and subject to evaluation. Second, Batista and colleagues (2018, 439) offered the following definitions: “restore (impart new life and vigor, promote recuperation) and regenerate (recuperate to a new, usually improved, state) materials,” adding that “both concepts entail the ‘recuperation’ or recovery of materials for further use.” In the same paragraph, the authors clarify that “for simplification we will use the terminology ‘restorative’ to also refer to the ‘regenerative’ capabilities of organizations and related supply chain operations.” While this suggests that Batista et al. view the concept of restoration as embodying the concept of regeneration, this use seems to muddy their definitions. This is particularly the case in using the expression “impart new life” in the definition of restore; given the etymology; the expression relates more to regeneration than to restore. Furthermore, they apply both concepts broadly when discussing materials, products, organizations, and networks of organizations without making distinctions in meaning and use.

Restoration in the CE literature is associated primarily with a need to restore to natural capital (e.g., Bastein, Roelofs, Rietveld, & Hoogendoorn, 2013; EMF, 2015a,b; Howard, Hopkinson, & Mieczczuk, 2018; Linder, 2017; Pauliuk, 2018; Pitt & Heinemeyer, 2015. The notion of natural capital was popularized by Hawken and colleagues (1999) to include natural resources used by humankind and the totality of living systems. Nature is identified as a store of capital to be maintained rather than a resource to be plundered (Pitt & Heinemeyer, 2015). In that context, the economy needs to be restorative and restoration occurs through rebuilding of natural capital.

A link to a role for regeneration in a CE can be traced back to Pearce and Turner (1990), the originators of the term “circular economy.” They proposed transformation of the linear “resource–products–pollution” paradigm into a circular “resource–products–regenerated resources” system (Jawahir & Bradley, 2016). In the specific context of a CE, regeneration has multiple interpretations. One is a concept that shapes society and
3.2 Restoration and regeneration in technical cycles

A central feature of a CE is the replacement of “the ‘end-of-life’ concept with restoration rather than destruction” EMF (2013, 7), where products and materials are not destroyed, but remain within production systems (Batista, Bourlakis, Smart, & Maull, 2018; Franklin-Johnson, Figge, & Canning, 2016; UNEP, 2012) as much as economics and technical feasibility will allow. The EMF (2015b) developed a material circularity indicator (MCI) to track restorative flows of products and to measure the overall flows of a company (see also Elia, Gnoni, & Tornese, 2017). This approach is consistent with the etymological meaning of restoration, specifically, “build up again.”

A wide range of processes and strategies that characterize technical cycles in a CE (see Potting, Hekkert, Worrill, & Hanemaaijer, 2017; Reike et al., 2018) are consistent with the concept of restoration (see Table 1).
Reuse, repair, renewal, refurbishment, remanufacture, maintenance, and upgrading are life-extension strategies for products (Morseletto, 2020). Except for reuse (in which an unchanged product passes from one user to the other), products return to the economy after modifications. Products are restored: a) to a like-new state, as in renewal and remanufacture (see de Jesus, Antunes, Santos, & Mendonca, 2018; Jawahir & Bradley, 2016; Lieder & Rashid, 2016); b) to a previously working state, as in repair and maintenance (Mobley, 2002; Murray et al., 2017); or c) to an improved/updated state, as in refurbishment and upgrading (Azevedo, Godina, & Matias, 2017; Cooper & Gutowski, 2017). Restorative activities can use discarded and second-hand materials or recovered parts and components thereby prolonging the life of these resources.

In a similar fashion, cascading and recycling are activities where materials can be re-employed several times in different products. All these strategies require restorative supply chains that support either or both closed-loop cycles (i.e., the logistics and processing of moving unwanted materials, components, and products from one part of the overall value chain to an appropriate point in the original supply chain for the product system) and open-loop cycles (i.e., the logistics and processing of moving unwanted materials, components, and products to organizations that are outside the original supply chain for different type of uses) (see Batista et al., 2018; Geyer, Kuczynski, Zink, & Henderson, 2016). Restoration can occur in both open and closed loops if materials, components, and products have sufficient value to remain in the overall economic system. However, environmental benefits and impacts may vary in open or closed loop solutions (see Geyer et al., 2016 for a thorough discussion).

In contrast to restoration, few studies refer to regenerating products and materials (e.g., Kalmykova, Sadagopan, & Rosado, 2018). In common language, a product (e.g., a printer or an oven) is regenerated when new parts substitute for old or defective ones as in refurbishing, remanufacturing, and upgrading (see, e.g., Tolio et al., 2017). In the case of refurbishing and remanufacturing, use of regeneration to describe these activities is synonymous with restoration. Upgrading, implies improvement and thus, the term regeneration may be more applicable; however, upgrading operations are more likely to be forms of restoration according to—for example—higher requirements of users or legislation.

Regeneration is also applicable to indicate the transformation of an unwanted material into a new useful material. For instance, Park and colleagues (2008) argue that waste can be regenerated into useful materials (they illustrate an eco-industrial park where materials and components are recovered from used electronic appliances). Another example is the recovery of plastic bottles, which can then be mechanically processed to generate raw materials for new products where virgin grade material is not necessary (e.g., plastic chairs), or chemically deconstructed into precursor substances for polymerization into virgin equivalent polymer suitable for any application. Currently, these operations are typically considered recycling (see Rahimi & Garcia, 2017). Similarly, the so-called regenerated nylon fibers employed in the carpet, textile, and fishing-net industries (e.g., Franco, 2017) have undergone a sophisticated process of recycling. Even used oil “regenerated” into new oil through re-refining (Rincón, Canizares, García, & Gracia, 2003), or exhausted resin, into a “regenerated” resin (Atasoy, Owusu-Agyeman, Plaza, & Ceteceoglu, 2018), are forms of recycling. In both examples, separation processes are used to recover substances with specific properties that are sufficient to create recycled versions of the original product.

More recently, regeneration has been associated with buildings, spatial areas, and cities in CE studies (e.g., Domenech, Bleischwitz, Doranova, Panayotopoulos, & Roman, 2019). The terms refer to new physical forms or uses of structures or improved wealth or connectivity within a defined geographic location. The terminology originated in urban planning and architectural and social studies rather than in a CE context (see Atkinson & Kintrea, 2002; Carley, 1990) and to date has been used primarily to describe recovery and reuse of construction materials (concrete, asphalt, etc.).

Following Pearce and Turner (1990), researchers in the CE community link regeneration and resources, whether as energy or materials (e.g., EMF, 2015a; Geisendorf & Pietrulla, 2018; Kalmykova et al., 2018; Smol, Kulczycka, & Avdiushchenko, 2017), either because of resource scarcity (Lieder & Rashid, 2016), a general need for efficiency in use of resources (Burger, Stavropoulos, Ramkumar, Dufourmont, & van Oort, 2019; de Jesus et al., 2018). There is general agreement that energy in a CE is from renewable sources (e.g., sunlight, wind, hydro, biomass, and geothermal), which Lacy and Rutqvist (2016) label regenerative energy without providing a rationale for the terminology or the conditions under which these sources could be considered regenerative. Rammelt and Crisps (2014, 27) introduced a distinction between non-living and living renewable resources: “non-living renewables (sолнит, wind or rivers) regenerate through a steady input that keeps refilling resource stocks. Living renewables regenerate through reinforcing feedback: more fish means more reproduction and therefore more fish, for example.” Although thought-provoking, the non-living/living renewable resources distinction is incomplete since it does not address resources such as forests and fresh-water aquifers where the rate of use may far exceed the rate of regeneration and result in irrecoverable depletion or explain the mechanisms of regeneration. Moreover, even if resources met criteria for being regenerated, it is not clear how the use of such resources would result in CE that is itself regenerative.

### 3.3 Restoration and regeneration in biological cycles

The concepts of restoration and regeneration are seemingly appropriate for biological cycles in a CE. Restoration, in the sense of bringing degraded ecosystems back to full function, and regeneration, as an effort to maintain and improve on current conditions, both make sense where natural capital requires constant reinforcement. The key question is how biological materials enter the economy and then return to the biosphere in a manner that is either restorative or regenerative.

Proponents of the notion of natural capital answer this question envisaging two main avenues for restoration. One avenue is that of organic/biological materials that exit safely from products and production processes to the biosphere. This interpretation echoes the idea in the Cradle-to-Cradle concept of a biological metabolism where biological nutrients (McDonough & Braungart, 2010), which can originate in
ecosystems (e.g., forests or the marine environment) or in industrialized systems (e.g., agriculture, mariculture, etc.), become “healthy waste” (Braungart et al., 2007) that can be returned to its source. According to the EMF (2015b, 2), "non-toxic materials are cascaded and eventually returned to the soil, thus restoring natural capital." Cascading is the further use of a biological material in multiple applications to extract additional value from the resource (Mair & Stern, 2017) before it becomes a “healthy waste.” According to this view, biological materials (e.g., food leftovers, natural fibers, bio-wastes from production) that have served their purpose can be transformed into compost and soil (EMF, 2013; Kalmykova et al., 2018) and be returned to either ecosystems or, more probably, to industrial systems. This is based on the assumption that biological materials can biodegrade safely and return to the soil to feed environmental processes.

Another avenue for restoring natural capital via biological cycles is expressed in terms of “reversing damage” (e.g., Brown et al., 2018; Pitt & Heinemeyer, 2015), meaning the damage to the environment caused by economic activities. CE scholars have not focused on how such damage is quantified, how it is reversed, and if it is fully or partially reversed through a CE. It is easier to identify examples of reversing damage in the linear economy where remediation is mandated by regulation or undertaken voluntarily (e.g., the restoration of altered hydrological features, re-establishment of destroyed habitats, removal of toxic contaminants, and reintroduction of niche species—Nugent, Packard, Brabon, & Vierra, 2016).

Pursuit of both avenues of natural capital restoration faces practical challenges. Biological materials do not necessarily (or immediately) transform into compost or healthy soil (Kononova, 2013). Moreover, compost and new soil production is not a significant topic in the CE literature (Haas, Kraussmann, Wiedenhofer, & Heinz, 2015), suggesting that they are far from being realized on a large scale. In this regard, the price of compost tends to be low, costs can vary considerably (according to transportation costs, technologies employed) while calculating the value of compost is difficult in ecological and economic terms (see Meyer-Kohlstock, Hädrich, Bidlingmaier, & Kraft, 2013). Similarly, healthy soil creation requires robust and well-developed inbound logistics (to processing sites) and outbound logistics (to destination sites). Furthermore, it is not clear who should bear the costs of soil creation or how to market the newly made soil.

Beyond this, there is a potentially significant risk in the return of biological material to the biosphere. Introducing large quantities of “used” biological matter can have vast effects (both expected and unpredictable) on ecosystems. For example, introducing excessive nutrients into water bodies can cause eutrophication where hyper growth in aquatic plants consumes oxygen such that it affects surrounding organisms (see Llorach-Massana, Farreny, & Oliver-Sola, 2015; Reijnders, 2008). Similarly, massive substance inputs can collapse the capacity of an ecosystem to assimilate them (Llorach-Massana et al., 2015). Assumptions about “reversing damage” may be too simplistic to address the sophisticated structure and intense network of interactions of large-scale ecosystems (see, e.g., Palmeri, Barausse, & Jorgensen, 2013). To be effective, the restoring damage concept would require detailed knowledge of an ecosystem prior to the specified damage as well as the desired state of a restored ecosystem, neither of which is easily determined.

Regeneration in the biological cycle is not easily distinguished from restoration. For EMF (2015a), regeneration in the biological cycle is derived from the Cradle-to-Cradle framework (Braungart et al., 2007) where biological nutrients regenerate the ecosystem (Homrich, Galvao, Abadia, & Carvalho, 2018). This is consistent with those views that associate regeneration with rebuilding and enhancing natural capital (EMF 2015c,d; Genoves, Acquaye, Figueroa, & Koh, 2017; Howard et al., 2018), but this approach is not sufficient to understand the practical meaning of regeneration, especially as to how it may differ from restoration.

In line with the “health of ecosystems,” other authors (e.g., Pauliuk, 2018; Pitt & Heinemeyer, 2015; Rhodes, 2015) interpret regeneration as creating better conditions to support the life-enhancing qualities of ecosystems. However, “better conditions” is an ambiguous expression absent a baseline (i.e., a detailed state in a previous point in time) and measurement of improvements against that baseline. Rhodes (2015) mentions that the improved conditions encompass the creation of habitat (including building soil), water purification, and enhancement of nitrogen/carbon-fixing processes in the soil, etc. The author also adds that it is possible to create larger regenerative systems by linking together smaller regenerative units. Again, there are some similarities with restorative, in particular, with the “reversing damage” proposition. Furthermore, there is a proactive attitude toward a more advanced relationship with nature. This is common to other concepts (see du Plessis, 2012) such as ecological design (seeking integration with nature’s processes—van der Ryn & Cowan, 2007), ecological engineering (building biological infrastructures—Mitsch, 1993), and positive development (promoting going beyond ecological compensation—Birkeland & Knight-Lenihan, 2016). However, even if these frameworks provide practical applications, they do not clarify how regeneration is distinguished from restoration.

There are some caveats to an understanding of regeneration as maintaining the health of nature and ecosystems. Multiple diverse disturbances to an ecosystem (Walker, 2012) can exceed the capacity of disturbance-adapted species to return to a “healthy state” (DellaSala & Hanson, 2015). Regeneration may take several years or even decades (e.g., Biringer & Hansen, 2005) and follow different trajectories and velocities (Holz & Placci, 2005). In contrast, agriculture seems to be a suitable field for applying the concept of regeneration in relation to the biological cycle. The EMF (2015c, 2019) advocates for regenerative agricultural practices such as no-till farming techniques and replacement of synthetic inputs. For instance, fossil-fuel-based fertilizers may be eliminated by cultivating leguminous grassland and using animal husbandry manure as fertilizer. Similarly, other studies propose regenerative farming practices as integral to a CE (Pascucci & Duncan, 2017; Torres & Parini, 2019; Unay-Gailhard & Bojnec, 2019). These build on the regenerative ideas of Rodale (1983) and Pretty (1995) to minimize the inputs of energy and materials, while recycling inputs like water, nutrients, and organic matter (Pearson, 2007; Toensmeier, 2016).
4 | ANALYSIS AND A SUGGESTED STEP FORWARD

Restorative and regenerative have been used to describe a metaphorical aspect of circularity. Restorative conjures up a circuit of endless use, reuse, and repair. Regenerative speaks to a sort of cycle of life that maintains and upgrades conditions of ecosystem functionality. These terms may be useful for advancing the concept of a CE, but they also may result in the concept being blurred and misunderstood as it occurs when concepts connect to a web of cultural meanings (see Keulartz, 2007; Larson, 2011; Morseletto, 2017).

Currently, agreed upon definitions of both concepts are lacking in the CE community, leading researchers to invoke their own interpretations, thereby amplifying the breadth of each term. If the concepts are going to have any value to the CE community, there is the need to come to shared definitions of restoration and regeneration in the context of a CE.

4.1 | Restoration

I propose the convergence to a simple definition of restoration: the return to a previous or original state. This is a plain definition that is respectful of etymology and in line with most interpretations in the CE literature.

The definition can easily be applied to the technosphere, where it is possible to restore various materials to a previous state (e.g., recycled glass or polymers, with almost identical or similar properties). This happens even with impurities, contamination, technical recovery difficulties, and the limits on the number of times some materials may be recycled (see Allwood et al., 2012; Blichtert-Toft, 2017; Haupt, Vandenbos, Zeltner, & Hellweg, 2017). Similarly, it is possible to restore products to a working/improved condition (e.g., repairing or upgrading an object). As previously noted, recycling, cascading, repair, renewal, refurbishment, remanufacture, maintenance, and upgrading are the main strategies/techniques for restoring and maintaining productive use of materials and products in the economy. Within the technosphere, biological elements may be employed in ways that are similar to non-biological materials and designed to be recovered, recycled, and used for additional purposes. For example, wood used in construction could be recovered from buildings that are renovated or demolished and recycled into different products. Similarly, byproducts from food production could be used to make polymers that are recovered after use for recycling back into usable polymers (see Mair & Stern, 2017; Sakai et al., 2003).

In the ecosphere, restoration is less straightforward. Introducing biological elements that have entered commerce back into an ecosystem requires precise methods, protocols, and procedures that address varied issues such as compatibility, toxicity (Chemat, Vian, & Cravotto, 2012; Lehmann & Kleber, 2015), recovery and recycling of nutrients (Tadesse, Oenema, van Beek, & Ocho, 2018; Withers, Doody, & Sylvester-Bradley, 2018), and complexity of ecosystem structures and functions (Palmer, Zedler, & Falk, 2016; Palmeri et al., 2013) along with a host of other issues. In this regard, restoration ecology (RE) can be a useful adjunct to the development of a CE construct. RE has become a well-established branch of ecology that aims to recover degraded, damaged, or destroyed ecosystems (SER, 2002) through a suite of tools developed within the discipline for accelerating the recovery of damaged ecosystems (see Hobs, 2018; Perring et al., 2015; Rohr, Bernhardt, Cadotte, & Clements, 2018). While there is much debate about ethical and philosophical issues in restoration (see Clewell & Aronson, 2013; Hertog & Turnhout, 2018; Keulartz, 2012; Wortley, Hero, & Howes, 2013), there is also much practical experience in restoring ecosystems to inform aspects of a CE (see Hobs, 2017; Hou & Aide, 2011; Rohr et al., 2018). In these terms, CE and RE scholars and practitioners should work together to define restorative protocols, guidelines, and procedures in relation to CE activities in the ecosphere. This would require facilitating greater collaborative activity between the CE and RE communities, possibly promoting a coevolutionary research agenda (see Kallis & Norgaard, 2010; Norgaard, 2006). Currently, the RE community is involved in a discussion on standards for the practice of restoration, as defined by the Society for Ecological Restoration (Gann et al., 2018; Hobbs, 2018; McDonald, Gann, Jonson, & Dixon, 2016). This could be an opportunity to advance the concept and practice of restoration in the CE, especially considering that the debate on CE standards is still in its infancy (Tecchio, McAlister, Mathieux, & Ardent, 2017).

4.2 | Regeneration

Regeneration in the context of a CE is not easily differentiated from restoration. I propose a definition of regeneration as the promotion of self-renewal capacity of natural systems with the aim of reactivating ecological processes damaged or over-exploited by human action. This definition, connoting a rebirth or restart, does not easily fit with technical cycles, where restoration may be more apt (e.g., addressing the impacts of mining and extraction processes to access metals and inorganics). Regeneration as in the proposed definition, may be most useful in agriculture, where it developed as a field of research and practical solutions (Pretty, 1995; Rodale, 1983). Even if used within CE to address biological cycles, regenerative agriculture overlaps with other agriculture frameworks including organic, biodynamic, low-input, resource-conserving, permaculture, and agroecology (see Pretty, 1995). Pearson (2007) noted that regenerative is a catchy word while other terminologies might be cumbersome and unlikely to attract public support. Where agricultural practices promote fertility, nutrient cycling, or ecological services, they support the regenerative capacity of nature (see, e.g., Hou & Aide, 2011; Perrow & Davy, 2002; Villamagna, Angermeier, & Bennett, 2013). This capacity—although debatable—can be defined as the ability of nature to revive itself, recover from disturbances, and rebuild its functions.
The question remains as to whether or not regeneration is a central principle of a CE if it is limited to a single sector of the economy—even one as important as agriculture. Absent a consensus around a single definition of regeneration that is distinct from restoration and a robust explanation of how it would widely apply across a CE, I suggest that regeneration not be considered a primary principle of a CE. Restoration, because it has pervasive application in a CE, can be a point of reference and a guiding principle for CE solutions. This does not preclude the possibility that other concepts may be needed to augment restoration.

Future research should explore how to specify better, improve, or complement the guiding principles of a CE because these are the constant reference point to inspire and orient actions of the framework. As theoretical core statements of a proposition, guiding principles must be clearly defined, consistent, and comprehensive. In a world dominated by buzzwords and dissonant meanings, clarity in language and consistent definitions of terms (not just in industrial ecology and sustainability discourse) are imperative to avoid misinterpretation, while facilitating effective implementation of frameworks like the CE one.

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CONFLICT OF INTEREST

The author declares no conflict of interest

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