The Relevance of Circular Economy Practices to the Sustainable Development Goals

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Summary

This paper identifies the extent to which circular economy (CE) practices are relevant for the implementation of the Sustainable Development Goals (SDGs). The results of a literature review and a matching exercise to determine the relationship between CE practices and SDG targets show that CE practices, potentially, can contribute directly to achieving a significant number of SDG targets. The strongest relationships exist between CE practices and the targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). The paper also explores synergies that can be created through CE practices among several of the SDG targets. Furthermore, it identifies several potential trade-offs between targets for decent work, safe working environments, human health and current CE practices relating to recycling of municipal waste, e-waste and wastewater, and provides suggestions how these can be overcome. The paper concludes that CE practices can be applied as a "toolbox" and specific implementation approaches for achieving a sizeable number of SDG targets. Further empirical research is necessary to determine which specific types of partnerships and means of implementation are required to apply CE practices in the SDG context.

Introduction

The circular economy (CE) has been gaining traction as an approach for achieving local, national, and global sustainability. It has received increased attention from multinational companies (Lacy et al. 2014) and policy makers in industrialized countries (EC 2015). However, with the notable exception of China (Yuan et al. 2006; Mathews and Tan 2011), the possible contributions of the CE approach for low- and middle-income countries of the global South have, so far, received relatively little attention. The academic research community (Chertow and Park 2016) and international development practitioners (Gower and Schroeder 2016) have only recently begun paying attention to CE practices in developing countries.

This paper examines the relevance of the CE approach for achieving the Sustainable Development Goals (SDGs) in developing countries. The research question this paper addresses is: To what extent are CE practices relevant for the implementation of the SDGs? To answer this question, the authors have taken the 17 goals and 169 targets set out in the document

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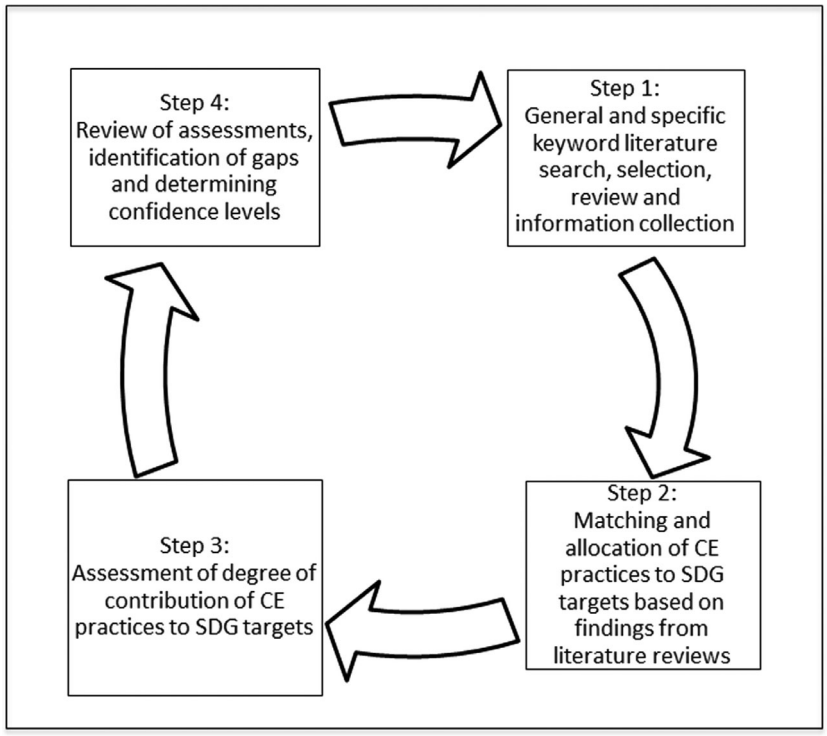

Figure 1 Research methodology and sequences. CE = circular economy; SDG = Sustainable Development Goals.

"Transforming our World: The 2030 Agenda for Sustainable Development" (UN 2015) and matched these targets with CE practices as identified from the emerging academic and nonacademic literature on CE. Through this analysis, we have identified the potential contributions of CE practices to these specific SDG targets.

The qualitative research method applied for this paper consisted of a four-step procedure, including literature search and narrative review (step 1), a matching exercise (step 2), an assessment about the degree of the contribution of CE practices to SDG targets (step 3), and a review and gap identification (step 4). This procedure was iterated three times (see figure 1).

The paper is structured as follows: First, it provides a short introduction to the literature review methods we used, followed by an introduction about the linkages between CE, international development cooperation, and global environmental challenges. Then, it moves to answer the question about the relationship of CE practices and the SDGs, and presents the findings of the matching exercise and analyzes how specific CE practices can help to achieve the SDG targets.

Linking Circular Economy and the Sustainable Development Goals

We used a narrative literature review approach for searching, organizing, and analyzing the literature on CE and SDGs (Hammersley 2001). Narrative reviews are a frequently used approach in the context of development studies. Although they are not as rigorous as systematic reviews (Hagen-Zanker and Mallett 2013), narrative literature reviews are valuable for linking together studies on different topics, either for purposes of reinterpretation or demonstrating interconnections (Baumeister and Leary 1997), as we attempt in this paper. The first step of the review was a keyword search, using online search engines Google and Google Scholar and academic databases Scopus, and search engines of the academic publishers Wiley Online Library and ScienceDirect to search and collect academic and nonacademic literature relating to CE and the SDGs. We started with general keyword searches for "circular economy SDGs" and "circular economy developing countries", and more specific searches regarding specific CE practices such as "industrial symbiosis developing countries" or "remanufacturing SDGs," and sector-specific CE practices such as "circular economy forestry," "circular economy recycling."

In total, more than 100 pieces of literature were reviewed for this article and informed the CE-SDG matching exercise. We aimed to achieve a balance between comprehensiveness and relevance to the topic. The literature review revealed that information about CE practices is widely dispersed over different fields and media. One of the contributions of this exploratory narrative literature review is the gathering of relevant materials from the fields of environmental sciences, industrial ecology (IE), business studies, and development studies.

Definition of Circular Economy Practices

The findings of the literature review highlight the fact that there is no agreed and simple definition of CE. For this paper, we

follow the CE concept of the European Environment Agency (EEA) (EEA 2016, 9):

> *"The concept can, in principle, be applied to all kinds of natural resources, including biotic and abiotic materials, water and land. Eco-design, repair, reuse, refurbishment, remanufacture, product sharing, waste prevention and waste recycling are all important in a circular economy."*

CE is thereby defined through specific actions and practices such as eco-design, reuse, refurbishment, remanufacturing (e.g., Nasr and Thurston 2006), repair, product sharing, and industrial symbiosis (IS) (Chertow and Ehrenfeld 2012; Lombardi and Laybourn 2012). We acknowledge that conceptual overlaps exist between these different CE practices, principles, or concepts, with other approaches such as cleaner production and IE. In a larger context, we consider CE practices as important elements for the transformation to systems of sustainable consumption and production (UNEP 2012).

In our discussion, we include CE practices that are practiced not only in manufacturing and municipal waste management, but also sectors such as forestry and agriculture, which are particularly relevant for developing country contexts. For example, a circular agricultural economy ("agrocology") to promote local food systems and sustain livelihoods in Africa has been promoted by Nabudere (2013). The notion of CE being "restorative and regenerative by design" (Ellen MacArthur Foundation 2013) are relevant for these two sectors, which we interpret as the application of practices that do not diminish the regenerative and restorative capacity of eco-systems underpinning the performance of forestry and agricultural sectors and their yields.

Benefits of Circular Economy for Economy, Environment, and Employment

Despite the focus on technical solutions, both the academic literature, gray literature, and relevant reports suggest that CE approaches could bring important benefits of cost savings, job creation, innovation, productivity, and resource efficiency in both developed and developing countries (e.g., Yuan et al. 2006; Friends of Europe 2014; Ellen MacArthur Foundation 2015; Gower and Schroeder 2016). The order of magnitude of estimated benefits is high. The Ellen MacArthur Foundation estimates that by 2030, a shift toward a CE could reduce net resource spending in the European Union (EU) by €600 billion annually, improve resource productivity by up to 3% annually, and generate an annual net benefit of €1.8 trillion (Ellen Mac Arthur Foundation 2015). Despite these promising economic benefits, so far only as little as 6% of all materials processed by the global economy are recycled and contribute to closing the loop. Although the degree of circularity within the EU economy is twice as high as the global average—about 13% of processed materials—it is still low (Haas et al. 2015).

In terms of environmental benefits, Sweden could become about 25% more energy efficient and increase overall material efficiency by 25% by organizing manufacturing along CE principles, minimizing waste, and maximizing the reuse and recycling of materials, compared to today (Wijkman and Skånberg 2015). According to Ecofys and Circle Economy (2016), CE practices such as chemical leasing, nutrient recovery in agriculture, materials substitution in construction sectors, and shared ownership models in transport systems could reduce up to 7.5 billion tonnes of carbon dioxide equivalent (CO_2-eq.) globally. This would bridge half of the existing emissions gap to reach the 1.5°C target as outlined under the Paris Agreement. The EEA (2016) finds that different combinations of more ambitious targets for recycling of municipal and packaging waste and reducing landfill in the EU could lead to a reduction in greenhouse gas emissions of around 424 to 617 million tonnes (Mt) of CO_2-eq. over 2015–2035. In addition, CE actions and resource efficiency in the sectors food and drink, fabricated metals, and hospitality services could reduce annual CO_2-eq. emissions by around 100 to 200 Mt (EEA 2016).

Regarding employment; in France, the CE represents roughly 800,000 full-time equivalent jobs, or 3% of the total French workforce (France Stratégie 2016). Morgan and Mitchell (2015) estimate that in the UK a "Transformation" scenario with substantial increases in recycling (up to 85%) and remanufacturing (up to 50%), 517,000 new skilled jobs could be created by 2030, compared to only 31,000 low-skilled jobs in a "No new initiatives" scenario. The European Environment Bureau (EEB) (EEB 2014) estimates European CE employment opportunities ranging from 634,769 (modest scenario) to 747,829 (ambitious scenario) by 2025. At the same time, a skills gap in the workforce and lack of CE programs at all levels of education were identified as major barriers to transform the linear to a CE (European Academies' Science Advisory Council 2015). Although we were not able to find evidence in the literature, it is very likely that similar potentials to create new employment through the CE exist in many industrialized and developing countries. The skills gap is likely to be even more significant in developing countries.

The Role of Circular Economy Business Models

Realizing the potential benefits described above will require strong action by the private sector. Many multinational companies and small- and medium-sized enterprises are becoming aware of the potential benefits and are beginning to explore the options of CE business models (Lewandowski 2016). Based on the classification of sustainable business model archetypes (Bocken et al. 2014), we find that core CE business models so far mainly cover the technological aspects of sustainable business models. This includes application of CE practices such as maximization of material and energy efficiency, creating value from waste, or applying biomimicry principles to move from nonrenewable to renewable resources. More socially oriented sustainable business models and practices, such as ethical trade, consumer education to reduce unsustainable consumption, and sufficiency-driven business (Bocken and Short 2016), are, so far, not core elements of CE business models.

One promising CE business model concept is the product-service system (PSS), which can be defined as "tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs" (Tukker 2004, 247). As PSSs usually do not allow consumers as much behavioral freedom and control over products, PSSs have not yet been widely implemented (Tukker 2015). The transformation to other CE business models is challenging for companies. Rizos and colleagues (2016) identified lack of support from the supply and demand networks and lack of capital as the two main barriers for European small and medium sized enterprises (SMEs) to adopt CE business models; the main enabling factor is an environmentally conscious corporate culture including management and staff.

Circular Economy and Developmental Challenges

CE can, potentially, solve developmental and environmental challenges relating to overconsumption of resources on global and local levels. On the global level, the amount of materials extracted has doubled since 1980, reaching close to 72 gigatonnes (Gt) in 2010, and is projected to reach 100 Gt by 2030 (OECD 2015a). In terms of waste, CE practices of recycling offer opportunities to address the waste management crisis in developing countries. CE recycling practices offer potentials for middle-income countries like Mexico and Brazil, which mainly rely on landfilling for both industrial and final consumer wastes (Tisserant et al. 2017). Environmental management approaches in industry, such as cleaner production, pollution prevention, environmental management and auditing, or energy efficiency, have already become important elements of international cooperation programs, often in the form of research, demonstration projects, and environmental policy cooperation (Baas 2005). While some CE practices have a precedent in development cooperation, CE as an alternative industrial development approach is currently almost absent from development discourse.

The CE also offers opportunities for employment and pressing issues such as health and sanitation in developing countries (Gower and Schroeder 2016). Many developing countries already possess vibrant repair and refurbishment sectors (Schmitz 2016), whose development and professionalization could be further supported through international development programs to reach their full potentials (Le Moign 2015). One important technology frequently discussed in the context of e-waste is repaired secondhand phones. While the repair of mobile phones does not result in significant displacement of new phones (Zink and Geyer 2017), for consumers in developing countries who would not be able to afford a primary phone, refurbished phones provide significant welfare benefits due to increased connectivity. Finally, businesses as emerging actors in development cooperation (Wach and Thorpe 2015) can also play an important role as enabler of CE practices in development cooperation, and thereby support the transition to sustainable consumption and production patterns in developing countries (Schroeder et al. 2017).

Matching Circular Economy Practices and Sustainable Development Goals Targets

Methodology

Extraction of information from the literature was done by searching the text and identifying specific CE practices as well as the type of real-world problem they have addressed or aim to address (e.g., waste management, water pollution, employment, or soil enhancement). This information was collected in a data extraction form, which formed the basis for the assessment table (see Supporting Information available on the Journals' website). During the second and third iterations of this first step, we conducted 40+ Google searches relating to particular SDG targets for which the first general search did not generate any literature. For example, the initial general search did not generate any literature linking CE practices to heritage conservation (Target 11.4). After a specific search on "waste recycling heritage sites Europe," we found information on a current relevant EU-funded project in this field. Another example of a specific keyword search, "women equal rights recycling" and "gender circular economy developing countries" relating to SDG Target 5.a., resulted in additional literature. An example of a specific search with negative results is "legal identity circular economy" for Target 16.9 ("By 2030, provide legal identity for all, including birth registration"), which informed the assessment that 16.9 does not have any link to CE practices. In the final iteration, additional literature suggested by the anonymous reviewers was included in the review and assessment.

For the steps 2, 3, and 4, we applied a heuristic research approach which can be defined as "a problem-solving technique in which the most appropriate solution is selected using rules" (Myers and Maulsby 1993). The qualitative heuristic approach is a process that begins with a question or problem which the researcher seeks to illuminate or answer (Moustakas 1990) and which allows for discovering qualitative relations such as structure or patterns (Kleining and Witt 2000), in our case relations between CE practices and SDG targets. According to Neth and Gigerenzer (2015), heuristics can provide accurate and robust inferences, especially under situations of uncertainty where optimization is not possible. Global sustainability efforts, international development, and the SDGs are processes fraught with uncertainty (Swart et al. 2004), and as this paper aims to inform these processes in a practical way, heuristics seems to be a suitable approach to find appropriate solutions to these complex problems. The qualitative heuristic approach also enabled the authors' combined professional experience of more than 45 years in international development to inform the assessment, an important element and common approach in development studies research (Mikkelsen 2005).

For the data extracting, matching exercise, and assessments, we employed start and stop rules. For data extraction from the literature, the search rule was to identify one or more specific CE practices. The stop rule was to stop once these were identified. For the matching exercise, the search rule was to identify an SDG target to which the CE practice could offer a solution

or contribution. Then, we worked our way through the 169 SDG targets which we set up in the spreadsheet and allocated the specific CE practices and literature sources to the individual targets. Once the SDG practices were allocated, we assessed the type or degree of contribution CE practices could potentially make to this specific SDG target. This process was continued until all 169 targets were assessed and the first matching and assessment step was stopped.

We then identified gaps where the literature did not provide links to the SDG targets which then activated the specific literature search (the first iteration), which followed the same search and stopping rules. The processes were then repeated twice more and assessments were revised based on extra information from additional literature and whether or not all authors agreed with the assessments. Decision rules for the finalizing assessment required agreement of all authors on the assessment result. We tried to minimize confirmation bias by re-evaluating our assessments and cross-checking with findings from the literature. In the same way, we tried to ensure interassessor reliability by reassessing initial findings after a certain period of time through the iterative process. Furthermore, assessments made by the main author were checked by the co-authors, and vice versa.

We acknowledge as a limitation of the review that more additional literature could have been found using alternative synonyms for "circular economy," for example, "closed-loop" or "cyclic." Furthermore, we acknowledge that a mixture of academic peer-review, public policy, and gray literature was reviewed and there is a range of quality in the evidence underpinning our analysis. We acknowledge that the final assessment of the matching exercise is, to some degree, based on subjective judgement and is not optimized, but we are confident that the method described above and the findings are robust and accurately reflect the potential contributions of CE practices to the SDG agenda.

Findings and Results

The following section discusses and analyzes the relationship between CE practices and the SDGs, the most recent global agenda for international cooperation on sustainable development (UN 2015). Although CE is closely related to SDG 12 (Sustainable Consumption and Production), it is not specifically mentioned in the SDG context. We argue that CE practices and principles are transversal and the adoption of CE practices will be necessary to achieve many targets outlined under several of the SDGs, not only for SDG 12.

We now try to answer the question this paper addresses: "To which extent are circular economy practices relevant for the Sustainable Development Goals?" To answer this question we used an exploratory matching exercise and relationship assessment using a simple relationship assessment grid consisting of five categories to determine the qualitative relationship between CE practices and the 169 SDG targets: (1) direct/strong contribution of CE practices to achieving the goal; (2) indirect contribution (via other SDG targets); (3) progress on target supports uptake of CE practices; (4) weak or no link; and (5) cooperation opportunity to promote CE practices. Additional explanations of the categories and examples are provided in table 1 below.

The rationale for each individual assessment, related literature sources, and the degree of confidence in the assessment has been included for each specific assignment of all 169 targets, which is provided in the Supporting Information on the Web. An example of a completed relationship assessment grid for targets of SDG 8 ("Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all") is provided in table 2 below. The rationale for using Goal 8 as an illustrative example is to show that the CE does not only relate to Goal 12, but CE practices are important for many of the other targets under different SDGs, for example, Target 8.4 on increasing resource efficiency.

After assigning each of the SDG targets to one of the five categories, as the next step we calculated the overall scores of the "CE practices-SDG targets relationship." The total score is 169 as only one category can be assigned to each target. The individual results for each of the SDGs and the summary score are shown in table 3 and the final scores per category are depicted in column chart format in figure 2.

The overall scores generated through this mapping exercise show that CE practices can directly contribute to achieving 21 of the targets and indirectly contribute to achieving an additional 28 targets. The strongest relationships and synergies between CE practices and SDG targets lie within SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Sustainable Consumption and Production), and SDG 15 (Life on Land) having high scores both for direct and indirect contributions. SDG 1 (No Poverty) and SDG 2 (Zero Hunger) and SDG 14 (Life Below Water) are impacted by CE practices mostly indirectly.

The targets of SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure), SDG 10 (Reduced Inequalities), SDG 13 (Climate Action), SDG 16 (Peace, Justice and Strong Institutions), and SDG 17 (Partnerships for the Goals) show a relationship in so far as progress on the targets would positively contribute to uptake of CE practices globally. This category had the highest score covering 52 targets. Specific targets which are highly important to support the CE in developing countries include 9.c (information and communication technology [ICT] and Internet access), as the CE is closely interconnected with digitalization (Webster 2016), and 12.c (phasing out inefficient subsidies for fossil fuels), which have been identified as an underlying barrier to the CE (European Academies' Science Advisory Council 2015).

Thirty-five (35) targets have shown no or only weak links with CE practices, particularly the targets of SDG 3 (Good Health and Well-being), SDG 5 (Gender Equality), SDG 10 (Reduced inequalities), SDG 11 (Sustainable Cities and Communities), and SDG 16 (Peace, Justice and Strong Institutions) have high scores in this category. All goals, except for SDG

Table 1 Assessment category description and examples

Relationship category	*Explanation of category*	*Example SDG target for this category*
1. Direct/strong contribution of CE practices to achieving the goal	The achievement of targets in this category is directly related to CE practices. Achieving targets without CE practices would be difficult or even impossible.	*11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management* CE practices such as 3Rs in waste management which prevent incineration and open burning of municipal waste are crucial to achieve this target.
2. Indirect contribution (via other SDG targets)	This category is assigned to targets to which CE practices indirectly contribute via other targets. It indicates synergies that can be created between different targets through CE practices.	*1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day* In the case of target 1.1, CE practices do not directly contribute to eradicate extreme poverty, but CE practices directly contributing to targets 8.2 and 9.2 will indirectly contribute to making progress on target 1.1.
3. Progress on target supports uptake of CE practices	This category indicates a target which has a reverse causality to CE. Rather than CE practices contributing to achieving the target, making progress on a specific target of this category will support the wider uptake of CE practices.	*4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs, and entrepreneurship* The wide uptake and diffusion of CE practices and related business models will depend on enhanced technical skills of workers and entrepreneurs.
4. Weak or no link	This category applies to targets for which no link or only weak connection was identified during the assessment.	*5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation* No link to CE in literature and practice found
5. Cooperation opportunity to promote CE practices	Under the SDGs, a number of targets specifically outline cooperation and means of implementation. This category has been assigned to targets which would offer opportunities for CE practices to be included in concrete cooperation initiatives emerging from the SDG process.	*6.5 By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate* Transboundary cooperation for integrated water management, in most cases, does not include CE practices. In the SDG context, cooperation mechanisms on this target could provide opportunities to include CE concepts and practices.

Note: CE = circular economy; SDG = Sustainable Development Goals.

9 (Industry, Innovation and Infrastructure) and SDG 16, have targets that would allow for cooperation and partnerships for implementation of CE practices, in particular SDG 17 (Partnerships for the Goals/Means of Implementation). The overall distribution of scores across the five categories is depicted for each target in figure 3 below.

Synergies and Trade-Offs in the Relationship of Circular Economy Practices and Sustainable Development Goals Targets

The literature on SDG implementation (e.g., OECD 2015b) is concerned with synergies, complementarities, and potential trade-offs between each of the SDGs. For instance, increasing agricultural production to achieve Goal 2 (Zero hunger) can have negative impacts on biodiversity covered by SDG 15 (Life on land) (ICSU and ISSC 2015). Our findings suggest that CE practices have the potential to address trade-offs, for example, between SDG 8 aiming for economic growth and SDG 9 promoting industrialization and infrastructure versus the need for climate protection under SDG 13 and biodiversity under SDG 15. At the same time, CE practices can, potentially, create additional trade-offs between SDG targets. An example would be the targets to improve waste management in cities under Target 11.6 and increasing recycling rates of Target 12.5, which might negatively impact on health of recycling workers, thereby potentially working against target 3.9, if not complemented with

Table 2 Assessment grid for relationship of CE practices to SDG 8 targets

Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	*Direct contribution of CE practices to achieve target*	*Indirect contribution of CE practices to achieve target (e.g., via other SDGs)*	*Achieving target will contribute toward CE*	*Weak or no link*	*Cooperation opportunities for CE promotion*	*Rationale for assessment (e.g., related CE practices, priority sectors, CE business models, synergies between targets)*	*Literature references*	*Degree of confidence in assessment*
8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7% gross domestic product growth per annum in the least developed countries		1				By creating new business opportunities and green jobs in LDCs (e.g., handicraft sector using renewable resources, waste collection and recycling, renewable energy services, repair), CE practices contribute to achieving this growth target.	Schroeder et al. (2017); Gower and Schroeder (2016)	Very high
8.2 Achieve higher levels of economic productivity through diversification, technological upgrading, and innovation, including through a focus on high-value-added and labor-intensive sectors	1					CE practices such as industrial symbiosis and remanufacturing are high-value-adding practices, with high innovation potentials. Recycling sectors are labor-intensive with much potential to increase productivity.	Chertow (2007); Lombardi and Laybourn (2012); Morgan and Mitchell (2015); Ferguson and Souza (2010); Li et al. (2007); WBCSD (2016)	Very high
8.3 Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises, including through access to financial services			1			Promotion of these policies would support development of new CE business models and green jobs (e.g., handicrafts, recycling, sustainable product design, extended producer responsibility programs, village-level energy service providers). Synergies with targets 8.2 and 8.4.	See 8.2 and 8.4	Very high

(*Continued*)

Table 2 Continued

Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	*Direct contribution of CE practices to achieve target*	*Indirect contribution of CE practices to achieve target (e.g., via other SDGs)*	*Achieving target will contribute toward CE*	*Weak or no link*	*Cooperation opportunities for CE promotion*	*Rationale for assessment (e.g., related CE practices, priority sectors, CE business models, synergies between targets)*	*Literature references*	*Degree of confidence in assessment*
8.4 Improve progressively, through 2030, global resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programs on sustainable consumption and production, with developed countries taking the lead	1					CE practices such as repair, remanufacturing, recycling, industrial symbiosis, closed-loop supply chains, very important for achieving higher levels of resource efficiency in production. New CE business models based on secondhand markets, product service systems (PSS), and local sharing economy complement these efforts on the consumption side.	Baines et al. (2007); Neto et al. (2010); Savaskan et al. (2004), Chertow (2007); Lombardi and Laybourn (2012), Castellani et al. (2015): Oliveira et al. (2015)	Very high
8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value		1				CE can help create new forms of employment and sources of income (but not necessarily create full and productive employment in the very sense), contribution via targets 8.2 (labor-intensive sectors), target 2.4 (sustainable agriculture).	Morgan and Mitchell (2015); France Stratégie (2016)	High
8.6 By 2020, substantially reduce the proportion of youth not in employment, education, or training		1				Same as target 8.5	See 8.5	High

(*Continued*)

Table 2 Continued

Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	*Direct contribution of CE practices to achieve target*	*Indirect contribution of CE practices to achieve target (e.g., via other SDGs)*	*Achieving target will contribute toward CE*	*Weak or no link*	*Cooperation opportunities for CE promotion*	*Rationale for assessment (e.g., related CE practices, priority sectors, CE business models, synergies between targets)*	*Literature references*	*Degree of confidence in assessment*
8.7 Take immediate and effective measures to eradicate forced labor, end modern slavery and human trafficking, and secure the prohibition and elimination of the worst forms of child labor, including recruitment and use of child soldiers, and by 2025 end child labor in all its forms				1		Weak link, possible link to forced labor and child labor in waste picking and informal recycling sectors	Rutkowski and Rutkowski (2015)	High
8.8 Protect labor rights and promote safe and secure working environments for all workers, including migrant workers, in particular women migrants, and those in precarious employment			1			Very important target to achieve safer working conditions for recyclers, e.g., in informal e-waste recycling, and reducing work-related hazards within industries in emerging economies. Progress on this target important to avoid potential trade-offs between targets 11.6 (improving waste management) and 3.9 (pollution impact on health)	Julander et al. (2014); Annamalai (2015)	Very high
8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products			1			Promoting policies for sustainable tourism can facilitate the take-up of CE concepts such as zero waste resorts, or eco-tourism in connection with conservation efforts.	Wimmer (2017); Schroeder et al. (2017);	High

(*Continued*)

Table 2 Continued

Goal 8. Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	*Direct contribution of CE practices to achieve target*	*Indirect contribution of CE practices to achieve target (e.g., via other SDGs)*	*Achieving target will contribute toward CE*	*Weak or no link*	*Cooperation opportunities for CE promotion*	*Rationale for assessment (e.g., related CE practices, priority sectors, CE business models, synergies between targets)*	*Literature references*	*Degree of confidence in assessment*
8.10 Strengthen the capacity of domestic financial institutions to encourage and expand access to banking, insurance, and financial services for all			1			Progress on this target will likely enhance access to finance for new CE business models and startups, which has been identified as a major barrier for CE business models.	Rizos et al. (2016); ING (2015)	High
8.a Increase Aid for Trade support for developing countries, in particular least developed countries, including through the Enhanced Integrated Framework for Trade-Related Technical Assistance to Least Developed Countries					1	Cooperation opportunity with World Trade Organization (WTO) on technology transfer and capacity building to include CE practices into the Aid for Trade frameworks	WTO (2015)	Medium
8.b By 2020, develop and operationalize a global strategy for youth employment and implement the Global Jobs Pact of the International Labor Organization					1	Cooperation opportunity with International Labor Organization (ILO) on technology transfer and capacity building to include CE practices and technologies into these frameworks for youth employment	ILO (2009)	Medium
Overall relation to Goal 8	2	3	4	1	2			

Note: CE = circular economy; LDCs = least developed countries; SDG = Sustainable Development Goals.

Table 3 Overall relationship scores of CE practices and 169 targets of the SDGs

	Direct contribution of CE practices to achieve target	*Indirect contribution of CE practices to achieve target (e.g., via other SDGs)*	*Achieving target will contribute toward CE*	*Weak or no link*	*Cooperation opportunities for CE promotion*
Goal 1	0	4	1	1	1
Goal 2	1	3	3	0	1
Goal 3	1	0	0	11	1
Goal 4	0	0	5	3	2
Goal 5	0	0	2	6	1
Goal 6	4	1	0	0	3
Goal 7	3	1	0	0	1
Goal 8	2	3	4	1	2
Goal 9	2	0	6	0	0
Goal 10	0	1	4	4	1
Goal 11	1	3	3	2	1
Goal 12	3	5	2	0	1
Goal 13	0	1	3	0	1
Goal 14	1	2	3	1	3
Goal 15	3	3	1	1	4
Goal 16	0	1	6	5	0
Goal 17	0	0	9	0	10
Total	**21**	**28**	**52**	**35**	**33**

Note: CE = circular economy; SDGs = Sustainable Development Goals.

additional measures to improve working conditions outlined under target 8.8.

In figure 4, we have clustered the goals according to economic, social, and environmental pillars and the type of relationship with CE practices. The arrows between the SDGs indicate the main interactions and connections between the goals in relation to CE practices.[1] For instance, we identified that many of targets under SDG 4 (Quality Education) have no direct link to CE practices; however, progress on the target 4.4 on technical skills and vocational training would contribute significantly to upscaling CE practices and achieving goals of economic pillar, in particular SDG 8 (Decent work and economic growth) and SDG 9 (Industry, innovation and infrastructure). Another example that demonstrates the cross-cutting nature of CE practices is SDG 3 (Good Health and Wellbeing). Most targets under this goal have no relationship with CE practices, but implementing CE practices under SDG 6 (Water and Sanitation) and SDG 7 (Affordable and Clean Energy) will contribute meaningfully to progress on health and well-being. Other examples are targets of SDG 13 (Climate Action) to which CE practices do not directly contribute. Achieving climate targets such as 13.2 ("Integrate climate change measures into national policies, strategies and planning") would greatly support uptake of CE practices related to renewable energy and contribute to achieving energy targets of SDG 7 (see figure 4 below).

The following subsections provide further insights into synergies and trade-offs in relation to specific CE practices. We focus the discussion on the CE practices of recycling (including household waste and e-waste), wastewater recycling and sanitation, IS, remanufacturing and repair, reduction and reuse of products, and CE practices for energy efficiency and renewable energy.

Sustainable Development Goals Synergies and Trade-Offs Related to Recycling of Municipal Household Waste and E-Waste

SDG Targets 11.6 and 12.5 both aim at reducing waste and promote recycling, one of the main CE practices already practiced widely worldwide. In developing countries, recycling of

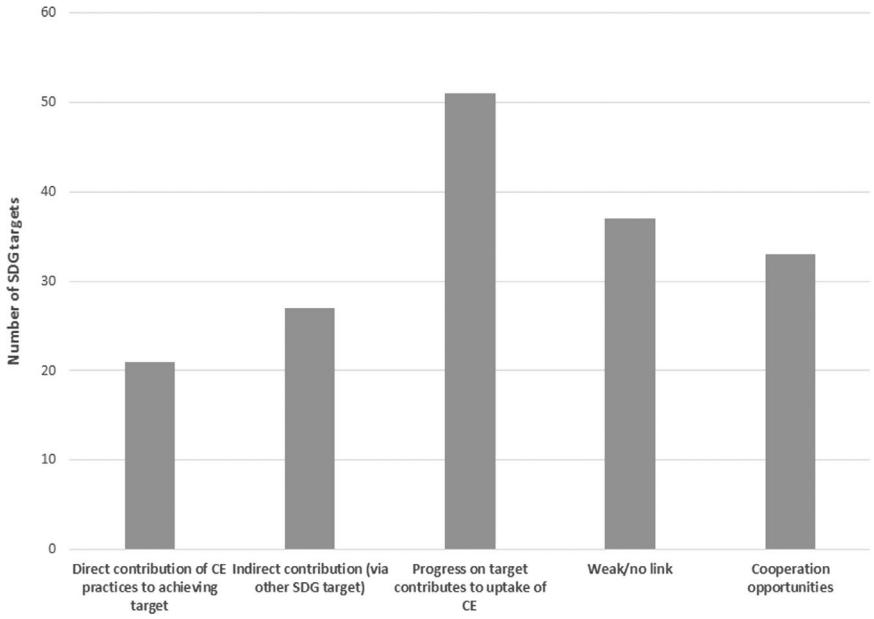

Figure 2 Relationship between circular economy (CE) practices and achieving Sustainable Development Goals (SDG) targets (17 SDGs with 169 targets in total).

municipal household waste is often carried out by informal sector workers (Ezeah et al. 2013; Chaturvedi et al. 2015). The contributions of informal plastic recycling in India to several of the SDGs have been highlighted by the World Business Council on Sustainable Development (WBCSD) (WBCSD 2016). The Indian informal sector collects and handles 4.4 Mt of plastics annually (compared to 0.2 Mt collected by the formal sector); however, environmental and social externalities such as decent working conditions are yet to be solved (WBCSD 2016).

E-waste is an even more difficult issue as it has both global and local dimensions, due to transboundary illegal shipments of e-waste and local, often informal, recycling activities (Bisschop 2015). Despite its global dimension, e-waste is not specifically mentioned in the SDG framework. There is a close link between these recycling activities and the Target 3.9 "substantially reduce by 2030 the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination." E-waste recovery and recycling has significantly lower life cycle impacts and lesser emissions to air, water, and soil than other options such as incineration or landfilling (Wäger et al. 2011). Recycling technologies and processes for e-waste which do not generate negative environmental impacts and chemical emissions exist (Li et al. 2007). However, the way most e-waste recycling operations are carried out at present causes negative impacts on workers' health and points to some of the potential goal conflicts around the CE practice of recycling. Notions of the social and solidarity economy applied to CE recycling practices can lead to more robust CE strategies toward environmental and social aims (Moreau et al. 2017), including protection of workers' health.

Target 8.8 aims to "protect labour rights and promote safe and secure working environments for all workers, in particular women migrants, and those in precarious employment," and is highly relevant for informal recycling workers. In India, according to Annamalai (2015), over 95% of the e-waste is treated and processed in urban slums where untrained workers carry out dangerous procedures without protective equipment and are exposed to a wide range of toxins detrimental to human health. Even formal e-waste recycling workers in countries with well-regulated recycling practices such as Sweden have high exposure to toxic metals (Julander et al. 2014).

An important objective to make CE work for SDG 3 and SDG 8 would be to eliminate CE practices with negative health impacts on workers in both informal and formal recycling sectors. This can be achieved by introducing stringent health and safety measures, supported by activities of Goal 4 of "quality education" and "technical skills and decent jobs" (Target 4.4). Moreover, what is required is the transfer of recycling technologies and processes that prevent chemical emissions with negative effect on the environment. This would contribute to achieving Targets 12.4 ("By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle"). Current recycling activities carried out by the informal sector will require strong stakeholder initiatives to implement capacity building, vocational training, and technology transfer to turn them into "decent jobs" (Targets 8.3 and 8.5).

Sustainable Development Goals Synergies and Trade-Offs Related to Circular Economy Practices and Water and Sanitation

CE practices associated with closed-loop systems for wastewater recycling and reuse (Jeffries 2017), and recycling of sewage sludge (Angelakis and Snyder 2015) will be indispensable to

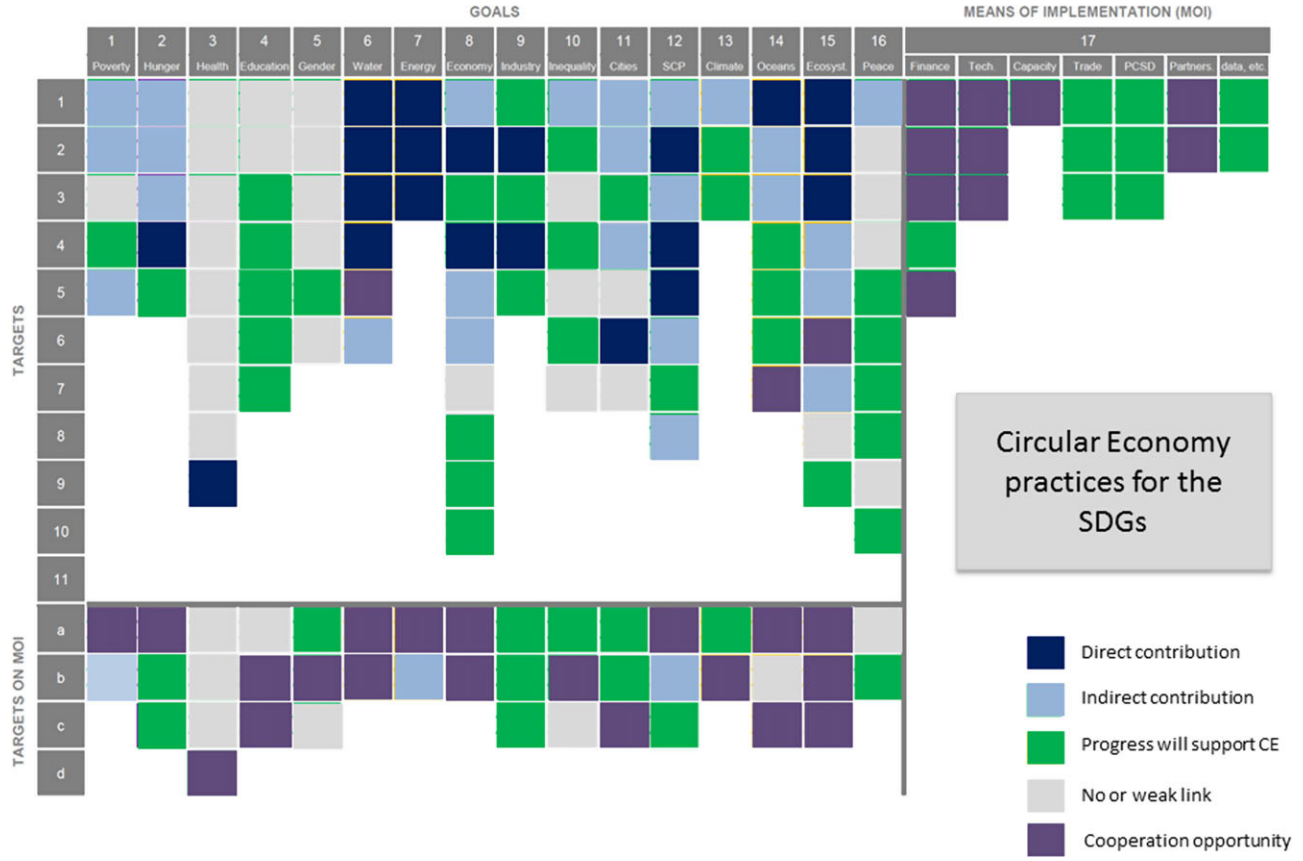

Figure 3 Relationship between circular economy (CE) practices and 169 Sustainable Development Goals (SDG) targets (visual presentation adapted from OECD 2015b).

achieve SDG 6 (Clean Water and Sanitation), in particular Targets 6.1, 6.2, 6.3, and 6.4, and Target 14.1 (Life Below Water). However, the existing infrastructure for water and wastewater systems in industrialized countries are not adequate to support the CE. Existing infrastructure will need to be optimized decrease wastage, while new infrastructure will need to be designed to fully enable advanced CE practices for water (IWA 2016).

Innovative CE practices can also be applied to solve sanitation challenges in developing countries. Examples include CE practices and business models working with composting toilets, which transform human waste into compost for agricultural use. Human waste can be used to grow insect larvae, which are used as feed for fish farms and other livestock-production systems (Vickerson 2016; Gower and Schroeder 2016), thereby also indirectly contributing to agricultural productivity and sustainable food production systems (Targets 2.4 and 2.5). These CE practices have been applied by both large companies and SMEs in developed and developing countries.

However, potential negative public health impacts associated with fecal sludge management of latrines (Myers 2016) and water and sludge recycling practices include risk of human exposure to waterborne contaminants during transport (Jin et al. 2014). Workers who handle and recycle human feces into fertilizer are at increased risk of becoming ill from waterborne diarrheal and parasitic diseases, which need to be prevented through safety measures so as not to create trade-offs with SDG 3 (Good Health and Wellbeing), in particular Targets 3.3 and 3.9. Relevant guidelines and basic hygiene practices for workers have been developed (Schönning and Stenström 2002) and their application can significantly reduce health risks.

Sustainable Development Goals Synergies and Trade-offs Related to Industrial Symbiosis

By turning one industrial facility's waste into resources of another, IS is an important CE practice. It offers potential contributions to several of the SDG targets, including Targets 3.9 (see above), 6.3 ("improve water quality by reducing pollution"), 8.2 ("higher levels of economic productivity through diversification, technological upgrading and innovation"), and 12.4 ("By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle). In terms of health impacts, Chertow (2007) found no evidence that IS practices and by-product reuse impact negatively on health of community of workers. At the same time, Chertow (2007) notes that environmental and health issues need to be carefully examined on a case-by-case basis, in particular in agricultural sectors, to minimize the spread of diseases. The IS approach by Lombardi and Laybourn (2012, 28) as a "network to

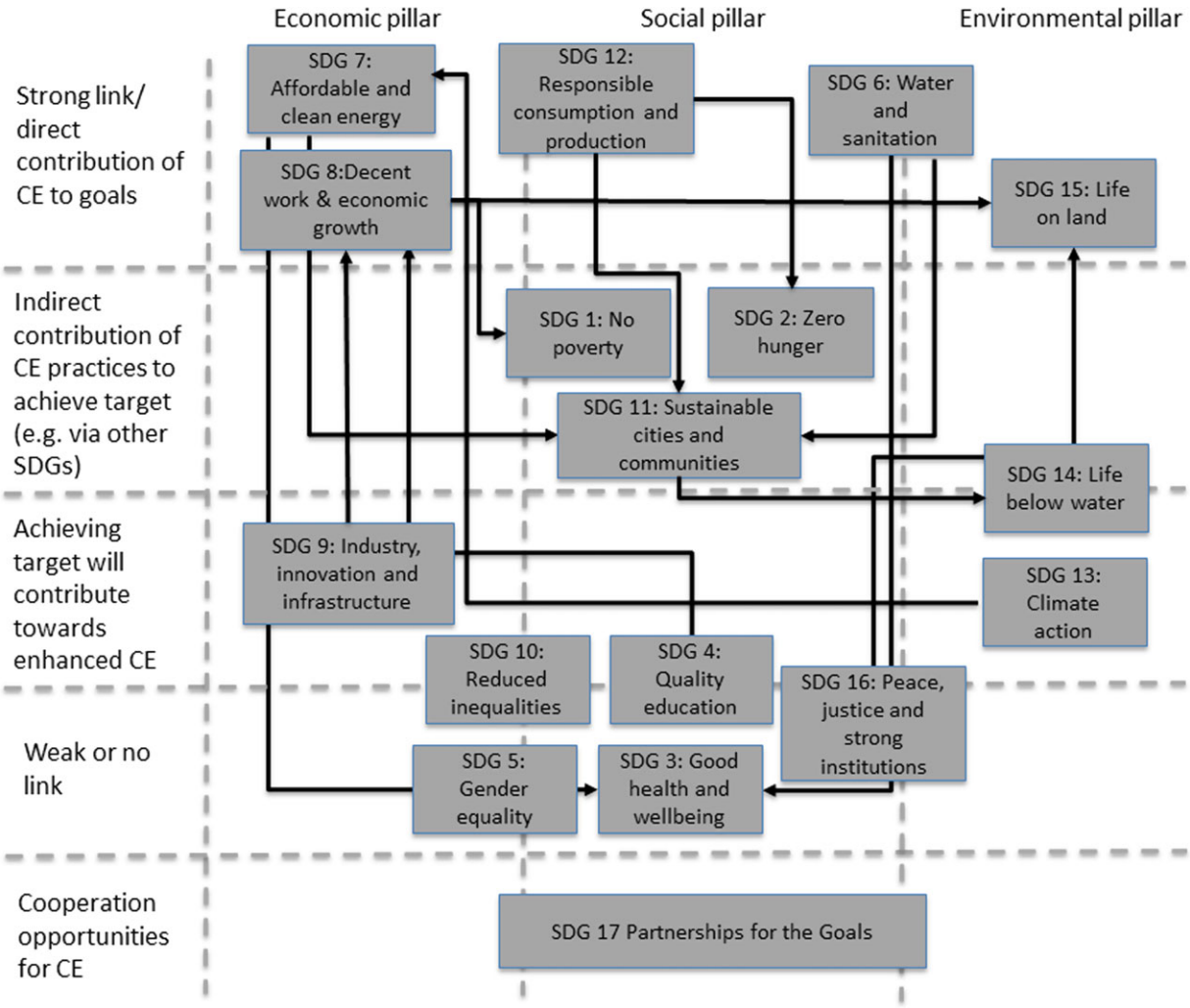

Figure 4 Relationships between Sustainable Development Goals (SDGs) in the context of circular economy (CE) practices.

foster eco-innovation and long-term culture change" and "creating and sharing knowledge through the network" has strong potential to contribute to Targets 8.2 and 12.4, especially if IS networks employ cross-sector engagement models across the life cycle of products chains. IS also offers significant potentials to contribute to Target 9.4 ("By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes").

Two key enablers for IS are geographical proximity and external coordinators; however, long-distance IS exchanges without external coordinators can also be feasible (Prosman et al. 2017), although they are less common. Due to the complexity of IS systems, its development and emergence is difficult to analyze and predict (Yap and Devlin 2017), posing no small challenges to industrial experts and developers. Specific challenges for the SDG context include the need for coordinating organizations to manage IS networks (Yap and Devlin 2017), the linking up of existing stand-alone facilities (Wolf and Petersson 2007) and financial barriers due to transport and processing costs of materials compared to low landfill costs (Lombardi and Laybourn 2012) in both developed and developing countries. Making IS work in developing country contexts will likely require technology transfer partnerships on favorable terms as outlined under Target 17.7.

Sustainable Development Goals Synergies and Trade-Offs Relating to Remanufacturing, Repair, and Refurbishment

Innovative business models employing CE practices which keep products and materials in use include remanufacturing (Nasr and Thurston 2006; Gray and Charter 2007), refurbishment (WRAP 2013), repair (Lacy et al. 2014), and reuse (Castellani et al. 2015). The capacity and functions are largely preserved, allowing recapture of the value-added to the materials, rather than allowing them to disappear into landfill or incineration after a single uses. Wider uptake and application of these practices would be required to achieve Target 8.4 ("Improve progressively, through 2030, global resource efficiency

in consumption and production and endeavour to decouple economic growth from environmental degradation"). Remanufacturing requires companies to manage high levels of complexity relating to processes and products (Seifert et al. 2013) and requires skills which are not present in many countries workforces, which could be particularly problematic for SMEs (Bourguignon 2016). Although SMEs have already begun to include sustainability criteria into their innovation processes and have generated value through eco-efficiency measures (Bos-Brouwers 2010), new CE business models are difficult to design and manage. Higher-value CE approaches, such as remanufacturing and repair, therefore require progress on targets under SDG 4, in particular "technical skills and decent jobs" (Target 4.4). Furthermore, for successful remanufacturing business models, retailers play a key role for effective collection from consumers and effective coordination mechanisms between suppliers and retailers are crucial (Savaskan et al. 2004).

Another challenge is that many original parts manufacturers do not remanufacture their products and, in some cases, even actively attempt to prevent the development of secondary markets for their products (Ferguson and Souza 2010). Refurbishment and repair business models are already important elements of developing country economies which are making use of disposed products from Western markets, in particular the automotive and electronics sectors (Schmitz 2016). In developing countries, remanufacture and repair of electronics such as mobile phones and household goods offer new employment opportunities (Brent and Steinhilper 2004) (Target 8.5) and, through improved connectivity, indirectly contribute to poverty reduction (Targets 1.1 and 1.2).

Refurbishment practices in construction sectors (WRAP 2013; ARUP 2016) offer promising solutions to Goal 11 (Sustainable Cities and Communities), especially to Target 11.6 ("By 2030, reduce the adverse per capita environmental impact of cities"). To scale up refurbishment and repair practices globally, international product standards need to be changed and improved to develop products that last longer and are easier to repair and refurbish. One barrier to this is that many product designers lack the skills to make products last longer or design them in ways to be refurbished and repaired (Bakker et al. 2014).

Sustainable Development Goals Synergies and Trade-Offs Relating to Reduction and Reuse of Products

For reduction of waste under target 12.5 ("By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse"), the CE practice of reuse provides an environmentally preferred alternative to many other waste management methods. Reuse promotes resource efficiency and reduces air, water, and soil pollution across the product life cycle, as demonstrated by Castellani et al. (2015). Extended product lifetimes and designing products for reuse, including modular systems (Stahel 2016), are important to achieve higher degrees of reuse and circulation. Consumer attitudes play an important role in reuse to shift away from the current "throwaway society" paradigm. This would not only entail conscious consumer choices for green and reusable products, but very likely also anticonsumption practices (Black and Cherrier 2010), such as voluntary simplicity and downshifting, to reduce material throughput and reject certain "linear" products. Another CE practice and innovative business model based on reuse principles is the PSS, which could contribute to Targets 8.4 and 9.4.

Moving away from the linear throwaway model is also relevant for the food retail sector, which is responsible for a large share of food waste. New business models and food sharing online marketplaces, based on circular thinking that connect retailers with charities, food recovery groups, and consumer groups, can reduce food waste at the retail level (Esposito et al. 2016), thereby contributing to achieving Target 12.3 ("By 2030, halve per capita global food waste at the retail and consumer levels"). Reuse and recycling of food waste as pig feed could reduce land use for livestock production. In the case of EU pork, which accounts for 20% of world production, potentially 1.8 million hectares of agricultural land could be saved (zu Ermgassen et al. 2016). This CE practice could reduce the need for soybean farming for animal feed in South America, which poses a significant threat to terrestrial biodiversity, thereby indirectly contributing to Targets 15.2 ("halt deforestation") and 15.5 ("halt the loss of biodiversity").

Sustainable Development Goals Synergies and Trade-Offs Relating to Circular Economy Practices for Energy Efficiency and Renewables

Several CE practices can contribute toward achieving targets under SDG 7 (Affordable and Clean Energy). Waste heat recovery from industrial processes and industrial waste-to-energy networks (Taskhiri et al. 2014), especially if applied in eco-industrial parks, offer significant potentials to improve industrial energy efficiency, outlined in the SDG Target 7.3 ("By 2030, double the global rate of improvement in energy efficiency"). Anaerobic digestion and biogas utilization could contribute to Target 7.2 ("By 2030, increase substantially the share of renewable energy in the global energy mix"), it can be used for household level and large- and medium-scale biogas plants for agricultural waste with large untapped potentials. According to Chen and colleagues (2012), China only uses 2% of its total amount of agricultural waste for anaerobic digestion. Similarly, in the EU, over 78 Mt of biodegradable waste were landfilled in 2012, which could generate 150 petajoules of renewable energy in the form of biogas or biomethane reducing 11 Mt CO_2-eq. (European Biogas Association 2015). Circular solutions can also be applied to energy infrastructures on small island developing states and for rural electrification (Target 7.b), for example, deploying closed-loop minigrids powered by solar photovoltaics (PV) to replace diesel-powered generators (Spiegel-Feld 2015; IRENA 2014). Issues that need to be considered to make these systems sustainable are appropriate collection channels and recycling facilities of end-of-life PV

panels (IRENA and IEA-PPSP 2016) and for used lead-acid batteries (Schroeder 2016).

Conclusions and Recommendations

The findings of this paper suggest that CE practices and related business models can help achieve several of the SDGs' targets. They directly contribute to achieving 21 of the targets and indirectly contribute to an additional 28 targets. The strongest relationships exist between CE practices and targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). CE practices also offer potential to create synergies between several SDGs, such as those promoting economic growth and jobs (SDG 8), eliminating poverty (SDG 1), ending hunger and sustainable food production (SDG 2), and those SDGs aiming for biodiversity protection in the oceans (SDG 14) and on land (SDG 15). While CE practices will not solve all the issues to be addressed by the SDGs—35 of the targets have no or little relation to CE practices—the CE offers potential as an implementation approach for specific SDG targets.

To make advanced CE practices and business models such as IS, remanufacturing, closed-loop supply chains, or PSSs work for the SDGs, more efforts on skills training, capacity building programs, technology development, and multistakeholder partnerships are required, as outlined under SDG 17. Active engagement of businesses along global supply chains will be needed. It will be crucial to establish synergies with SDG 4 (Quality education) to build the skills and capacity required for scaling-up and replicating CE practices. Which specific international implementation partnerships are suitable to include CE practices into their programming, and to which effectiveness they can help in achieving specific SDG targets, requires further in-depth empirical research.

Our analysis also shows that CE practices relating to recycling of household waste, e-waste, sewage sludge, and human waste will require additional efforts through skills training and health and safety measures to prevent trade-offs with Targets for human health and well-being (Target 3.9) and safe working environments (Target 8.8). Although this paper provided an overview on the relationship between CE practices and SDGs targets, additional research will be required to further explore and analyze in depth the synergies and opportunities between CE practices and SDG targets in specific country contexts.

As much as the CE can help in achieving many SDG targets, the SDGs also can help the promotion of CE practices. Progress on many of the other SDG targets, which are not directly related to CE, will benefit the uptake of CE practices. Of particular importance are SDG 16 (Peace, Justice and Strong Institutions), SDG 4 (Quality education) representing the "software" elements of governance and skills, and SDG 9 (Industry, Innovation and Infrastructure) representing the "hardware" elements of facilities and infrastructures for a circular economic system. Finally, given the limitations of this study, we recommend further in-depth research to generate more empirical evidence on the linkage between CE and the SDGs, to extend and build on this exploratory review.

Note

1. The interactions between the SDGs would be different for other organizing approaches or implementing frameworks, for example, using integrative landscape approaches (Reed and Sunderland 2015) or ecosystem approaches (UNEP 2016).

References

Angelakis, A. and S. Snyder. 2015. Wastewater treatment and reuse: Past, present, and future. *Water* 7(9): 4887–4895.

Annamalai, J. 2015. Occupational health hazards related to informal recycling of E-waste in India: An overview. *Indian Journal of Occupational and Environmental Medicine* 19(1): 61–65.

ARUP. 2016. *The circular economy in the built environment*. London: ARUP.

Baas, L. W. 2005. Cleaner Production and Industrial Ecology: Dynamic Aspects of the Introduction and Dissemination of New Concepts in Industrial Practice. Eburon Uitgeverij B.V. Erasmus University Rotterdam, Netherlands.

Bakker, C., F. Wang, J. Huisman, and M. den Hollander. 2014. Products that go round: Exploring product life extension through design. *Journal of Cleaner Production* 2014(69): 10–16.

Baines, T. S., H. W. Lightfoot, S. Evans, A. Neely, R. Greenough, J. Peppard, et al. 2007. State-of-the-art in product-service systems. *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 221(10): 1543–1552.

Baumeister, R. and M. Leary. 1997. Writing narrative literature reviews. *Review of General Psychology* 1(3): 311–320.

Bisschop, L. 2015. *Governance of the illegal trade in E-waste and tropical timber: Case studies on transnational environmental crime*. London: Ashgate.

Black, I. and H. Cherrier. 2010. Anti-consumption as part of living a sustainable lifestyle: Daily practices, contextual motivations and subjective values. *Journal of Consumer Behaviour* 9(6): 437–453.

Bocken, N. M. P., S. W. Short, P. Rana, and S. Evans. 2014. A literature and practice review to develop sustainable business model archetypes. *Journal of Cleaner Production* 65: 42–56.

Bocken, N. M. P. and S. W. Short. 2016. Towards a sufficiency-driven business model: Experiences and opportunities. *Environmental Innovation and Societal Transitions* 18: 41–61.

Bourguignon, D. 2016. Closing the loop. New circular economy package. European Parliamentary Research Service. Briefing January 2016. www.europarl.europa.eu/RegData/etudes/BRIE/2016/573899/EPRS_BRI(2016)573899_EN.pdf. Accessed 12 January 2018.

Bos-Brouwers. 2010. Corporate sustainability and innovation in SMEs: Evidence of themes and activities in practice. *Business Strategy Environmental* 19(7): 417–435.

Brent, A. C. and R. Steinhilper. 2004. Opportunities for remanufactured electronic products from developing countries: Hypotheses to characterise the perspectives of a global remanufacturing industry. In AFRICON, 2004. 7th AFRICON Conference in Africa, 15–17 September, Gaborone, Botswana.

Castellani, V., S. Sala, and N. Mirabella. 2015. Beyond the throwaway society: A life cycle-based assessment of the environmental benefit of reuse. *Integrated Environmental Assessment and Management* 11(3): 373–382.

Chaturvedi, A., K. Vijayalakshmi, and S. Nijhawan. 2015. *Scenarios of waste and resource management: For cities in India and elsewhere*. IDS Evidence Report No. 114. Brighton, UK: IDS.

Chen, L., L. Zhao, C. Ren, and F. Wang. 2012. The progress and prospects of rural biogas production in China. *Energy Policy* 51: 58–63.

Chertow, M. 2007. "Uncovering" industrial symbiosis. *Journal of Industrial Ecology* 11(1): 11–30.

Chertow, M. and J. Ehrenfeld. 2012. Organizing self-organizing systems: Toward a theory of industrial symbiosis. *Journal of Industrial Ecology* 16(1): 13–27.

Chertow, M. and J. Park. 2016. Scholarship and Practice in industrial symbiosis: 1989–2014. In *Taking stock of industrial ecology*, edited by R. Clift and A. Druckman. New York: Springer International.

EBA (European Biogas Association). 2015. Contribution of anaerobic digestion to the European Circular Economy. Brussels: European Biogas Association, 12 November.

EC (European Commission). 2015. Closing the loop—An EU action plan for the Circular Economy. COM(2015) 614 final, Brussels, 2.12.2015. Brussels: European Commission.

Ecofys and Circle Economy. 2016. Implementing Circular Economy Globally Makes Paris Targets Achievable. www.ecofys.com/en/publications/circular-economy-white-paper-ecofys-circle-economy/. Accessed 12 January 2018.

EEA (European Environment Agency). 2016. Circular Economy in Europe—Developing the Knowledge Base. EEA Report No 2/2016. Copenhagen: European Environment Agency.

EEB (European Environmental Bureau). 2014. *Advancing resource efficiency in Europe: Indicators and waste policy scenarios to deliver a resource efficient and sustainable Europe*. Brussels: European Environmental Bureau.

Ellen MacArthur Foundation. 2013. *Towards the circular economy*. Cowes, UK: Ellen MacArthur Foundation.

Ellen MacArthur Foundation. 2015. *Delivering the circular economy: A toolkit for policymakers*. Cowes, UK: Ellen MacArthur Foundation.

Esposito, M., T. Tse, and K. Soufani. 2016. The circular economy takes on food waste. *Stanford Social Innovation Review*, 1 April. http://ssir.org/articles/entry/the_circular_economy_takes_on_food_waste. Accessed 10 June 2016.

European Academies' Science Advisory Council. 2015. Circular economy: A commentary from the perspectives of the natural and social sciences. European Academies' Science Advisory Council, Brussels and Halle. www.easac.eu/fileadmin/Reports/Easac_15_CE_web_corrected.pdf. Accessed 12 January 2018.

Ezeah, C., J. Fazakerley, and C. Roberts. 2013. Emerging trends in informal sector recycling in developing and transition countries. *Waste Management* 33(11): 2509–2519.

Ferguson, M. and G. Souza, eds. 2010. *Closed-loop supply chains: New developments to improve the sustainability of business practice*. New York: Tayler & Francis Group.

France Stratégie. 2016. *Economie circulaire: combien d'emplois?* [Circular economy: how many jobs?] Note d'analyse n° 46, April 2016. www.strategie.gouv.fr/sites/strategie.gouv.fr/files/atoms/files/na46_economie_circulaire_07042016_finale-web.pdf. Accessed 12 January 2018.

Friends of Europe. 2014. Circular economy: Scaling up best practices worldwide. Brussels: Friends of Europe. www.friendsofeurope.org/event/circular-economy-scaling-best-practices-worldwide. Accessed 12 January 2018.

Gower, R. and P. Schroeder. 2016. Virtuous circle: How the circular economy can save lives and create jobs in low and middle income countries. London, UK: Tearfund and Institute of Development Studies.

Gray, C. and M. Charter. 2007. Remanufacturing and Product Design—Designing for the 7th Generation. The Centre for Sustainable Design & South East England Development Agency. Farnham, UK: University College for the Creative Arts.

Haas, W., F. Krausmann, D. Wiedenhofer, and M. Heinz. 2015. How Circular is the Global Economy? An Assessment of Material Flows, Waste Production, and Recycling in the European Union and the World in 2005. *Journal of Industrial Ecology* 19(5): 765–777.

Hagen-Zanker, J. and R. Mallett. 2013. How to do a rigorous, evidence-focused literature review in international development: A guidance note. ODI Working Paper, September. London: Overseas Development Institute.

Hammersley, M. 2001. On 'systematic' reviews of research literatures: A 'narrative' response to Evans & Benefield. *British Educational Research Journal* 27(5): 543–554.

ICSU (International Council for Science), ISSC (International Social Science Council). 2015. *Review of the sustainable development goals: The science perspective*. Paris: International Council for Science (ICSU).

ILO (International Labor Organization). 2009. *Recovering from the crisis: A global jobs pact*. Geneva, Switzerland: International Labor Organization, 19 June.

ING. 2015. *Rethinking finance in a circular economy: Financial implications of circular business models*. Amsterdam: ING, Economics Department.

IRENA (International Renewable Energy Agency). 2014. *Renewable energy opportunity for island tourism*. Masdar City, Abu Dhabi, United Arab Emirates; Bonn, Germany: International Renewable Energy Agency, August.

IRENA (International Renewable Energy Agency) and IEA-PPSP (International Energy Agency Photovoltaic Power Systems Programme). 2016. *End-of-life management: Solar photovoltaic panels*. Abu Dhabi: International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems Programme.

IWA (International Water Association). 2016. *Water utility pathways in a circular economy*. London: International Water Association. http://circulatenews.org/2017/01/applying-the-circular-economy-lens-to-water/. Accessed 12 January 2018.

Jeffries, N. 2017. Applying the circular economy lens to water. *Circulate News*, 26 January. http://circulatenews.org/2017/01/applying-the-circular-economy-lens-to-water/. Accessed 12 January 2018.

Jin, Y., X. Qu, Y. Li, R. Yu, and K. Ikehata. 2014. Health effects associated with wastewater treatment, reuse, and disposal. *Water Environment Research* 86(10): 1970–1993.

Julander, A., L. Lundgren, L. Skare, M. Grander, B. Palm, M. Vahter, and C. Liden. 2014. Formal recycling of e-waste leads to increased exposure to toxic metals: An occupational exposure study from Sweden. *Environment International* 73: 243–251.

Kleining, G. and H. Witt. 2000. The qualitative heuristic approach: A methodology for discovery in psychology and the social sciences. Rediscovering the method of introspection as an

example. *Forum: Qualitative Social Research* 1(1): Art. 13. www.qualitative-research.net/index.php/fqs/article/view/1123/2495

Lacy, P., J. Keeble, R. McNamara, J. Rutqvist, T. Haglund, M. Cui, A. Cooper, et al. 2014. Circular advantage: Innovative business models and technologies to create value in a world without limits to growth. Chicago, IL, USA: Accenture.

Le Moign, R. 2015. Can emerging countries benefit from the circular economy? *Circulate*, 23 September. http://circulatenews.org/2015/09/can-emerging-countries-benefit-from-the-circular-economy/. Accessed 12 January 2018.

Lewandowski, M. 2016. Designing the business models for circular economy—Towards the conceptual framework. *Sustainability* 8(1): 43.

Li, J., H. Lu, J. Guo, Z. Xu, and Y. Zhou. 2007. Recycle technology for recovering resources and products from waste printed circuit boards. *Environmental Science & Technology* 41(6): 1995–2000.

Lombardi, D. R. and P. Laybourn. 2012. Redefining industrial symbiosis. *Journal of Industrial Ecology* 16(1): 28–37.

Mathews, J. and H. Tan. 2011. Progress toward a circular economy in China the drivers (and Inhibitors) of eco-industrial initiative. *Journal of Industrial Ecology* 15(3): 435–457.

Mikkelsen, B. 2005. *Methods for development work and research: A new guide for practitioners*, 2nd ed. New Delhi: Sage.

Morgan, J. and P. Mitchell. 2015. Employment and the circular economy: Job creation in a more resource efficient Britain. London: WRAP and Green Alliance.

Moreau, V., M. Sahakian, P. van Griethuysen, and F. Vuille. 2017. Coming full circle: Why social and institutional dimensions matter for the circular economy. *Journal of Industrial Ecology* 21(3): 497–506.

Moustakas, C. 1990. *Heuristic research: Design, methodology, and applications*. Newbury Park, CA: Sage Publications.

Myers, J. 2016. The long-term safe management of rural shit. In *Sustainable sanitation for all*, edited by P. Bongartz, N. Vernon, and J. Fox. Rugby, UK: Practical Action.

Myers, B. and D. Maulsby. 1993. Appendix C glossary. In *Watch what I do: Programming by demonstration*, edited by A. Cypher. Cambridge, MA, USA: MIT Press. http://acypher.com/wwid/BackMatter/Glossary.html.

Nabudere, D. 2013. *From agriculture to agricology: Towards a glocal circular economy*. Johannesburg, South Africa: Real African.

Nasr, N. and M. Thurston. 2006. Remanufacturing: A key enabler to sustainable product systems. In 13th CIRP International Conference on Life Cycle Engineering, 31 May–2 June, Leuven, Belgium.

Neto, J. Q. F., G. Walther, J. Bloemhof, J. A. E. E. van Nunen, and T. Spengler. 2010. From closed-loop to sustainable supply chains: The WEEE case. *International Journal of Production Research* 48(15): 4463–4481.

Neth, H. and G. Gigerenzer. 2015. Heuristics: Tools for an uncertain world. In *Emerging trends in the social and behavioral sciences: An interdisciplinary, searchable, and linkable resource*, edited by R. Scott and S. Kosslyn, 1–18. New York: Wiley Online Library.

OECD (Organization for Economic Cooperation and Development). 2015a. *Material resources, productivity and the environment*. Paris: OECD Green Growth Studies, OECD Publishing.

OECD (Organization for Economic Cooperation and Development). 2015b. *Policy Coherence for Sustainable Development in the SDG Framework*. Paris: OECD Publishing.

Oliveira, M., G. Mendes, and H. Rozenfeld. 2015. Bibliometric analysis of the product-service system research field. *Procedia CIRP* 30: 114–119.

Prosman, E., B. Wæhrens, and G. Liotta. 2017. Closing global material loops: Initial Insights into firm-level challenges. *Journal of Industrial Ecology* 21(3): 641–650.

Reed, J. and T. Sunderland. 2015. How landscape approaches can help achieve the SDGs—In three (challenging) steps. CIFOR Blog Forest News (blog), 4 December 2015. http://blog.cifor.org/38373/how-landscape-approaches-can-help-achieve-the-sdgs-in-three-challenging-steps?fnl=en. Accessed 12 January 2018.

Rizos, V., A. Behrens, W. van der Gaast, E. Hofman, A. Ioannou, T. Kafyeke, A. Flamos, et al. 2016. Implementation of circular economy business models by small and medium-sized enterprises (SMEs): Barriers and enablers. *Sustainability* 8(11): 1212.

Rutkowski, J. and E. Rutkowski. 2015. Expanding worldwide urban solid waste recycling: The Brazilian social technology in waste pickers inclusion. *Waste Management & Research* 33(12): 1084–1093.

Savaskan, R., S. Bhattacharya, and L. N. van Wassenhove. 2004. Closed-loop supply chain models with product remanufacturing. *Management Science* 50(2): 239–252.

Seifert, S., S. Butzer, H.-H. Westermann, and R. Steinhilper. 2013. Managing complexity in remanufacturing. Proceedings of the World Congress on Engineering 2013 Vol I, WCE 2013, 3–5 July, London, United Kingdom.

Schmitz, H. 2016. Africa's biggest recycling hub? Institute of Development Studies Blog (blog), 20 November 2015. www.ids.ac.uk/opinion/africa-s-biggest-recycling-hub. Accessed 12 January 2018.

Schönning, C. and T. A. Stenström. 2002. *Guidelines on the safe use of urine and faeces in ecological sanitation systems*. Stockholm, Sweden: Swedish Institute for Infectious Disease Control (SMI) and Stockholm Environment Institute.

Schroeder, P., K. Anggraeni, S. Sartori, and U. Weber, eds. 2017. Sustainable Asia: Supporting the transition to sustainable consumption and production in Asian developing countries. Singapore: SWITCH-Asia and World Scientific.

Schroeder, P. 2016. Will solar PV create a wave of toxic battery waste in rural Africa? 13 December 2016, IDS Blog (blog). www.ids.ac.uk/opinion/will-solar-pv-create-a-wave-of-toxic-battery-waste-in-rural-africa. Accessed 12 January 2018.

Spiegel-Feld, D. 2015. Deploying solar powered microgrids on small island developing states: Breaking through the barriers to realize the benefits. New York: Guarini Center on Environmental, Energy and Land Use Law, New York University School of Law.

Stahel, W. 2016. The circular economy. *Nature* 531(7595): 435–438.

Swart, R. J., P. Raskin, and J. Robinson. 2004. The problem of the future: sustainability science and scenario analysis. *Global Environmental Change* 14: 137–146.

Taskhiri, M., S. Behera, R. Tan, and H. Park. 2014. Fuzzy optimization of a waste-to-energy network system in an eco-industrial park. *Journal of Material Cycles and Waste Management* 17(3): 476–489.

Tisserant, A., S. Pauliuk, S. Merciai, J. Schmidt, J. Fry, R. Wood, and A. Tukker. 2017. Solid waste and the circular economy: A global analysis of waste treatment and waste footprints. *Journal of Industrial Ecology* 21(3): 628–640.

Tukker, A. 2004. Eight types of product-service system: Eight ways to sustainability? Experiences from SusProNet. *Business Strategy and the Environment* 13(4): 246–260.

Tukker, A. 2015. Product services for a resource-efficient and circular economy—A review. *Journal of Cleaner Production* 97: 76–91.

UN (United Nations). 2015. *Transforming our world: The 2030 agenda for sustainable development*. New York: United Nations General Assembly, 11–12 August.

UNEP (United Nations Environment Program). 2012. *The Global Outlook on SCP Policies. Taking action together*. Nairobi Kenya: United Nations Environment Program.

UNEP (United Nations Environment Program). 2016. SDGs and ecosystem approach. United Nations Environment Program, March. www.unep.org/ecosystemmanagement/water/regionalseas40/Portals/50221/SDG_EBM_AfricanOG.pdf.

Vickerson, A. 2016. Transform waste into protein. In *Circular economy: Getting the circulation going*. *Nature* 531(7595): 443–446.

Wach, E. and J. Thorpe. 2015. Introduction: Changing perspectives in business and development. In *Business, state and society: Changing perspectives, roles and approaches*. *IDS Bulletin* 46(3): 1–6.

Wäger, P. A., R. Hischier, and M. Eugster. 2011. Environmental impacts of the Swiss collection and recovery systems for waste electrical and electronic equipment (WEEE): A follow-up. *Science of the Total Environment* 409(2011): 1746–1756.

WBCSD (World Business Council on Sustainable Development). 2016. Informal approaches towards a circular economy—Learning from the plastics recycling sector in India. Geneva, Switzerland: World Business Council on Sustainable Development, EMPA and World Resources Forum.

Webster, K. 2016. The circular economy is part of the irresistible unfolding of a digital revolution. *Circulate News*, 24 June 2016. http://circulatenews.org/2016/06/the-circular-economy-is-part-of-the-irresistible-unfolding-of-a-digital-revolution/. Accessed 12 January 2018.

Wijkman, A. and K. Skånberg. 2015. The Circular Economy and Benefits for Society Swedish Case Study Shows Jobs and Climate as Clear Winners. The Club of Rome, April 2015. Rome, Italy.

Wimmer, R. 2017. Zero carbon resorts: Conserving resources and energy self-sufficiency. In *Energy Innovation Austria*. Vienna: Austrian Federal Ministry for Transport, Innovation and Technology. http://www.energy-innovation-austria.at/article/zero-carbon-resorts-2/?lang=en. Accessed 12 January 2018.

Wolf, A. and K. Petersson. 2007. Industrial symbiosis in the Swedish forest industry. *Progress in Industrial Ecology* 4(5): 348–362.

WRAP (Waste and Resources Action Program). 2013. Built Environment Circular Economy. www.wrap.org.uk/sites/files/wrap/WRAP%20Built%20Environment%20-%20Circular%20Economy%20Jan%202013.pdf. Accessed 12 January 2018.

WTO (World Trade Organization). 2015. Nairobi Ministerial Declaration. Adopted on 19th December 2015. Geneva, Switzerland: World Trade Organization.

Yap, N. T. and J. F. Devlin. 2017. Explaining industrial symbiosis emergence, development, and disruption—A multilevel analytical framework. *Journal of Industrial Ecology* 21(1): 6–15.

Yuan, Z., J. Bi, and Y. Moriguichi 2006. The circular economy: A new development strategy in China. *Journal of Industrial Ecology* 10(1–2): 4–8.

Zink, T. and R. Geyer. 2017. Circular economy rebound. *Journal of Industrial Ecology* 21(3): 593–602.

zu Ermgassen, E., B. Phalan, R. Green, and A. Balmford. 2016. Reducing the land use of EU pork production: Where there's swill, there's a way. *Food Policy* 58: 35–48.

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