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Principles for a sustainable circular economy

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ABSTRACT

The pressure that the human species exerts on the natural environment through the extraction of materials and generation of wastes is widely recognised. Circular economy has emerged as a potential solution to make better use of resources. Positioned as a technology-focused concept that can generate economic gains while alleviating pressure on the environment, circular economy enjoys a positive reception by organisations in public, private and civic sectors and, increasingly, academia alike. However, concerns have been raised regarding some purported circular economy practices being promoted as 'sustainable' yet resulting in detrimental impacts on environment and society. We briefly revisit the systems ecology literature that construed the context for both circular economy and sustainable development. Values and principles in core sustainable development literature are analysed to offer a foundation against which circular economy can be discussed. We then analyse and critically reflect upon the strengths, shortcomings and theoretical flaws within the values and principles that emerged from the evolving circular economy literature. We propose a value framework and set of ten principles for the design, implementation and evaluation of a sustainable circular economy. We finish with a call for action for both practitioners and a research agenda for academia.

1. A preamble to the need to reconcile circular economy and sustainable development

Concerns about the environment and finite resources drove the World Commission on Environment and Development to initiate the seminal Brundtland report (WCED, 1987) that still shapes the global agenda on sustainable development. It offered a positive compromise between the prevailing boundless economic growth philosophy and the environmental and social catastrophes forecasted by authors such as the Club of Rome (Meadows et al., 1972). Born from a rich body of systems ecology literature in the 1960s and 1970s were numerous disciplines and concepts to reduce natural resource extraction and the generation of waste, which would later synthesise into "circular economy" (Fig. 1).

Circular economy has been defined in almost as many ways as there are circular economy researchers and practitioners, as demonstrated eloquently by Kirchherr et al. (2017). Arguably the only common denominator across all definitions is the striving to make better use of resources, although what constitutes "better" remains debatable. Nevertheless it is clear that globally the depletion of natural resources (and associated carbon emissions) continues to accelerate while paradoxically mountains of waste (and associated pollution) are still piling up (Velenturf and Purnell, 2017), and it is hence logical that a circular economy should strive to minimise resource exploitation and maximise waste prevention (Fig. 1). But given the deep risks to the stability of an environment that is amenable to the thriving of the human species caused by depletion and pollution (see e.g. Rockström et al., 2009; Steffen et al., 2015), circular economy should strive to restore and regenerate the environment (EMF, 2021) by, as will be argued in this article, contributing to sustainability from the whole system perspective of optimising social, environmental, technical and economic values of materials and products in society (Fig. 1).

Development of circular economy in the last decade has been strongly practitioner-led. This perspective article will demonstrate how circular economy has been criticised by other authors for having a limited conceptual grounding and a lack of coherence on how it can contribute to sustainable development. This article will show that sustainability is neither as integrated into the implementation of circular economy practices nor as pervasive in circular economy research as one might hope or expect. This risks the loss of momentum for a strategy with a tremendous potential for sustainable development, and circular economy proponents must urgently prioritise embedding sustainability throughout the design, implemen-

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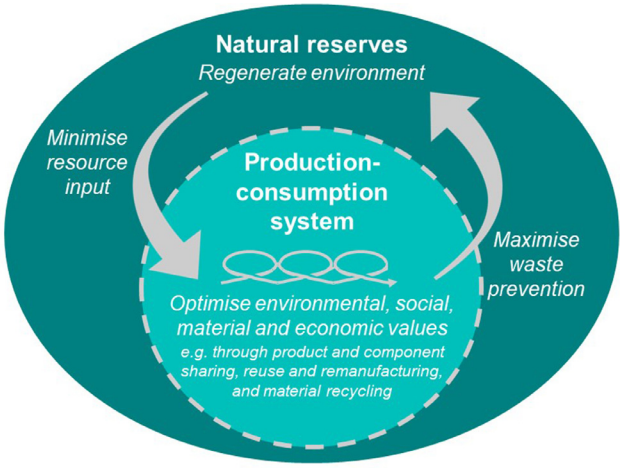

Fig. 1. In a circular economy resource use is improved by minimising the extraction of natural resources, maximising waste prevention, and optimising the environmental, social, material and economic values throughout the lifecycles of materials, components and products.

tation and evaluation of circular economies. This article analyses these criticisms and seeks to reconcile circular economy and sustainable development. It synthesises a manifesto for a sustainable circular economy by critically debating and proposing novel values – i.e. what is considered important and desirable – and principles – i.e. a basic idea or rule that explains or controls how something happens or works (Suárez-Eiroa et al., 2019).

Section 2 of the paper introduces who is interested in circular economy and why, and examples of how it is currently being implemented. It then outlines the weak relationship between circular economy and sustainable development despite their shared roots in systems ecology. Section 3 narrates how values and principles associated with sustainable development have evolved, while those associated with circular economy continued on its original trajectory. Consequently, sustainable development and circular economy are found on diverging pathways. The overview of sustainability values and principles in Section 3 offers a benchmark to compare to circular economy in Section 4. With sustainable development currently hardly integrated into circular economy, Section 4 proposes a novel manifesto with a value framework and principles for the design, implementation and evaluation of a sustainable circular economy to reunite circular economy with sustainable development. Section 5 concludes with actions for research and the implementation of sustainable circularity.

2. A tale of compromise between alternative world views and the mainstream

This section demonstrates the requirement for a critical review and articulation of novel principles for a sustainable and circular economy. It introduces why many actors have started to implement a circular economy, highlighting various arguments in favour of sustainability that are being used (Section 2.1). However, some circular economy practices introduced under the banner of sustainability appear to achieve the opposite, revealing the weak relation between circular economy and sustainable development (2.2). The section concludes on an exploration of the reasons why the relation between circular economy and sustainable development has remained relatively unsubstantiated for this long by offering a different take on the shared roots of these concepts compared to perspectives published so far (2.3).

2.1. Actors across society are interested in circular economy

Circular economy has gained momentum in the past decade, primarily through the approach of practitioners such as the Ellen MacArthur Foundation positioning it squarely within the "green growth" discourse, claiming that primary resource consumption and associated emissions can be decoupled from GDP to legitimise continued economic growth (Parrique et al., 2019). Governments are committed to implementing a circular economy, from transnational initiatives such as by the EU to countries such as China and cities such as Tokyo, New York and London (Purnell et al., 2020). In 2013 a third of global CEOs reported an active interest in circular economy driven by personal beliefs, business interests and sustainability concerns (Accenture and Compact, 2013). The Ellen MacArthur Foundation's "CE100" scheme offers companies a supportive environment to learn and adopt circular practices (EMF, 2019). Global leaders in this declared practice-based circular economy include for example Apple, Coca-Cola and Rolls Royce (Kiser, 2016; Purnell et al., 2020).

The widespread enthusiasm is no wonder given the estimated benefits. Lacy and Rutqvist (2016) forecasted global economic benefits to a total of $4.5 trillion by 2030, rising to $25 trillion by 2050; by comparison, the global economy was $80 trillion in 2017 (World Bank, 2019). Circular economy can generate new business opportunities, limit material costs and price volatility (Kalmykova et al., 2018), reduce dependency on imports and increase resource security (Mathews and Tan, 2016; Stahel, 2016). Global greenhouse gas emissions could be reduced by as much as 63% by 2050 through the uptake of low-carbon and resource efficient strategies (Circle Economy, 2019). Improvements to quality of life and creation of new jobs have been suggested as social benefits (Kalmykova et al., 2018; Mathews and Tan, 2016).

Accounts of successful implementations of circular economy have been collated by the Ellen MacArthur Foundation (EMF, 2020), displaying a very wide variety of interpretations of circular economy; mixtures of technological, policy and business model interventions; and metrics used to monitor success. Circular economy solutions are successfully practiced by numerous companies. Table 1 offers a few examples of companies targeting specific materials to reduce waste; others offer solutions giving products a new life; more radical solutions involve the redesign of products to increase circular economy potential throughout product lifecycles; and others developed digitally-enabled business models for existing technology to deliver circular economy benefits (Core Centric Solutions, 2020). Table 2 shows that circular economy is also embraced by city governments to deliver policy outcomes.

2.2. The weak relation between circular economy and sustainable development

Circular economy undoubtedly has a significant sustainability potential. However, a limited conceptual grounding and weak connection to sustainable development have allowed "circular economy solutions" to be put forward which have adverse effects on sustainability.

Circular economy has been implemented for economic purposes for hundreds of years. Industrial history is rich with examples of "industrial symbiosis" where by-products from one industry form inputs for another (Desrochers and Leppala, 2010). Industrial symbioses may be sustainable, but they can also contribute to locking-in unsustainable material systems such as the network of petrochemical industry infrastructure, many aspects of which are now considered essential for social and economic reasons thereby perpetuating a dependency on fossil fuel extraction (see e.g. Bansal and McKnight, 2009; Wu et al., 2015). In another energy-related example, the diversion of "residual" waste from

Table 1
Examples of business implementing circular economy (Core Centric Solutions, 2020; Purnell et al., 2020).

Material focused: The Winnow smart metre uses AI-enabled image analysis to classify the contents of restaurant kitchen bins. By correlating waste data to sales data to inform behaviour change in kitchens, waste can be reduced by up to 70% and savings of $25 M per year have been realised by businesses at >1000 sites. **Product focused:** Hyla Mobile repurposes and reuses mobile devices and/or components and is estimated to have given a 'second life' to 50 million devices, making $4Bn for their original owners and diverting 6500t of e-waste from landfill. The Brazil-based eStoks recovers defective new items in this sector which are either refurbished (50%), repaired (25%) or dismantled for component reuse. Their outlet stores allow a lower-income demographic to access premium devices. CoreCentric do the same for larger consumer electrical goods through remanufacturing, return for repair and product return management, recovering 2 m parts and 700,000 products in 2017. **Redesign:** Mattresses, furniture and carpets often cannot be recycled owing to their manufacture from inseparable multiple materials. The Niaga division of DSM (Netherlands) have redesigned such products so they can be refurbished and/or recycled through application of design heuristics (i.e. use as few materials as possible, use sustainable or recycled materials, and reversible connections) and advanced materials technology (e.g. adhesives that debond 'on demand' through the application of microwaves). These innovations have delivered a reduction in GHG of 17% (2016–19), 2.3% energy efficiency improvements year-on-year, and contributed to ~$1.6 Bn profits. **Digitally enabled services:** Kaer (Singapore) provide air-conditioning as a service (ACaaS) to clients. They take control of design, installation and maintenance, avoiding over-specification by unskilled clients and using Internet of Things-based monitoring to ensure that installed systems run at optimal efficiency. Energy costs are decreased by up to 70%. Schneider Electric combine leasing and pay-per-use business models to prolong product lifespans, specification of recyclable and recycled content, and take-back schemes in the supply chain. These circular economy operations now account for 12% of corporate revenue. They have increased waste recovery (from 8% to 95%, with 200 sites now zero waste to landfill) and reduced primary resource consumption by 120kt.

Table 2
Examples of cities implementing circular economy (Austin Materials, 2020; Purnell et al., 2020).

Austin: The city of Austin (Texas) has established the "Materials Marketplace", an online exchange platform to encourage industrial symbiosis and push towards zero-waste goals, combined with other ordinances e.g. mandating property owners to provide recycling systems for tenants and employees. **Shenzhen:** The Chinese city of Shenzhen has switched to electric mobility under a circular economy banner to cut noise pollution and improve air quality. E-buses have replaced 16,000 internal combustion engine equivalents, matched with heavy investment in infrastructure (500 charging stations, 5000 charging points). E-buses are rented from manufacturers on 8-year contracts, avoiding large upfront costs. This business model also keeps buses in use for longer, encouraging upgrading of batteries and drivetrains. Annual reductions of over 4Mt+ of particulate matter released to air and 40% in GHG per km have been achieved. It recognised that to achieve more circular operation, the energy mix used in charging stations needs to change – only 1% comes from renewable sources – but the establishment of demand is assumed to drive this change. **Toronto:** Toronto (Canada) has implemented a Circular Economy Procurement Plan that aims to "drive waste reduction, economic growth and social prosperity". Progress will be measured on a wide variety of metrics including cost savings, the fraction of waste diverted from landfill, CO_2 savings, the recycled content of goods procured, the quantities of raw materials avoided, the number of jobs created and staff trained, and the extent of asset sharing activities.

landfill to thermal waste-to-energy processes releases the carbon emissions embodied in materials, destroys resources that could have been recycled (particularly where energy-from-waste over-capacity is endemic), and maintains a higher dependency on the input of raw materials into the economy than would have been the case with better recycling rates (European Commission, 2017; Farmer et al., 2015). In these cases, the wider trade-offs of circular economy practices arguably do not outweigh the sustainability benefits.

Circular economy measures have also been used for socially and politically motivated resource security and propaganda purposes for decades. In the Second World War, the UK government implemented a National Salvage Scheme, particularly for metals, during which "ornamental" objects such as iron railings were collected from buildings ostensibly to allow the production of munitions during primary steel shortages. Some half a million tonnes of railings and gates alone were collected (Hansard, 1943). While this may have promoted "active citizenship" and thus arguably achieved social aims (Irving, 2016), the fate of this material remains debated, with some commentators suggesting it was simply dumped as processing capacity and/or material quality was insufficient (Bullus, 2017).

Environmental drivers for circular economy include the decarbonisation potential (Barrett and Scott, 2012) but making use of this opportunity requires whole system thinking to avoid simply shifting emissions from one part of the system to another. For example, more widespread uptake of biological materials to replace mineral resources is promoted as part of circular economy, but at a system level this would require water resources far beyond sustainable levels of supply (Giampietro and Funtowicz, 2020). Measures with widespread adverse impacts abound in the biomaterials sector. For example the production of palm oil for biofuel is perceived as reducing dependence on fossil fuels, reducing primary resource consumption and supposedly net carbon emissions, but has contributed to accelerated deforestation e.g. in Borneo (Murray et al., 2017).

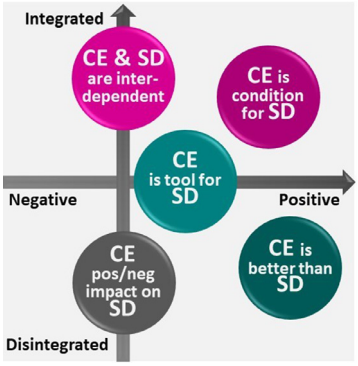

Fig. 2. Conceptual relations between circular economy (CE) and sustainable development (SD) can be characterised along the continuums of positive to negative and fully integrated to disaggregated (Geissdoerfer et al., 2017; Schroeder et al., 2019; Suárez-Eiroa et al., 2019).

To prevent ill-positioned circular economy measures, the currently weak relation between circular economy and sustainable development should be strengthened (Geissdoerfer et al., 2017) to clearly demonstrate how circular economy research and practice can contribute to sustainability; and indeed where it might not, as it is difficult convincing people to adopt circular economy practices when examples of such that harm sustainability proliferate. The conceptual relations between circular economy and sustainable development (Fig. 2) can be characterised along a continuum from a more integrated and positive connection to a disaggregated and potentially adverse interaction (Geissdoerfer et al., 2017; Schroeder et al., 2019; Suárez-Eiroa et al., 2019). As Fig. 2 shows, from a conceptual perspective it is debatable whether the pursuit of a circular economy will necessarily promote sustainable development; whether circular economy is better than, a condition for or fully interdependent with sustainable development; or whether circular economy is one of the tools for sustainable devel-

opment. Analyses suggest that circular economy is integral to delivering various UN Sustainable Development Goals (SDGs) (Fig. 3) (Schroeder et al., 2019; UN, 2015; Velenturf and Purnell, 2017) i.e. in order to achieve the SDGs, circular economy practices will have to be implemented, but it is important to distinguish different types of circular economy and their ability to contribute to sustainability – a point further explained in Section 4.

The perceived relation between circular economy and sustainable development is often not made explicit (Fig. 2). This is obvious from the analyses of circular economy definitions: only 12% integrate sustainable development (Geissdoerfer et al., 2017). However, this could be explained by the fact that sustainable development and circular economy stem from the same literature in the 1960–70s (as will be argued in Section 2.3) and hence it would seem odd to "define" the relations; circular economy is seen *a priori* as an expression of sustainability and defining the relations would be like investigating an apple to ensure it is indeed coming from an apple tree. A more important question concerns the manner in which we can ensure that circular economy, in all of its diverse ways, does indeed contribute to sustainable development (Millar et al., 2019), just like we have to continue to ensure that practices adopted under the sustainability banner indeed do so as well.

Text Box 1: IPAT and natural and man-made capital.

IPAT: environmental impact (I) = population (P) x affluence (A) x technologies (T)

The IPAT formula has been used to estimate the environmental impacts of economic growth, multiplying population growth, affluence, and technological change. The foundations of economic growth include labour, natural capital and capital produced by people. Thought leaders disagreed about the substitutability of natural capital and 'man-made' capital, and the role of technological change to unlock infinite growth (Gutés, 1996):

- Solow (1974) assumed people cannot manufacture materials and products in the absence of natural capital, and over time per capita consumption would have to reduce;
- Stiglitz (1974) considered technological change as the enabler to make better use of natural and man-made capital, and allow for sustainable per capita consumption;
- Dasgupta and Heal (1979) assumed full substitution between natural and manmade capital and found no limits to growth based on non-renewable resources, and in their view technological change opened the doors to infinite growth.

2.3. Shared roots in systems ecology

Similar to sustainable development, circular economy is a fluid concept that is still evolving. Both literatures are rooted in the systems ecology literature of the 1960–70s and herein it will be argued that their shared history has led to their interrelation being assumed rather than made explicit, by introducing their joint evolution up to 1990. This provides a basis for the analyses and novel perspectives on the evolution of values and principles in sustainable development (Section 3) and circular economy (Section 4).

Sustainable development dates back to the 1960s when the environmental risks associated with economic and societal developments started to become evident. Articles by e.g. Boulding (1964), Fuller (1969), Commoner et al. (1971), Meadows et al. (1972) and Ward and Dubos (1972) took a radical, interdisciplinary, whole-system view on resource exploitation and economic growth. The "IPAT" model, stemming from discussions between Ehrlich and Holdren (1971); Ehrlich and Holdren (1972) and (Commoner, 1972; Commoner et al., 1971) led to different strategies being proposed such as environmental regulation, population control and a growing belief in science, technology and innovation (Text box 1). The coexistence of continued economic growth and a healthy living environment was challenged; the Club of Rome (Meadows et al., 1972) extrapolated population growth, resource demand, industrialisation, food production and pollution and forecasted system collapse within 100 years. Conversely, the Brundtland report (WCED, 1987) did not set limits to growth, but noted the limitations of technology and society to organise environmental resources and manage the ability of the biosphere to absorb the effects of human activity (Geissdoerfer et al., 2017). Meadows et al. (1972) argued that technological progress alone would only delay system collapse and a change in values, i.e. what we as a society consider important, was required. Even those who argued for a "stable, closed-cycle, high-level technology" (Boulding (1966) acknowledged that social interventions must be at the heart of change. Ward and Dubos (1972) proposed pathways to raise living standards without breaking environmental limits (see Rome 2015), essentially laying the basis for "doughnut economics" (Raworth, 2017).

Some circular economy principles emerged long ago from resource stewardship (Reike et al., 2018) hundreds of years before the sustainable development debate. Waste management has always been an integral part of the formation of cities; physically, by dumping solid waste into shorelines or floodplains to create new land areas (Hill, 2016), and through civic governance emerging to manage sewerage and nascent industrial effluents (Luckin, 2008), but Lieder and Rashid (2016) argue that historical resource stewardship meant inorganic wastes were a relative unknown before the industrial revolution. Since then, the relation between people and their belongings has changed, driven by economic systems that amplify material consumption with designed obsolescence (Andrews, 2015). Mass production and consumption has reduced prices such that many people need not value products that contribute to their well-being. Human society appears to have dipped into a period of carelessness regarding resources, transitioning towards linear "take-make-use-waste" patterns of consumption. Only now are we starting to return to more "circular" practices, such as repair and recycling, out of concerns over the environment, growing inequality and economic stability – in other words, out of sustainability concerns.

Nonetheless, efficient use of resources – and wastes – has often been a norm for those running industries (Desrochers 2000); e.g. Hofman opined in 1848 that a chemical factory ideally has no waste (Lancaster, 2002; Murray et al., 2017). The governance of nature was a tenet of early economic 'physiocrats' who considered agriculture as the source of wealth, from which flowered holistic perspectives on industrial metabolisms, the emergence of "industrial symbiosis" in the 1930s and industrial ecology by the end of the 1980s (Jelinski et al., 1992; Murray et al., 2017; Renner, 1947). Environmental economics emerged during the 1970s oil crisis to investigate links between environmental management and economic growth, spawning ecological economics and socio-ecological economics recognising the importance of ecological and social aspects of sustainability respectively (Murray et al., 2017; O'Riordan and Turner, 1983; Spaargaren and Mol, 1992; Stanfield, 1983). All of these offered important building blocks for "circular economy", which some consider founded by Stahel and Reday-Mulvey (1976), Meadows et al. (1972) and Boulding (1966) (e.g. in Kalmykova et al., 2018;

Lieder and Rashid, 2016; Murray et al., 2017). Thus the founding literature of circular economy overlaps with the roots of sustainable development.

Given the long interest in natural resources and wastes, it seems odd that we are currently in the grips of a resources and waste crisis. Several resources are becoming "critical" yet waste arisings – many of which contain the very materials becoming critical – increase annually (Velenturf and Purnell, 2017). The cause of the crisis may have sprung from the preference for convenience – humans following the ecological process of taking the path of least resistance – which was enabled e.g. by the US government's economic recovery policy promoting obsolescence since the 1930s (Andrews, 2015), the lowering of virgin material prices, and the massively increased scale and complexity of our production and consumption. The contrast between (a) the vast body of radical ecological systems literature challenging the throwaway culture that had emerged by the 1960–70s (as introduced above), and (b) the solutions that actually came to the fore focused on end-of-pipe waste management, is a reflection of this. We are yet to develop, let alone implement, systemic solutions for overconsumption and waste to deal with the perfect storm of ecological, social and economic crises that are unfolding. Sections 3 and 4 will demonstrate that both the fluid concepts of circular economy and sustainable development have their limitations and must continue to evolve in response to our growing understanding of sustainability challenges.

3. Evolving values and principles in sustainable development

The relation between circular economy and sustainable development is weak and debatable (Section 2). Given the urgency to solve pressing sustainability concerns, it is important that circular economy contributes to sustainable development. Section 3 analyses key sustainable development literature to discern values and principles, which will form a foundation for the critical discussion of existing, and the articulation of novel, values and principles for a sustainable circular economy in Section 4.

The WCED (1987) report Our Common Future, better known as "the Brundtland report", set out the values and principles that still frame the sustainable development debate. It was a positive response to the grave concerns raised in the 1960–70s by authors such as Meadows et al. (1972) for the Club of Rome, stating that *"Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs"*. While this is the most common definition of sustainable development, there are ca. 300 other definitions in circulation; this has been perceived as a constraint for effective research and implementation (D'Amato et al., 2017; Geissdoerfer et al., 2017) and confusing analysis of how the field of sustainability science has evolved (Kajikawa et al., 2007). Sustainable development has been characterised as a fuzzy, value-laden concept, within which different people perceive different aspects as important (Korhonen et al., 2018b). Others insist sustainable development should instead be understood as a process of change in which resource exploitation, technology development, investment, and institutional change are consistent with future and present needs (WCED, 1987). One of the major disagreements within the subject area revolves around the notion of "weak" and "strong" sustainability (covered in Section 3.1.6). Such differences of perspective challenges our ability to evaluate the extent to which changes have actually contributed to sustainable development. A similar challenge is faced by circular economy, as will become apparent in Section 4.

3.1. Sustainable development principles

Sustainable development values and principles were derived through the review of the Brundtland report, UN SDGs, top-cited academic contributions that offered overviews of sustainability science and articles explaining key concepts that emerged, adding new articles to the analysis until no significant new findings were found:

3.1.1. Simultaneous progress to maintain and/or grow economy and raise living standards within environmental limits

There is agreement that sustainable development requires simultaneous improvement of environmental, social and economic outcomes. Opinions around their relations vary from them each being of equal importance to a hierarchical relation with economy and society embedded in the environment (revisited in Fig. 5). These differences become apparent in the implementation and evaluation of sustainable development (Sala et al., 2015). While some derive from the literature that implementing one aspect should not degrade the others (e.g. Millar et al., 2019), others clearly put the necessity of on-going economic growth to question (e.g. Schröder et al., 2019) and Bruntland appeared to differentiate growth requirements for poorer countries from the wealthier countries (WCED, 1987), with poverty eradication seen as a prerequisite for maintaining peace and preventing ecological disaster (WCED, 1987). Brundtland moreover demonstrated the interdependencies between environment, society and economy, putting the management of environmental resources into their wider context. Brundtland believed that people could change the planet, but that there could be a balance between people and their environment while generating economic benefits therefrom. Now increasingly controversial, Brundtland perpetuated the belief that economic growth could go hand in hand with the preservation or indeed the improvement of environmental resources, a belief that has found wide resonance in the circular economy community. Economic growth was considered critical for reducing poverty, as was environmental quality. The risk was, however, that economic growth was associated with environmental degradation and it is here that circular economy professes to offer solutions (Section 4.1). Overall, sustainable development takes a global and long-term perspective for a prosperous, just, and secure future (WCED, 1987).

3.1.2. Intra and inter-generational equity

A key aspect of sustainable development is the strengthening of social foundations and reducing poverty, promoting equality within and between generations. Fair access to resources is important for equal opportunities for current and future generations. For example, our current depletion of non-renewable resources impinges on the opportunities of future generations. Moreover, natural resources (e.g. oil, cocoa, bauxite) in developing countries are being used as security for loans from developed countries, often to pay for the latter to build infrastructure in the former as part of geopolitical efforts to ensure continued flow of raw material imports (Bettencourt and Kaur, 2011; ERA, 2009). Circular economy, however, has so far paid very little attention to both intra and inter-generational equity (Kirchherr et al., 2017).

3.1.3. Whole-system perspective: environmental, social and human systems bridging local and global scales

Sustainable development research and practice must take a holistic approach (Komiyama and Takeuchi, 2006; Sala et al., 2015), linking global processes with local ecological and social characteristics (Kates et al., 2001). Sustainability science has been defined as *"an emerging field of research dealing with the interactions between natural and social systems, and with how those interactions*

affect the challenge of sustainability: meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support system" (Kates et al., 2001). Sustainability challenges tend to emerge on the intersections of systems, seen as the environment provides the basis for human survival while human activity, organised via social structures, affects the environment (Komiyama and Takeuchi, 2006). Kates et al. (2001) argued that sustainability science is about understanding the fundamental character of interactions between nature and society, making fundamental advances in the ability to address issues in complex self-organising systems, and about (irreversible) responses of the nature-society system to multiple stresses.

3.1.4. A change in social values is essential to balance economy with environment

Technological solutions alone are unlikely to suffice to steer away from environmental collapse and a change in social values is necessary (Boulding, 1966; Meadows et al., 1972). In a compromise, Brundtland set out that the state of technology and the social organisation of resources was holding back sustainable development, both of which believed to be manageable for economic growth (WCED, 1987). Social values and human attitudes must change through education, debate, and public participation, and especially in wealthy countries resource-hungry lifestyles and the provisioning systems that stimulate and support them have to be brought in line with the preservation of the life support system of the Earth (Kates et al., 2001; Seyfang, 2009; Spaargaren and Van Vliet, 2000; WCED, 1987; Wiedmann et al., 2020). This pertains in particular to changing perceptions on what human needs really are, which has been contested by many (see e.g. Daly and Farley, 2004 and Redclift, 2005 for an insight into this complex discussion).

3.1.5. Sustainable resource use, moving away from linear economy and instead realising a "resource circulating society"

Building on the changes in lifestyles and provisioning infrastructure introduced in the preceding point, these extend to the consumption of non-replaceable goods and services (Geissdoerfer et al., 2017). Concerns about resource depletion were already raised in 1798 by Malthus and returned on the global agenda thanks to Osborn and Vogt in 1948 (Rome, 2015), with sustainable use of environmental resources becoming a cornerstone of sustainable development named more than 600 times in the Brundtland report (WCED, 1987). The linear models of extraction, production, consumption and waste generation are fundamentally incompatible with sustainable development (Millar et al., 2019; Sala et al., 2015), as the Brundtland commission implied with *"a growing realization in national governments and multilateral institutions that it is impossible to separate economic development issues from environment issues; many forms of development erode the environmental resources upon which they must be based*" (WCED, 1987). Komiyama and Takeuchi (2006) – in their inaugural publication for the journal Sustainability Science – discussed the importance of a "resource circulating society", a direct analogy to circular economy, that would be capable of sustainable production and consumption, implementing reduce-reuse-recycle policies, developing manufacturing processes that circulate resources, and fostering resource-conserving lifestyles.

3.1.6. Natural capital, or the total of man-made and natural capital, does not decline over generations

Natural capital can be described as *"a stock of natural assets serving economic functions"*, from life support systems and human welfare to raw material supplies and waste storage (Pearce, 1988). Within sustainability science a distinction is made between weak and strong sustainability (Neumayer, 2013). Weak sustainability assumes that natural and man-made capital can be substituted and form one pool of total capital, and it is that pool of total capital that should not decline between generations (Bond et al., 2011). Strong sustainability on the other hand believes that there is critical natural capital which provides functions that cannot be substituted by man-made capital and that must not decline for future generations (Bond et al., 2011). With the publication of planetary boundaries, Rockström et al. (2009) offered an insight into the natural capital that we should consider as critical for the preservation of environmental conditions that are conducive to human society.

3.1.7. Collaborative change

Sustainable development involves all countries, and (inter)national collaboration and decision making has had to change as a result (WCED, 1987). The largest change in (inter)national governance pertains to on-going efforts to embed economic policies into environmental protection and enhancement. Collaboration for sustainable development reaches beyond governments and includes a broad range of societal actors. This brings together *"different ways of learning and knowing"* in simultaneous processes of research and implementation with use-inspired research and research committed to action (Kates, 2011; Kates et al., 2001); for example through participatory action research which integrates theory with applied science and change in policy, industry and the general public (Bettencourt and Kaur, 2011; Komiyama and Takeuchi, 2006). There is a thin line between action-orientated and action-led science, and while sustainability research is now generally considered to fall into the former category, the practitioner-led circular economy appears to still fall into the latter in the absence of sufficient academic grounding (Korhonen et al., 2018a) which risks biased decision-making and research and insufficient insight into the consequences of practices being implemented (Section 4.1). In both sustainable development and circular economy research, the urgency of the issues under investigation often push the analyses of phenomena towards the solving of problems even before phenomena are fully understood. Under such circumstances it is important to take a precautionary approach (Komiyama and Takeuchi, 2006; Sala et al., 2015). Within academia, fundamental and applied research across disciplines must be brought together to comprehensively analyse sustainability challenges, identify relations between challenges and suggest new solutions (Kates, 2011; Komiyama and Takeuchi, 2006). Sustainability science can offer a long-term vision, analyse scenarios for global sustainability and develop transition pathways for implementation, flexibly combined through iterative processes within which the academic knowledge is combined with knowledge from across society (Kates, 2011; Komiyama and Takeuchi, 2006; Wise et al., 2013).

3.1.8. Implementation is context dependent

While all of the above suggest general values and principles that apply to all sustainable development activities, their implementation should be tailored to the particularities of implementation in different situations and parts of the world. A diversity of solutions should be pursued in order to be able to respond to issues in diverse environmental and cultural contexts (Komiyama and Takeuchi, 2006). Pursuing a diversity of solutions and pathways towards sustainable development can also mitigate risks in case a solution does not deliver the anticipated benefits. The preparation of practical strategies for sustainable development can bring together various elements and visions such as Agenda 21 (UN, 1992), planetary boundaries (Rockström et al., 2009) and the UN SDGs (UN, 2015). Strategies are likely to vary across geographic regions because sustainability challenges may differ. This was recognised in the new UN SDGs: *"The Sustainable Development Goals and targets are integrated and indivisible, global in nature and universally applicable, taking into account different national realities, capacities*

and levels of development and respecting national policies and priorities". There is an inherent risk in these translation processes of global sustainable development principles and goals into context-specific strategy and action, as they are open for interpretation from different perspectives such as the more ecocentric, biocentric or anthropocentric value systems discussed by Barrett and Grizzle (1999) and can set different parts of the world onto diverging pathways towards varying sustainability outcomes, of which some may be less holistic.

3.2. Changes in direction of the global sustainable development agenda

Since the publication of the Brundtland report in 1987 sustainable development research and debate has continued, resulting in a change of direction in the recent sustainable development agenda with the goals for 2030 being more people-centred than before (UN, 2015). Compared to the Brundtland report, the new framework of goals and targets has a wider scope with economic, social and environmental objectives plus peace and inclusivity, and incorporates means of implementation and an even more integrated approach. The agenda also recognises the opportunities in terms of information technology and potential to create knowledge societies. The agenda is more explicitly guided by and grounded in the wider set of UN documents including the UN charter and various declarations, treaties, conference and summit outcomes, and international law. Poverty eradication and inequality within and between countries; peaceful, just and inclusive societies; human rights, gender equality, and empowerment of women and girls; collective change and social inclusion; are priorities alongside protecting planet and natural resources; and sustained, inclusive and sustainable economic growth taking into account different levels of national development and capacities.

The new "people first" principle has increased the distance from circular economy which, as we will see in the next section, has so far remained centred on resources, technology and economy. The agenda emphasises that the goals and targets are "integrated and indivisible". The focus for people and planet appears largely unchanged from the Brundtland report, but for prosperity it is notable that, at least initially, "economic growth" is not mentioned and instead the aim is to ensure that all human beings can enjoy prosperous and fulfilling lives and that economic, social and technological progress occurs in harmony with nature. Later, however, economic growth is back on the agenda, and the UN SDG website for example still defines the three pillars of sustainability as economic growth, social inclusion and environmental protection, but it certainly looks like eternal economic growth is no longer undisputed in the formal agenda. The agenda adds high-level points about fostering peace and partnerships to mobilise means for implementation of the goals and targets. For implementing the agenda, economic growth and assistance via trade relations is mentioned as a means of generating domestic resources, and this may closely align with the strengthening of international partnerships for mutual benefits through sustainable development. The new agenda seems to align with, or at least does not exclude, emerging ideas in circular economy around redistributing economic value to social and environmental value through the improved use of resources (Velenturf and Jopson, 2019). Economic growth is still part of the goals, e.g. SDG 8–9 which relate economic growth to resource efficiency and the main mechanism proposed to achieve a balance is through decoupling. SDG12 does not mention circular economy literally but it does cover the sustainable management and efficient use of natural resources, reducing and preventing wastes, uptake of reuse etc., and changes in lifestyles, procurement policy and business reporting; all of which are closely aligned with circular economy principles. Targets under sixteen out of the seventeen SDGs are related to circular economy (Fig. 3).

4. New frontiers in circular economy

Sustainability science is rooted in concerns around resource overexploitation and environmental decline during continued growth (Section 3). Circular economy stems from the same founding literature (Section 2.3) but brings together diverse concepts (see e.g. Geissdoerfer et al., 2017; Ghisellini et al., 2016; Korhonen et al., 2018b; Suárez-Eiroa et al., 2019), leading circular economy to have a pluralist definition with the only collective focus being improved resource use (Kirchherr et al., 2017; Kiser, 2016; Millar et al., 2019).

This leaves circular economy open to multiple interpretations, allowing the emergence such as unsustainable "pseudo-circular" practices discussed in Section 2 . The UK Resource Recovery from Waste programme (RRfW) co-produced visions and approaches for a circular economy with academic, government and industry stakeholders (Velenturf and Purnell, 2017; Velenturf and Purnell, 2018; Velenturf et al., 2018). The diversity of perspectives was captured under three classifications (Green Alliance, 2019; Velenturf and Purnell, 2017; Velenturf and Purnell, 2018; Velenturf and Purnell, 2020; Velenturf et al., 2018):

1 A circular economy relying on "closing loops" with energy-from-waste, requiring minimal changes in production and consumption. It destroys products and materials that are then replaced, with associated environmental consequences. This model holds limited sustainability benefits and is arguably not "circular", but was articulated by parts of the resources sector and government.
2 A circular economy that maximises resource recovery with recycling and landfill-mining technologies, requiring changes to production (design for recycling) and waste collections, but leaving consumption patterns the same. Recovering and recycling materials is likely to induce energy and/or water demand, and loss of materials in consecutive cycles is inevitable. This model represented the most common ground.
3 Models that recognise the low sustainability of 1 and 2, and that prioritise waste prevention, reuse, repair and remanufacturing, were grouped under an economy that is circular by design. This requires far-reaching changes in production, consumption and waste management, and collaboration and coordination to visualise implementation.

These can be positioned on a continuum: from resource efficiency, improving existing practices, and weak sustainability on the one hand (Section 3.1.6); to resource productivity and strong sustainability on the other hand, requiring radical changes to resource use in our society (discussed below) and similar to the weak circular economy vs. stronger eco-cycle of Johansson and Henriksson (2020).

Section 4.1 evaluates the representation of sustainability values and principles – identified in Section 3 – in circular economy scientific literature and the extent to which sustainable development and circular economy thinking must be integrated. Section 4.2-4.7 critically review circular economy values and principles within the context of sustainable development, take on board critiques on circular economy, and articulate a new, coherent set of values and principles for building a stronger foundation for circular economy research and practice.

Fig. 3. Circular economy can enable a significant number of targets under the UN Sustainable Development Goals. Legend: Fraction of targets under each goal that would be strongly (red) and partially (orange) enabled by implementation of circular economy measures. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.1. Comparing sustainable development and circular economy

Kirchherr et al. (2017) argue that circular economy aims to contribute to sustainable development and Suárez-Eiroa et al. (2019) add that circular economy operates under the banner of a sustainable development framework. However, only 38% of circular economy publications self-identify with sustainable development or sustainability (Fig. 4). The body of literature on circular economy and sustainable development/ sustainability totals 3333 publications on named search date. The top key words (following the search terms circular economy, sustainability and sustainable development) being recycling, waste management, life cycle, economics and environmental impact, confirms a prevailing narrative of weak sustainability relying on recycling and end-of-pipe thinking for economic benefits and a reduction in environmental impacts, in line with the observation by RRfW that there may be a current consensus around a circular economy that primarily relies on resource recovery solutions.

Table 3 links key terms from Section 3 to literature on circular economy and sustainable development. Despite considerable contributions from the social sciences (10% of the publications), less than 1% speak of equity or equality (e.g. Christmann, 2018; Fioramonti et al., 2019) and social values or human attitudes (e.g. Afshari et al., 2020; Todeschini et al., 2017), and only ca. 1% covers poverty (e.g. Cheng et al., 2019; Liu et al., 2005) and ca. 2% participation (e.g. Hao et al., 2020; Inigo and Blok, 2019) – all key components of sustainable development principles. More positive is that 5% of publications pertain to education (e.g. Kopnina, 2019; Mendoza et al., 2019; Webster and Vare, 2012). The literature is devoid of critical discussion on distinguishing human "wants" and "needs" and only 1% mention lifestyle (e.g. Esposito et al., 2018; Guo et al., 2017; Williams, 2016). International collaboration/ coordination is deeply underrepresented with less than 1% of publications even giving this a mention (e.g. Geng et al., 2019; Velis, 2017) and this clearly represents a missed opportunity given the prevalence of global trade relations and the critical importance of global collaboration for sustainable development as recognised in the UN SDGs and the initiatives that are underway to integrate circular economy into the climate change agenda. There is no indication of self-awareness regarding maintaining academic independence in the light of being policy and/or action orientated or led – a high risk in a practice-driven subject area such as circular economy (Korhonen et al., 2018b; Murray et al., 2017). Turning to the implementation of global ideas within local contexts, less than 2% explicitly cover this "translation" process (Buch et al., 2018; Kiss et al., 2019). This process may be investigated more within the 13–14% of publications that mention the term "context", as suggested by a further refinement in the search for studies on policy and decision making and support (e.g. Kravchenko et al., 2019; Ngan et al., 2019; Sileryte et al., 2018).

The subject areas business, management and accounting and economics, econometrics and finance make up 10% and 4% respectively of publications in this body of literature. While this involvement is considerable, only ca. 6% of publications mention "economic growth" (Table 3) and critical reflection upon the possibility to maintain economic or "green" growth while restoring the environment is fairly minor; more about this in Section 4.2. Mentions of the sufficiency related alternative – economic prosperity – are minimal (e.g. Kirchherr et al., 2017; Ness and Xing, 2017) and appears to have failed to gain momentum within circular economy so far.

Turning to musings on the interaction between nature and society, a key aspect of sustainable development, articles actually discussing how a circular economy fits within practical restoration of ecosystems are extraordinarily sparse (e.g. Cao et al., 2018). The terms nature and society are discussed in parallel in less than 2% of publications (Table 3). This is a major omission from a subject area that imagines to promote practices that are *"restorative and regenerative by design"*. Only 1–2% of publications mentions natural capital or ecosystem services at all (e.g. Kapsalis et al., 2019;

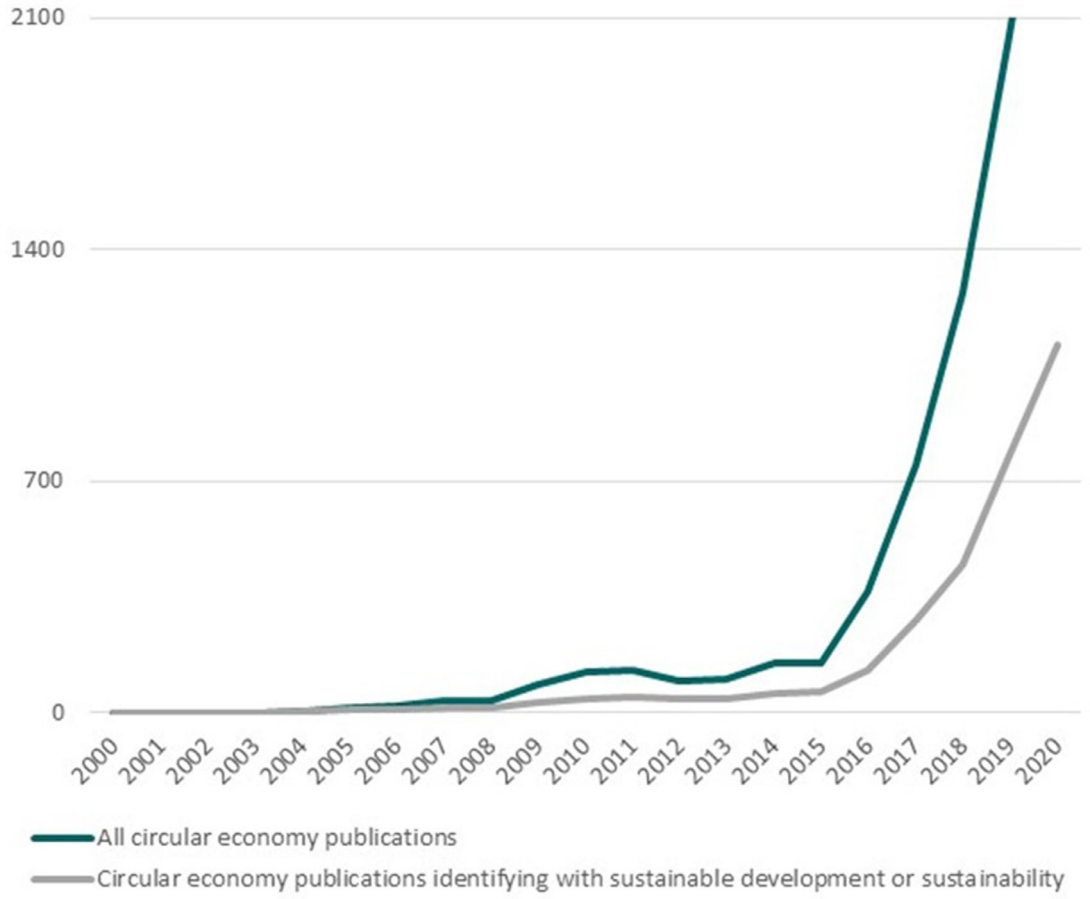

Fig. 4. Circular economy publications that self-identify with sustainable development or sustainability by mentioning these terms in their article title, abstract or key words (grey line) compared to all circular economy publications (blue line), based on Scopus search results on 31 January 2021. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 3
Number of publications on sustainable development related search terms within the body of literature on circular economy and sustainability or sustainable development, based on Scopus search results on 31 January 2021.

Sustainable development search terms related to Section 3	Number of circular economy publications
3.1.1: economic growth	191
3.1.1: economic prosperity	7
3.1.1: poverty	35
3.1.2: equity or equality	27
3.1.2: intra or inter-generational	4
3.1.3: global and local	56
3.1.3: ecosystem restoration	4
3.1.3: nature and society	49
3.1.4: social values or human attitudes	14
3.1.4: participation	59
3.1.4: education	159
3.1.4: democracy	4
3.1.4: wants and needs	9
3.1.5: resource security	4
3.1.5: resource scarcity	51
3.1.5: lifestyle	30
3.1.6: natural capital	19
3.1.6: critical natural capital	0
3.1.6: ecosystem services	37
3.1.6: weak or strong sustainability	15
3.1.7: international collaboration or cooperation	12
3.1.7: action orientated or led	3
3.1.7: precautionary	3
3.1.8: context and implementation or translation	104

Martins, 2016; Velenturf and Purnell, 2017). Most do not question the evidently incorrect and impossible notion of striving for a closed loop production and consumption system in relation to the wider ecosystem (further discussed in Principle 1), reflecting a lack of ecological understanding of the relation between people and their environment (Skene, 2018; Velenturf et al., 2019a). Critical natural capital is mentioned nowhere, implying an alignment with weak rather than strong sustainability. Weak sustainability is covered by four publications (e.g. Loiseau et al., 2016) and strong sustainability is critically brought to the attention to the circular economy audience by a number of others (e.g. D'Amato et al., 2017; Martins, 2016, 2018; Schröder et al., 2019). Despite fears of looming exhaustion of natural capital for certain resources, resource security or scarcity did not surface as a key word in the body of literature on circular economy and sustainable development or sustainability. While environmental concerns are supposedly at the heart of circular economy, the precautionary approach or principle appeared only in three articles (e.g. Aravossis et al., 2019).

Meanwhile, critiques on the weak conceptual grounding of circular economy are rife (e.g. Buchmann-Duck and Beazley, 2020; Cullen, 2018; Giampietro and Funtowicz, 2020; Hobson and Lynch, 2016; Skene, 2018; Velenturf et al., 2019a). As Korhonen et al. (2018a) put it, more is required than a circular economy that just aims to add reverse material flows to the economy. Such a circular economy would risk failing to solve the sustainability challenge relating to overconsumption (Schröder et al., 2019). It perpetuates the belief in indefinite economic growth without questioning the role of neoliberal economic growth philosophy in establishing the unsustainable model of linear production and consumption. It would be a circular economy that rearranges the deckchairs on the Titanic, similar to former convictions in sustainable development that we can create economic, social and environmental triple-wins for all – this is what Reike et al. (2018) defined as "reformist" circular economists. Transformative circular economists believe that, for circular economy to contribute to true sustainable development, radical changes in the political-economy are inevitable (Reike et al., 2018). Here we offer a framework of principles bringing together aspects that are considered important by leading academics and thought leaders in circular economy, we respond to its critics and put forward a transformative framework for a sustainable circular society (summarised in Table 4).

4.2. Value framework for a sustainable circular society

Section 4.1 has highlighted how the value framework for a circular economy must be altered to align with sustainable development. Circular economy is primarily seen as a manner to maximise economic and environmental benefits, mainly through the provision of technical solutions, thereby automatically delivering benefits in economic, environmental and social domains (Korhonen et al., 2018a). Arguments on how circular economy contributes to sustainable development rarely cover all three dimensions of sustainability by strongly biasing towards economic matters, paying less attention to environmental quality, and hardly covering social equity (Geissdoerfer et al., 2017; Kirchherr et al., 2017). Thereby circular economy does not meet the traditional triple bottom line perspective that, as seen in Section 3, typifies sustainable development (Fig. 5). Indeed, while Kirchherr et al. (2017) outlined that the aim of a circular economy is sustainable development, creating environmental quality, economic prosperity and social equity to the benefit of current and future generations, and Ghisellini et al. (2016) speak of achieving *"a better harmony in economic, environmental and social aspects"*, the reality of circular economy research (Section 4.1) and practice (Section 2.2) appears far out of touch with such laudable values.

Circular economy should be brought into step with sustainable development (Section 3.1.1-3.1.2) by a) becoming more explicit in the manner in which it can bring society within ecological limits (Schroeder et al., 2019), bringing together respect for environmental limits, social equity, and economic prosperity (Millar et al., 2019); and b) taking a longer-term perspective covering intra and inter-generational equity. To enable this, circular economy should strive for a set of environmental, social and economic values (Section 4.2.1-4.2.3), the interrelations of which should leapfrog towards the more recent emerging sustainability perspective in which the economy becomes a means for reorganising society and environment, rather than being considered a means on its own (Fig. 5 and further covered in Sections 4.2.3 and Principle 9). Indeed, rather than a purely "economic" striving, the aim is for a sustainable circular society (Section 3.1.5, Komiyama and Takeuchi, 2006).

4.2.1. Social and individual well-being

Section 4.1 confirmed that social aspects are underrepresented in circular economy research and, additionally, that still only 1% considered intergenerational aspects (Kirchherr et al., 2017). Reducing the generation of wastes and limiting the extraction of natural resources are expected to benefit the human species, but Millar et al. (2019) argue that these claims are rarely substantiated with empirical evidence. Analysis of social benefits often do not reach beyond the potential for job generation (Stahel, 2016). Consideration of social equity, justice, welfare, power relations in value chains, roles and rights of consumers, users and citizens, labour exploitation and the distribution of resources is weak at best (Merli et al., 2018; Moreau et al., 2017; Murray et al., 2017; Schroeder et al., 2019; Suárez-Eiroa et al., 2019). Resource distribution is an issue because, as Parrique et al. (2019) wrote: *"The preservation of non-renewable resources is a matter of intra- and intergenerational equity. Each non-renewable resource used in one place is a resource that will not be available in another place, and each non-recyclable resource used today is a resource that will not be available tomorrow"*. The current circular economy perspective reflects its ties to the prevailing neoliberal economic discourse biased to short-term economic growth (D'Amato et al., 2017), which has been part of its successful uptake so far (Section 2) but is now a rapidly emerging risk for its credibility in terms of contributing to sustainable development.

Converse to sustainable development, the importance of social change and changing what society considers to be important – i.e. our value system – is downplayed and the belief that superficial technological solutions can fix our problems has persisted so far in circular economy (Section 3.1.4). In shifting gears to a more sustainable circular economy (Section 4 opening), preserving and preferably improving social and individual well-being has to be fully integrated (Table 4). This will require a step up in research efforts for which circular economists could draw inspiration from other disciplines such as socio-ecological economics (Murray et al., 2017) and the degrowth community (Schröder et al., 2019). And while research is catching up, Suárez-Eiroa et al. (2019) rightly argue that governments and companies already should behave in socially responsible manners within sustainable development frameworks.

4.2.2. Environmental quality

Within the circular economy community a range of beliefs are displayed regarding environmental quality. First, there is the striving for *reduced* impacts of supply chains and industrial systems through the redesign of product lifecycles (D'Amato et al., 2017) and thereby significantly reducing carbon emissions (Barrett et al., 2018). Reducing impacts, i.e. making our production and consumption practices less bad, is not synonymous to delivering absolute

Table 4
A Manifesto for a Sustainable Circular Society.

Value framework:
Sustainable circular society: An equitable society that maintains environmental quality and economic prosperity for current and future generations: **A Social and individual well-being:** Create conditions that offer equity in realising quality of life that at least meets human rights standards for all. **B Environmental quality:** Using resources within planetary boundaries, enhancing natural capital within and across generations. **C Economic prosperity:** Collective organisation of fair access to resources within and across generations to enable social and individual well-being and enhance environmental quality.
Principles:
1 Beneficial reciprocal flows of resources between nature and society: Society is an open system embedded in the biophysical environment for their mutual sustainable co-existence. Reciprocal flows of materials both extract from and add value to natural capital, with rates of resource extraction and return to environment lower than the regenerative and absorptive capacity of the Earth. **2 Reduce and decouple resource use:** Promote resource sufficiency, efficiency and dematerialisation through governance that decouples progress from unsustainable material use. **3 Design for circularity:** Design, select and transform industrial systems, supply chains, materials and products, using "R-ladders" and whole-system assessments of solutions to optimise stocks and the degree of closing loops of resource flows, minimising raw material extraction and waste generation, optimising value generated for people, and enabling reintegration of materials into natural biogeochemical processes at end-of-use, through continuous processes nurturing sustainable solutions, through innovation, and phasing out unsustainable practices, through exnovation, to implement and maintain a sustainable circular society. **4 Circular business models to integrate multi-dimensional value:** Develop innovative business models and accompanying governance frameworks to internalise social and environmental costs of materials and products into their prices and reward circular practices more than resource intensive practices to enable the optimisation of resource values. **5 Transform consumption:** Move away from producer-driven consumerism and towards systems-of-provision that enable responsible, reduced, demand-driven resource use and more sharing, service and experience-based consumption. **6 Citizen participation in sustainable transitions:** Enable participatory systems to involve citizens in social innovations driven by transformative resource use, connecting grass root initiatives, ideas and opinions to local, national and supranational policy development and decision-making. **7 Coordinated participatory and multi-level change:** Coordinate the development, integration and implementation of circular economy strategies and actions across societal actors – incl. government, industry, civic sector, consumers and academia – and across local to global scales, identifying key intervention points where the dedication of resources such as investment, policy change and expertise offers the most benefits for realising a circular economy. **8 Mobilise diversity to develop a plurality of circular economy solutions:** Promote a plurality of perspectives and solutions for circular economy and a culture of knowledge exchange and learning across society, to generate a global knowledge base in support of local, context-dependent implementation, to build-in resilience against uncertainty that accompanies transition processes with sufficient back-up solutions, and to adopt a precautionary approach for solutions that may not be as sustainable as envisioned. **9 Political economy for multi-dimensional prosperity:** Embed strong sustainability in political-economic systems, moving from a narrow focus on short-term economic progress i.e. GDP growth to long-term multi-dimensional prosperity in environmental, social and economic terms. **10 Whole system assessment:** Take a whole system approach to understand challenges and the potential of proposed solutions in a precautionary manner, and optimise material use within the value framework for a sustainable circular economy through a process of continuous improvement guided by whole system assessments using holistic indicators before, during and after the implementation of circular economy practices.

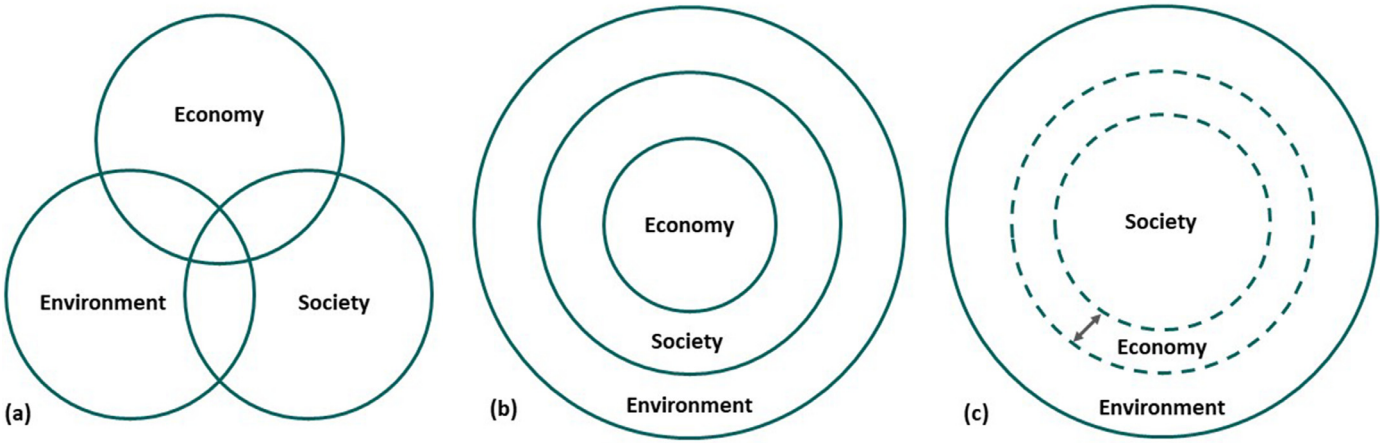

Fig. 5. Perspectives on sustainability have evolved from the triple bottom line in which economy, society and environment are considered of equal importance (a), to understanding economy as the organisation of society while both are dependent on the environment (b), and considering economy as a tool to organise resources for the purpose of maintaining or enhancing social well-being, environmental quality and economic prosperity (c).

improvements from a whole-system sustainability perspective. Indeed, reducing impacts will not suffice in the light of strong sustainability values (Section 3.1.6) now embedded in global and national targets. For example, the UK strives for net-zero carbon emissions by 2050, while improving the environment for the next generation is to become law (BEIS, 2017; DEFRA, 2020). The "new" target that circular economy has to strive for in practice is, as the EMF has argued for over a decade, a circular economy that is restorative and regenerative by design (EMF, 2021). In other words, circular economy has to transition from focusing on reduced environmental impacts to preserving (zero impact) and preferably enhancing (environmental net-gains) natural capital (Table 4).

It is at this point, however, that circular economy is departing from long held beliefs that formed the foundations of the very discussions on limits to growth: that people cannot create natural capital (Text box 1, Section 3.1.6). While in sustainable development the debate regarding the ability of people to regenerate natural capital rumbles on, circular economy is explicit in its be-

lief that people, aided by technological advances, can restore and regenerate natural capital (in the footsteps of WCED, 1987). Subjects such as conservation biology and restoration ecology show that people can regenerate some forms of natural capital such as strengthening biodiversity and improving water quality, but many ecosystem changes are considered irreversible and restoration of ecosystems and natural capital therein, to the same state as before, may not be possible or preferable in the light of on-going evolution of our natural environment (Hobbs et al., 2009; Murcia et al., 2014) – further discussed in Principle 1. It is also unclear whether we can all live well at the same time as regenerating the environment (Section 3.1.1), and what role circular economy can play in such regeneration processes. This is an area of huge uncertainty to support the potential for enacting one of the core values of circular economy to deliver net-gains for environmental quality, but at the same time it appears inevitable to adopt this value, for the alternative that would further destabilise our planetary system (Rockström et al., 2009) is unthinkable.

4.2.3. Economic prosperity

The circular economy community largely subscribes, consciously or subconsciously, to the neoliberal economic narrative, which has become the theory for shaping economies for the purpose of generating wealth for an increasingly small percentage of the global population. In such an economy, the goal is short-term economic progress measured primarily in GDP growth; the aggregate of all final goods and services produced in a country, with economic (de)growth expressed as the difference in this measure over time. An arguably more sustainable alternative is the green growth narrative, which does not question the necessity and possibility of economic growth, aiming for sustainable development through relative and absolute decoupling (Section 3.2) and reconciling economic growth with environmental protection through technological progress (D'Amato et al., 2017). In line with green growth, circular economy is currently positioned as an alternative to the linear economy that promotes continuous economic growth and increasing resource throughput… by promoting a circular model that also aims for continuous economic growth and increasing resource flows albeit in different places i.e. roundput. In this conception, circular economy is indeed nothing more than an alternative flow model (Korhonen et al., 2018a). In this model, the speed of resource depletion and waste generation could be reduced (Lieder and Rashid, 2016) and incremental improvements can be delivered (Ghisellini et al., 2016). Millar et al. (2019) rightly reason that the outcome along this pathway will, eventually, be the same as with a linear economy.

Both sustainable development (Section 3.2) and circular economy rely on the decoupling of resource exploitation from economic growth. But Parrique et al. (2019) are deeply sceptical about the possibility to decouple sufficiently calling *"the hypothesis that decoupling will allow economic growth to continue without a rise in environmental pressures appears highly compromised, if not clearly unrealistic"*. With sufficient decoupling unlikely to occur, there is a high demand for fundamental research into alternative economic models "post-green growth", particularly in Western countries (further discussed in Principle 9). The implication is that the imaginary potential for infinite economic growth, as theorised half a century ago (Text box 1), must finally be left behind to transform our society for a sustainable outcome. As Raworth (2017) argues, becoming growth agnostic may be the next step, while recognising that economic prosperity is a boundary condition for sustainable development (Section 3.1.1). Indeed, in a sustainable circular economy, the purpose of the economy has changed from being a money making machine to a way to organise resources for the purpose of maintaining or enhancing social well-being and environmental quality (Fig. 5, Table 4).

4.3. Principles for redefining the relation between nature and society

Principle 1: Beneficial reciprocal flows of resources between nature and society

Circular economists imply that the production and consumption system in society can operate in isolation or independently from nature by fully closing loops of resource flows (criticised by e.g. Giampietro and Funtowicz, 2020; Millar et al., 2019; Velenturf et al., 2019a). There are, however, multiple biophysical realities that make such a scenario unlikely. Recycling materials via technical processes is energy intensive and regenerating materials via primary production of biomass requires fresh water resources far beyond the planet's availability, not to speak of the generally inevitable material quality losses when resources move through consecutive cycles of production and consumption (Cullen, 2017; Giampietro and Funtowicz, 2020; Hernandez and Cullen, 2019). The circulation of organic and inorganic materials in separation from each other, as proposed in the cradle-to-cradle philosophy in biological and technical cycles respectively (McDonough and Braungart, 2003), is not feasible for large swathes of materials due to their naturally integrated characteristics (Velenturf et al., 2019a). Limited extraction of natural resources could be considered antisocial for developing economies that are still growing resource stocks to build infrastructure such as homes, roads and utilities that are essential for well-being. Conversely, the world's wealthiest are disproportionally responsible for over-consuming natural resources (Wiedmann et al., 2020) and, on average, resource consumption per person has to be reduced to bring the size of our global resource economy back within the planet's capacity to regenerate natural resources and absorb "wastes" (Suárez-Eiroa et al., 2019, Table 4).

People are indivisible from nature through our very being, breathing and the natural resources that must pass through our lives for our nourishment, shelter and well-being. This is the principle of ecosystem stewardship which recognises people as an integral part of the environment (Chapin et al., 2009) described by some as "bio-participation" (Murray et al., 2017). Within this worldview the challenge is not the closing of loops per se but rather the optimisation of resource stocks and flows within our society while enabling the positive reintegration of resources into natural biogeochemical processes to enhance our environment (Velenturf et al., 2019a, Table 4). This view builds upon the Brundtland report (WCED, 1987) and goes even further in defying long-held beliefs that the pathway from natural capital to man-made capital is a one-way street, suggesting people can generate natural capital of which some may be critical to maintaining the stable conditions for the well-being of humankind (Section 4.2.2). The very idea of isolating society's production and consumption system conceptually contradicts the striving for environmental regeneration, as this would require an interaction between people and the materials that make up our environment. Not only is it impossible to have a closed loop society, it is also not preferable when the aim is to enhance the environment.

Principle 2: Reduce and decouple resource use

The likelihood that sufficient decoupling will happen, whether in a relative sense with resource use growing at a slower rate than economic growth or in absolute terms with an overall reduction of resource use, is low (Section 4.2.3). With evidence of decoupling already scattered (Wiedmann et al., 2015), government reports on improved resource productivity can be pulled into question even further as it turns out that impacts have, in fact, been offshored with a reducing manufacturing base in developed countries such as the UK while per capita material consumption was stable or increased (Druckman and Jackson, 2009; Hardt et al., 2018; Wiedmann et al., 2015). Within circular economy the focus

has been on relative decoupling (Reike et al., 2018) but most countries will have to shift gear to absolute decoupling in the light of sustainable development (Parrique et al., 2019, Section 3.2).

Even maintaining an economy's size depends on continued raw material and energy input and this chimes with observation of Suárez-Eiroa et al. (2019) that the very size of the resource economy in most countries will have to decrease. This calls for dematerialisation and truly decoupling increasingly service-based economies from their material foundations (Wiedmann et al., 2015), opening new questions about the material intensity of services (Parrique et al., 2019) and whether it is feasible and desirable to decouple economic growth from the material wealth of a country (more in Principles 4 and 10).

The OECD (2011) called policy interventions to steer towards dematerialisation. While resource efficiency improvements have a relatively low impact on societies, as both producers and consumers can continue existing practices albeit with less resource use and waste per unit consumed, dematerialisation introduces more radical sufficiency measures to reduce and slow down the rate of resource use altogether (e.g. Schröder et al., 2019; Stahel, 2016). This involves the downscaling of production in many sectors (termed "exnovation", Principle 3) and reducing average per capita consumption in high consumption countries (Parrique et al., 2019). Arguably this is the only way to respect the precautionary principle (Section 3.1.7). With companies not feeling able to change the economic system within which they must survive (Accenture and Compact, 2013), and impacts on the lives of citizens and their communities likely far-reaching (more in Principle 5–6), governments will have to play a pivotal role in the transformative changes involved with reducing the size of resource economies (Velenturf and Jopson, 2019).

4.4. Principles for transforming production

Principle 3: Design for circularity

This principle covers how the aim of design should change in a sustainable circular economy by combining design efforts at the levels of material selection and product design, supply chains and overarching industrial systems (Fig. 6), in an effort to create resource circulating societies (Section 3.1.5). This section ties three sub-principles together:

From flow to stock optimisation: Circular economy proponents argue that products, components and materials must be kept at their highest utility and value at all times. Products at their end of use should be turned into resources for others, argues Stahel (2016). Resource yields should be optimised, agrees EMF (2021). The focus appears to be skewed towards resource *flows*, but arguably there is more sustainability potential in the optimisation of resource *stocks* and the minimisation of flows altogether (Kalmykova et al., 2018; Schröder et al., 2019) because this would limit energy use and pollution that can be associated with resource flows. The principle of preserving the values and functions of stocks of materials, components and products should be maintained, however, as long as materials can be reintegrated into natural biogeochemical processes when they cannot be circulated back into the economy (Principle 1).

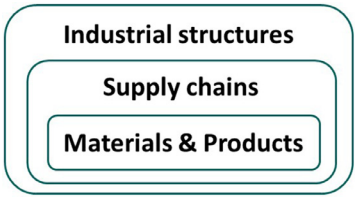

Fig. 6. Multi-level approach to transforming production.

Combining R-ladders and whole system approaches: Kirchherr et al. (2017) argue that the product-centred "R-ladders" – such as reduce, reuse, recycle or indeed the longer 10-R variant (see Reike et al., 2018) – are increasingly replaced or contextualised by the growing appearance of the principle of "whole system approaches" in the recognition of required system level changes. A sustainable circular economy that takes a whole system perspective (Section 3.1.3) can use R-ladders as a tool to outline potential scenarios for the optimisation of resource stocks and flows, and the best option for a supply chain in a given context (Section 3.1.8) can be derived from a whole system assessment combining economic, social, technical and environmental values (Millward-Hopkins et al., 2018) – detailed in Principle 10.

Transforming industrial systems: Circular economy is often posited as an ideal end state which would not change anymore once it has been achieved. The reality of human society is, however, that it has always evolved and most likely will continue to do so. Hence it would be better to think about circular economy as a continuous process within which production systems, and indeed consumption systems, society and the wider context (Section 3.1.8) continue to evolve. Fig. 7 demonstrates the current evolutionary process of developing circular economy conceptions, in which the linear society was challenged and the current compromise being a recycling economy that has become the mainstream (Section 4 opening and 4.1); the sustainability of the recycling economy is challenged and the circular economy evolution must now go further towards dematerialisation (Principle 2). The change from a "recycling" to a "dematerialisation" circular economy involves a shift in design efforts from design for recycling and eco-design which aim to design out waste and limit environmental impacts (Kiser, 2016), to transform industrial systems, supply chains, and materials and products for a sustainable circular society (Section 3.1.5) capable of delivering the social and environmental net-gains while maintaining economic prosperity (i.e. in line with the value system outlined in Section 4.2). The evolutionary perspective demonstrates that implementing a circular economy is a process of continuous improvement in which the sustainability of practices is continuously monitored, evaluated and adapted (Principle 10). Adaptation involves the nurturing of innovations while unsustainable practices are phased out through "exnovation" (Fig. 7). While governments tend to show motivation for the promotion of sustainable, circular and low-carbon innovations, dealing with the other side of the coin on which we find the necessity to significantly reduce or entirely phase out fundamentally unsustainable industries (e.g. Schröder et al., 2019) proves far less popular. This is the process of creative destruction (Abernathy and Clark, 1985; Gunderson and Holling, 2002; Schumpeter, 1934) and circular economy research now has to reach out further to translate this concept into action, helping stakeholders to leave behind unsustainable practices and tap into the plentiful sustainable opportunities.

Principle 4: Circular business models to integrate multi-dimensional value

The uptake of transformed production practices (Principle 3) will depend on the availability of viable circular business models (Kirchherr et al., 2017). Circular business model innovation adds value to sustainable development (Section 3) through the articulation of insights into how resource use can change. Business models were not generally recognised as an enabler of circular economy until recently (Geissdoerfer et al., 2017; Kirchherr et al., 2017), but key aspects such as product-service systems and internalising social and environmental costs are more established. Each is briefly

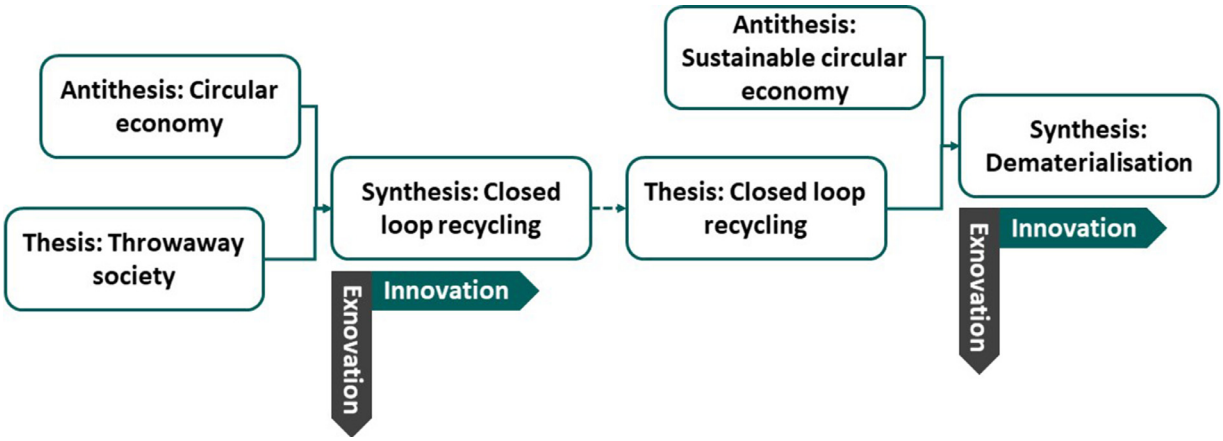

Fig. 7. Societal change as a continuous evolution between the current status quo (thesis) and a proposed alternative state (antithesis) progressing towards greater sustainability (synthesis), requires innovation for more sustainable practices and exnovation of practices that are no longer sustainable.

introduced before gaps in understanding around business models in a sustainable circular economy are highlighted.

Product-service systems involve the shift from ownership to stewardship of materials (Stahel, 2016) through selling services instead of products, either to be used individually or shared by multiple consumers. Establishment of such systems has been coupled to "intelligent decentralisation", making products available for sharing in the locations where they are needed (Stahel, 2016). While such service-based systems are purportedly less resource intensive, economies have so far not dematerialised as service sectors grew (Parrique et al., 2019; Wiedmann et al., 2015), possibly due to services being offered in addition to a materials economy rather than substituting products (Parrique et al., 2019). Stronger evidence is required to show how services can reduce environmental impacts from a whole system perspective (Principle 10) and some sectors may not become sustainable even with service-based business models and must be consolidated or eliminated (Principles 2–3).

Incorporating social and environmental value as well as economic value into the price of materials and products would make linear economy practices less profitable than circular economy practices. The price of resources, and the products that add value thereto, should reflect the environmental and social cost of their production and use. Critiques on circular business models emphasise the importance of greater integration of social aspects such as ethical trade, consumer education and sufficiency (Bocken and Short, 2016). Circular business models and economies must offer stronger solutions and evidence on their potential to enhance social and environmental benefits in absolute terms rather than just reducing adverse impacts (Section 4.2.1-4.2.2, Principle 1). This raises challenges around capturing added social and environmental value to motivate companies to adopt circular practices.

Internalising social and environmental costs into business models would involve governments for three reasons. First, the estimated costs of, for example, climate change are around $8 trillion (Galey, 2019, based on Economist Intelligence Unit analyses) largely borne by governments and thus requiring increased taxation. Collaboration with industry (Principle 7) is necessary to avoid that taxation and higher prices would disproportionally affect the least affluent groups (Section 4.2.1). Second, the process would strongly benefit from international cooperation and strong governance given global trade relations (Section 3.1.7 and Principle 7). Third, technology to enable greater circularity could result in monetary cost savings for companies, and it has been proposed that these could in part be redirected to delivering social and environmental net-gains, reducing the risk of reinvestment into further resource exploitation causing rebound effects. Government should ensure that linear economic practices are preferentially subjected to such measures to avoid emerging circular business models being outcompeted while they scale-up, reaching their full competitive potential (Velenturf and Jopson, 2019). This proposes in effect the transformation of monetary capital back into social and natural capital, a notion that requires substantial fundamental empirical research to determine the extent to which this is really possible and achievable given the required parallel political-economic changes (Section 4.2.3 and Principle 9).

4.5. Principles for co-creating social value with consumers, citizens and communities

Principle 5: Transform consumption

Circular economy literature underplays the importance of changing consumption patterns (Kirchherr et al., 2017). Consumption as usual, driven by technological progress and the quest for endless economic growth, risks circular economy remaining stuck in the linear economic paradigm (Korhonen et al., 2018b). Eco-efficiency measures paradoxically support this as saved costs are spent to drive more production and consumption i.e. the rebound effect (Bocken and Short, 2016; Chitnis et al., 2013; Velenturf and Jopson, 2019).

For sustainability (Section 3.1.5 and 3.2), average consumption per person must be reduced (Section 4.3.2 and Principle 2). Efficiency improvements must be combined with sufficiency approaches. Producer-driven overconsumption must be replaced by more demand-driven, shared consumption of products and experience-based "consumption" (Bocken and Short, 2016; Stahel, 2016; Wieser, 2016). Sufficiency embraces durability, upgradability, service and repair, and rejects designed obsolescence and marketing aimed at boosting sales before the end of the technical lifetime of products, as observed in for example telephone and clothing markets (Bauwens et al., 2020; Wieser, 2016). Sufficiency can be supported by regulations that restrict unnecessary turnover of goods, encourage them to stay in service for longer such as adopted in France (Wieser, 2016), place the responsibility for preservation of materials on manufacturers and retailers, and prioritise reduced consumption and reuse, repair and refurbishment.

Transforming consumption must go hand-in-hand with the establishment of responsible systems of provision. The mainstream view that production follows consumption – the public gets what the public wants – has been challenged by many investigators. Fine et al. (2018) argue that *"Producers (and production) might be*

deemed to play an independent role in consumption through manipulative advertising in shaping consumer preferences, or through imperfectly competitive pricing in distorting their fulfilment". Systems of provision for specific goods do not operate according to generalizable laws of economics. Each is unique, shaped by the specific historical, social and national contexts in which they develop and operate and specified according to *"the combination of material processes of provision and the material cultures associated with the commodity"*; an argument shaped herein with regard to there being no "one size fits all" approach to a sustainable circular economy (Section 3.1.8 and Principle 8).

Transforming consumption involves a rethink of material necessities in the pursuit of a good quality life, invoking the debate about human needs and wants in sustainable development (Section 3.1.4). A sustainable circular economy may involve far-reaching changes in lifestyles and cultures and will only be successful and sustainable when coproduced with the involvement of citizens; coercive pathways are ethically questionable and fruitless in a globalised economy. Integrating sufficiency into societies has to follow a participatory process that is sensitive to the preferences of citizens in a particular region or country (Principle 6).

Principle 6: Citizen participation in sustainable transitions

The importance of involving producers as well as *consumers* in the transition towards a circular economy has been recognised (Yuan et al., 2006), with practice-orientated research pleading for raising public awareness and participation (Geng et al., 2009). Nevertheless, circular economy research on participation processes and coproduction with involvement of *citizens* are still rare.

Citizen engagement is crucial for sustainable development by empowering citizens to coproduce circular economy solutions in an inclusive manner (Section 3.2 and 3.1.7) that meet their needs and offer fair access to resources to have a good life (3.1.1, 3.1.2 and 3.1.4) and enable change in social values (3.1.4). In a transformative circular economy, societies and communities – the manner in which we live and interact, and the matters that we care about – must change. Existing knowledge in participatory research approaches involving government and companies (e.g. Velenturf et al., 2019b; Velenturf et al., 2018) and individuals as consumers (e.g. Borrello et al., 2017; Lehner et al., 2020; Sijtsema et al., 2020; Stein et al., 2020) should be expanded with the inclusion of citizens in their communities. Citizens become more than mere consumers and are entrusted with the creation of communities and systems of provision that meet their needs in a sustainable manner.

The argument for action-research to coproduce shared value systems and to translate visions into approaches and actions has been heard from various circular economy scholars and practitioners. It would only seem right to involve citizens upon proposing radical changes to their lifestyles and, moreover, such changes are only likely to be successful when embedded in local (cultural) contexts supported by willing citizens to be part of such circular society. Coproduction of change for sustainable communities, like circular economy, tends to follow a narrative believing in green technologies, smart and efficient resource use, and using assessment tools driving innovation and competition (Sharifi, 2016); a discourse that offers little space to reconsider the function of current social, technical and economic structures, but rather focuses on improving the current status quo to minimise adverse impacts. In coproduction too, there is a demand for space to ask fundamental questions about the ways in which we are living our lives and whether there are more socially and environmentally positive manners in which we could shape our communities and societies.

Coproduction originates from the 1970s commons context, about the processes through which different organisations bring inputs together for the production of goods and services (Ostrom, 1996). Coproduction also has made its appearance in adaptive governance – as a means to increase efficiency, effectiveness and legitimacy of adaptation processes involving communities – and in research – to enrich the academic method of knowledge creation with other perspectives, thereby increasing the relevance and contribution of academic research to societal change. A commons approach seems an essential part of a sustainable circular economy, in which we must agree to avoid destruction of resources that are essential for current and future generations to live well (Ostrom, 1990). Circular economy could borrow the concept of "re-commoning" from resilience literature, to emphasise how circular economy broadens the ownership base from which values can be generated, including private, public and common owned initiatives, ideas, societal structures, infrastructure and the benefits that these provide (Brown et al., 2012; Petrescu et al., 2016).

Resilience has made its entry into circular economy related research on citizen engagement (Petrescu et al., 2016). Resilience literature is rich in useful examples of community initiatives such as Transition Towns and these could be linked more to the commons movement to rebalance the private and public with the commons ownership (Barnes, 2014; Brown et al., 2012; Ostrom, 1990). After all, if citizens are expected to take more responsibility in a sustainable circular society, then they are likely to need and want more power to direct resources accordingly. For example, Sorkun (2018) found that citizens who assume responsibility for recycling may let go of this positive behaviour if they perceive a lack of behavioural control in the light of municipalities failing to facilitate recycling. Indeed, resilience is considered most effective when coproduced with citizens to meet the needs within a community (Petrescu et al., 2016), similar to arguments for context specific circular economy implementation (Principle 8).

4.6. Coordinating the transition

Principle 7: Coordinated participatory and multi-level change

Community led action requires coordination across systems and system levels (Kalmykova et al., 2018; Kirchherr et al., 2017; Reike et al., 2018). Sustainable development requires participatory whole-system approaches (Section 3.1.3 and 3.1.7) but circular economy implementation is still plagued with a lack of systems approaches leading to widespread unintended consequences (Section 2.3). For example the introduction of bioplastics can be positive, but poor consumer engagement regarding the segregation of plant-based and petrochemical plastics can contaminate the whole waste stream and reduce overall recycling. The need to connect grass roots initiatives to local, national and supranational policy development is well recognised in the circular economy community (e.g. Ghisellini et al., 2016; Lieder and Rashid, 2016; Mathews and Tan, 2016). Circular economy practices inevitably have to be implemented locally, but harmonised at regional and national levels (see e.g. Jensen et al., 2011; Mathews and Tan, 2016; Petrescu et al., 2016). Actions within communities, regions and countries can be influenced by trade relations and global agreements and vice versa (Kalmykova et al., 2018, Section 3.1.3 and 3.1.8). Thinking across different geographic scales often gets fused with the consideration of the micro (e.g. products, individual companies – Stahel, 2016), meso (e.g. eco-industrial parks – Mathews and Tan, 2016) and macro level (e.g. city, region, nation – Kirchherr et al., 2017; Suárez-Eiroa et al., 2019) in implementing circular economy (Principle 3, Fig. 6).

Circular economy implementation is complex and requires parallel and consecutive changes from various stakeholders. For example, recycling is often suppressed by the availability of cheap primary materials, the technical capability to recover materials is underexploited due to the lack of ambitious resource recovery targets, and the finance sector still largely rewards short-term mone-

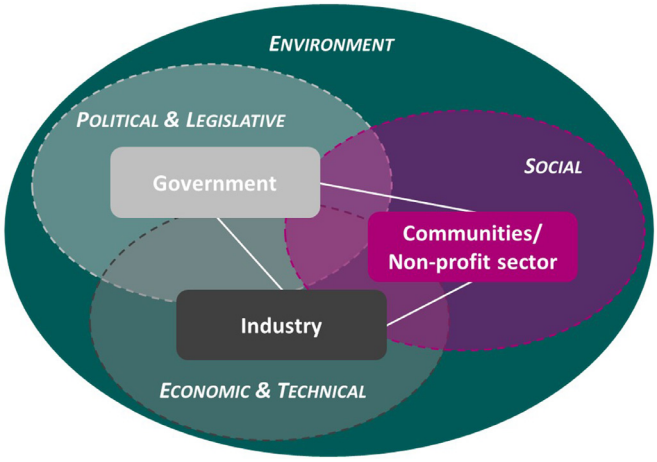

Fig. 8. Stakeholders across society are interacting and shaping each other's contexts, and can thereby enable or constrain progress towards a sustainable circular economy.

tary growth rather than long-term economic, social and environmental stability. Governments are reluctant to implement ambitious circular economy targets, fearing the departure of companies to locations with lower social and environmental standards, resulting in losses of tax income and jobs with effects on political popularity. Citizens and consumers have limited ability to drive change as business and government structures constrain the choices that they can make. In short, actors throughout society create contexts for each other which constrain uptake of circular economy practices (Fig. 8). Implementing a transformative and sustainable circular economy requires coordination or "intermediaries" – e.g. industry champions, third party organisations, government bodies or academic organisations – to break through such interdependencies that lock-in unsustainable practices (Hobson, 2013; Jensen, 2016; RRfW, 2019). Systems approaches that map out the enablers, constraints and stakeholders can identify key intervention points and who controls them (see for example Penn et al., 2016; Velenturf and Jopson, 2019). In this way change can be driven in a cost-effective manner and across multiple system levels.

Radical change challenges all actors, thus it is essential to establish why change is necessary. This will not happen spontaneously and coordination is required to agree upon the overarching values of a sustainable circular economy (adding detail to the values introduced in Section 4.2) and translate these into action (as also argued by Suárez-Eiroa et al., 2019). The perspectives of different stakeholders must be analysed and brought together in joined-up strategies for sustainable development (Section 3.1.7-3.1.8) through the implementation of a circular economy (e.g. Ghisellini et al., 2016; Stahel, 2016; Velenturf and Purnell, 2017).

Principle 8: Mobilise diversity to develop a plurality of circular economy solutions

Circular economy solutions are not universal; despite a tendency to the contrary in the circular economy community, they cannot be simply transferred without consideration of their context. Contexts vary substantially, with stakeholders facing diverse sets of interdependent environmental, social and economic challenges (Przywojska et al., 2019). For example, approaches for planned top-down eco-industrial park developments were relatively successful in China but failed to gain momentum under the different conditions in the USA (Gibbs and Deutz, 2007), wasting money, time and the goodwill of stakeholders. Such failures are preventable with a more thoughtful consideration of different cultural, institutional and economic contexts, as recognised within the sustainable development community (Section 3.1.8).

Embedding a sustainable circular economy requires a knowledge of local contexts to devise considerate technological, social and economic interventions. For example, low-carbon energy plans that rely on technically-efficient electric vehicles and wind turbines that are heavily reliant on critical materials may be appropriate where supply chains for such materials are well established through trade bloc (e.g. EU-China) agreements. Where supply chains are less stable (e.g. post-Brexit UK), alternative technologies should be retained as options (a point not lost on Tesla – Desai, 2018). Matching business models, policies and technologies to local contexts, rather than assuming "one size fits all", will be essential for successful sustainable circular economy implementation. Circular economy has a rich diversity of technologies, perspectives and ideas to solve major sustainability challenges and this diversity can be harnessed to tailor local, context dependent implementation of circular economy practices (Section 3.1.8). By developing a global knowledge base that includes how and why specific circular economy approaches and solutions did or did not work within a particular context, new transition pathways tailored to different contexts can be designed. In addition, stakeholders have many different views on what a sustainable circular economy may look like, but all have a role to play in the transition process and a broad shared vision is required to keep them at the table, deliberating progress through a series of syntheses (such as demonstrated in Fig. 7). The challenge for coordinating a circular economy transition (Principle 7) is to articulate such a vision with space for all perspectives (see e.g. Petrescu et al., 2016; Velenturf and Purnell, 2020).

Nurturing diversity is an important insurance policy. Implementing circular economy is happening under great uncertainty, imperfect information and constantly evolving contexts. It is therefore necessary to take calculated risks, learn and improve continuously, and accept the potential to fail within the boundaries of a precautionary approach (Section 3.1.7), balancing the environmental risk of proposed solutions with the risk of not taking action. Making decisions under deep uncertainty is a complex social process, but the rich literature on the subject (e.g. Kwakkel et al., 2016; Malekpour et al., 2020; Roelich and Giesekam, 2019) can help us design the changes inherent in a transition to a circular economy to be enabled and steered in a desirable direction (Malekpour et al., 2020). Modelling tools to support the collective, iterative envisioning of various plausible circular economy futures have been developed (see e.g. Iacovidou et al., 2017a; Kwakkel et al., 2016). Such tools often fall short of understanding the roles and perspectives of multiple actors (Roelich and Giesekam, 2019), a critical addition for which fundamental yet participatory circular economy research is necessary given that responsibility and agency for change is carried by multiple stakeholders at multiple levels (Principle 7). Plausible scenarios – and the circular economy practices that constitute them – require whole system assessments before, during and after implementation to foster a culture of continuous learning across society (Principle 10).

4.7. Principles for governance of progress towards sustainable circularity

Principle 9: Political economy for multi-dimensional prosperity

Under the current stresses of the cumulative and global health, economic, climate and biodiversity crises, there is no question that the relations between citizens, societies, markets and governments will change. In a sustainable circular economy, the purpose of the political-economic system would be transformed from a focus on short-term economic growth to long-term multi-dimensional

prosperity in environmental, social and economic terms. This requires far-reaching changes in the political-economic fabric of many countries where doing the right thing for sustainability is easier and rewarded more than the environmental and social destruction that is currently celebrated as "progress". As implied in Section 4.2, fair access to resources for social and individual well-being and absolute improvements to the environment would no longer be left to markets alone but facilitated through decentralised governance.

The changing role of governments has to be accompanied by revisiting what "success" looks like (developing it further from the outline proposed in Section 4.2). GDP is an incomplete measure of prosperity and progress that has become an aim in itself rather than being considered as the mere indicator that it is. Circular economists, in general, insufficiently question whether GDP growth is necessary and preferable, continuing to lean heavily on the unsustainable neoclassical economic model under the umbrella of green growth and a promise of decoupling – neither of which have nor are likely to become a sustainable reality. Parrique et al. (2019) argue that alternatives must be developed to the green growth discourse within which circular economy is embedded (Section 4.2.3).

Leaving green growth behind presents a cliff-edge of economic theory. It goes beyond our scope to propose new economic theory, but it is clear that a sustainable circular economy does not fit into any theory where centralised planning and control of resources is the covert or overt purpose – which appears to rule out most of capitalism, neoliberalism, socialism and communism. Instead, a sustainable circular economy is organised in a decentralised manner with strong involvement of local communities though within global boundaries of sustainability. It is redistributive at heart, to balance environmental, social and economic values and share prosperity with the population and avoid concentration in the hands of the few. Sustainable circularity fits within the emerging school of thought on "doughnut economics" (Raworth, 2017). In sum, a sustainable circular economy calls for novel economic theory.

Principle 10: Whole system assessment

The development of metrics, assessment tools and approaches is a very active research subject area within circular economy (see e.g. Alamerew et al., 2020; Lokesh et al., 2020; Silk et al., 2020; Silvestri et al., 2020; Völker et al., 2020) but there remains a misalignment with sustainable development in terms of the timing of whole system assessments and the aspects that are being measured.

Circular economists risk becoming overly focused on short-term implementation, neglecting to analyse potential long-term, unintentional detrimental effects (Kirchherr et al., 2017) – as demonstrated in Section 2.3 – yet realising a circular economy is a process of continuous improvement, adapting to evolving environmental, social, technical and economic conditions taking place under great uncertainty, and research must progress alongside of this (Section 3.1.7). Strategies to progress towards and maintain a sustainable circular economy will need regular evaluation and optimisation to stay on track towards the core values of environmental quality, social equity and economic prosperity (Sections 3.1.1 and 4.2).

This will require systems both for the rapid assessment of sustainability potential of proposed circular economy practices before implementation, and to monitor contributions to sustainable development during and after implementation (Kalmykova et al. (2018); which is also important for adhering to the precautionary principle (Section 3.1.7). Ex-ante evaluations are not common practice in circular economy or sustainable development, but they are important for the selection of the most effective interventions and practices (Principle 7).

In circular economy the focus is generally still on individual practices rather than system-wide optimisation (Reike et al., 2018). The value framework for a sustainable circular economy provides the foundations upon which the evaluation of specific circular economy practices can be based. Evaluating actions for a circular economy with a whole system perspective – i.e. within planetary boundaries and the social foundations as outlined in the UN SDGs (Section 3.2) and across micro, meso and macro-levels (Principle 7) – is not straightforward because there are many variables to consider (Fig. 9), including: The level of circular economy ambition (Section 4 opening); Stakeholders involved (Fig. 8, Principle 7); System level and scale (Principle 7); Resource type (Fig. 1, Principle 3); Indicators across the main circular economy values (Section 4.2); Time dimension from short to long-term; Implementation stage; etc. Fig. 9 is not exhaustive and further aspects may need to be included.

The development of holistic sets of metrics to measure progress, going beyond GDP which insufficiently aligns with sustainable circular economy values (Section 4.2 and Principle 9), is a constant work in progress (see e.g. FAO, 2002; Iacovidou et al., 2017b; Mathews and Tan, 2016; Ren et al., 2013; Stahel, 2016). Uptake of such metric systems by governments is held back by data availability. Holistic assessment of circular economy scenarios is data intensive and major coordinated efforts are required to establish data systems to monitor the stocks and flows of materials and products within economies (e.g. Chen et al., 2017; Velenturf, 2019).

5. Closing remarks: actions for research and implementation for sustainable circularity

Circular economy can contribute positively to most of the sustainable development goals, but sustainable development and circular economy are on diverging pathways. While the sustainable development agenda puts people front and centre with economic prosperity recognised as a means for living fulfilling lives in harmony with nature, circular economy remains fixated on technological solutions, the implementation of which is driven by a promise of traditional economic growth.

Circular economy must be fully integrated with sustainable development. This necessitates a profound reconsideration of circular economy, broadening its scope from closed-loop recycling and short-term economic gains, towards a transformed economy that organises access to resources to maintain or enhance social well-being and environmental quality. Superficial changes, i.e. to accommodate recycling, to prevailing economic models will not suffice. This article proposed a set of three core values and ten principles for the design, implementation and evaluation of a sustainable circular economy and exposed numerous gaps in expertise.

Circular economy should be understood as an emerging practical ideology that lacks an evidence-based theoretical framework to guide implementation. It lacks an economic theory that can pragmatically guide the transition from the prevailing neoclassical model towards one that would drive the transition towards a sustainable circular economy and be palatable for governments. This is directly linked to the gaps in circular economy regarding the creation, measurement and appropriation of social benefits, and regarding coproduction of new values for sustainable futures through democratic processes that join up community, national and global governance. Realising and sustaining a circular economy, given the deeply uncertain and dynamic contexts, will require processes and structures for reciprocal, continuous, collective learning and change. These processes and the role required of circular economy facilitators are very poorly understood and require urgent research and action.

At the heart of circular economy we find largely unsubstantiated and implicit assumptions regarding the ability to transform

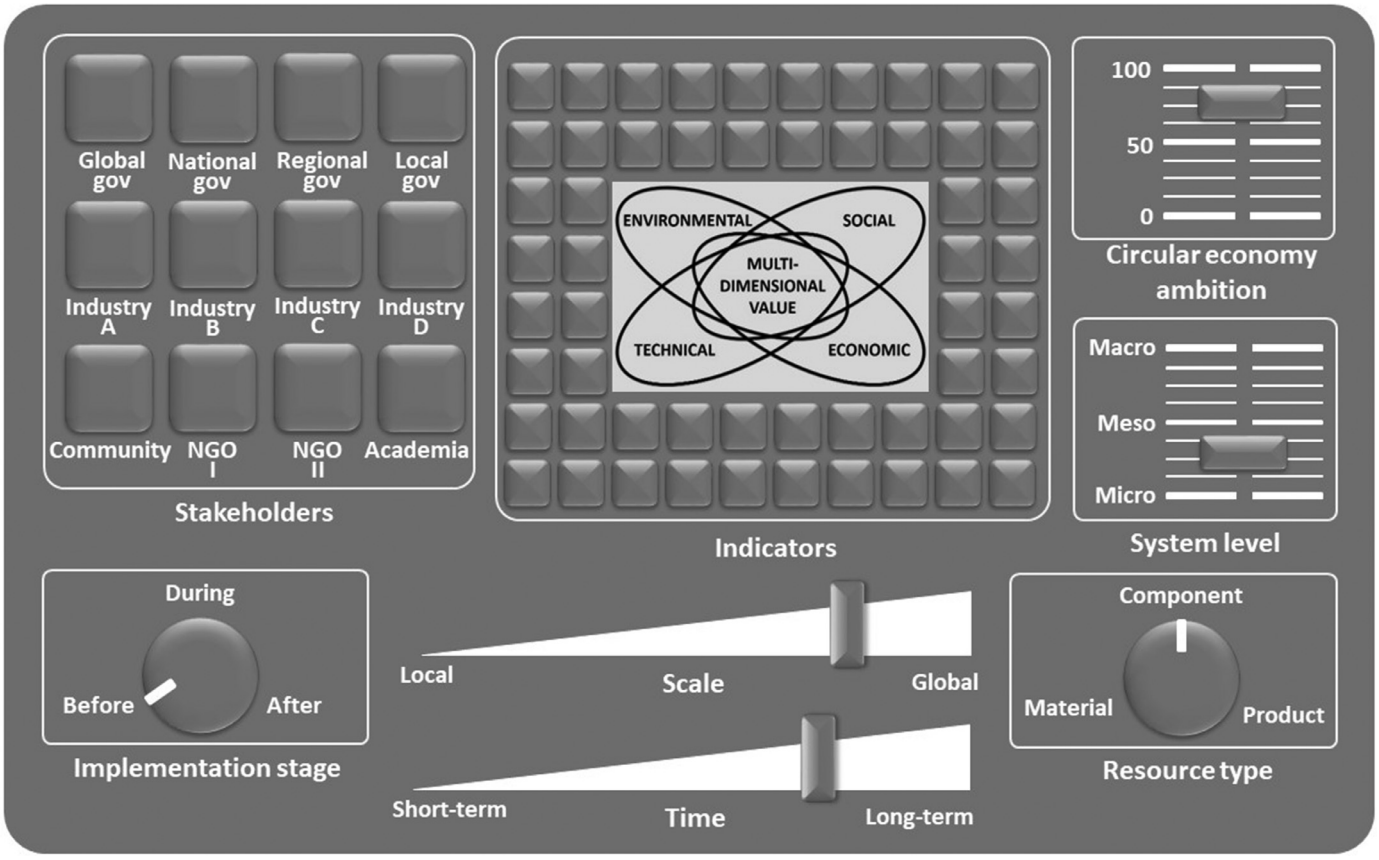

Fig. 9. Conditions and settings to consider in the sustainability assessment of circular economy practices.

economic values into social and environmental values and vice versa. Can people indeed restore natural capital – and in particular, critical natural capital – and can we all live well at the same time? How much energy and water does it cost to keep materials in circulation and to raise or maintain material standards in support of well-being? How large can our resource economy be without depleting natural capital and the absorptive capacity of the planet? How can organic and inorganic materials be reintegrated into natural biogeochemical processes? And how resource intensive is a service-based economy? All of these questions require an answer.

These gaps in the evidence base should not however prevent practitioners from moving forward. Designers have a broad spectrum of strategies to help select materials and design products with a sustainable circular economy in mind. This should inform socially and environmentally responsible behaviour from companies, particularly to halt designed obsolescence and the promotion of wasteful overconsumption. Governments are in the driving seat to change political-economic models that encourage the emergence of a sustainable circular economy both to fulfil their constitutional duty to create conditions that offer equitable opportunities for all citizens, and their obligations to deliver absolute improvements to the environment. Such improvements are impossible without revisiting industrial structures, using industrial strategies to grow sustainable industries and phase out unsustainable practices.

Determining which practices and systemic changes are indeed sustainable and circular requires rapid assessment tools with a whole system perspective. The tools available are generally not rapid, demanding considerable research time. They also fall short in holistic sets of indicators integrating economic, social and environmental outcomes, and guidance on how to use such multi-pronged assessments in decision making. Whole-system assessments are data intensive. Sectoral or national data systems that capture qualitative and quantitative technical, economic, social and environmental characteristics of the stocks and flows of materials, components and products are rarely available, but are essential to enable decision making for the progression towards a sustainable circular economy.

Stakeholders throughout society should use the values and principles from the manifesto to design, implement and evaluate a sustainable circular economy (Table 4). Resource overexploitation and waste is a global challenge and circular economy measures should be integrated into global agendas on sustainable development and climate change, neither of which can succeed without a sustainable circular economy. This will provide more impetus for national governments and industries to take responsibility.

We conclude with a note of pragmatism. Every actor should do their very best to develop a more sustainable circular economy. Not acting upon the destabilising environments, societies and economies due to our unsustainable resource use is not an option. But there will be failure and it will never be perfect. We have to accept this yet not be discouraged to act. Sustainable development is fraught with imperfection and so is circular economy. The critiques on circular economy should be understood as much as a critique on sustainable development itself, and both require research and constant learning to ensure progress towards sustainability. The manifesto proposed in this article can hopefully be one step on the way towards a sustainable circular economy or, rather, a circular society.

Author contributions

AV designed article concept and performed analysis, AV and PP wrote first draft, critically reviewed analysis and revised article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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