Key Elements
of the Circular Economy

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please contact info@circle-economy.com for comments and revisions

Note to readers:

This document is a draft literature review on strategies for a circular economy.

The purpose of this document is to ensure that the framework we use at Circle Economy adequately reflects strategies that are being implemented in support of a low carbon, just circular economy across nations, cities, and businesses.

The next iteration of this research will add additional information on the application of the elements across emerging economies, and look at the application of these strategies to cities, businesses and nations more explicitly.

Please contact us at info@circle-economy.com should you have any questions, concerns or comments regarding this research and its application, or if you wish to be involved in reviewing and contributing to such texts going forward.

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Authors:

Esther Goodwin Brown
Marijana Novak
Laxmi Haigh
Ana Birliga Sutherland
Dino Wildi
Sophie Wynaendts
Joke Dufourmont

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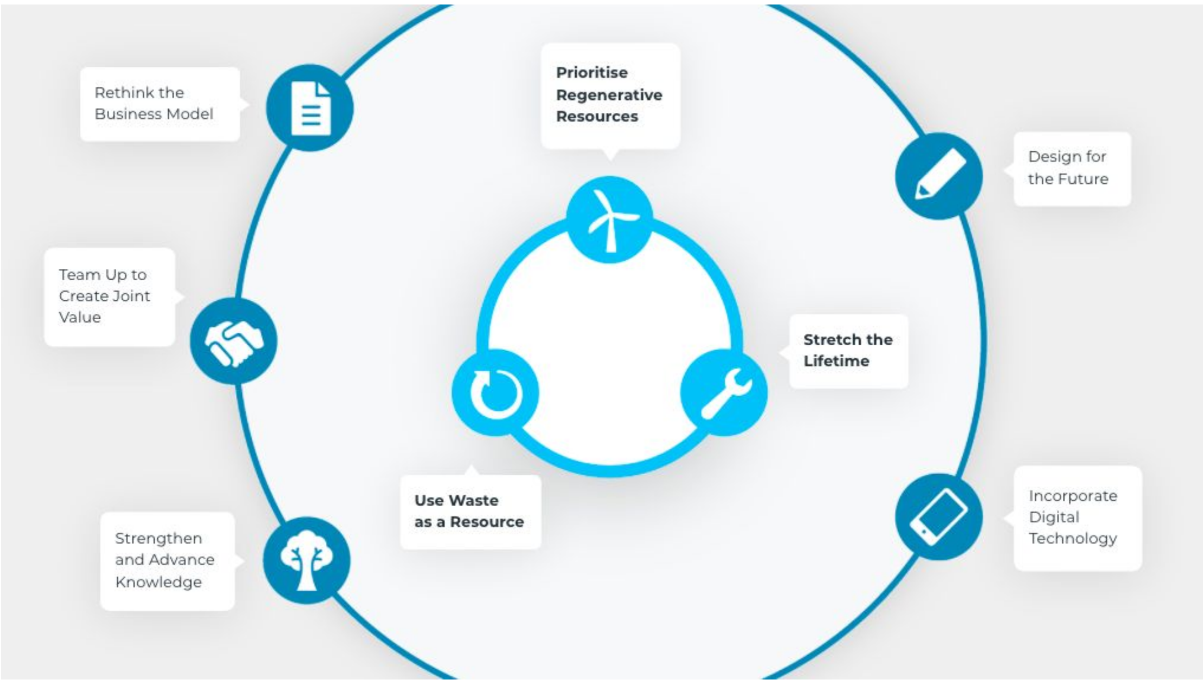
Introduction

The global population is at risk from climate change, and with its impacts threatening our future here on earth, solutions for the crisis have become a crucial focus of governments, policy makers and academics. We've seen the sustainability paradigm shift as the circular economy—a system based on designing out waste, keeping materials and products in use and regenerating natural systems (Ellen MacArthur Foundation (EMF), n.d.-a)—is increasingly used as a basis for change.

The circular economy is now, more than ever, perceived as an auspicious approach to improving global sustainability, with many governments, from the EU, to China, Japan and Chile, adopting circular strategies as part of their environmental action plans (Bocken et al. 2016). Yet definitions and categorisations of what does or does not belong under the umbrella term 'circular economy' remains ambiguous. There is a clear need for organisational frameworks that make the concept more accessible—and Circle Economy's 'Key Elements' framework aims to do just this. It maps various circular economy terms and definitions used across organisations and distills the common themes into fundamental strategies. The framework outlines core strategies (those that are related directly to material flows) and enabling elements (those that remove obstacles to the implementation of core strategies). For the first time, this paper conducts a deep-dive into the literature that has contributed to the formation of these key elements, giving a holistic overview of the core and enabling strategies for a circular economy.



Core elements of the circular economy

The core elements of the circular economy relate directly to product, material and energy flows, with the aim of cycling them so as to decouple value creation from resource use. There is consensus within the literature on the strategies that make up these core elements, with the exception of some variation in the language and exact names used by different parties. Two increasingly prominent frameworks in the field are the 10R Framework, its simplified version the 5R Framework, and the Flow Framework devised by Bocken et al.

Bocken proposes that a circular economy requires material and energy loops to be narrowed (less materials are used to achieve the same outcome), slowed (the same assets or materials are used for longer before disposal), closed (waste streams form inputs into other production processes), or regenerated (toxins, pollutants and fossil fuels are removed) (Bocken et al. 2016).

The 10R framework prioritises strategies towards a zero waste economy, cascading down from reduce to reuse to recycling. Recycling is ordered by the extent of the value of recoverable materials, with the worst scenario considered as energy recovery from waste (EMF 2015; Jabbour et al. 2019; Lieder et al. 2015).

We illustrate how these frameworks correspond to the core elements of the Circular Economy as indicated by Circle Economy in the table below.

CIRCLE ECONOMY'S CORE ELEMENTS	STRATEGIES FOR RESOURCE CYCLING[13]	10R FRAMEWORK	5R FRAMEWORK
Prioritise Regenerative Resources	Regenerate flows		
	Narrow flows	Refuse	
		Reduce	Reduce
		Rethink	
Stretch the Lifetime	Slow flows	Reuse	Reuse
		Repair	Repair
		Refurbish	Refurbish
		Remanufacture	
Use Waste as a Resource	Close flows	Repurpose	
		Recycle	Recycle
		Recover	

Now, we will elaborate on how cycling materials—decoupling value creation from resource use—can be operationalised through our three core circular economy strategies: prioritise regenerative resources, preserve and extend what's already made and use waste as a resource.

PRIORITISE REGENERATIVE RESOURCES

Renewable, reusable and non-toxic resources in water, material and energy cycles replace non-regenerative resources, with corresponding processes to support regeneration.

Ensuring that renewable, reusable and non-toxic resources are used in the most efficient way possible is central to the circular economy (EMF 2015). Prioritising regenerative resources applies to creating regenerative water, material and energy cycles, regenerating and maintaining ecosystems and designing out waste.

Regenerative water management includes replacing freshwater with rainwater where possible and applying measures to increase water use efficiency, as well as reuse of wastewater (Lewandowski 2016; Voulvoulis 2018). Circular water management would close the loops of the water cycle and enable reuse more locally. This might be especially beneficial in densely populated urban areas (Espíndola et al. 2018). In a linear model, water management results in increased levels of pollution at each stage of the system and thus prohibits future reuse (Stuchtey 2015). Currently, rainwater is often drained into the sewage system instead of fulfilling its full circular potential, namely recharging underground aquifers (Sharma et al. 2015) or use in permaculture. In contrast, circular interventions can restore the water cycle. These include the implementation of green areas to increase evapotranspiration (movement of water from soil, canopy interception and water bodies to the air), installation of rainwater harvesting systems, and the usage of infiltration systems (Gleason 2014). Reforestation—which increases evapotranspiration and consequently, precipitation—can be coupled with the installation of rainwater harvesting, greywater and wastewater systems, to increase water supply (Espíndola et al. 2018). Harvested rainwater may often be polluted by bacteria or toxic chemicals (those that are hazardous to human health or the environment (European Commission 2017a)), but can be treated regeneratively with slow sand filtration and solar technology before usage (Helmreich & Horn 2009).

Regenerative material management entails the use of bio-based, reusable, non-toxic and non-critical materials for products; as well as warranting their most efficient use in the production process (Jabbour et al. 2019). Material efficiency, for example, can be bolstered by 3D printing, which can reduce the energy demand of small plastic products between 41% and 64% compared to large-scale manufactured goods (Kreiger & Pearce 2013). In the right context, the use of one tonne of bio-based materials can save up to 55 gigajoules of primary energy and three tonnes of CO_2 equivalents compared to conventional methods (Weiss et al. 2012). Critical raw materials—materials which have potential supply issues, insufficient substitutes and crucial applications (Gaustad et al. 2017)—should be avoided if possible or recycled at end-of-life.

Although many critical raw materials theoretically have 'high recycling potential', rates are currently quite low across the EU, due to high sorting and recycling technology costs, difficulty in recovering dissipated materials and the high level of materials locked in durable products (Mathieux et al. 2017). The growing demand for critical raw materials combined with inadequate recycling contributions thereby indicates a need for prioritising regenerative material management. Recent developments and innovation for electric vehicles, for example, have seen a significant reduction in the rare earth elements neodymium and praseodymium in neodymium-iron-boron used (Pavel et al. 2016). Pilot concepts for hybrid vehicle motors free of critical materials have shown promising preliminary results, with equal power, durability and efficiency to motors based on rare earth elements (Pavel et al. 2016; Riba et al. 2016).

Regenerative energy management means that electricity is generated from renewable resources, combustion engines are electrified and efficient use of energy is pursued (Harvey 2019). Renewable energy comes in many forms—geothermal, hydropower, solar, wind, bioenergy, ocean—all of which have the potential to contribute to sustainable development, energy security and low-carbon economic growth (International Renewable Energy Agency 2020). Sources like solar and wind are becoming progressively more tenable as alternatives to fossil fuels—and according to research from Stanford University, there are no technological or economic barriers to converting to renewable sources, only a lack of societal and political resolve (Bergeron 2011). Energy efficiency goes hand in hand with the transition away from fossil fuels, reducing both direct emissions from combustion or consumption and indirect emissions from electricity generation (International Energy Agency (IEA) 2019). Electrification of combustion engines significantly reduces emissions, as no greenhouse gases are emitted locally but only through the production of electricity; additionally, battery operated vehicles perform better than combustion engines in terms of efficiency (European Environment Agency 2018). Energy systems can be centralised or decentralised, with decentralised or distributed systems based on a network of independent local controllers rather than a single primary controller (Karavas et al. 2015). Decentralised approaches for renewable energy, especially in small-scale generation units, have a number of environmental and social benefits. In-use greenhouse gas emissions are drastically reduced from such systems (Vezzoli et al. 2018), which also boast reliability as a selling point: if one controller fails, the rest of the system can continue to operate (Karavas et al. 2015). Additionally, research shows that decentralised renewable energy could facilitate a 'democratisation of energy access' (Vezzoli et al. 2018), thereby improving the self-sufficiency of communities and decreasing inequality. Skierka (2016) found that decentralised renewable energy has the capacity to equip more than one billion people with access to energy by 2025.

The role of the circular economy in improving and maintaining ecosystem services should also be considered under the lens of prioritising regenerative resources. Such services concern active regeneration and maintenance of nature areas and adjustments to activities that are deeply entrenched in nature such as tourism (or eco-tourism). Ecosystem services have been listed as crucial for sustainable development by the UN Millennium Ecosystem Assessment (UNMA 2005) and the World Business Council for Sustainable Development (WBCSD n.d.), and are classified as both services and goods that provide supporting, provisioning, regulating and cultural benefits to society (Wojtach 2016).

The benefits the circular economy brings are also rooted in the improvements it encourages in the way we produce and consume. In a transitional phase towards circularity, the majority of efforts are focused on improving production efficiency and reducing material resource use; yet in more mature phases, the circular economy should ideally revolve around ecosystem services to halt biodiversity loss (Wojtach 2016). A coordination of values between circular economy and ecosystem services approaches is already cultivating successful 'green' practices of eco-industrial parks (Genovese et al. 2017; Park et al. 2016; Shi et al. 2012). Liu and Coté (2017) write of innovative policies for integrating ecosystem services into China's circular economy approach, particularly in this realm. The eco-industrial park Tianjin Economic-Technological Development area, for example, has advanced initiatives related to restoring ecosystem services, reducing pollution and improving biodiversity. Additionally, eco-industrial parks can implement policies such as 'eco-compensation', an institutional arrangement that protects ecosystem services and adjusts the distribution of costs and benefits between stakeholders through economic measures (Liu et al. 2008).

The final component to be considered under this element is designing out waste. Whilst certain circular strategies enable products or materials to be cycled, for instance by making them more durable, modular, or able to be disassembled, these design choices do not *necessarily* bring about a waste reduction. This is because, ultimately, there is still a behavioural or business model shift required to affect change. Designing out waste negates the possibility of wasting, and refers to reduction of materials entirely through design strategies—for example, banning single use packaging or removing the packaging entirely. Traffic management can also be considered as designing out waste as transport resource costs and resultant emissions are reduced (Ghose et al. 2004). In some contexts, sourcing locally may be an appropriate strategy to design out waste from transport and losses/damage during transport—however this is dependent on the capacity for production locally, as well as wider systemic effects concerning unwinding the production capacity of the originally supplying context (de Jong et al. 2016).

STRETCH THE LIFETIME

Resources and products are maintained, repaired and upgraded to maximise their lifetime and usage intensity.

Maximising the lifetime of products and resources by means of maintaining, repairing and upgrading them and giving them a second life through take-back strategies when applicable is also central to the circular economy (Andrews 2020; Bocken et al. 2016). Extending the life of products can substantially reduce the negative environmental impacts attributed to their production and use, and lowers waste generation, resource and energy use, as well as greenhouse gas emissions (Downes et al. 2011). In some cases, such as mobile phones, extending the service life of the product is considered a key measure to both close loops and increase loop efficiency (Sinha et al. 2016). In cases where the production stage is the primary contributor to environmental impact, using products for longer would have similar benefits even with rapid improvements in material and energy efficiency (Frey et al. 2008; Güvendik 2014; Kwak 2016). Repairing broken or malfunctioning products is key to extending service life, as well as careful use and preventative maintenance that averts the need for repairs. Culture has a role to play in this realm, with only 23% of Germans and 28% of Americans having had their phones repaired, compared to 66% of Chinese and 64% of South Koreans (Greenpeace 2016). While a London-based study found largely negative consumer attitudes towards repairs; consumers cited lack of trust in repairers, lack of awareness of repair options and the high cost of repair compared to low cost of new items. Participants who did not undertake 'do it yourself' repairs at home—approximately 50%—cited lack of knowledge, skills and confidence, fear, and motivation issues (Cole & Gnanapragasam 2017). Given the substantial impact of extending service life—one additional year of smartphone usage can reduce its carbon footprint by 31% (Benton et al. 2015)—changing consumer perspectives on the matter through education or marketing emerges as a crucial enabling factor for extending product lifetimes.

Old goods can be refurbished or remanufactured and parts of them used as a basis for new goods where possible (Andrews & Whitehead 2019). While often conflated in the literature, 'refurbished' and 'remanufactured' products are not entirely the same: remanufacturing focuses on returning the product to a 'like new' state, while refurbished products must meet certain standards but are not necessarily required to be returned to the original condition (van Weelden et al. 2016). Both procedures are beneficial in preserving and extending the lifetime of products, because a complete dismantling of the product is not required, a significant portion of the original energy used for production is maintained (van Weelden et al. 2016). While both remanufacturing and refurbishment can benefit companies economically (Atasu et al. 2008; Linton 2008; Ovchinnikov et al. 2014), companies often don't fully understand or recognise their value, and may be deterred by high investment costs (Abdulrahman et al. 2014; Govindan et al. 2015; Hatcher et al. 201; Vasudevan et al. 2012). A lack of technical abilities and skills capacity also prevent companies from instigating refurbishment facilities (Sharma et al. 2016; Wei et al. 2015), while poor remarketing strategies and low consumer acceptance also deter company investments (Govindan et al. 2015; Sharma et al. 2016). Despite this, successful remanufacturing and refurbishment do take place, particularly for vehicle components, industrial digital printers, and heavy-duty off-road equipment parts (International Resource Panel 2018).

Furthermore, goods can be reused or shared between users to make them accessible to more people, either by facilitating peer-to-peer sharing or by making products available on a service basis (Antikainen et al. 2018; Jabbour et al. 2019). Direct reuse—whereby products are passed on or sold to friends, family, or charity—is a critical step in the circular consumption of goods (Wieser & Tröger 2018). There are two dimensions to a thriving reuse system: (i) consumers buy second-hand instead of new items, and (ii) items in good working condition need to be passed on to the correct outlets to guarantee a constant supply of second-hand products available (Wieser & Tröger 2018). Encouraging reuse of products may also encounter social or psychological barriers; around 80-90% of phones, for example, are bought new (Wieser & Tröger 2018), as rapid changes in technology and the emergence of the mobile phone as an 'object of fashion' (Fortunati 2005) have lowered consumer perceptions of purchasing second-hand. Nonetheless, in some fields, reuse is especially critical to the success of the circular transition. Electric vehicles, for example—which are set to increase to 56 million in the EU by 2030 (IEA 2018)—require lithium-ion batteries that heighten the demand for raw materials and pose a potential problem at end-of-use (as waste batteries need to be collected and treated to prevent the inflow of hazardous materials into the environment). When such batteries are replaced, they usually still retain up to 80% of their original capacity (Ahmadi et al. 2017, Admadi et al. 2014, Bobba et al. 2018). Opportunities exist in this area to reuse batteries for further operations that require lower energy performance—such as the building sector—thus ensuring the energy and material resource used in production do not go to waste (Cusenza et al. 2019).

This element must also take into account stretching the lifetime of biological products through management, preservation and conservation. Soil, a crucial non-renewable resource that provides a variety of ecosystem services, is one example where preservation is necessary—especially as soil quality recovery is an exceedingly slow process. The implementation of circular practices will impact the way we manage land and soil, ensuring vital nutrients are retained and thereby preserving vital natural capital (Breure et al. 2018). Here the difference between preservation, restoration and regeneration becomes pertinent. (Morseletto, 2020)

USE WASTE AS A RESOURCE
Where waste creation is not avoidable, recover it for recycling, using waste streams as a source of secondary resources.

When there is no option for regenerative resources or lifetime extension, and waste streams are still generated, they should be recovered and processed to be used as inputs into production processes (Bocken et al. 2016). Using waste as a resource can happen with varying levels of complexity. An organisation can design processes such that they themselves can manage the cycling of their own materials or waste internally, or they can design and operationalise this exchange across their own network. An organisation can also operate with other organisations, as seen in industrial eco-parks (de Mattos & de Albuquerque 2018). Finally, organisations can transact their waste streams in the market, or source secondary resources as inputs into their own production processes (Jabbour et al. 2019). Ideally, resource loops can be closed entirely through using the waste of a product as a resource for the production of the same product. Where this is not possible, resources can flow across industries in an open-loop cycle. Waste can be delayed by using end-of-life products as an input for a different loop, although this likely corresponds to a loss in value (EMF 2015; Geissdoerfer et al. 2016).

Bocken et al. (2016) outlines different categories of waste recycling in the case of plastics in a circular context, highlighting the multiple use pathways a product may encounter at end-of-life: primary, secondary, tertiary and quaternary. Primary recycling, also known as closed-loop recycling, is the circular ideal, whereby a good is reprocessed into another product with analogous properties (Hopewell et al. 2009). This category includes 'upcycling', which focuses on maintaining the properties of a resource (McDonough & Braungart, 2013). Secondary recycling can also be referred to as 'downcycling', and involves reprocessing materials into products with lower property standards (Hopewell et al. 2009). Tertiary recycling is known as chemical or feedstock recycling, whereby the chemical components of a material are broken down into their core constituents and rebuilt into materials with similar properties to the original (Kumar et al. 2011)—such as in the case of depolymerisation and repolymerisation. Finally, quaternary or 'thermal' recycling recovers energy from materials, emblematically through waste-to-energy. While Bocken et al. (2016) state that this category cannot be included as 'recycling' within the context of a circular economy (due to the re-use of only part of the energy content of a product), waste-to-energy will still be examined as a viable option for using waste as a resource (Malinauskaite et al. 2017), albeit at the bottom of the waste management hierarchy.

The upcycling of a product at its end-of-life has been widely recognised as a favourable means to reduce energy and material use (McDonough & Braungart 2002; Sung 2015; Szaky 2014). One increasingly critical form of upcycling—considering the challenges climate change presents in the context of global food security—is the reuse and recovery of nutrients from food waste (Xu et al. 2018), for example through the use of waste and by-products for animal feed. While the criticisms of animal-based foods are far reaching, the literature acknowledges that livestock can provide nutritional benefits within a circular system, by upcycling food waste and food processing by-products into meat (Garnett 2011; van Hal et al. 2019; van Zanten et al. 2018). This would increase land efficiency, as livestock could provide nutrient-rich food to humans without requiring the additional land currently used to grow feed crops (van Zanten et al. 2018). While the use of swill has been banned across the EU, Japan and South Korea have seen great success through establishing a modern, regulated process that eliminates the risk of viruses such as foot-and-mouth disease. The latter countries recycle about 40% of their food waste as livestock feed—which provides a number of social co-benefits as well as environmental; for example, a reduction of feed costs by up to 60% (Salemdeeb et al. 2017). Further research implicates that if food waste in Europe was recycled at a similar scale to Asia, the land used to produce pig feed could be reduced by 20% (zu Ermgassen et al. 2016).

Secondary recycling—or 'downcycling'—doesn't enable a truly circular flow of materials, but rather extends the linear flow of resources, as the material is reprocessed into that of a lower value (Lee et al. 2001; McDonough & Braungart 2002). Nonetheless, it remains a relevant strategy for the use of waste materials that cannot be upcycled.

The use of coal fly ash—the inorganic residue remnant from the burning of pulverised coal—exemplifies this. China uses 66% of fly ash produced (China Electricity Enterprises Union 2007), innovating applications in many areas: cement production, other construction products, wastewater treatment and agricultural applications (Yang & Zhang 2004). Similarly, waste produced during the process of flue-gas desulphurisation contains gypsum, which can be used in a variety of ways akin to that of coal fly ash (Li et al. 2010). Other desulphurised waste can be used as chemical improvement agents to treat acidic and alkali soils (Li et al. 2004), and ash from the dry desulphurisation process can be used in cement production (Su et al. 2005).

Tertiary feedstock recycling is particularly pertinent in the chemical industry. While most industries use fossil fuels for energy production, half the chemical industry's demand is attributable to feedstock; fossil fuels are used as raw materials for the production of plastics and fertilisers, among other things (DENA 2019). Blank et al. (2020) note that non-conventional (non-fossil) feedstocks thus have a number of conditions to fulfill, and must be notably beneficial in terms of cost, availability, and ease of use. On a global level, we produce upwards of 350 million tonnes of plastic per year (PlasticsEurope 2018), with 4.8 billion tonnes currently in landfills (Geyer et al. 2017); within the circular economy, the valorisation of post-consumer plastic and its use as a feedstock must be considered (Blank et al. 2020). Currently, 80% of all plastic produced has not been reused due to insubstantial infrastructure and technology (Geyer et al. 2017), but the potential of plastic as feedstock remains high (Blank et al. 2020).

Quaternary recycling uses waste as a resource to produce energy through incineration. The practice is viewed through a critical lens in some literature (Bocken et al. 2016), with Zero Waste

Europe (2016) stating that conceptually, it cannot be considered part of the circular economy, as loops are only closed when there is nothing more to burn. The practice may also encourage wastefulness and therefore prevent significant waste reduction, and incinerators that burn such waste release harmful toxins and greenhouse gases. Despite this, it remains key to the EU's action plan for the circular economy adopted in 2015 (Malinauskaite et al. 2017)— provided that the EU waste hierarchy is used as a foundation, and that higher levels of prevention and recycling are prioritised (European Commission 2017b). Other waste to energy technologies, such as anaerobic digestion, pyrolysis and gasification, provide further potential to reclaim materials from the waste stream not allowed by incineration, and are being increasingly deployed in Europe (Malinauskaite et al. 2017).

Enabling elements of the circular economy

Despite the increased interest in and efforts towards implementing core elements of the circular economy, there are persistent obstacles to their implementation. Some of the main obstacles to achieving the transition are that dominant economic incentives largely rely on traditional linear ways of creating value; it's difficult to keep track of cycled resources; or recover resources from existing products and a general lack of awareness and knowledge about the circular economy.

Enabling elements are strategies that help to adopt circularity by removing some of these obstacles. They can use new technologies to create opportunities for circular activities, but they can also change the economic, social, or legal environment in a way that makes circular activities easier to adopt. Some of them explicitly facilitate a specific action, for example the implementation of a marketplace to facilitate the exchange of secondary materials, whereas others create a broader environment that is conducive to circular activities, for example, training on the circular economy.

DESIGN FOR THE FUTURE

Design systems to facilitate regeneration, restoration, repair, reuse, or disassembly, or utilising waste as a resource

The Ellen MacArthur Foundation defines circular product design as eliminating the negative consequences of economic activity that harm humans and nature—greenhouse gasses, pollutants and toxins. Additionally, in a circular economy, the design of products would facilitate cycles of repair, disassembly and reuse; 'consumable' products would be primarily made of biological resources that can return to the biosphere at end-of-life, whereas 'durables'—made of ingredients not suitable for the biosphere (metal and plastic)—would be designed for reuse from their conception (EMF 2013). Here, biomimicry becomes a facilitating concept for sustainable design: using nature as a model, a measure and a mentor.

Designing for the future entails a systemic approach, which would reward lower resource use or longer usability of products (Lieder et al. 2015). This goes beyond the product itself, and speaks to the business, value chain and policy environment in which the product must operate.

For example, systems in agriculture and food production are also designed in a linear way; ultimately they too have a focus on short-term efficiencies. The increased need for food production has led to rapid industrialisation around the world, increasing yields but also spurring a host of environmental and social consequences (Berthet et al. 2018; Vanloqueren & Baret 2009).

Increasingly, the limitations of the linear system have stimulated a renewal of agriculture's traditional design model. This allows for more decentralised, contextualised and participatory approaches (Bethet et al. 2018). The ecological services of agriculture—aside from food production—are also steadily being recognised in policy, prompting a new design that is regenerative, circular and prioritises soil health and biodiversity (Frossard et al. 2009).

Design for the future also crucially considers how to design 'cyclability' into products, meaning that future repair, disassembly and recycling should be considered. This is vital for encouraging the adoption of more circular techniques and materials within a range of sectors, including construction, textiles, and electronics (Stijn, 2019) (Moyer, 1997) (Haeggblom, 2020) A prime example is designing buildings for renovation and disassembly rather than demolition, enabling used buildings materials and components to be collected and applied in other construction projects.

Design for disassembly can be encapsulated in three key aspects: the interface between materials in a product, the building components, and systems (Brandão et al. 2018). These principles of disassembly can be incorporated into regenerative building practices—namely, building with mass timber or cross-laminated timber, materials that boast renewability as well as strong structural performance (Krötsch & Huß 2016), lower embodied emissions than cement or steel, and carbon sequestration. An innovative new connection system, X-RAD, allows for the quick assembly and disassembly as well as modular construction of cross-laminated timber panels (Polastri et al. 2017). Governments can explore policy instruments that support the above design strategies, and businesses can explore new collaborations and business models, as well as skills development that support such design strategies.

The design element also concerns the use and role of a product. More recently, sustainable design methodologies have begun exploring the meaning and value of material goods in our lives (Chapman 2009). The concepts of emotional and physical durability are re-emerging after a long period of 'planned obsolescence' (London 1932), during which durable design clashed with commercial interests. Consumers may also dispose of durable products that are still fully functional for a number of reasons, such as wear and tear, improved utility of new models, improved expression and new desires (van Nes & Cramer 2005); this tendency towards disposal can be tempered through increased emotional durability, a rather nascent field of study (Haines-Gadd et al. 2018).

Product attachment can, however, be increased through a number of concepts, six of which have been defined in Chapman's (2009) experiential framework: narrative, detachment, surface, attachment, fiction and consciousness. 'Narrative', for example, allows users to build a unique personal history with their product (often taking into account how the product was acquired), 'surface' describes a product that develops a physical character through years of use/misuse, and 'attachment' details the strong emotional connection users can feel for a product due to its function and meaning (Chapman 2008). Physical durability is also a key element of design for the future, and goes hand in hand with emotional attachment (den Hollander et al. 2017). Designers must consider the 'events' of a product's lifetime: what will it go through, and how will it be used (Schischke et al. 2016). Reparability must also be considered as a facet of durability, with research finding that 'do it yourself' repairs by consumers (made easier by modular design) contributes to a longer product lifetime. For example, printer users prefer minor paper jams that can be fixed at home to more serious but less frequent jams, which require the assistance of external service staff (Schischke et al. 2016).

Circular product design is an indispensable enabling activity for the sound implementation of all core elements of the circular economy. How easy it is to, for example, recycle, disassemble, or reuse materials in a product is dependent on the design of the product and the choice of materials. This makes product design one of the most important activities to close and narrow material loops (Bocken et al. 2016). It follows that the design of a product determines the financial viability, scalability and quality of core circular economy strategies.

RETHINK THE BUSINESS MODEL
Shift incentives and adjust business models to price the entire life-cycle of products and capitalise on cooperation and long-term relationships.

A sizable body of research exists surrounding organisational frameworks for circular business models (Kraaijenhagen 2016; Lewandowski 2016; Manninen et al. 2018; Urbinati et al. 2017), that explores how companies eager to join the circular transition adapt and innovate. Kraaijenhagen (2016), for example, provides a ten-step approach for businesses of all sizes to initiate and execute their transition, from pilot to circular businesses. Urbinati et al. (2017) cites many examples of organisations that have included elements of circularity in their business models (Renault, Puma, H&M), noting that these varied case studies demonstrate the multiplicity of circular economy approaches. From this, the authors make a case for creating a two-dimensional framework to better understand the 'circular shift', studying both the customer value proposition and interface (the implementation of circularity in proposing value to customers) and the value networks (interactions with suppliers and reorganisation within the company).

In transitioning from a linear to a circular model, the focus of the value proposition shifts from selling a material good to giving access to its functionality (Lieder et al. 2018). Changing the value proposition of the product entails changing business models that focus on the sale of products to service- or lifetime-based models, which provide services and generate profit over the entire lifetime of a product (Bocken et al. 2016; Lieder et al. 2015). ~~Altering this value proposition could have a domino effect through design and production, for instance through the use of secondary materials as opposed to virgin, or designing products so that they may be reused.~~

This can happen through the renting and sharing of goods or through the servitisation of products (Antikainen et al. 2018; Lewandowski 2016). Traditional retailers can, for example, offer complementary repair services, shifting their business model towards making profit over a longer time with repairs and services and having an incentive to ensure longer life time of products (Whicher et al. 2018).

Similarly, refurbishment models can open up new income streams as products, which once returned to the producer and refurbished, are sold back into the market with full warranty, at a reduced price (Circle Economy 2020). In the case study of Swedish washing machines, Lieder et al. (2018) found that the number of remanufacturing cycles—connected to a publicised reduction in CO_2 emissions—could have a significant positive impact on customers' perception and likelihood of purchasing, demonstrating businesses' potential for success in implementing circular strategies. Another popular circular business model—Product Service Systems—can also have a positive environmental and social effect if properly and explicitly designed into both the model and product design (Manninen et al. 2018; Tukker 2015). These systems have the potential to encourage circularity by providing incentives for businesses to prolong the service life of products, thereby making them more cost- and resource-effective (Tukker 2015).

In a circular economy, labour is seen as a resource whose value also needs to be maximised and nurtured (Stahel 2012). It can also help to address the disconnect between areas of economic activity and areas of labour shortage, as it is more reliant on workers than on resources (Mitchell & James 2015). Changing the value proposition for people includes fairer interactions between workers and suppliers, providing security, fair wages, and avoiding dependency, bad working conditions, and precarity.

In some cases, circular activities are carried out by social organisations that provide paid employment to people who face challenges in the mainstream labour market. In Northern European countries including The Netherlands and Belgium, this labour may be subsidised by the government (Willeghems & Bachus 2018). Circular value propositions put forward long-term collaboration, which can improve workers' well-being due to increased job security (Reinecke et al. 2019), especially because a circular economy can provide new opportunities for employment and business growth (European Commission 2015; Ghisellini et al. 2016; Stiftungsfonds für Umweltökonomie und Nachhaltigkeit et al. 2015). For example offsite factory-based work is more reliable that traditional onsite construction (Rreuse 2015).

Incentives need to be aligned along the supply chain, and this can be enabled by relevant policies. Mutually beneficial long-term arrangements allow for needs on the buyer's side to be met, while creating value for the supplier (Mishra et al. 2019). Verified labels and regimes for sustainable investments with support from the buyers, as well as more radical interventions such as models of collective ownership can also support this value proposition (ILO 2017) (Pazaitis, 2017). These strategies require collaboration with financial institutions, and regulatory and economic instruments from relevant governments.

Linear business models often strive to drive down costs and maximise sales, focus on increasing the number of sales and limiting costs, which incentivise cheaper and shorter-lasting products often at the expense of labour standards (Andrews 2020; Reinecke et al. 2019). Circular value propositions create value for all people, producers and consumers, buyers and suppliers, investors and local communities. (Circle Economy, 2020)

INCORPORATE DIGITAL TECHNOLOGY
Employ digital technologies to facilitate connecting actors and keeping track of resources.

Digital technology is a crucial enabler to the large-scale implementation of core circular strategies through the use of data to enable asset tracking and the use of digital platforms to stakeholder engagement.

Data collection and processing is necessary to keep track of resources in the economy and to identify and solve inefficiencies in production processes (Andrews & Whitehead 2019; Jabbour et al. 2019). The connection of goods through an Internet of Things (IoT) approach can create further synergies for transacting secondary resources (Andrews & Whitehead 2019). IoT—supplying products with sensors, which allow them to communicate through an information network (Rymaszewska et al. 2017)—enables companies to conduct remote monitoring of the usage, status, and location in real-time (Baines & Lightfoot 2013; Pagoropolous et al. 2017; Spring & Araujo 2017). Producers may then use the knowledge gained from IoT to transform manufacturer-consumer relationships; the needs of customers may be analysed, allowing for improvements in product design (Bressanelli et al. 2018).

Van Loon and van Wassenhove (2017) and Bakker et al. (2014) both view this as an opportunity to design products for maintenance, upgrades, and disassembly, thus extending lifetimes and closing product loops through remanufacturing and recycling. These activities, also including collection and refurbishment, can be further enabled by the IoT as companies have access to information regarding product condition and geo-localisation (Pagoropolous et al. 2017). Furthermore, as manufacturers use digitalisation to make devices 'smart', the potential for companies to only upgrade digital components of products, like firmware, will increase (Rymaszewska et al. 2017), thus combatting product obsolescence and consequential material waste (Pialot et al. 2017).

Relational database management systems (RDMSs) further support and enable the transition to circularity, as they collate the abundance of data supplied by collection systems like the IoT (Pagoropoluos et al. 2017). Product lifecycle management systems are a relevant example of RDMSs that amalgamate data across various life cycles and stakeholders in the value chain. Lieder et al. (2016) found that product lifecycle management systems are particularly important at the company level, because they allow for observation of products and parts across multiple lifecycles. Overall, such digital technologies play a crucial enabling role in the circular transition by enhancing forward material flows and enabling reverse flows.

Data can also be used to track the impact or implementation of circular strategies at urban and national levels, such as is visible in Europe's central statistics database Eurostat. In support of circular strategies, Europe indicates the need for a common data space to drive applications and services such as product passports, resource mapping and consumer information (CE Action Plan, European Commission, 2020). Data tools such as material flow analysis, urban mining and spatial analysis are crucial for scaling up interventions to city or country-level policies (Sanchez, April 2020). Material flow analysis, for example, can help urban changemakers pinpoint areas where there are negative environmental impacts, thus highlighting where interventions should be focused. Similarly, spatial analysis can clarify where these impacts are taking place, allowing policy makers to create unique profiles and action plans for different neighbourhoods such as was piloted in the Europe Repair Project. Urban mining assessments can facilitate improvements in resource efficiency by identifying resources available for reuse in a city—thus negating the need to import resources from beyond the cities' bounds (Metabolic 2020).

Digital platforms can facilitate matchmaking of people and materials, as well as knowledge exchange for a circular economy. For materials, this is necessary to match supply with demand for resources and services in value networks, where supply chains are no longer connected in a linear way (Antikainen et al. 2018; EMF 2015; Lieder et al. 2015). Jabbour et al. (2019) sees a lack of knowledge amongst supply chain actors about possible interactions and synergies with other value chains as the main hurdle to a more circular economy. Digital platforms are a very valuable tool to overcome the lack of awareness of waste streams here, and connect companies across sector and industry boundaries (Jabbour et al. 2019). An example of such platforms are secondary material marketplaces (Antikainen 2018; Jabbour et al. 2019). Moreover, digital platforms can also connect actors to facilitate new models for sharing and renting goods through product-as-a-service (PSS) business models (Antikainen 2018). An example of such platforms are material libraries for clothes, tools and appliances (Circle Economy 2020).

Digital platforms may also improve information sharing between actors, as in the case of Reverse Resources, which offers textile factories the ability to monitor and track their own and others' production leftovers; all manufacturers involved are able to see how much and what kind of fabric leftovers are available, and where. A Brazilian phone app called Cataki connects informal waste pickers—who collect recyclable goods to on-sell to scrap centres—to those that need their services, leading to more work, increased pay and more recycling (Parkin 2019).

Knowledge is also disseminated through the creation and maintenance of digital platforms. Improved knowledge sharing can impact the circular transition on a number of levels, by raising awareness in the general public, guiding action and inspiring policymaking and legislation. Digital solutions can facilitate connections between stakeholders to this end, and can also influence people to become 'active participants in the data-economy and co-creators of knowledge' (Hedberg & Šipka 2020, p. 19).

COLLABORATE FOR JOINT VALUE CREATION
Work together with actors to implement circular economy strategies on the systems level.

Structural collaboration amongst actors is required to implement core circular economy strategies systemically. Collaboration can overcome barriers such as a lack of capital, knowledge and tools for efficient operations, as well as developing a new or emerging market or sector, by pooling resources (de Mattos & de Albuquerque 2018; Mishra et al. 2019; Ngan et al. 2019). This structural collaboration should happen throughout the value chain, within organisations, across the public, private and social sector and across sectors and value chains.

Research has postulated that collaboration is an essential enabler of the circular economy (Mishra et al. 2019; Witjes & Lozano 2016), that improves process efficiency, provides better access to markets and knowledge, and increases interdisciplinary learning (Witjes & Lozano 2016). Collaborations between enterprises in an industry can lead to positive alliances throughout the value chain—or the broader society—an important foundation for building the circular economy. Even informal alliances between companies have value, as they facilitate the network building and knowledge exchange needed to eventually forge formal alliances (Witjes & Lozano 2016). Collaborations between companies that focus on circular business models are also pertinent in a developing country context, with one modelling study finding that collaborations lead to improvement in resource efficiency and clean technology (Mishra et al. 2019). Successful industry collaboration also has the potential to create joint competitive advantage, thereby instigating value creation beneficial to all actors (Cao & Zhang 2011).

The Gorengedaan project in the Netherlands, for example, aims to bring together automobile renting companies to create a label for sustainable car leasing, operating on criteria such as waste management, CO2 emissions and sustainable employment, thus creating a shared benefit for all companies involved.

Government collaboration is also a significant enabler of the circular economy, particularly as a number of institutional, economic and social barriers exist regarding its implementation. Governments are crucial actors in including circular strategies in long-term policy goals and policy action that is sure to last beyond one cabinet term could facilitate a shift in companies' concern for short-term profits, and consequently, influence changes in investment strategy (van Buren et al. 2016). A number of early adopters have written circular economy into law, for example with the enactment of Germany's Closed Substance Cycle and Waste Management Act in 1996 (Su et al. 2013), Japan's Basic Law for Establishing a Recycling-Based Society in 2002

(Ministry of Economy, Trade and Industry 2004) and China's Circular Economy Promotion Law of the People's Republic of China in 2009 (Lieder & Rashid 2016).

On a municipal level, cities are deriving their circular economy strategies through collaborative processes. Through Circle Economy's City Scan Process, the Swiss cities of Bern and Basel, for example, have identified the most apt strategies for the circular transition, spearheaded by both city officials and urban changemakers.

Consumer collaboration also encourages circular behaviour and relationships between customers and companies, which may be demonstrated in the cases of take-back programmes, customisation and co-creation. Patagonia's 'Worn Wear' program, which allows customers to trade in functionally-perfect but cosmetically-flawed items, is just one example of consumer-company collaboration that facilitates circularity. Literature highlights the synergistic effect of such take-back programs; the company's waste is addressed concurrently with the customers' burden of disposal (French 2008). Mass customisation may have similar environmental benefits: the manufacturing of such products is enabled by modular components, which allow companies to manufacture a variety of products using different combinations of product modules. This architecture allows for easier disassembly and reuse in future items (Pourabdollahian & Steiner 2011). 'Emotional durability', meaning that customers want to use a product for longer, is also a beneficial characteristic of customisation and co-creation (Haines-Gadd et al. 2018).

STRENGTHEN AND ADVANCE KNOWLEDGE

Develop research, structure knowledge, encourage innovation networks and disseminate findings with integrity

The successful implementation of the circular economy is founded on a solid knowledge base—across contexts and industries, as well as different actors of the value chain. Lack of knowledge, poor knowledge management and the absence of coherent systems for defining and researching circular economy have been identified as barriers to its success (Kirchherr et al. 2018; Klapalová 2020; Schiuma et al. 2012); it therefore emerges as a highly significant enabling element.

Increasing the knowledge level of circular concepts can be achieved in a number of ways, including research and development and knowledge management, which then feed into education, workplace training and wider communications to the general public.

However, because it has been noted that 'an exact definition of circular economy still lacks consensus' (Chamberlin & Boks 2018; Kircherr 2017), frameworks can be used across all of these contexts to solidify and define the circular economy and its concepts. Such frameworks can be general (such as Circle Economy's Key Elements, which we discuss in depth in this paper, and the Ellen MacArthur Foundation's Butterfly Diagram) or context specific (such as the Circular Procurement Framework and Circular Strategies for Manufacturing). Frameworks can also provide standardised data—which are consistent across geographies, accurate, and unbiased; for example, the European Union Circular Economy Monitoring Framework utilises four categories of indicators (production and consumption, waste management, secondary raw materials and competitiveness and innovation) to generate systematised data for member states.

Leadership, the role of executives, and collaborative, enthusiastic attitudes have also been identified as crucial for knowledge generation and sharing within circular economy networks (Brown et al. 2019; de Abreu & Ceglia 2018). These pioneers pave the way for improved knowledge management and dissemination. However, stakeholder analyses of NGOs, governmental organisations and industry councils show that the average level of knowledge regarding the circular economy is low. The varying levels of expertise are fragmented in different industries and among different stakeholders (Verboon & Wardenaar, 2016); this lack of knowledge leads to stagnation, as stakeholders are either unaware of circular solutions or pessimistic about their potential. It therefore becomes clear that coherent knowledge management is necessary to process, store, visualise and share data about stakeholders, processes, products and materials involved in the circular economy (Klapalová 2020), which would be particularly suited to online platforms (de Abreu and Ceglia 2018).

In addition, research and development plays a complementary role to knowledge management, with a clear need for research from universities, institutions and NGOs to contribute to a circular transition (Palkova & Bozic Cerar 2017). A European Commission (2017c) report notes that in the context of the circular economy, more than just traditional R&D is needed; efforts underpinning policy ambitions should be innovative and mobilising. The City of Amsterdam's Circular Innovation Program exemplifies this goal. It provides insight into prevalent circular innovation projects and developments and uses those insights to accelerate the circular transition.

Raising the knowledge level of the general consumer also poses a significant challenge. To date, little research has incorporated a marketing and communications perspective on the circular economy. The applicability of design frameworks in analysing the marketing strategies of circular businesses has been studied, finding binary approaches (green marketing) to be less effective (Chamberlin & Boks 2018), and while people are generally in favour of 'environmental' behaviours, lifestyle changes are more difficult to instigate (Lazarevic & Valve 2017) and 'green' products may often be viewed as unpleasant or inconvenient (Grant 2007). 'Design for Sustainable Behaviour' is a nascent field of design research that explores how to influence the consequences of consumers' activities during the use of a product—because while traditional marketing approaches may convince a consumer to change brands, the success of the circular economy is tied to the ability of consumers to adopt new behaviours, such as product return, rental, or reuse (Chamberlin & Boks 2018). Further education is also necessary to change consumer perspectives of 'circular' items that have been repaired or remanufactured, which have been historically ascribed negative descriptors: Abbey et al. (2015) wrote on the barrier of 'disgust', Bardhi and Eckhardt (2012) wrote of 'contagion', Baxter et al. (2017) wrote of 'contamination', and van Weelden et al. (2016) found the 'lack of the thrill of newness' to be a common consumer complaint.

Perceptions and practices of the circular economy might be further improved by vocational training. While some organisations, such as the Nordic Circular Hotspot and Circular Economy Forum Austria, aim to provide general educational platforms that connect stakeholders and promote knowledge exchange, several programs offer more depth and aim to introduce the circular economy within particular fields. This is particularly prevalent in the field of consultancy; sustainable strategy firm Finch & Beak, for example, offers an executive training program targeted at senior professionals in strategy, sustainability, and innovation to increase the understanding of circular economy and better leverage the opportunities it presents. Meanwhile, Furn360 is a European project that aims to introduce a vocational curriculum to facilitate the transition to circular business practices in the furniture sector; similarly, Design4Circle seeks to support European designers in the textile and fashion sectors through the implementation of an innovative learning curriculum focused on shifting to circular business models, products and services.

Education on the circular economy should also be visible outside the workplace, ideally making its way into school and university programs and societal education. While this field is relatively new, researchers have designed an undergraduate course that introduces the circular economy to students, with favourable outcomes (Kirchherr & Piscicelli 2019). This research could be further developed by lecturers eager to include circular concepts in their curriculum. Educational training on circular economy should be non-unidirectional and involve interactive instruction, such as project or consultancy based learning. The complexity of the concepts, frameworks and knowledge relating to circular economy negate the effectiveness of the traditional teacher-centric model that characterises today's education (Türkeli & Schophuizen 2019). This hands-on, interactive approach that seems to be most beneficial in classroom learning is easily transferable to broader, society-focused training on the circular economy.

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